



SOUTH EAST QUEENSLAND
HEALTHY WATERWAYS
PARTNERSHIP

**A Review of Water Quality and
Maintenance Costs of Constructed
Water Bodies in Urban Areas of
South East Queensland**

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1 INTRODUCTION

Constructed urban waterbodies (commonly referred to as 'lakes') are a popular feature of urban development in many countries, including Australia. Such waterbodies may be created for a variety of social, economic and environmental reasons. From the perspective of land developers, urban waterbodies can provide scenic amenity as well as recreational opportunities and wildlife habitat, which commonly lead to higher land values in surrounding areas.

Whilst constructed urban waterbodies may confer many benefits upon their local communities, maintenance of acceptable water quality over the long term has proven to be a significant challenge. Poor water quality in constructed urban water bodies is commonly observed and can potentially result in a range of environmental problems, such as excessive macrophyte growth or weed infestation, fish kills and odour problems. In the USA, 80% of all urban waterbodies are classed as either eutrophic or hypereutrophic since they receive higher phosphorus (and nitrogen) loads than waterbodies within non-urban catchments (Mitsch and Gooselink 2000). For this reason, algal populations within urban waterbodies can be highly productive, rapidly reaching bloom-like proportions. In many urban lakes, cyanobacteria blooms are common, creating both public and environmental health issues (Reynolds 1995; Sommarunga and Robarts 1997; Ferber et al. 2004).

After the initial construction and establishment period of artificial urban waterbodies (of the order of 3 to 10 years), ownership typically passes to a local government authority, which then becomes responsible for all maintenance activities associated with the waterbody. Anecdotal evidence from local government officers in South East Queensland (SEQ) indicates that water quality within urban waterbodies is typically poor, resulting in a substantial maintenance burden. However, very limited information is presently available to characterise the observed water quality in the region's urban waterbodies, or to provide an estimate of the most likely maintenance requirements and costs.

In October 2006, a project steering committee of local government representatives, hosted by the South East Queensland Healthy Waterways Partnership, initiated a survey of local governments in SEQ to obtain information on:

- The number and physical characteristics of urban waterbodies within their jurisdiction,
- Observed water quality within these waterbodies, and
- Actual or estimated expenditure on maintenance activities for these waterbodies.

Using the data collected from the local government survey, this report aims to characterise the observed water quality and maintenance requirements of artificial water bodies within SEQ, and to identify the key management issues for constructed urban water bodies in SEQ.

2 KEY MANAGEMENT ISSUES

Constructed water bodies within urban areas are usually designed to be a central feature of a development or residential precinct. Generally, catchment area to lake area ratios are high, however several significant water bodies within SEQ (e.g. Forest Lake, Burleigh Lake System) are large with respect to their contributing catchments.

Examination of the literature relating to urban water bodies indicates that few detailed studies of the limnology of these systems have been undertaken. However, stratification within a number of these systems has been observed, and various management approaches have been developed to counteract this. Very little information is available on the response of urban water bodies to specific management strategies.

Common water quality issues for constructed urban water bodies (Duncan 1998, Statwell and Cordery 1998, Butler and Davies 2000, Morris et al. 2003, Walsh 2004) include:

- Excessive algal growth;
- Cyanobacterial blooms;
- Eutrophication (excessive water plant growth due to high nutrient levels);
- High turbidity concentrations; and
- General non-point source pollution.

Of these, excessive algal and water plant growth appeared to be the major issue in those systems studied in the literature, with 80% of all urban water bodies classed as either eutrophic or hypertrophic (Mitsch and Gooselink 2000). Associated with this, cyanobacteria ("blue-green algae") blooms were also common, causing public and environmental health concerns (Reynolds 1995, Sommarunga and Robarts 1997; Ferber et al. 2004).

The occurrence of aquatic macrophytes within urban lakes (both submerged and emergent) are sometimes considered undesirable in maintaining aesthetics and recreational function. However, macrophytes play a vital role in proper ecosystem function. Submerged macrophytes are considered the most effective in managing nutrient uptake, reducing turbidity, and providing suitable habitat for certain aquatic fauna. However, the presence of macrophytes does not reduce the need to effectively manage catchment loads.

Aquatic systems dominated by submerged macrophytes can be resilient to low levels of nutrient inputs from catchments. However, higher catchment loads can compromise the assimilative capacity of systems such that catastrophic failure of the entire lake ecosystem may occur and a switch over to one that is dominated by phytoplankton blooms (Bailey et al. 2002).

Management action should therefore aim to maintain submerged water plants wherever possible, in addition to managing catchment nutrient loads, because they can protect against algal blooms by:

- Providing habitat and refuge for zoo plankton which can consume algae;
- Reducing light available for algal growth;
- Producing compounds which inhibit algal growth; and

- Reducing nutrients available for algal growth (Morris et al., 2003, 2004).

Occasionally, it may be necessary to harvest macrophytes to manage the various lake functions. However, care should be taken when nutrients in the water column are high, as removal of macrophytes under these conditions may increase the likelihood of phytoplankton blooms and prevent the re-establishment of submerged plants (Bailey et al. 2002).



Figure 2-1 Submerged and Emergent Macrophytes in an Urban Lake

The subtropical climate of South East Queensland (SEQ) has some specific characteristics that increase the risk of water quality problems within storages that collect urban stormwater runoff. These characteristics include:

- Relatively high temperatures that increase the productivity of algae, macrophytes and cyanobacteria. Over an annual cycle, restricted productivity due to low temperature is almost non-existent.
- High inflow variability due to the seasonality of rainfall and the occurrence of high-intensity storms with substantial inter-event periods. Under these conditions, impounded water is not regularly flushed, potentially resulting in the depletion of dissolved oxygen through algal and bacterial processes.

In summary, the performance of constructed urban water bodies is the result of complex interactions between climate, land use, adopted management strategies within the catchment, and physical, chemical and biological processes within the water body.

