Extended Cost-Effectiveness of Water Supply Options: Case Study of the Total Water Cycle Management Plan for Moreton Bay Regional Council

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The Urban Water Security Research Alliance (UWSRA) is a $50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

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FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, through targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, eWater CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a $50 million partnership over five years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- ensuring the reliability and safety of recycled water systems.
- advising on infrastructure and technology for the recycling of wastewater and stormwater.
- building scientific knowledge into the management of health and safety risks in the water supply system.
- increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at http://www.urbanwateralliance.org.au/about.html.

Chris Davis
Chair, Urban Water Security Research Alliance

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EXECUTIVE SUMMARY

This report demonstrates the use of extended cost-effectiveness analysis for evaluation of water supply options. The case study has two parts – a section that defines pollutant costs and benefits and a section that applies the pollutant costs to water supply options evaluation. Two catchments within the Draft Total Water Cycle Management Plan (TWCMP) for Moreton Bay Regional Council (MBRC) were used as a case study.

The use of extended cost-effectiveness analysis can simplify triple bottom line assessments of water supply options and is particularly applicable to catchments with receiving water constraints. The extended cost includes the cost of water supply and the cost of abatement of pollution from the water supply option. The monetisation of pollutant flows allows water supply and environmental costs to be added together as an alternative to weighting processes in Multi Criteria Analysis.

'Willingness to pay' studies in South East Queensland (SEQ) suggested that water quality issues capture most of the benefits associated with resource management. The benefit of avoiding decline in waterway health in the Caboolture catchment over the next 20 years was about $330 million dollars in present value. Achieving legislated water quality objectives would provide an additional benefit of $138 million in present value.

Marginal Abatement Cost Curves were developed for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS). The following curves illustrate the average abatement cost and benefit per tonne of pollutant to meet the 'no worsening' load target over the 20-year planning period. In summary, the weighted average cost of abatement was $334 000 per tonne, $40 000 per tonne and $213 per tonne for TP, TN and TSS, respectively. A cost of $23 per tonne was assumed for greenhouse gas (GHG) emissions.

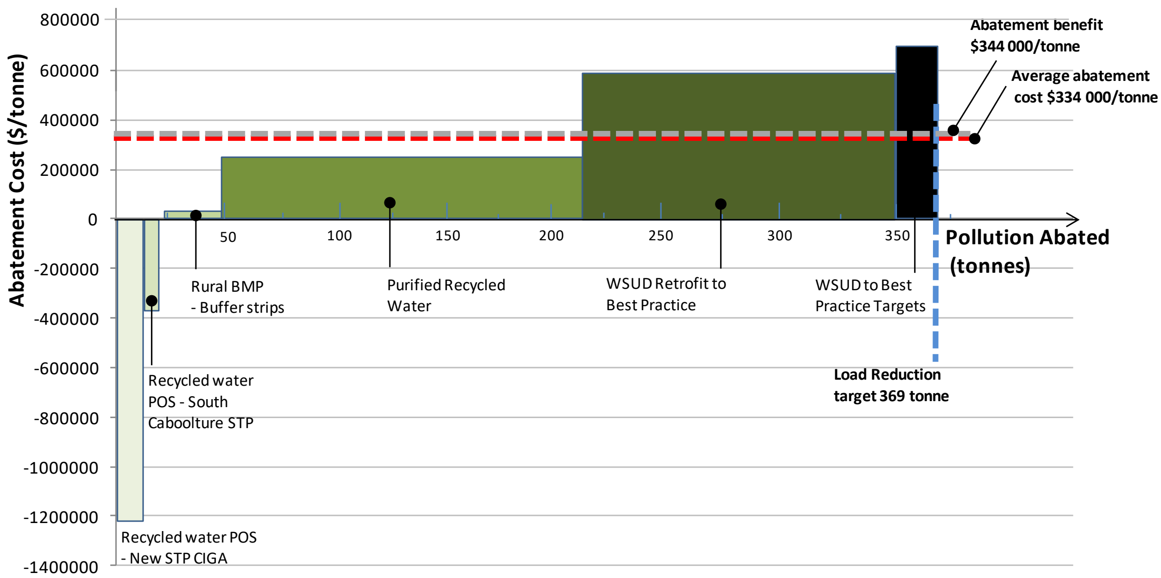

Figure 1. Total Phosphorus Marginal Abatement Cost Curve for 'no worsening' of waterways in the Caboolture catchment.

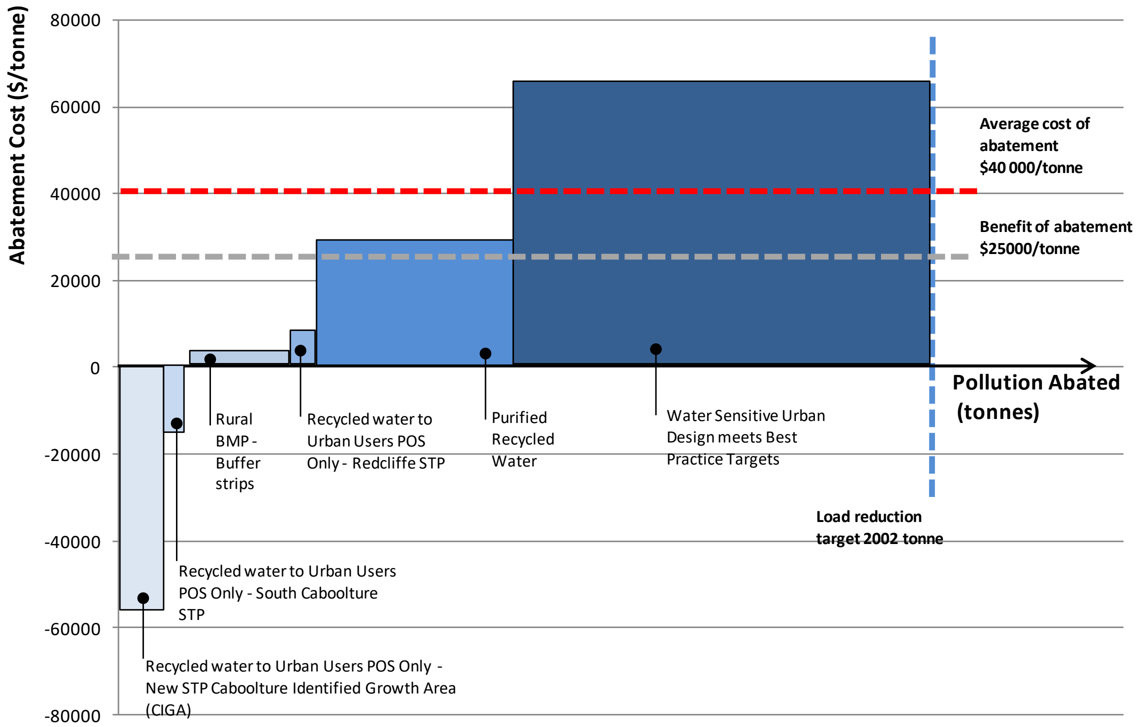

Figure 2. **Total Nitrogen abatement cost and benefit for 'no worsening' load reduction target.**

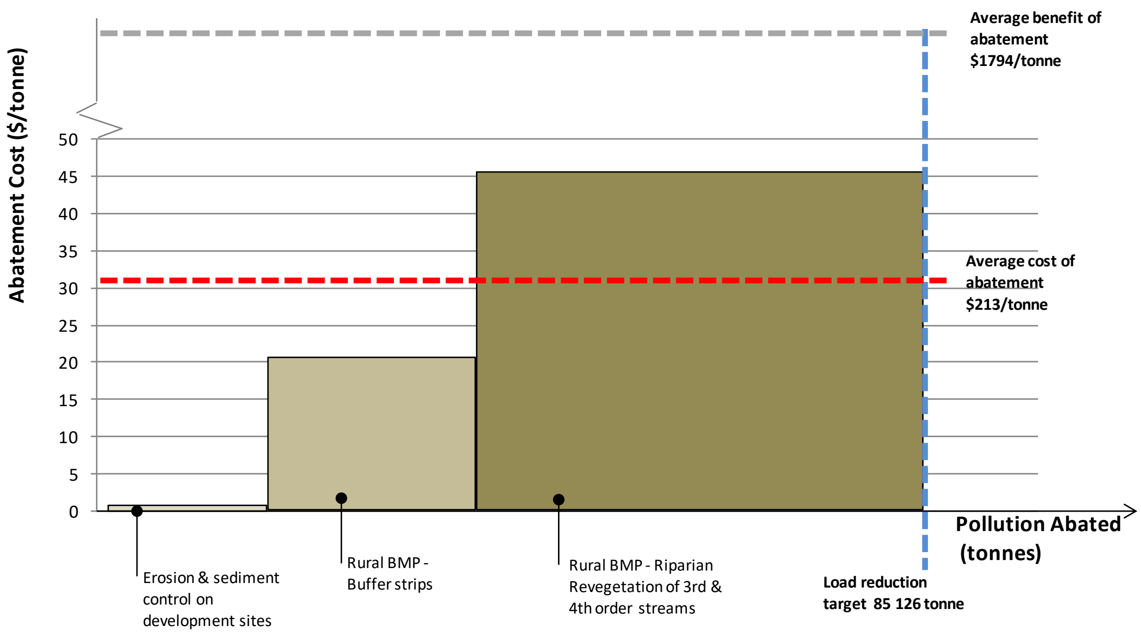

Figure 3. **Total Suspended Solids abatement cost and benefit for 'no worsening' load reduction target.**

The abatement of TSS had a very high benefit to cost ratio for achieving the 'no worsening target'. This suggests it should be a priority for water quality expenditure and that additional abatement beyond 'no worsening' should be considered because the marginal benefit is likely to be greater than the marginal cost. This also suggests that it may be more cost-effective to 'trade' pollution abatement of nutrients for sediment abatement to achieve water quality improvements.

The following results show a comparison of water supply and water supply plus pollution costs. Water supply options such as water recycling, stormwater harvesting and rainwater tanks reduced water pollution flows which resulted in cost savings for abatement. The ranking of options did not change when considering pollutant costs. However, the sensitivity analysis suggested that upper range value for pollutant abatement costs could potentially change the ranking of options such as recycled water compared to the bulk water supply.