3 ARTIFICIAL WATER BODIES IN SEQ

3.1 Data Collection and Limitations

The data collected for this study was obtained from SEQ local governments in late 2006. To focus the study on major urban water features, data was requested only for waterbodies with a surface area of greater than 0.5 ha (5,000 m²) and substantially urbanised catchments. This eliminated water supply dams and most stormwater treatment devices (such as sedimentation basins and constructed wetlands) as well as a very large number of small impoundments, such as golf course ponds and in-stream pools, from the investigation. Tidal systems were not included in the study. Using these criteria, data was obtained on 83 waterbodies across 7 of the 18 local government areas in SEQ. The number of water bodies identified within each of these authorities is shown in Figure 3-1.

It should be noted that the information provided in the survey is unlikely to represent all of the waterbodies in the region, since some local governments had minimal data on relevant waterbodies, or inadequate resources to respond to the data request. In addition, not all urban water bodies within SEQ fall under the jurisdiction of local government authorities, with some being managed by body corporates or private companies. Hence, this report provides a brief overview of the typical condition of artificial water bodies in SEQ, rather than a comprehensive analysis.

3.2 Physical Characteristics

As part of the survey, local governments were asked to identify the physical characteristics of the water bodies that were known within their region. This raw data, presented in APPENDIX B, gives all information on physical dimensions as collected, and this is summarised in Table 3-1. It is important to note that not all the physical characteristics were identified for each water body. The “n” value shows the number of water bodies represented in the calculation of each of the statistical parameters.

3.2.1 Water Body Surface Area

The surface area of the majority of urban water bodies within SEQ is less than 10 ha, with the mean of all data collected being 6.7 ha as shown in Table 3-1. However, this does not imply that they are all typically that size, as there was a significant variance in range with a minimum of 0.5 ha up to a maximum of 95 ha. From the raw data, it is apparent that the larger water bodies within urban areas in SEQ tend to be centred around the Gold Coast. Eighty percent of water bodies identified in the survey were less than 6 ha in size, as indicated by the box and whisker plots in Figure 3-2.

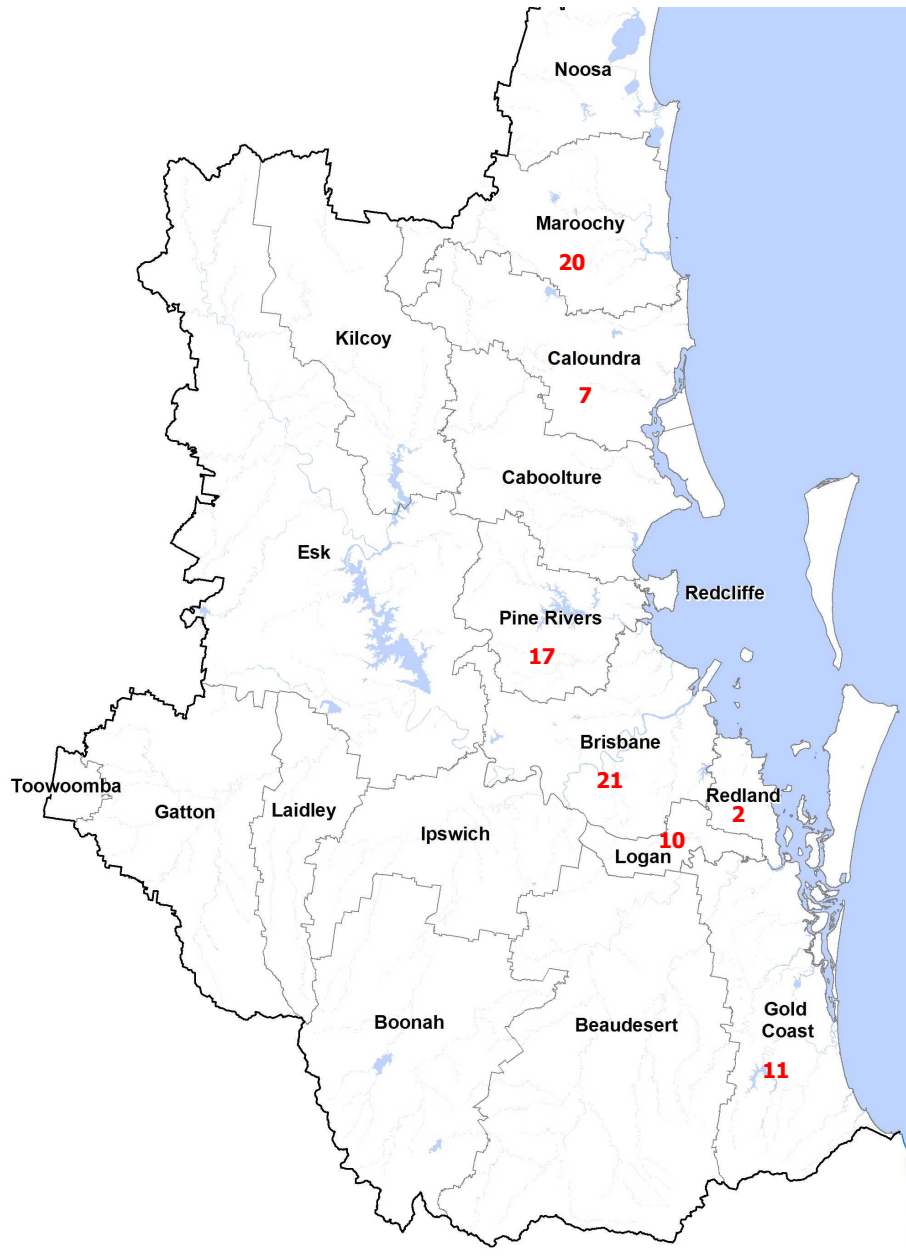


Figure 3-1 Numbers of urban water bodies identified in SEQ

Table 3-1 Physical Characteristics, Summary Data

	Surface Area (ha)	Volume at Full Supply Level (ML)	Maximum Depth (m)	Average Depth (m)	Perimeter (m)	Total Contributing Catchment (ha)	Urbanisation of Contributing Catchment (%)
Max	95	12000	10	6.7	20000	3500	100
Min	0.5	11	1.5	1.0	290	2	5
Mean	6.7	940	4.6	3.0	1400	220	71
Median	2.2	38	3.9	2.8	780	77	80
20th %ile	0.89	27	2.4	1.5	450	9	50
80th %ile	5.6	170	7	4.0	1200	190	100
n	73	14	26	22	64	49	38

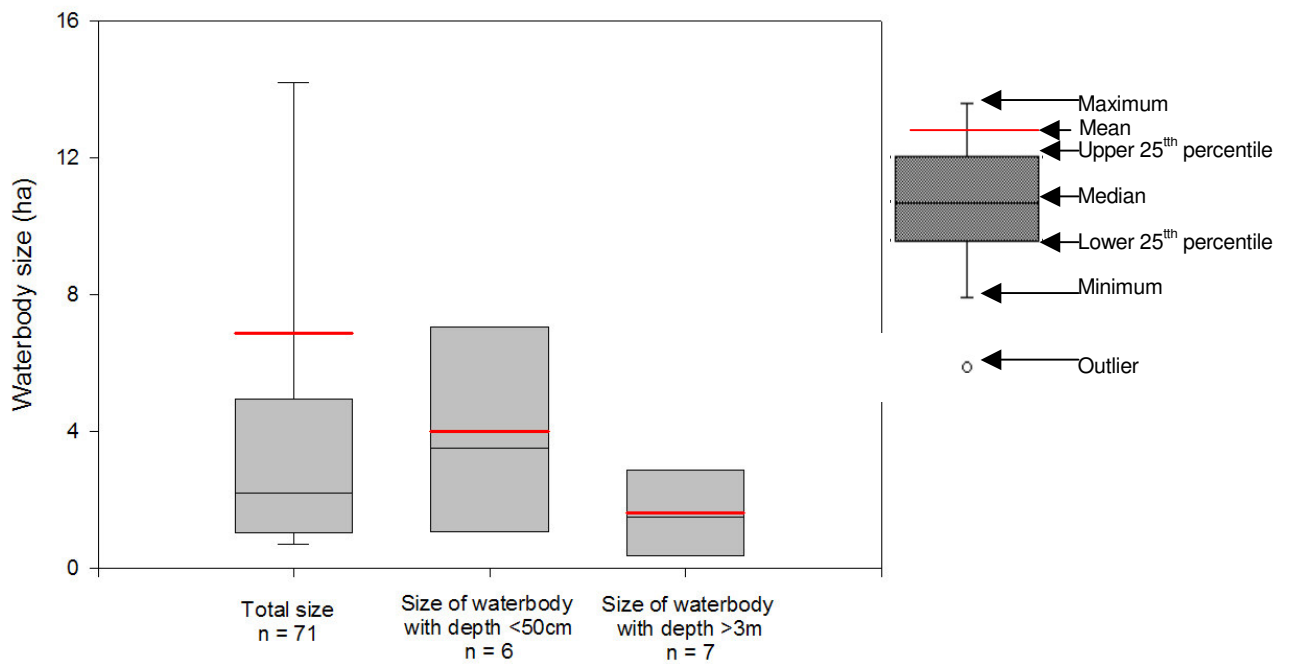


Figure 3-2 Water Body Surface Area

3.2.2 Water body Volume

From the data supplied, only 14 of the 83 water bodies had information regarding their volumes. Hence, the calculated statistics for water body volume may not be truly representative of the region's urban water bodies. From the data available, the median volume was approximately 38 ML with a range of 11 to 12000 ML.

3.2.3 Water body Depth

Maximum water body depth was provided for 26 of the 83 water bodies and showed that a maximum depth of 10 m, with a median depth of 3.9 m. Anecdotal evidence suggested that some water bodies within the Gold Coast have maximum depths significantly greater than this, especially in the Burleigh Lakes system.

3.2.4 Waterbody perimeter

Most participating councils provided relatively good information of the perimeter of waterbodies within their jurisdiction. Perimeter data was reported for 64 of the 83 water bodies. The range in water body perimeter length was large (290m – 20,000m) within the data set, with the Gold Coast Council waterbody “Clear Waters Island” being 13,000m longer than any other waterbody within SEQ. This lead to the calculated mean waterbody perimeter within SEQ being greater than the majority of the data set. Approximately 75% of the waterbodies within the participating SEQ local government areas have a perimeter length of between 500 and 1000m. Four out of the eleven waterbodies within Gold Coast City exceed a perimeter length of 3000m.

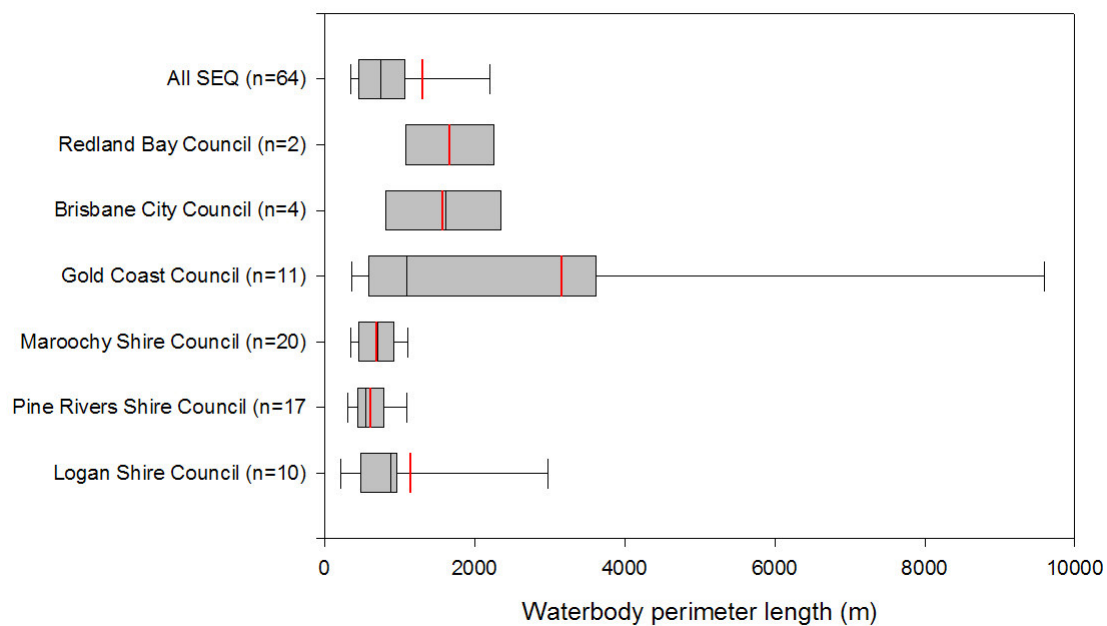


Figure 4: Perimeter length of waterbodies within SEQ LGA's. Note n values.