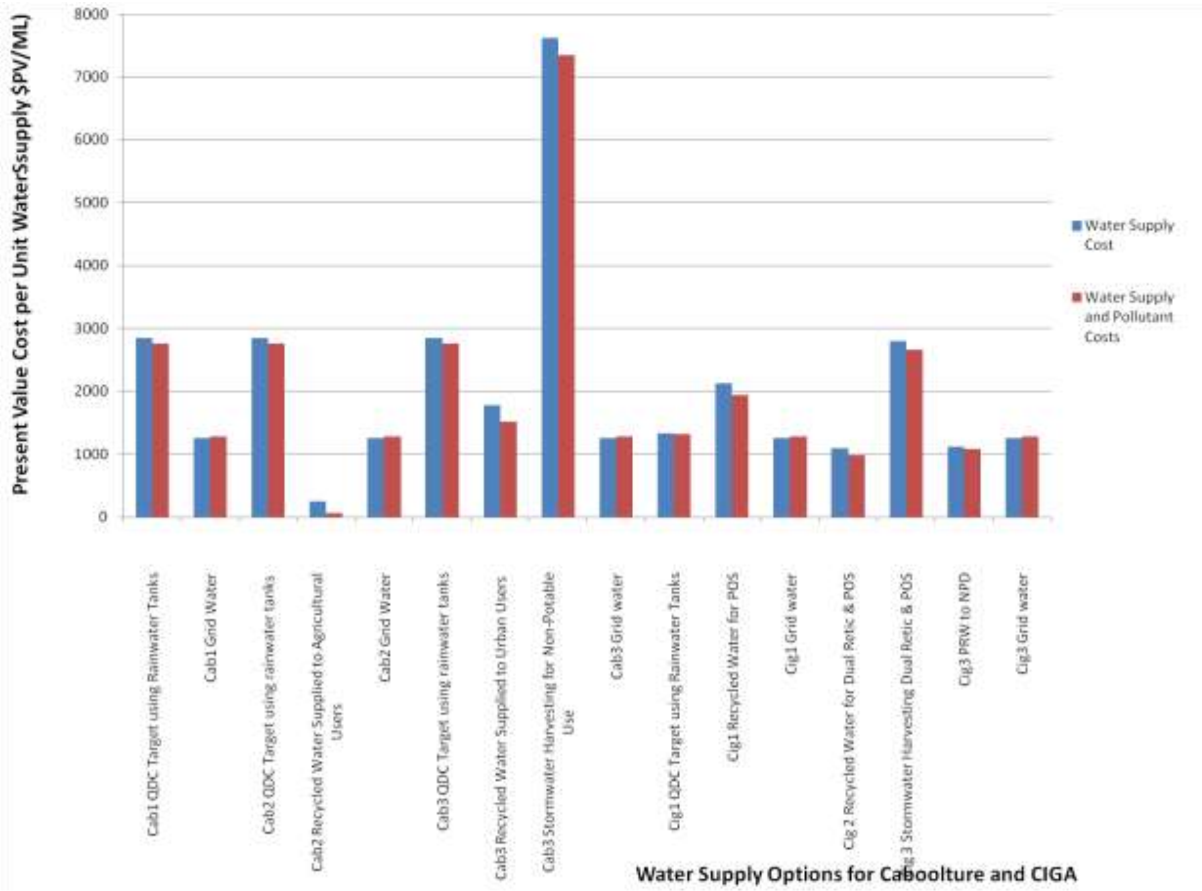

Figure 4. Comparison of Project Cost and Extended Cost-effectiveness for a unit of water supply for Caboolture and CIGA Catchment Options.

The following figure provides a comparison of the cost components for the extended cost of water supply options. Nutrient abatement for water supply options such as recycling had the largest effect on the cost-effectiveness. Water supply options such as stormwater harvesting also had a small cost saving for sediment abatement while grid water had a very small additional cost for GHG pollution. The effect of various pollutants on the cost-effectiveness was largely a function of the abatement cost. For example, the abatement cost per tonne of TP was over ten thousand times higher than the cost for abating carbon dioxide.

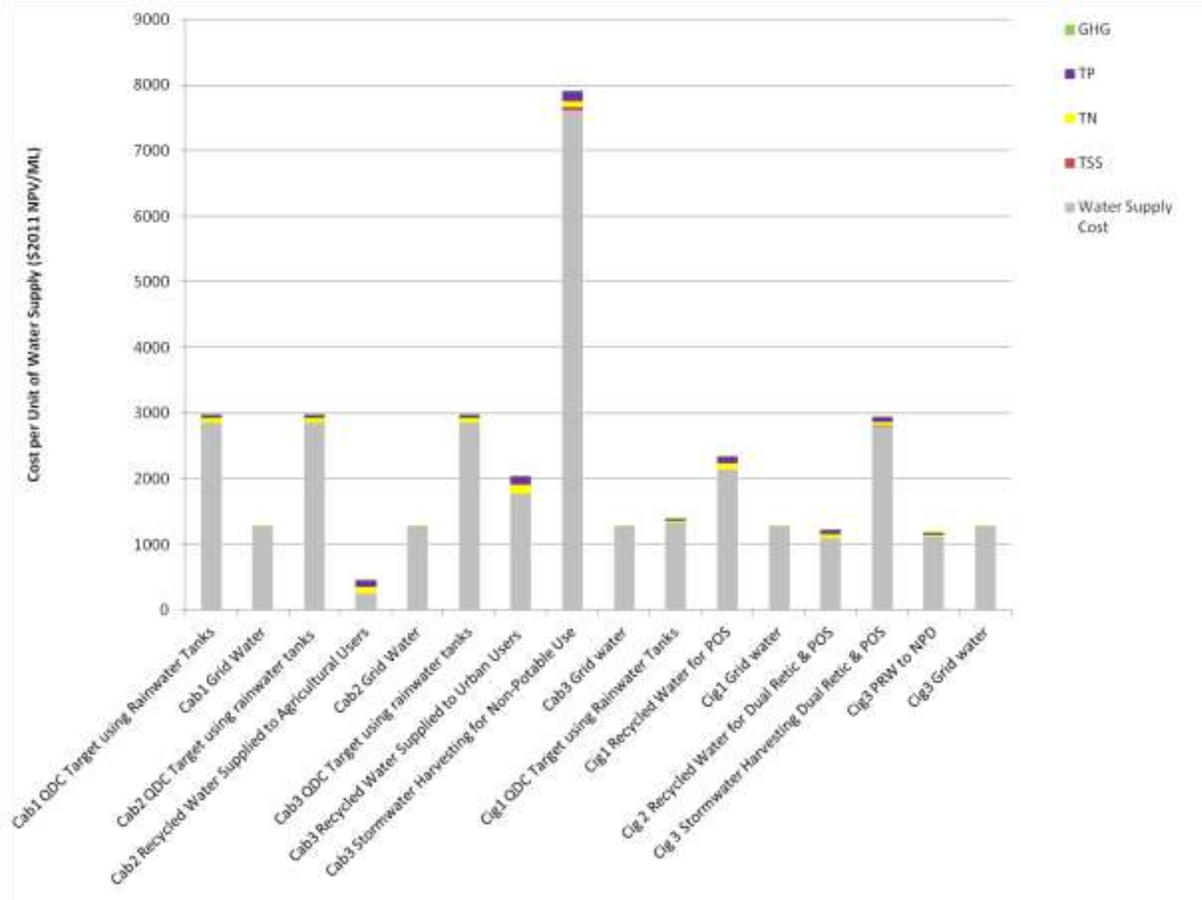

Figure 5. Contribution of water supply and pollution costs to the extended cost-effectiveness of water supply options.

Some caution is required when applying the data in this report to another TWCMP. The cost of pollution depends upon the range of abatement options available in the catchment. The abatement options in the case study were based upon the draft TWCMP for MBRC and did not include point source or agricultural abatement of nutrients. In addition, catchment characteristics such as slope can affect cost and performance of abatement options and need to be considered for each catchment.

The pooling of resources from a number of TWCMPs may provide the most cost-effective approach to improving water quality in the region. Willingness to pay studies suggest that residents in one part of SEQ are willing to pay for improvement in other parts of SEQ if it is more cost-effective. This would require setting priorities for improvement across the region and may link with policies such as Water Quality Trading. However, this requires cooperation and coordination across council areas and linking TWCMPs rather than consider them in isolation.

1. INTRODUCTION

This report provides an example of applying pollution abatement costs to Total Water Cycle Management (TWCM) planning, and aims to support water supply options evaluation by including pollutant costs in cost-effectiveness analysis. A case study for Moreton Bay Regional Council (MBRC) Total Water Cycle Management Plan (TWCMP) was used as a demonstration. The case study has two parts – a section that defines pollutant costs for MBRC and a section that applies the pollutant costs to options evaluation. The method draws upon the companion report *Cost of Pollution: Supporting Cost-effective Options Evaluation and Pollution Reduction* (Hall 2012).

The current Draft TWCMP for MBRC uses Multi Criteria Analysis (MCA) for options evaluation (BMT-WBM 2010; BMT-WBM 2012). Many of the environmental, social and economic criteria in the MCA were related to water quality. In addition, a 'willingness to pay' study performed in the region found that most benefits for natural resource management were related to water quality (Binney 2010). This suggests that capturing water quality costs and benefits in dollars may provide an approximation of the broader scope of externalities. The dollar value for externalities can then be added directly to capital and operating costs for supplying water and options ranked by cost-effectiveness.

2. CASE STUDY DESCRIPTION

Moreton Bay Regional Council selected a case study region of the Caboolture Catchment and the Caboolture Identified Growth Area (CIGA) to demonstrate the use of Extended Cost-Effectiveness Analysis for water supply options evaluation. The CIGA is part of the Caboolture Catchment and represents a potential development pressure on the catchment over the coming decades. Figure 6 illustrates the location of the catchment on the east coast of Australia as well as important catchment features.

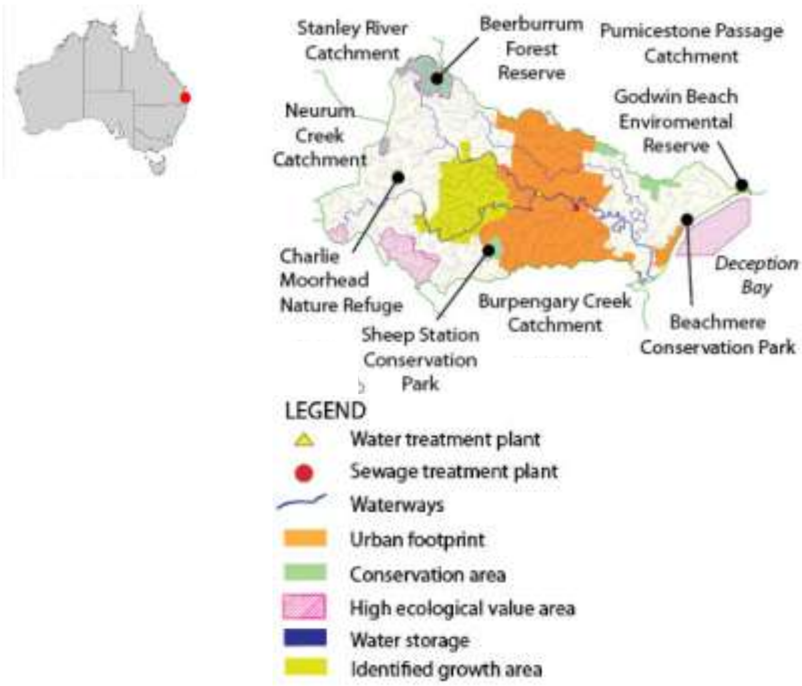

Figure 6. Case study region illustrating catchment location and features including the location of the Caboolture Identified Growth Area (BMT-WBM 2012).

The water supply options were defined by the Draft TWCMP (BMT-WBM 2012). Table 1 provides a summary of the water quantities, pollutant flows and indicative costs to supply water in Net Present Value. These values were used to define the options and provide input to extended cost-effectiveness calculations. The Draft TWCMP also considered a number of pollution abatement options as 'solutions' as part of each 'management scenario'. These abatement options were considered separately using marginal abatement cost curves for the Caboolture catchment. The average cost of abatement in the catchment was then used for calculating pollutant abatement costs for 'solutions' that supplied water. For further details of the case study region, refer to the Draft TWCMP (BMT-WBM 2012).

Table 1. Summary of material flows and cost for water supply options for Caboolture and CIGA.

Catchment	Management Scenario	Solution ^	Potable Water Saving (ML/yr)	Water Pollutant Flow ^ (kg/yr)			GHG Pollutant Flow * (t/yr)	Indicative Cost to Supply Water ($M 2011 PV) *
				TSS	TN	TP		
Caboolture	Scenario 1	Future Development meets QDC Alternative Water Supply Target	869	17,370	1,581	112	1,737	49.47
		Grid water	13,635				21,680	5.96
	Scenario 2	Future Development meets QDC Alternative Water Supply Target	869	17,370	1,581	112	1,737	49.47
		Recycled Water Supplied to Agricultural Users	2,920	5,840	7,300	876	2,044	14.90
		Grid water	13,635				21,680	5.96
	Scenario 3	Future Development meets QDC Alternative Water Supply Target	433	8,665	788	56	866	24.68
		Recycled Water Supplied to Urban Users	2,297	5,932	7,689	890	2,076	81.62
		Stormwater Harvesting for Non-Potable Use	184	36,161	436	81	713	27.97
		Grid water	10,641				16,920	4.65
CIGA	Scenario 1	Future Development meets QDC Alternative Water Supply Target using Rainwater Tanks	1,064	21,280	1,936	137	2,128	28.34
		Recycled Water for POS	671	3,815	4,769	572	1,335	28.63
		Grid water	5,840				9,285	2.55
	Scenario 2	Recycled Water for Dual Reticulation & POS	1,688	9,066	11,333	1,360	2,047	37.02
	Scenario 3	Stormwater Harvesting Dual Reticulation & POS	1,232	326,310	3,933	733	1,297	68.90
		PRW to NPD	3,626	7,751	4,832	934	5,802	81.22
		Grid water	2,717				4,320	1.19

* Grid water Greenhouse Gas emissions assume 1.59 MWh/ML and 1 tC02e/MWh (Hall, West *et al*. 2009). The indicative cost to supply water was based on the bulk water price path considered in the method. Marginal bulk water supplies are likely to be from desalination and this was considered in the Sensitivity Analysis.
^ Queensland Development Code (QDC), Public Open Space (POS), Potable Recycled Water (PRW), Non Potable Demand (NPD), Mega Litre (ML), TSS (Total Suspended Solids), Total Nitrogen (TN), Total Phosphorus (TP), Present Value (PV).

3. METHOD

3.1. Extended Cost-Effectiveness Analysis

Cost-Effectiveness Analysis (CEA) is an established economic method for evaluating the cost of an option to achieve an objective (Pearce, Atkinson *et al.* 2006). The application of cost-effectiveness analysis in assessing water quality interventions in SEQ has also recently been reviewed (Alam, Rolfe *et al.* 2008; Hall 2012). Cost-effectiveness analysis can be used for evaluating both pollution abatement options as well as water supply options. In this case, pollution abatement costs were reviewed to extend the cost-effectiveness analysis of water supply options. This method was noted as being suitable for capturing sustainability issues of sub regional TWCMPs for water supply conservation and water supply augmentation (Hurikino, Lutton *et al.* 2010, p12; Fane, Blackburn *et al.* 2010, p12). This method also supports National Water Initiative pricing principles for including full cost recovery, including recovery of environmental externalities (DEWHA 2010). This study considered pollution abatement costs for greenhouse gases, nutrients and sediments to extend the cost-effectiveness analysis. Figure 7 illustrates the cost components considered for the supply of water.

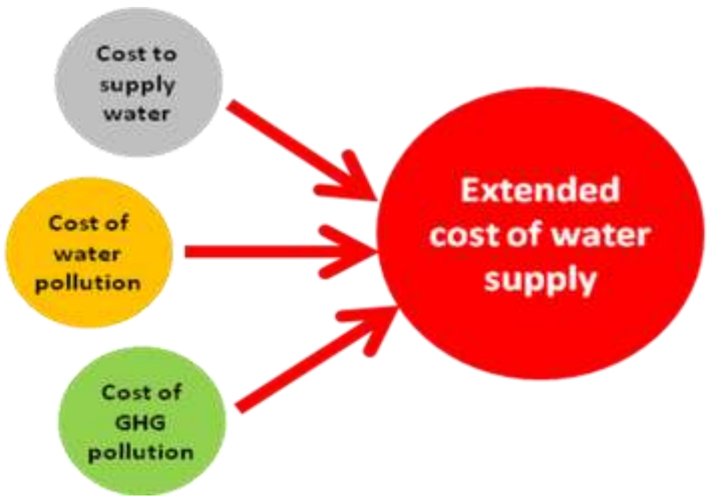

Figure 7. Cost components considered for the cost-effectiveness of water supply options.

Equation 1 captures the algebraic relationship of the cost components for calculating the extended cost-effectiveness. Note that the capital and operating costs as well as the flow of pollutants relate to the water supply option. The value of the pollution was defined by pollution mitigation costs for achieving a particular pollution reduction target.

$$Y = C_p + O_p + \sum_{j}^{m} P_j . W_j \qquad \text{Equation 1}$$

Where

Y = extended cost-effectiveness

C_p = capital cost per unit of water supplied

O_p = operating cost in present value per unit of water supplied

P_j = pollution emitted by the water supply option per unit of water supplied

W_j = unit value for pollution abatement for a defined reduction target

j = first pollutant considered

m = last pollutant considered

Figure 8 illustrates the comparison of two water supply projects using the extended cost-effectiveness. The capital and operating costs for supplying water are shown in grey. The costs of abating pollution from the water supply project is added for Greenhouse Gas emissions (GHG), Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solids (TSS). The example also illustrates that the most cost-effective option may change depending on the scope of costs considered. Water supply Project A appears more expensive if only the capital and operating costs for supply water are considered. However, Project A appears less expensive when pollution costs are included.

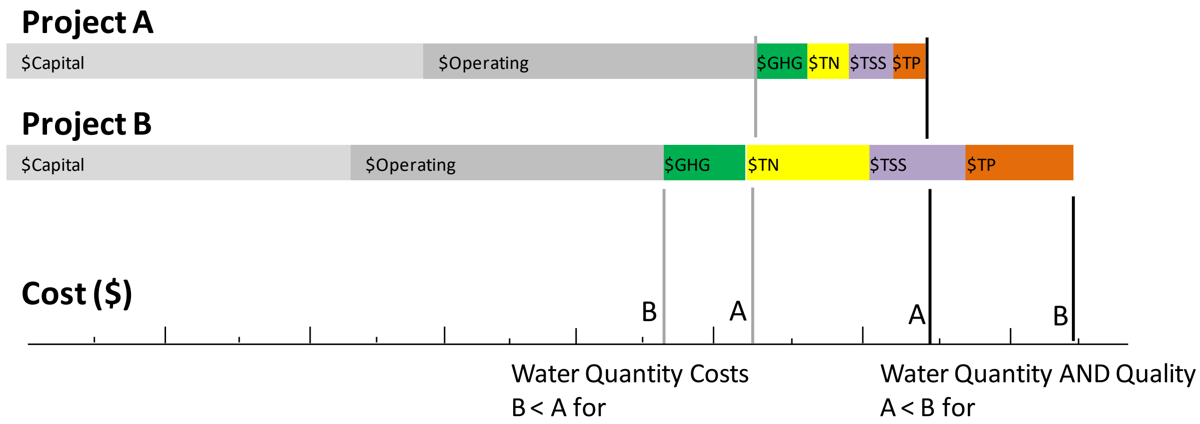

Figure 8. Options evaluation with costs extended for pollution.

Pollutant costs were developed using pollutant targets and Marginal Abatement Cost Curves (Hall 2012). The case study drew upon pollution costs and quantities calculated for the TWCMP for MBRC (BMT-WBM 2010; BMT-WBM 2011; BMT-WBM 2012).

3.2. Pollution Abatement Costs

The following three steps provide a summary of the method used to calculate pollution costs and draws upon the National Academy of Science process for designing stormwater control measures (SCM) on a catchment (watershed) scale (NAS 2009 – pp422-423).

Pollution status. Consideration of current catchment ecosystem health, current pollutant loads, future pollutant loads and sustainable pollutant load targets.

Mitigation options. Mitigation options available and approximate cost-effectiveness and load reduction potential for the catchment.

Value of pollution and cost-effective strategy. Development of a cost curve and illustrating the relationship of pollutant value to sustainable load targets and cost-effective options to achieve targets.

The approach was different to the Draft TWCMP, where abatement options were selected and modelled on a sub-catchment basis to achieve Water Quality Objectives in each sub catchment.

Detailed calculations for steps 1 and 2 for the pollution status and the mitigation options are provided in the Appendices. This information was used to construct the Marginal Abatement Cost Curves with the following methodological considerations.

3.3. Multiple Objectives

Cost-effectiveness analysis typically focusses on achieving one objective and does not seek to account for other benefits. This can create a methodological problem when there is more than one objective (Jones-Lee 2003; Pearce, Atkinson *et al.* 2006). This problem was addressed for abatement options that reduce more than one pollutant by considering a common metric of 'water quality' and by accounting for other benefits as 'avoided costs'. A water quality metric was developed based upon the load reductions required to achieve legislated pollutant concentrations which maintain the environmental values of the ecosystems (QG 2009). This was similar to an allocation based upon Water Sensitive Urban Design (WSUD) minimum reductions in pollutant loads for urban stormwater (DERM 2009; Hall 2012). The WSUD-allocation apportioned 43%, 24% and 32% of costs to TSS, TN and TP respectively. The main difference was for TN which may suggest that TN pollutant loads in MBRC are closer to the sustainable load target than the other pollutants.

The allocation presented in Table 2 was modified by apportioning the TSS allocation to the TN and TP. There was a large difference in this allocation compared to reported cost drivers for point source abatement measures that reduce both total nitrogen and total phosphorus. For example, a survey of cost drivers for Australian wastewater utilities reported that approximately 75% of the cost was allocated to nitrogen abatement and 25% to phosphorus abatement (Pickering and Marsden 2007). This assumption was similar to an allocation assumed by the US EPA (USEPA 2008).

Table 3 shows a variation of the allocation for recycled water. It was assumed that water recycling would affect water quality only through reductions in nutrients.