3.2.5 Contributing Catchment Area

Contributing catchment area was reported for 49 of the 83 water bodies. The size of the contributing catchment varied significantly, ranging from 7.5 ha to 12,000 ha. The median catchment area of submitted data was 77 ha. Combining this with the median surface area of 2.2 ha yields a median surface area to catchment area ratio of 2.8%. Contributing catchments containing a mean of approximately 70% urbanised area. Of the 38 systems which had data on percentage urbanisation, 13 reported catchments with greater than 90% urban area.

3.3 Water Quality

3.3.1 Overview

Table 3-2 summarises the water quality data obtained through the survey and also provides a comparison of the measured parameters against regional guidelines for physico-chemical parameters in lakes and reservoirs in South East Queensland (Table 2.5.1.1, EPA 2006).

Based on the high nutrient and chlorophyll-a concentrations, the collected data indicates that urban water bodies in SEQ are typically eutrophic to hypertrophic. Hence, control of nutrient loads into urban water bodies is a key management issue if phytoplankton and cyanobacterial blooms are to be minimised.

Table 3-2 Summary of water quality data for urban water bodies

	No. waterbodies with data	Total no. of samples	Min.	Max.	Median	Std Dev	Guideline Value
Turbidity (NTU)	9	333	0.87	27.3	3.3	8.5	1 - 20
TN (mg L ⁻¹)	13	545	0.34	3.25	0.55	0.79	0.35
TP (mg L ⁻¹)	28	545	0.01	0.34	0.10	0.08	0.01
Chlorophyll <i>a</i> (µg L ⁻¹)	7	275	6	50	10	17.9	5
DO (%)	29	426	36.60	125.0	87 (Mean)	22.31	90 - 110

In addition to the quantitative water quality data, local governments were requested to provide a qualitative anecdotal description of water quality in their water bodies. This general water quality description rated water quality as typically good, fair, poor or very poor. Anecdotal descriptions were provided for 41 of the 83 water bodies. This anecdotal information provides an indication of the number of issues raised for particular systems, rather than an assessment of actual water quality data. The anecdotal reports indicated:

- 17 systems with “good” water quality,
- 14 systems with “fair” water quality,
- 5 systems with “poor” water quality,
- 4 systems with “very poor” water quality.

Further anecdotal comments received from some of the participating local government officers included:

- The presence of large bird populations was perceived to have a negative impact on water quality;
- Cyanobacteria blooms were noted to occur in some water bodies;
- Odour issues were identified in many of these water bodies.

3.3.2 Turbidity

Turbidity indicates the clarity of the water column, a key feature of the aesthetics of a water body. Turbidity within water bodies can be very high during the construction phase of urban development (see Figure 3-3), but will typically decline during establishment of a functional aquatic ecosystem.

In the case of water bodies in SEQ, the median turbidity was determined as 3.3 NTU, which is within the range of the QWQG WQO of 1-20 NTU. The maximum recorded turbidity in any of the data sets was 27 NTU, which while high, still indicates a system that is relatively stable (values of 100 NTU or greater would indicate a system still influenced by construction phase inputs). This low median turbidity indicates that the majority of urban water bodies have low turbidities. While this may be seen as desirable, when combined with elevated nutrients, it would suggest that conditions in the majority of systems are conducive to phytoplankton production.



Figure 3-3 Turbid Water During Construction Phase

3.3.3 Nutrients (Nitrogen and Phosphorus)

The concentrations of nutrients, such as Nitrogen and Phosphorus, are important parameters in assessing the overall ecosystem health of a water body. Elevated nutrient concentrations can indicate the effects of catchment or point source pollution and substantially increase the risk of phytoplankton or cyanobacterial blooms.

Determining the concentrations for Nitrogen and Phosphorus requires skill and care in the sampling, preservation and analysis and several techniques are available, each of which can potentially yield significantly different results. For this reason, it is important to consider these methods when reviewing nutrient results before any detailed comparisons between different water quality data sets can be made. In the review of the data collected in this study, measures of nutrient concentration

obtained by in-situ or handheld probes (which are usually only sensitive to one nutrient species) were not included in the analysis.

Collation of the data for nutrients indicated a maximum Total Nitrogen concentration of 3.3 mg/L, with a median value of 0.55 mg/L. This median is greater than the QWQG WQO of 0.35 mg/L and would indicate eutrophic conditions generally dominate urban water bodies in SEQ.

The occurrence of eutrophic conditions is further supported by the median Total Phosphorus concentrations of 0.10 mg/L, which is an order of magnitude greater than the QWQG WQO of 0.01 mg/L. For the 28 water bodies with water quality data available, only two had concentrations equal to or less than the TP WQO.

3.3.4 Chlorophyll-a

The use of chlorophyll-a as an indicator is beneficial in gauging the phytoplankton biomass and can be the best indicator in determining whether “bloom” conditions are occurring. In some larger water storages in the region, chlorophyll-a concentrations have been directly related to phytoplankton blooms such that regression equations for the two parameters have been developed.

Unfortunately in urban water bodies, chlorophyll-a is not regularly determined in the majority of systems, hence data was only available for seven water bodies. These indicated a median chlorophyll-a of 10 ug/L, which is significantly higher than the QWQG WQO of 5 ug/L. A maximum value of 50 ug/L was also recorded in the data which likely indicates a phytoplankton bloom was occurring when this result was obtained.

3.3.5 Dissolved Oxygen

Dissolved Oxygen is a measure of how much available oxygen is present within the water column. As this is a critical factor in the survival of most aquatic fauna, low dissolved oxygen concentrations can indicate that the aquatic ecosystem is not able to sustain organisms. The difficulty of using dissolved oxygen as an indicator is that it is significantly influenced by a range of factors, including photosynthesis and respiration of aquatic plants, which may raise or lower dissolved oxygen depending on the time of day when it is measured (i.e. diurnal variation). As such, dissolved oxygen readings are only an indicator of water body ecosystem health and should be viewed with some caution.

From the data provided, the mean dissolved oxygen saturation was 87%, only slightly below the lower limit specified in Queensland Water Quality Guidelines (QWQG) the water quality objective (WQO) of 90-110%. The maximum of all data was 125%, suggesting super-saturation of dissolved oxygen, which can be associated with eutrophic conditions.

3.3.6 Management Measures to Improve Water Quality

From the submitted data, some form of stormwater quality treatment was provided for 23 of the 83 identified systems. Water quality treatment measures were identified as either pre-treatment of inflows (using, for example, constructed wetlands, gross pollutant traps or bioretention systems), or in-situ treatment (such as mechanical destratification, aeration or recirculation). In-situ treatment of water bodies was usually through mechanical aeration and/or destratification devices which aimed to improve mixing of the water column.

The presence of in-situ treatment devices or pre-treatment measures did not correlate with water bodies having better water quality. This may be for a range of reasons, including treatment measures still in establishment phases or possibly that water bodies with the poorest water quality usually receive a larger investment in water quality treatment. It should be noted also that no correlation was found between anecdotal water quality and catchment size to water body surface area ratio or any other variable.



Figure 3-4 Water body Bioretention Pretreatment System

4 MAINTENANCE PRACTICES AND COSTS

Maintenance cost data was provided for 20 of the 83 water bodies identified in the survey. In recent research on WSUD maintenance costs for a local government in SEQ, it was found that itemised costs were often not tracked against individual assets, but as part of other maintenance programs (e.g. grass cutting, park maintenance etc), or were simply collated into an overall stormwater maintenance program (BMT WBM 2007). This method of cost tracking made it difficult to clearly identify maintenance costs for individual water bodies.

Maintenance activities can be divided into **routine** maintenance and **corrective** maintenance. Routine maintenance consists of regular tasks or expenses necessary to operate and maintain an acceptable level of functionality of the system. For example, vegetation harvesting, cleaning of pre-treatment devices or running costs for an artificial recirculation system. These are costs that can be anticipated on a regular cycle. Corrective maintenance includes works required to restore deteriorated or malfunctioning components of the system. For example, repair of revetment walls or installation of an in-situ treatment system. These costs are more difficult to estimate and can often involve substantial expenditure. Major corrective maintenance activities were undertaken by all councils submitting cost data. Based on the analysis of the maintenance data, the **management of vegetation** within waterbodies and **corrective maintenance procedures** were the two most significant maintenance activities undertaken by councils.

Typical maintenance activities undertaken by councils to manage constructed urban water bodies included:

- Vegetation management (macrophyte harvesting, terrestrial weed management etc);
- Desilting (removal of accumulated sediment from specific areas or the whole water body);
- Corrective maintenance (usually to fix specific issues);
- Decommissioning/disposal (filling in of waterbodies or complete replacement with other systems, e.g. wetlands);
- Development of management plans (to address specific issues or for overall water body management);
- Edge treatments (e.g. replacement or establishment of revetment walls);
- Water quality monitoring;
- Bathymetry surveys;
- Management of animal pests;
- In-situ treatment costs (e.g. destratification systems);
- Research; and
- Pretreatment maintenance (e.g. GPT maintenance).

The distribution of costs to these activities is shown in Figure 4-1 and Table 4-2.

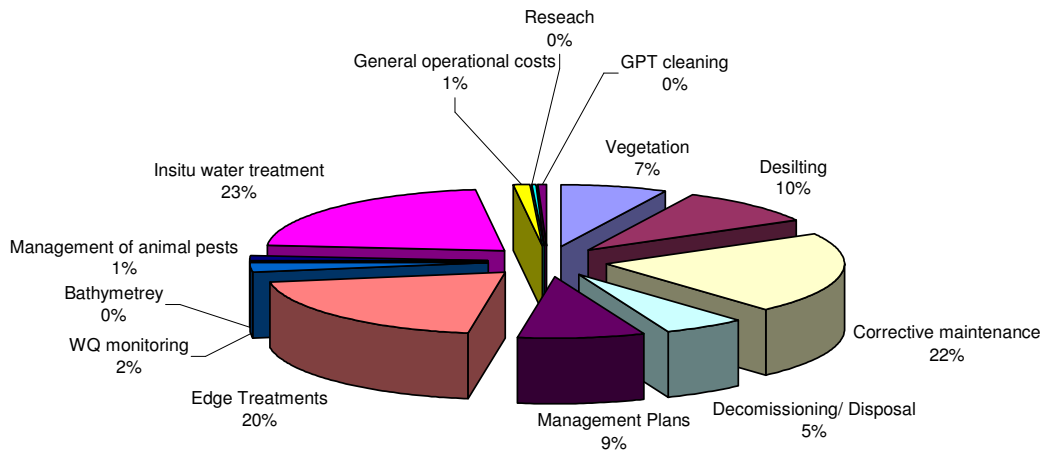


Figure 4-1 Distribution of costs to maintenance activities

Table 4-1 Maintenance Cost Summary (2006 \$K)

Maintenance Practice	Sum for practice	Min	Max	Median	Mean	n
Vegetation	\$351	\$4	\$100	\$10	\$18	18
Desilting	\$457	\$7	\$300	\$150	\$152	3
Corrective maintenance	\$958	\$52	\$750	\$200	\$334	3
Decomissioning/ Disposal	\$255	\$250	\$250	\$250	\$250	1
Management Plans	\$412	\$8	\$350	\$50	\$136	3
Edge Treatments	\$925	\$5	\$900	\$13	\$233	4
WQ monitoring	\$111	\$1	\$48	\$6	\$10	11
Bathymetry	\$7	\$7	\$7	\$7	\$7	1
Management of animal pests	\$56	\$5	\$20	\$6	\$8	8
Insitu water treatment	\$1,011	\$15	\$520	\$105	\$168	6
General operational costs	\$69	\$2	\$23	\$8	\$10	5
Research	\$123	\$9	\$9	\$9	\$9	2
GPT cleaning	\$20	\$20	\$20	\$20	\$20	1
<i>For all systems where data was provided</i>						
	Total Expenditure	Min	Max	Median	Mean	n
2006 \$K	\$4,755	\$1.2	\$1,586	\$32	\$233	20

Table 4-2 Summary of total routine and corrective maintenance costs for 20 urban waterbodies within SEQ during 2005/06.