An additional allocation rule was developed for Water Sensitive Urban Design, rainwater tanks and stormwater harvesting. This rule illustrates a refinement of the original approach based upon the results. The results indicated these options (after accounting for water supply avoided costs) would not be adopted on a least-cost basis to abate TSS for 'no worsening' of catchment conditions. This meant that the primary pollution abatement purpose of these options was nutrient abatement and TSS was an additional benefit. The weighted average cost for TSS abatement from the MACC was considered as an 'avoided cost' for these options and the remainder allocated to nutrients. For example, a TSS abatement cost of $213/t reduced the present value of WSUD by about 10%. The remaining costs were then allocated to TN and TP following the approach in Table 3.

Table 2. Water quality allocation for cost and benefit of water pollution.

	TSS	TN	TP	Total
Sustainable load	2,762	140.9	8.63	
Load reduction required to achieve sustainable load	34,013	576	88	
Distance from sustainable load target	12.3	4.09	10.2	26.6
Allocation	0.46	0.15	0.38	1

Table 3. Water quality allocation for cost and benefit of water pollution for recycled water.

	TSS	TN	TP	Total
Allocation	0	0.28	0.72	1

An allocation based upon the load reduction required to achieve 'no worsening' was not adopted because it does not account for the current load levels and their effect on water quality. For example, existing sediment loads due to agriculture would not be captured, although they may contribute significantly to the current state of waterway health. This approach captures the relative importance of abating various pollutants to improve existing water quality.

3.3.1 Moreton Bay Bulk Water Price

If an abatement option also provided a water supply, then the value of water was subtracted from the capital and operating costs and the remaining costs allocated to pollution abatement. Table 4 presents the Queensland Water Commission (QWC) bulk water price path for MBRC (Queensland Water Commission http://www.qwc.qld.gov.au/reform/bulkwaterprices.html). This price path was inflation adjusted but not discounted. Figure 9 provides the value of bulk water in present value for discount rates of 3 and 5.5%. Note that the revised QWC price path appears to cap bulk water prices at $2812/ML. Moreton Bay reaches this cap in 2016 and the same price is applied in 2017 (other Councils such as Somerset reach this cap in 2014). It was assumed that the price was also capped up to 2030. The value of water is sensitive to this assumption because the trajectory of bulk water prices prior to 2016 suggests a much higher value of water.

Table 4. Queensland Water Commission Bulk Water Price Path for Moreton Bay Regional Council.

	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Bulk Water Price Path ($2011/ML)	$1,652	$1,875	$2,086	$2,286	$2,475	$2,653	$2,812	$2,812

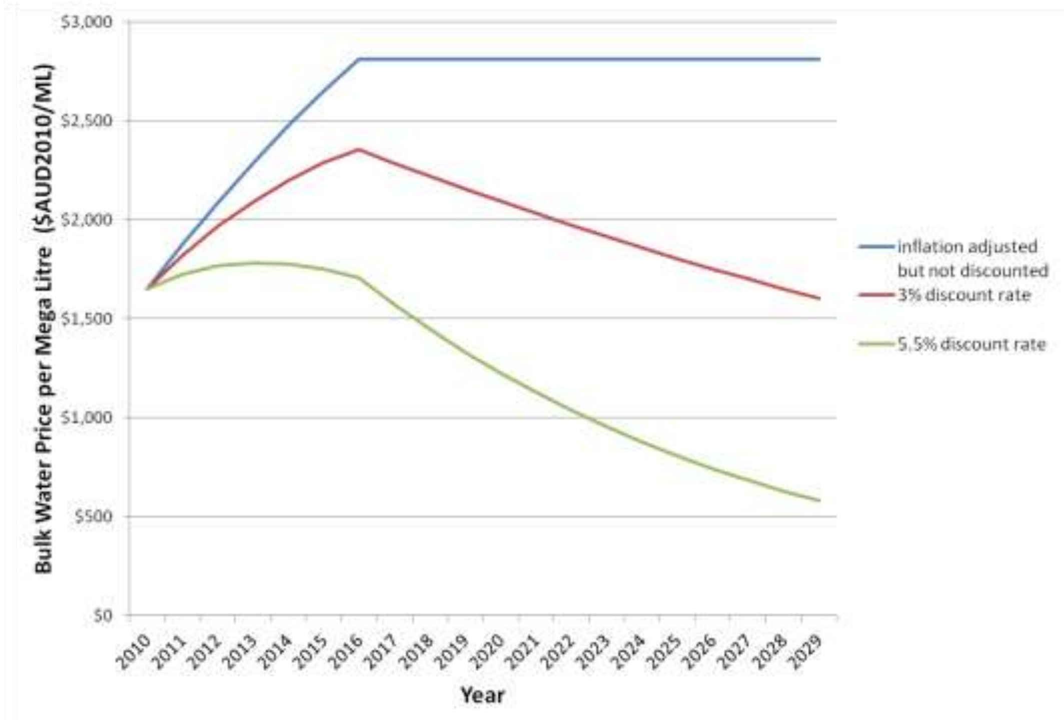

Figure 9. Assumed value of water based upon the QWC bulk water price path for Moreton Bay.

3.3.2 Agricultural Water Price

A value of $3.80 per megalitre was assumed for agricultural water based upon Schedule 14 Water Charges of the *Water Regulation 2002* (QG 2011). This water has a relatively low value compared to bulk water for the urban water supply. It was assumed that no other higher value use of the water was available and that the provision of recycled water to agriculture provided a disposal option that minimised impact on receiving waters. The recycling of water to agriculture may also reduce the treatment requirements, such as Class B effluent rather than Class A+ effluent. This means that recycled water to agriculture is not an urban water supply option. If it is argued that the use of recycled water avoids the use of urban water supplies then the value of the avoided cost is the bulk water price. Nonetheless, the option is retained in the results to illustrate the cost saving of pollution abatement compared to the cost of the water.

4. DEFINING THE OBJECTIVE FOR POLLUTION REDUCTION

The objective for pollution reduction was assumed to focus on water quality within the catchments of MBRC outlined in the draft TWCMP. This means that abatement options in other catchments that may be more cost-effective or address more pressing pollution problems were not considered. For example, abatement measures in the Lockyer Valley may be more cost-effective for improving water quality in Moreton Bay but were not considered in this study. It should be noted that residents in SEQ are willing to invest in other areas for water quality improvement if it is more cost-effective (Binney 2010).

Objectives for waterway health have been defined in the Environmental Protection (Water) Policy 1997 (EPP Water) and the South East Queensland Natural Resource Management Plan 2009-2031 (SEQ NRM Plan). The SEQ NRM Plan references the EPP Water and has three targets that are particularly relevant to pollution impacts on SEQ waterways:

- In 2031, High Ecological Value (HEV) waterways scheduled in the EPP Water will maintain their 2008 classification (W5 – High Ecological Value waterways).
- In 2031, Water Quality Objectives (WQO) to achieve Environmental Values (EV) scheduled in the EPP Water will be achieved or exceeded for all SEQ waterways (W6 – Waterways maintenance and Enhancement).
- By 2031, waterways that are currently classified as ranging from slightly to moderately disturbed and/or highly disturbed will have their ecosystem health and ecological processes restored (DERM 2009 - p34-35).

The environmental values have been defined and mapped for the Caboolture catchment and tributaries. In addition, pollution concentrations to achieve the Water Quality Objectives (WQO) have been defined for TN, TP and TSS. Further details are provided in the Appendices.

The following section outlines how the objectives were considered for the MBRC TWMP. In general, the objective for pollution reduction was defined in terms of a load reduction and the associated benefit for a level of waterway health.

4.1. Load Reductions to Achieve Waterway Health Objectives

Load reductions can be defined to achieve objectives which can range from: ‘do nothing’; maintaining the current condition as the population increases; achieving Water Quality Objectives for Environmental Values; to returning the waterways to their original condition. Each load reduction target has both a cost and a benefit for pollution abatement.

Two load reductions were initially considered, namely a ‘no worsening’ and a ‘sustainable’ load target to achieve the EPP Water WQO. Benefits for pollution abatement were available for both targets. However, the quantification of the actual load reduction associated with the targets became complicated due to modelling constraints. Calculating the load reduction was required to express both the costs and benefits in terms the amount of pollution abated.

The calculation of ‘no worsening’ load reductions was relatively uncomplicated because it assumed the long-term average for current conditions and based the future load upon projections of development for the catchment. However, assuming the average load meant that available modelling for determining the sustainable load was no longer compatible (Pers. Comm, Nicole Ramilo BMT-WBM 16 April 2012). The sustainable load calculation was based upon 2005-6 data due to modelling constraints (BMT-WBM 2012 – p6-1). This was a dry year, which means that the pollutant loads were low, which in turn had two effects. Firstly, the low pollutant loads meant that the reduction in load from the current dry year to a sustainable dry year was low. This reduction in load was actually less than the load reduction for average conditions for ‘no worsening’. This illustrates that the same conditions (preferably typical conditions) should be used for the calculation of both the ‘no worsening’ and ‘sustainable’ loads. In addition, the modelling suggested that loads needed to be reduced to less than pre-European conditions in some cases to meet the EPP (Water) pollution concentrations. This suggests EPP (Water) pollution concentrations are unlikely to be achieved all the time in all parts of the catchment, regardless of the level of abatement.

4.1.1 Current and Future Pollution Loads

The following tables provide a summary of the current and future loads based upon BMT-WBM (2010 – Tables 3-4, 3-7, 3-17, 3-20). This data does not include reductions for urban stormwater based on WSUD requirements. Consequently, this data provides a good starting point for considering all possible abatement measures.

Table 5. Current (2010) stormwater annual pollution loads in MBRC catchments.

Catchment	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Bribie Island	585	13	1.4
Pumicestone Passage	3,111	73	9.3
Redcliffe	1,143	19	2.6
Mary River	797	20	1.6
Caboolture River	8,816	136	16.3
Burpengary Creek	2,415	34	4.5
Hays Inlet	2,603	42	5.3
Brisbane Coastal	922	15	2.0
Byron Creek	50	1	0.1
Neurum Creek	1,595	36	3.3
Sideling Creek	1,195	15	1.8
Lower Pine Creek	7,980	109	12.6
Upper Pine Creek	4,466	87	8.0
Stanley River	5,981	133	12.7
Total	**41,659**	**733**	**81.5**

Table 6. Current (2010) STP annual pollution loads in MBRC catchments.

Catchment	STP	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Stanley	Woodford	0.271	0.421	0.03
Bribie	Bribie Is	3.949	2.962	0.355
Caboolture	Burpengary East	7.126	13.895	0.428
	South Caboolture	5.912	4.729	0.591
Upper Pine	Dayboro	0	0	0
Lower Pine	Murrumba Downs	14.242	21.363	3.561
	Brendale	4.681	8.894	0.468
Hays	Redcliffe	10.369	20.738	0.518
Total		**46.55**	**73.002**	**5.951**

Table 7. Future (2030) stormwater annual pollution loads in MBRC catchments.