Maintenance Type	Total Cost (\$)	Cost per ha Surface Area (\$)
Routine maintenance	\$3,025,000	\$11,300
Corrective maintenance	\$1,730,000	\$6,500
Total (Routine & corrective maintenance)	\$4,755,000	\$17,800

Note: Total surface area of costed waterbodies = 268 ha.

The total sum of routine and corrective maintenance costs for the 2005/06 financial year for the 20 identified waterbodies was \$4,755,000. As shown in Table 4-2, routine maintenance of the relevant urban waterbodies in 2005/06 totalled just over \$3 million dollars. Corrective maintenance procedures over the same period totalled about \$1.7 million. The distribution of costs to different maintenance activities for the three local governments submitting cost data is shown in Figure 4-2.

Based on the surface area of maintained urban waterbodies (268 ha), the total cost of routine maintenance procedures per unit area is about \$11,300 per ha for 2005/06. Corrective maintenance costs over this period totalled \$6,500 per ha for the 05/06 annual period (Table 4-2). Note that unit area costings should be considered with caution, since maintenance expenditure is dependent upon a wide range of factors and thus highly non-linear. However, in the absence of better information on maintenance costs, these figures provide an indication of the order of magnitude of costs for maintenance of constructed urban water bodies in SEQ.

The costs collected in the survey do not account for the adequacy of the maintenance program. Based on feedback from local government officers during the data collection process, it is likely that many of these water bodies are “under-maintained”, with maintenance costs deferred until water quality or some other element of the system deteriorates to a level which generates community complaints. Restoration of such degraded (typically eutrophic) systems was consistently identified as being costly, with significant uncertainty around the likely success of any proposed corrective maintenance program.

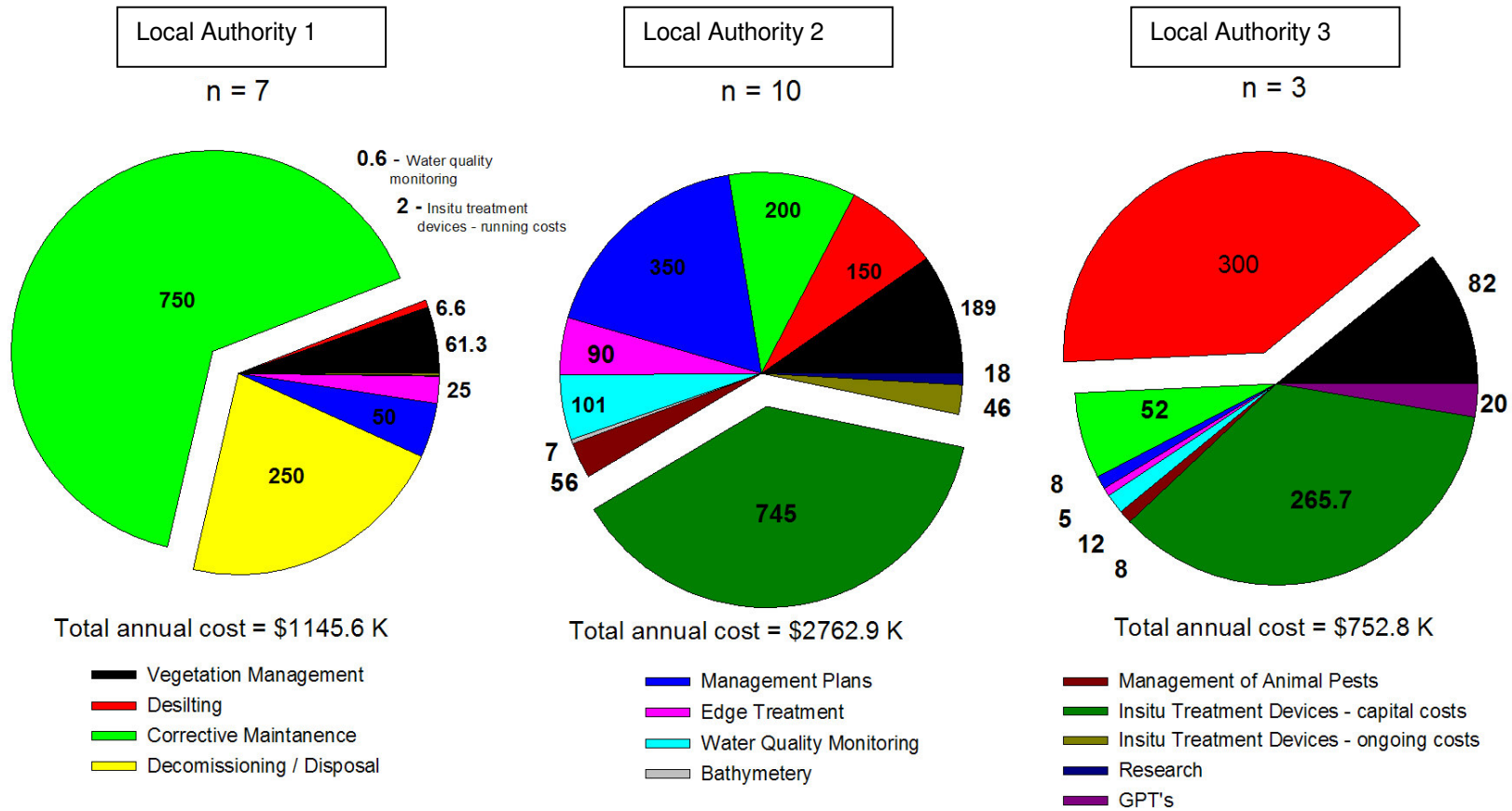


Figure 4-2 Individual LGA Maintenance Costs

5 CONCLUSION

Data provided by SEQ councils indicates that local government in this region is responsible for the maintenance of at least 83 major constructed urban waterbodies. This does not include the large number of smaller water bodies (less than 0.5 ha) which were excluded from the study. The median surface area of waterbodies identified in the survey was 2.2 ha, with a combined total surface area exceeding 490 ha.