Catchment	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Bribie Island	725	15	1.7
Pumicestone Passage	3,557	79	10.4
Redcliffe	1,344	21	3.1
Mary River	797	20	1.6
Caboolture River with CIGA	12,382	199	27.2
Burpengary Creek	2,832	43	6.3
Hays Inlet	4,021	60	9
Brisbane Coastal	956	15	2.1
Byron Creek	50	1	0.1
Neurum Creek	1,595	36	3.3
Sideling Creek	1,215	16	1.9
Lower Pine Creek	9,652	132	17.4
Upper Pine Creek	4,477	86	7
Stanley River	6,118	135	13.2
Total including CIGA	**49,721**	**858**	**104.3**

Table 8. Future (2030) STP annual pollution loads in MBRC catchments.

Catchment	STP	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Stanley	Woodford	0.7	1.8	0.4
Bribie	Bribie Is	6.0	4.5	3.0
Caboolture	Burpengary East	12.7	19.0	1.9
	South Caboolture (includes CIGA)	23.8	29.7	3.6
Upper Pine	Dayboro	0.0	0.0	0.0
Lower Pine	Murrumba Downs	23.8	35.7	6.0
	Brendale	11.3	14.1	2.8
Hays	Redcliffe	13.6	33.9	0.7
Total including CIGA		**91.8**	**138.7**	**18.3**

4.1.2 'No Worsening' Load Reduction Target

A 'no worsening' load reduction target was calculated for the abatement required to offset the increase in pollutant loads due to population and development over the next 20 years. The calculations of the 'no worsening' load reduction considered the change in the annual load for the current load and the 2030 load. It was then assumed that there would be a linear increase in load from the current load to the 2030 load. This can be thought of as the pollution abatement required each year to maintain loads at their current levels. The load reduction required over the period was calculated as the sum of the abatement required each year to achieve 'no worsening' of pollutant loads.

Tables 9 and 10 illustrate the change in annual load predicted over the next 20 years for stormwater and Sewage Treatment Plants (STP) as the population increases based upon the *Total Water Cycle Strategy for Moreton Bay Regional Council* (BMT-WBM 2010 – Tables 3-4, 3-7, 3-17, 3-20). The Caboolture River (with the CIGA) catchment will experience the largest increase in load of any of the catchments. Note that Burpengary East STP and Burpengary Creek were included in the loads as they discharge to the estuary. On the other hand, the loads do not include WSUD stormwater load reductions which were considered as an abatement option.

Table 11 summarises the projected *annual* increase in loads by 2030 of approximately 8107, 191, 35 tonnes per year for TSS, TN and TP respectively. Assuming a linear increase in annual load, this amounts to a total increase in load over the period of 2010 to 2031 of approximately 89,179 tonnes of TSS, 2097 tonnes of TN and 386 tonnes of TP.

Table 11 also provides a comparison of point and diffuse loads for the all of the MBRC catchments. Stormwater in urban and rural catchments is the main source of pollution and contributes twice the load of STPs for nutrients and almost all of the sediment load. This is an important consideration for identifying abatement options to meet load reduction targets.

Table 9. Projected increase in stormwater annual load for MBRC catchments for 2010 compared to 2031.

Catchment	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Bribie Island	140	2	0.3
Pumicestone Passage	446	6	1.1
Redcliffe	201	2	0.5
Mary River	0	0	0.0
Caboolture River with CIGA	3566	63	10.9
Burpengary Creek	417	9	1.8
Hays Inlet	1418	18	3.7
Brisbane Coastal	34	0	0.1
Byron Creek	0	0	0.0
Neurum Creek	0	0	0.0
Sideling Creek	20	1	0.1
Lower Pine Creek	1,672	23	4.8
Upper Pine Creek	11	-1	-1.0
Stanley River	137	2	0.5
Total including CIGA	**8,062**	**125**	**22.8**

Table 10. Projected increase in Sewage Treatment Plant annual load for MBRC catchments for 2010 compared to 2031.

Catchment	STP	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Stanley	Woodford	0.4	1.4	0.3
Bribie	Bribie Is	2.0	1.5	2.6
Caboolture	Burpengary East	5.6	5.1	1.5
	South Caboolture (includes CIGA)	17.9	25.0	3.0
Upper Pine	Dayboro	0.0	0.0	0.0
Lower Pine	Murrumba Downs	9.6	14.4	2.4
	Brendale	6.6	5.2	2.3
Hays	Redcliffe	3.2	13.2	0.2
Total including CIGA		**45.2**	**65.7**	**12.3**

Table 11. Summary of the projected increase in annual average load for Moreton Bay Regional Council Catchments for 2010 compared with 2031.

Load Source	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Stormwater	8,062	125	23
STP	45	66	12
Total	**8,107**	**191**	**35**

Table 12. Abatement Required over the Analysis Period to Achieve 'No Worsening' of Pollutant Loads.

Year	TSS (t/yr)	TN (t/yr)	TP (t/yr)
2010	0	0	0
2011	405	10	2
2012	811	19	4
2013	1,216	29	5
2014	1,621	38	7
2015	2,027	48	9
2016	2,432	57	11
2017	2,838	67	12
2018	3,243	76	14
2019	3,648	86	16
2020	4,054	95	18
2021	4,459	105	19
2022	4,864	114	21
2023	5,270	124	23
2024	5,675	133	25
2025	6,080	143	26
2026	6,486	153	28
2027	6,891	162	30
2028	7,296	172	32
2029	7,702	181	33
2030	8,107	191	35
Total load reduction over the period of analysis for 'no worsening'	**85,126**	**2,002**	**369**

4.2. Benefit for Achieving a Waterway Health Objective

There has been a significant amount of recent work to quantify the value of SEQ waterways (Windle and Rolfe 2006; Binney 2010; Binney and James 2011; MJA and BCC 2011). It was estimated that the present value[1] of avoiding further decline in SEQ coastal, marine, and inland waterways over the next 20 years is approximately $2 billion (Binney and James 2011 – p5). This estimate does not include benefits to businesses that are affected by water quality such as water treatment, fisheries or tourism. In terms of TWCMP, it is interesting to note that some of the 'externalities' are not far removed from the provision of water. For example, it was estimated that riparian revegetation of the Lockyer Creek could reduce chemical costs for Mt Crosby water treatment by around $240,000 per annum (AUD2005) (Weber 2005). This follows the well-known example of New York City where it was estimated that $1.5 billion spent over 10 years on watershed protection avoided over $6 billion in capital and $300 million in annual operating costs for water filtration (Postel and Thompson 2005).

[1] Assuming a 5.5% discount rate.

Household 'willingness to pay' to achieve SEQ Natural Resource Management (NRM) targets was used to calculate the benefit for pollution reduction. This data was expressed per household and scaled to the population in MBRC. It was reported that households were willing to pay $120 per year to avoid declines in the condition of creeks, rivers and coastal environments (Binney 2010 – p48). It was also estimated households were willing to pay approximately $50[2] per year to enhance water quality in creeks and rivers to achieve SEQ NRM targets by 2031 (Binney 2010 – p51). It was assumed that the enhancements would be achieved at a linear rate over the life of the SEQ NRM plan[3]. It was also noted that the value of marginal enhancements was lower than the value of marginal declines for resource condition. This is consistent with the expected relationship of marginal benefits and costs of pollution abatement (Aldrich 1996). As noted in *Managing What Matters* this suggests that the community has a strong economic preference for investing to stop decline rather than rehabilitating later on. This may also reflect the psychological effect of valuing losses more than gains. Kahneman notes that the willingness to pay depends on the reference point and a loss has a greater value than a gain of the same amount (Kahneman 2011 – p293, 283).

Figure 10 illustrates the assumed annual benefits for avoiding decline and also for achieving Water Quality Objectives of the EPP Water and SEQ NRM. The increasing benefit reflects the increasing number of households projected for the catchments in MBRC which was multiplied by the household willingness to pay. The benefits over this period can be discounted to give a present value of approximately $330 million to avoid decline and an additional $138 million to achieve the Water Quality Objectives of the EPP Water and SEQ NRM[4].

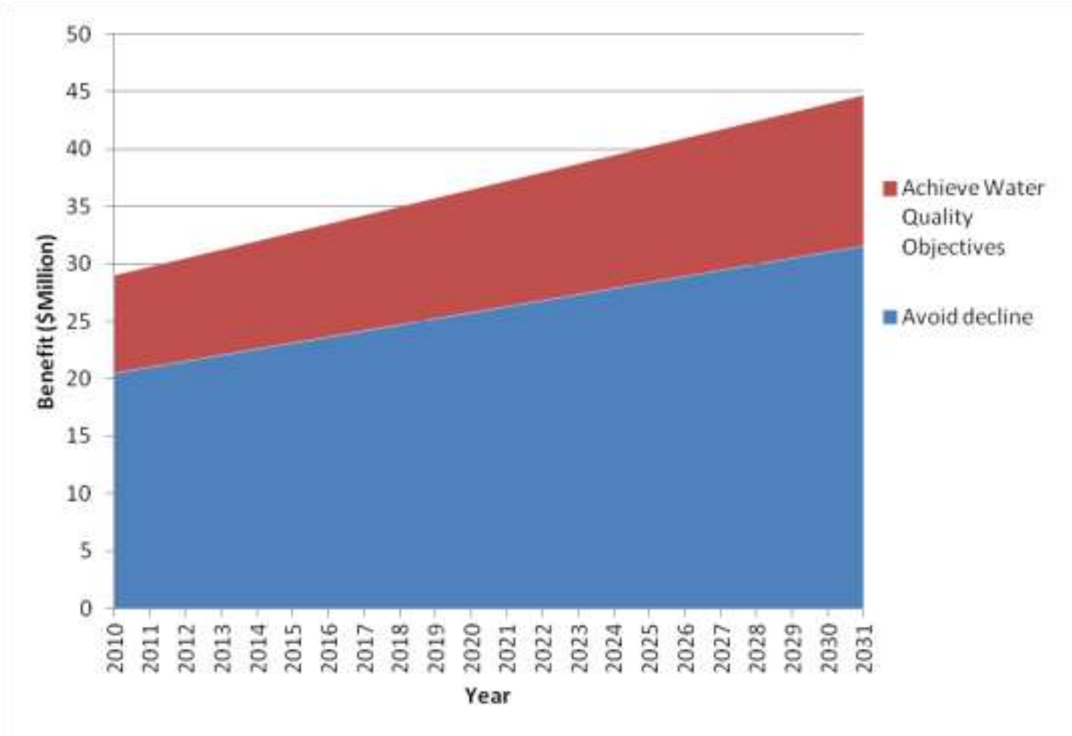

Figure 10. Benefit of avoiding decline and achieving Water Quality Objectives in waterways of Moreton Bay Regional Council.

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[2] $100 per household per year was reported for achieving SEQ NRM targets and 50% of the benefits were attributable to enhancing water quality in creeks and rivers.

[3] The increase in pollutant loads was also assumed to be linear. In practice, a new development is likely to produce a spike in emissions while a lull in development will reduce the rate of growth. The linear rate assumes the starting and end points from the references material and assumes a constant rate of change for each year. An annual load reduction allows the present value of costs and benefits to be calculated for the assumed pollutant load for each year in the period of analysis.

[4] Assuming a 5.5% discount rate and a 20 year period of analysis – which covers a planning period of 2010-2030. A 3% discount rate over the same period gives a present value of $417 million to avoid decline and an additional $178 million to achieve the Water Quality Objectives of the EPP Water and SEQ NRM.

The present value of benefits was used to calculate the benefit per unit of abatement to achieving the 'no worsening' load reduction target. The marginal benefit for achieving the sustainable load was also available but could not be converted into a unit benefit for pollution abatement due to problems with the calculated sustainable load reduction target. However, it was anticipated that the marginal benefit would decrease based on the lower willingness to pay for improvements and the potentially large pollutant load reduction required to restore the current condition of waterways. This suggests that the marginal benefit based on 'no worsening' provides a maximum pollution abatement benefit per tonne of pollution. Consequently, any pollution abatement costs above this level of benefit may be difficult to justify based on marginal pollution abatement costs and benefits.

Table 13 presents an allocation of benefits for pollution abatement based upon the distance to target for sustainable loads. The benefit for the abatement of a tonne of TN was relatively low compared to the benefit for a tonne of TP abatement. The allocation suggested that TN was closer to the sustainable load than other pollutants and additional abatement would have a lower benefit.

Table 13. The approximate marginal benefit in present value per tonne of pollution abated for the period 2010-2031 to achieve 'no worsening' of waterways.

	TSS	TN	TP	Total
Allocation of Benefits Based on Distance to Target	0.462235	0.153443	0.384322	1
Marginal benefit for achieving no worsening (Present Value, Million$AUD2010)	153	51	127	330
Load reduction to achieving no worsening over analysis period (tonnes)	85,126	2,002	369	
Marginal benefit for achieving no worsening per tonne of abatement (Present Value $AUD2010/tonne)	1,794	25,327	344,630	

5. MARGINAL ABATEMENT COST CURVES

The marginal abatement cost curves (MACC) were based upon the abatement costs and quantities developed in the Draft TWCMP. Details of the calculations are provided in the Appendices.

Figures 11, 12 and 13 provide a summary of the MACC for TP, TN and TSS. The average cost of abatement for achieving the 'no worsening' load reduction target is shown by the red dotted line. In summary the average cost of abatement per tonne of pollution was $220 000/t, $26 000/t and $213/t for TP, TN and TSS respectively. Note that the abatement cost is a present value based on the cost of abatement and the load reduced over the 20-year period of analysis. The benefit for pollution abatement based on the willingness to pay by residents in the catchment to achieve 'no worsening' is shown by the grey dotted line. Note that the curve does not express the marginal benefit for pollution abatement. This means that the optimum level of pollution where marginal costs equal benefits cannot be defined. However, the marginal benefits are expected to be higher for initial abatement efforts and then decrease as more load is abated. A very simple marginal benefits curve could be developed by coupling the additional load reduction to achieve water quality objectives with the additional benefit achieved.

Nonetheless, the comparison of average costs and benefits provides insight into the cost benefit ratio for each pollutant assuming that the 'no worsening' load reduction target will be achieved. For example, the average benefit for abating TSS is over eight times greater than the cost. This suggests that there is a large benefit for abating TSS and the cost is relatively low. This is a function of the assumption that current TSS loads are a long distance from the sustainable load target and have a large effect on the water quality. Under these assumptions, TSS abatement appears to be a priority based on its high benefit/cost ratio. Conversely, TN abatement has average abatement costs which were very similar to the average benefit. This reflects the assumption that TN pollution does not have a large distance to its sustainable load and further abatement would have a relatively smaller effect on water quality than abatement of other pollutants.

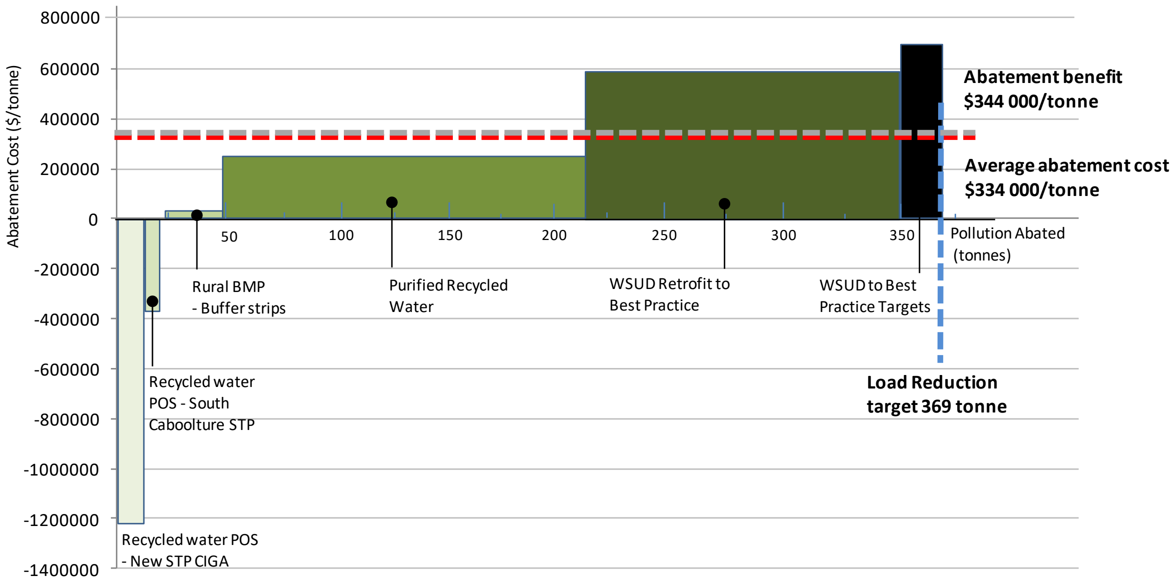

Figure 11. Total phosphorus abatement cost and benefit for 'no worsening' load reduction target.

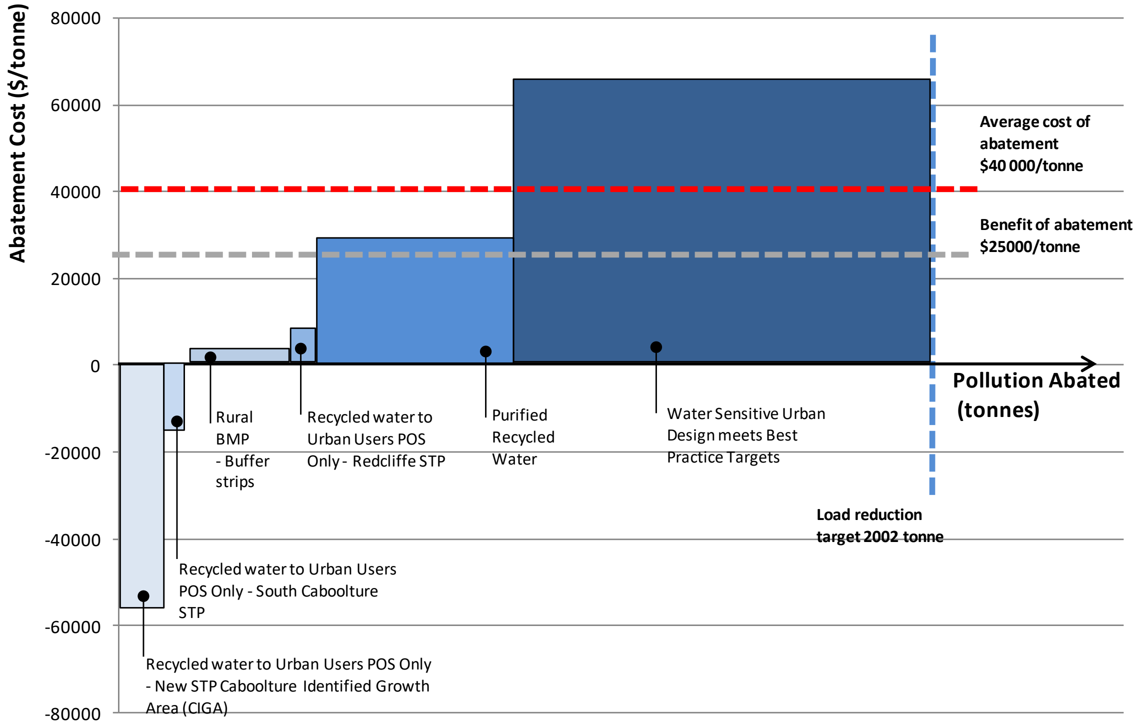

Figure 12. Total nitrogen abatement cost and benefit for 'no worsening' load reduction target.

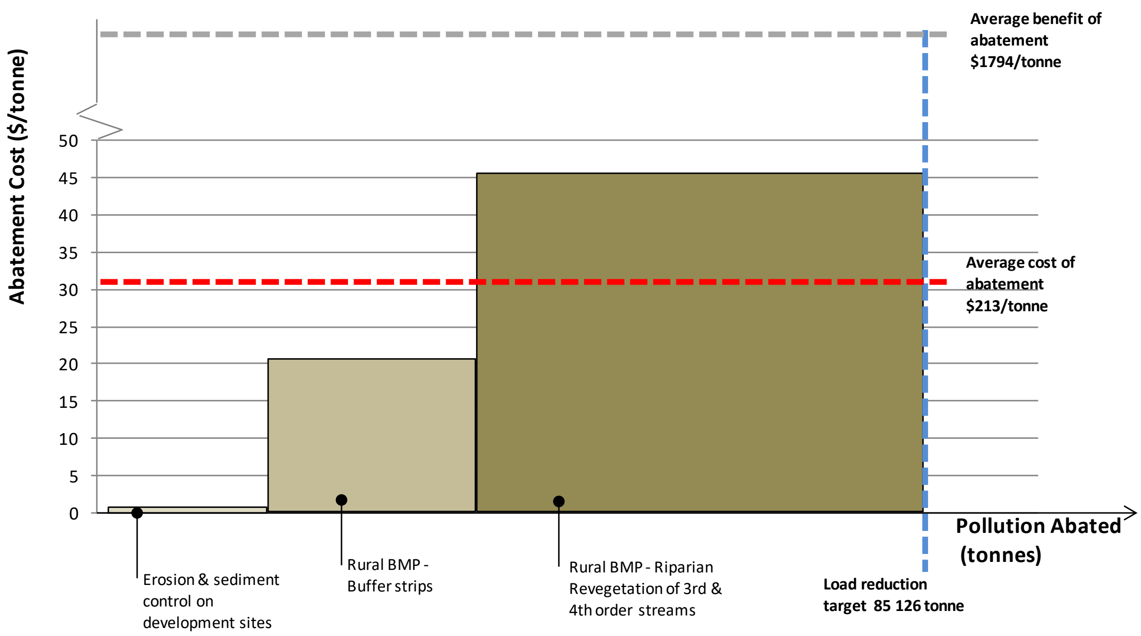

Figure 13. Total suspended solids abatement cost and benefit for 'no worsening' load reduction target.