Representative nutrient concentrations in urban waterbodies across the region substantially exceed guideline values for acceptable water quality. Whilst stormwater inflows are the dominant source of nutrient compounds in urban waterbodies, the behaviour and ultimate fate of nutrients within the water column will ultimately depend on the trophic links within the system. An oversupply of nutrients, relative to the assimilative capacity of the system, will most likely result in the degradation of water quality, either through algal blooms, cyanobacteria blooms or excessive macrophyte growth. This appears to be the case in many of the artificial urban waterbodies in SEQ. Since most Australian freshwater aquatic environments tend to be phosphorus limited (Davis and Koop 2006), reducing the supply of phosphorus to a waterbody may have a greater water quality benefit than reducing the nitrogen supply.

In the 2005/06 financial year, Brisbane City, Maroochy Shire and Gold Coast City spent an estimated total of nearly \$4.8 million on maintenance activities for constructed urban waterbodies. Almost two-thirds of this amount was spent on routine maintenance (such as vegetation harvesting and cleaning of pre-treatment devices) and the remainder on corrective maintenance required to restore deteriorated or malfunctioning components of the system. Management of aquatic vegetation was identified as the most significant routine maintenance cost.

The available data, though limited, provides an indicative routine maintenance cost of the order of \$11,000 per ha per year for the constructed waterbodies represented in this study. It is possible that the cost per hectare for maintaining smaller water bodies (less than 0.5 ha), which were not included in the study, could be substantially higher. Applying this indicative unit rate across all waterbodies represented in the survey, the total annual cost of routine maintenance is of the order of \$5 million. Corrective maintenance activities are a significant additional cost. Since most waterbodies do not meet relevant water quality objectives, it is likely that this underestimates the full cost that would be required to maintain waterbodies at an acceptable water quality standard in the long term.

The data collected during this study, provides some insight into the magnitude of maintenance issues associated with constructed urban waterbodies, as well as key areas of research and management action to improve system performance and reduce maintenance costs in the long term. Key research and management issues that can be inferred from the results of the study include the need for:

- Ongoing research to improve the understanding of nutrient cycling processes and limnological behaviour of typical urban waterbodies under local conditions. The USEPA are currently undertaking such a research program in the USA (the "National Lakes Inventory", USEPA 2007).
- Development of reliable remediation strategies for eutrophic systems. Waterbody remediation guidelines would provide an increased level of confidence that a proposed

remediation strategy would achieve a defined level of improvement in water quality at minimum cost.

- Development of locally-relevant design and maintenance guidelines for urban waterbodies. These guidelines would ensure that any new systems are designed, constructed and maintained to prevent eutrophication.
- Wider dissemination of learnings between different local governments. Some of the work that has been undertaken by councils in studying and developing management plans for their constructed water bodies should be shared with others across the region.
- Development of a regionally consistent water quality monitoring program for constructed urban water bodies to ensure that data is collected with similar frequency and analysed using consistent methods across the different local government areas.
- Implementation of a regionally consistent protocol for collection of data on maintenance activities and costs for constructed urban waterbodies. The data generated through this process would improve the ability of local government to plan the allocation of maintenance resources.
- Local government to consider options to ensure that a financially sustainable management regime is implemented for any proposed new urban waterbodies.

APPENDIX A: REFERENCES

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APPENDIX B: RAW DATA – PHYSICAL PROPERTIES

Council area	Waterbody Name	Surface Area (ha)			Stored Volume at Full Supply Level (ML)	Maximum Depth (m)	Average Depth (m) [Vol/Area]	Perimeter Length (m)	Total Catchment Area Including Upstream Storages (ha)	Proportion of Catchment Urbanised (%)
		Total	< 0.5 m Depth	> 3 m Depth						
LoganCC	Riverlak	3.5	.	.	.	.	680	20	65
LoganCC	South Gr	1.2	.	.	.	.	890	.	.
LoganCC	North Gr	2.4	.	.	.	.	930	.	.
LoganCC	Berrinba	16	.	.	.	.	5500	3000	70
LoganCC	J J Smit	2.2	.	.	.	.	1290	3500	70
LoganCC	Griffith	1	.	.	.	.	360	65	80
LoganCC	Griffith	3.1	.	.	.	.	980	80	75
LoganCC	Lake Den	2.2	.	.	.	5	670	20	85	
LoganCC	Cable Sk	4.8	.	.	.	.	900	10	40
LoganCC	Riverdal	0.6	.	.	.	.	420	7.5	15
PRSC	Black Du	2.55	.	.	.	.	862	29.72	100
PRSC	Black Du	1.8	.	.	33	3.85	576	10.04	100	
PRSC	Black Du	1.1	.	.	.	.	342	53.72	80
PRSC	Black Du	3.19	.	.	.	.	723	75.63	50
PRSC	Black Du	1.38	.	.	.	.	465	92.25	80
PRSC	Black Du	3.43	.	.	.	.	714	111.3	75
PRSC	Halpine	4.5	.	.	.	.	1196	47.95	9
PRSC	Ross Res	1.56	.	.	.	.	856	380.4	60
PRSC	Barwon S	0.92	.	.	.	.	518	26.59	95
PRSC	Mungara	0.87	.	.	.	.	431	19.5	35