6. EXTENDED COST-EFFECTIVENESS ANALYSIS OF WATER SUPPLY OPTIONS

Figure 14 presents a comparison of the water supply cost with the extended cost (water supply cost and pollution abatement costs) for a unit of water supply for the Caboolture catchment and the Caboolture Identified Growth Area. The water supply options were ordered by the catchment and scenario name from the Draft TWCMP and are abbreviated at the beginning of each water supply 'solution', e.g. cab1 refers to Caboolture catchment Scenario 1. This grouping enables comparison of competing options within a catchment. The pollution costs were calculated by multiplying the weighted average cost of abatement by the pollutant load for the water supply option. The assumed weighted average cost of abatement was \$334,000/t, \$40,000/t, \$213/t for TP, TN, TSS respectively, as shown in Figures 11, 12 and 13. An abatement cost of \$23/t was also adopted for carbon dioxide (CO_2) based upon the Clean Energy Futures policy of the Commonwealth Government. The loads for each water supply option were from the Draft TWCMP and summarised in Table 1.

Figure 14 suggests that pollution costs were relatively small compared to capital and operating costs for a water supply option. This meant that pollution costs did not change the ranking of options based upon the cost of supplying water. In some cases the difference between options was reduced, such as the case of 'Cab3 Recycled Water Supplied to Urban Users' and 'Cab3 Grid Water'. It also needs to be stressed that the cost of the bulk water option was based upon the bulk water price path for MBRC. However, if considered from the perspective of the actual cost of the marginal bulk water supply then this comparison may change. For example, if the marginal bulk water supply to the area is desalination, then water supply costs may be higher. In this case, the 14% cost saving from pollution abatement for the recycled water option may affect the ranking.

Figure 15 illustrates the ranking of the water supply options by least cost regardless of where it is implemented in the catchment. This has general implications about types of water supply but may not be useful for the case study catchment. That is, if a water supply is needed in a particular location then a cheap water supply option in some other catchment is not relevant. The extended cost-effectiveness was lower than the water supply cost for water recycling, stormwater harvesting and rainwater tanks. These water supply options reduce pollution loads and provide a cost saving for pollution abatement. The grid water supply option had slightly higher extended costs due to GHG emissions. In general, the most cost-effective options were recycled water for dual reticulation, potable recycled water for non potable demand (PRW for NPD) and grid water[5]. Rainwater tanks and stormwater harvesting were the least cost-effective water supply options.

Table 14 presents the percentage reduction of water supply costs when pollution abatement savings were considered. In the case of grid water, there was about a 2% increase in costs due to GHG emissions rather than abatement.

[5] Recycled water to agriculture was not considered as a water supply option because the water was valued at the agricultural water price. This option was considered as a water disposal option and included to illustrate the cost of the water compared to the cost saving for pollution abatement.

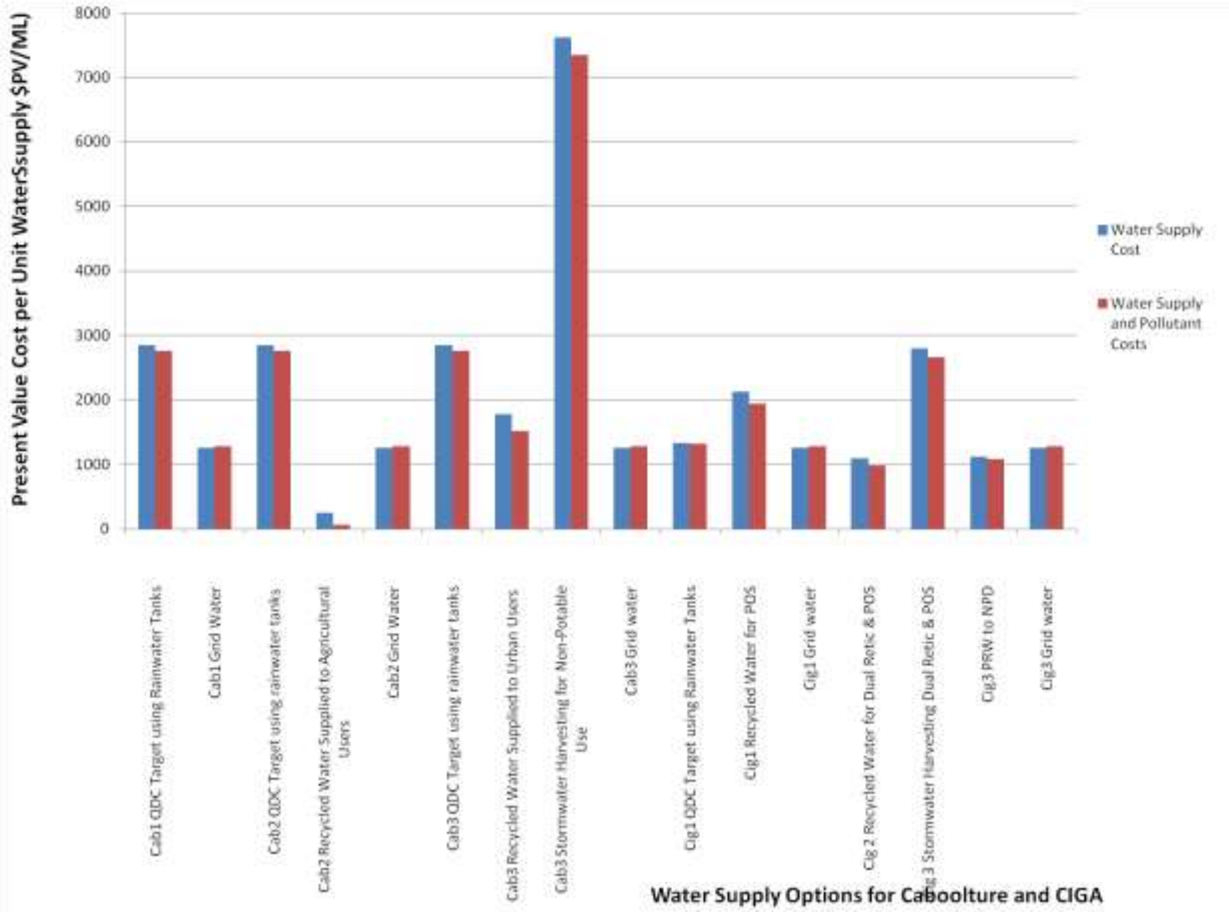

Figure 14. Comparison of project cost and extended cost-effectiveness for a unit of water supply for Caboolture and CIGA Catchment options.

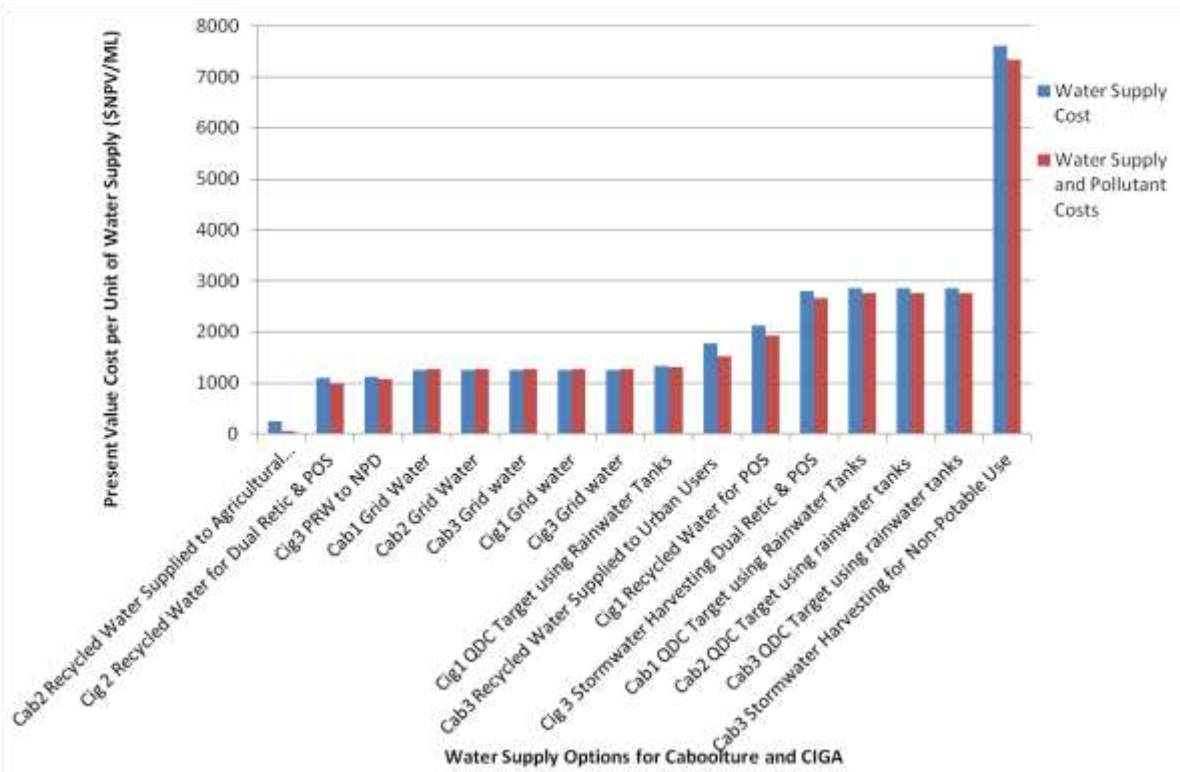

Figure 15. Caboolture and CIGA water supply options sorted by water supply cost.

Table 14. Percentage reduction of water supply costs to water supply and pollutant costs.

Name (CatchmentScenario# solution name)	Water Supply Cost ($/ML)	Water Supply and Pollutant Costs ($/ML)	Percentage Reduction of Water Supply Costs
Cab2 Recycled Water Supplied to Agricultural Users	255	64	-75
Cig 2 Recycled Water for Dual Retic & POS	1,097	979	-11
Cig3 PRW to NPD	1,120	1,088	-3
Cab1 Grid Water	1,259	1,281	2
Cab2 Grid Water	1,259	1,281	2
Cab3 Grid water	1,259	1,281	2
Cig1 Grid water	1,259	1,281	2
Cig3 Grid water	1,259	1,281	2
Cig1 QDC Target using Rainwater Tanks	1,332	1,314	-1
Cab3 Recycled Water Supplied to Urban Users	1,777	1,523	-14
Cig1 Recycled Water for POS	2,132	1,934	-9
Cig 3 Stormwater Harvesting Dual Retic & POS	2,797	2,660	-5
Cab1 QDC Target using Rainwater Tanks	2,848	2,755	-3
Cab2 QDC Target using rainwater tanks	2,848	2,755	-3
Cab3 QDC Target using rainwater tanks	2,848	2,755	-3
Cab3 Stormwater Harvesting for Non-Potable Use	7,618	7,342	-4

Figure 16 illustrates the contribution of pollutants to the extended cost for water supply. The pollutant values were expressed as absolute numbers (in contrast to the total extended cost-effectiveness which adds pollution costs and subtracts pollution abatement). Nutrient abatement had the largest effect on the extended cost. Water recycling abated relatively large amounts of nitrogen compared to phosphorus. However, the relatively large unit abatement cost for phosphorus meant that it had almost the same effect as nitrogen abatement on the extended cost. Nitrogen and phosphorus abatement were also important for rainwater tanks and stormwater harvesting. Stormwater harvesting had a small cost saving for sediment abatement and grid water had an additional cost for GHG emissions.