Council area	Waterbody Name	Surface Area (ha)			Stored Volume at Full Supply Level (ML)	Maximum Depth (m)	Average Depth (m) [Vol/Area]	Perimeter Length (m)	Total Catchment Area Including Upstream Storages (ha)	Proportion of Catchment Urbanised (%)
		Total	< 0.5 m Depth	> 3 m Depth						
PRSC	Hayward	0.58	.	.	.	.	.	442	31.8	55
PRSC	Pine Riv	3.04	.	.	.	.	.	795	146.6	20
PRSC	Lake Ede	5.14	.	.	.	.	.	1448	184.3	55
PRSC	Pine Riv	1.15	.	.	.	.	.	441	166.1	80
PRSC	Pine Riv	1.26	.	.	.	.	.	584	192.8	80
PRSC	Kumbartc	0.84	.	.	.	.	.	509	77.07	5
PRSC	Willow G	0.61	.	.	.	.	.	303	58.73	5
MarooSC	Lake-Dal	3.04	.	.	.	.	.	1029	.	.
MarooSC	Lake-Mt	2.64	.	.	.	.	.	990	.	.
MarooSC	Lakeshor	2.46	.	.	.	.	.	1165	.	.
MarooSC	Mapleton	2.14	.	.	.	.	.	866	.	.
MarooSC	Mountain	1.85	.	.	.	.	.	787	.	.
MarooSC	Nelson P	1.71	.	.	.	.	.	1051	.	.
MarooSC	Allora G	1.47	.	.	.	.	.	746	.	.
MarooSC	Kolora P	1.05	.	.	.	.	.	591	.	.
MarooSC	Botanic	0.79	.	.	.	.	.	501	.	.
MarooSC	Mangrove	0.76	.	.	.	.	1.5	339	.	.
MarooSC	Un-named	0.5	.	.	.	.	.	290	.	.
MarooSC	Chancell	0.68	.	.	11.44	3.04	1.82	469	82	.
MarooSC	Chancell	0.71	.	.	16.06	3.37	2.11	385	95	.
MarooSC	Chancell	1.61	.	.	26.15	3.32	1.57	684	162	.
MarooSC	Chancell	1.02	.	.	31.39	5.47	3.06	446	162	.
MarooSC	Chancell	0.83	.	.	29.61	4.45	3.57	363	184	.
MarooSC	Chancell	1.31	.	.	64.31	6.5	5.03	798	198	.

Council area	Waterbody Name	Surface Area (ha)			Stored Volume at Full Supply Level (ML)	Maximum Depth (m)	Average Depth (m) [Vol/Area]	Perimeter Length (m)	Total Catchment Area Including Upstream Storages (ha)	Proportion of Catchment Urbanised (%)
		Total	< 0.5 m Depth	> 3 m Depth						
MarooSC	Chancell	1.78	.	.	64.97	7.2	3.79	520	218	.
MarooSC	Chancell	2.97	.	.	162.65	8.65	6.69	1190	265	.
MarooSC	Chancell	2.91	.	.	172.23	8.5	6.07	867	296	.
GoldCC	Robina S	65	2	55	12000	9	4	7000	3.3	100
GoldCC	Robina W	20	1	15	.	7	3	4000	3.3	100
GoldCC	Clear Is	95	3	85	.	10	6	20000	119	60
GoldCC	Rosser P	2.4	.	.	42	3	2	960	4	100
GoldCC	Lake Lom	6	.	.	.	.	.	480	4	100
GoldCC	Pizzey P	6	.	.	.	.	3	1100	4	.
GoldCC	Lake Hug	17	1	8	.	.	2.5	3500	3	100
GoldCC	Waterhen	9	.	.	.	.	.	1100	3	98
GoldCC	Oxenford	7	.	.	.	.	.	620	3	100
GoldCC	Coomera	3	.	.	.	.	.	450	.	50
GoldCC	Lake San	5	.	1.5	.	.	3	780	2	100
CalCC	Poole Rd	4	.	.	.	1.5	.	.	.	.
CalCC	Parreara	40	.	.	.	2	.	.	.	.
CalCC	Lake Mag	11	.	.	.	2	.	.	.	.
CalCC	Lake Kaw	50	.	.	.	2	.	.	.	.
CalCC	Ivadale	0.7	.	.	.	4	.	.	.	.
CalCC	Ivadale	0.6	.	.	.	4	.	.	.	.
CalCC	Farm dam	1.2	.	.	.	3	.	.	.	.
BCC	Nudgee W	.	.	.	.	.	.	.	.	.
BCC	Dowse La	13	.	.	420	1.8	1.5	1228	30	100
BCC	Einbumpi	.	.	.	.	.	.	400	.	.

Council area	Waterbody Name	Surface Area (ha)			Stored Volume at Full Supply Level (ML)	Maximum Depth (m)	Average Depth (m) [Vol/Area]	Perimeter Length (m)	Total Catchment Area Including Upstream Storages (ha)	Proportion of Catchment Urbanised (%)
		Total	< 0.5 m Depth	> 3 m Depth						
BCC	Third L	.	.	.	.	.	2000	.	.
BCC	Fourth L	.	.	.	.	.	.	.	.
BCC	Canterbu	.	.	.	.	.	.	.	.
BCC	Harold K	.	.	.	.	.	.	.	.
BCC	Yorks Ho	.	.	.	.	.	.	.	.
BCC	Cressey	0.5	.	.	.	.	.	113	100
BCC	Duckpond	.	.	.	.	.	.	.	.
BCC	DuckPond	.	.	.	.	.	.	.	.
BCC	DuckPond	.	.	.	.	.	.	.	.
BCC	Lakewood	11.6	8.25	3.35	.	.	.	.	.
BCC	Forest L	10.9	.	.	272	4	2	2700	248	
BCC	Westlake	5	3.5	1.5	.	3.5	1.5	.	108	
BCC	Bowies F	0.8	0.25	0	.	2.4	1.2	.	195	
BCC	Tilleyda	.	.	.	.	.	.	.	.
RSC	Orchard Beach	1.32	.	.	.	.	.	2258	.
RSC	Old Turf farm	0.98	.	.	.	.	.	1081	.