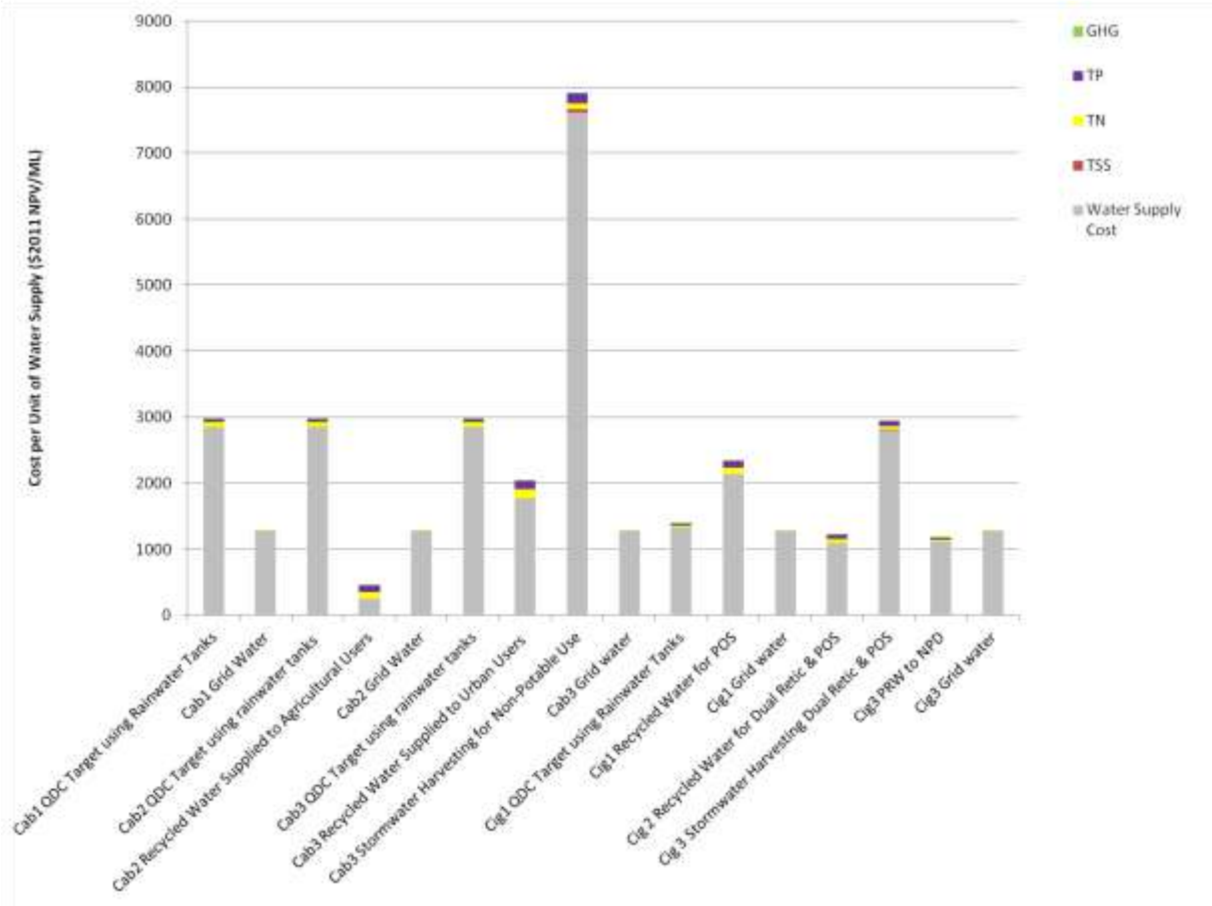

Figure 16. Contribution of water supply and pollution costs to the extended cost-effectiveness of options.

7. SENSITIVITY ANALYSIS

The sensitivity analysis explored changes in pollution costs and the effect upon the ranking of water supply options by extended cost-effectiveness. Figure 16 identified the contribution of pollution costs to the extended cost-effectiveness. This suggested that the extended cost-effectiveness may be sensitive to changes in the cost of nitrogen and phosphorus abatement but unlikely to be affected by changes for other pollutant costs.

Water Sensitive Urban Design reduced a large amount of the nutrient pollutant load in and was important for calculating the average abatement cost for nutrients in the MACC. The cost of abatement for bioretention can change significantly depending on site factors and capital investment as well as the amount of pollution abated. A review of abatement costs based upon Water by Design case studies (Hall 2012) indicated that a flat site can double the costs compared to a sloping site. There was also a large range in the assumed pollution runoff and effectiveness of abatement. The GHG emission intensity of the grid water supply can also change depending on the assumption about the water supply. A doubling of the emission intensity was assumed to capture a change from average grid water (1.6 tCO2e/ML) to the assumed marginal supply of desalination (4.4 tCO2e/ML).

Figure 17 illustrates the change in the effect of a doubling of pollutant costs on the ranking of water supply options. The largest change was for 'Cab3 Recycled water supplied to urban users'. The extended cost was slightly lower than grid water extended cost. Similarly 'Cig1 QDC target using rainwater tanks' was now also slightly lower than the grid water extended cost. These differences are unlikely to be significant and it would be difficult to differentiate the extended cost-effectiveness given the uncertainty in the data.

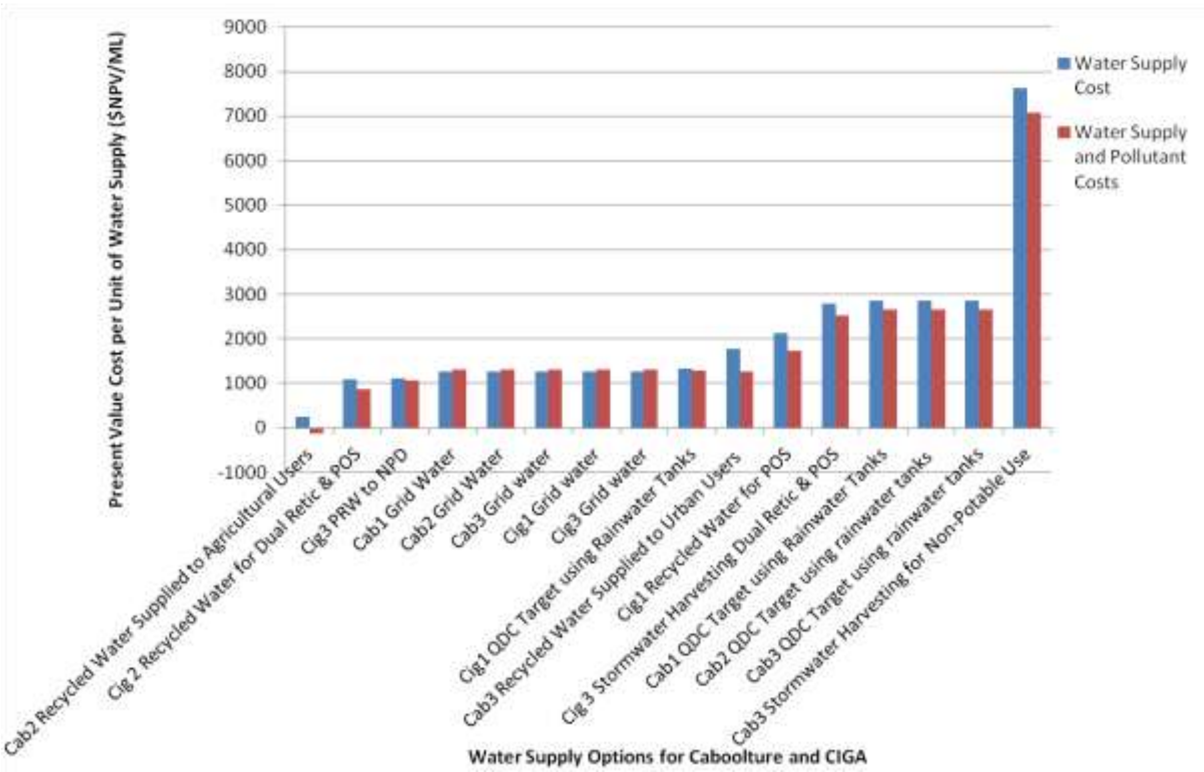

Figure 17. Sensitivity of extended cost-effectiveness to a doubling of pollutant costs.

8. DISCUSSION

Water supply options provide the obvious benefit of a water supply as well as changes in pollutant flows. Considering pollution costs of water supply options allows water quality objectives to be included in selecting the most cost-effective option. This approach can be applied to other regions that are developing Total Water Cycle Management Plans. In particular, extended cost-effectiveness can potentially simplify triple bottom line assessments of water supply options where water supply costs and receiving water quality are the primary concerns. The monetised pollution flows can be added to water supply costs as an alternative to weighting processes in Multi Criteria Analysis. The results highlight that pollution abatement costs can be important for options such as water recycling and can potentially change the ranking of water supply options. The data was sensitive to pollution costs for some water supply options and suggests the need to refine the data and define the uncertainty. It also suggests that care is required when applying the data from this study to other regions. For example, the slope of the land and assumptions about abatement efficiency can have a large effect on the cost-effectiveness of abatement using bio retention. This can have a large effect on the cost of pollution applied to water supply pollutant flows. In addition, the range of abatement options considered in the MACC was not exhaustive and only relates to those options considered in the Draft TWCMP for MBRC. Abatement options for agricultural or point source pollutants may also be cost-effective in some catchments.

The method used integrated other studies that considered the amount of abatement required to achieve water quality objectives as well as studies that considered the associated benefit. This can potentially provide insight into how much pollution abatement to pursue by comparing marginal abatement costs and benefits. Both studies are required to express 'willingness to pay' estimates for an environmental condition into a benefit per unit of pollution abatement. In the case study, an appropriate sustainable load calculation was not available and a marginal benefit curve could not be calculated. Nonetheless, the average benefit could be compared to the average cost per unit of pollution abatement for the 'no worsening' target to identify the pollutant with the highest benefit/cost ratio for abatement. In the results presented, total suspended solids appeared to have the highest benefit/cost ratio due to the large unabated load affecting water quality and the relatively low cost of abatement. Other pollutants that have already been the focus of abatement efforts now have relatively high costs of abatement and were also closer to target conditions. This may provide insight to water quality trading which aims to maximise water quality improvement at least cost. The further development of MACCs to calculate pollutant costs for water supply options evaluation would also support Water Quality Trading.

A final point to consider for TWCMP is whether pollution abatement options are required to be performed in the same catchment area as the water supply demand. For example, it may be more cost-effective to abate pollution in the Logan Albert to improve water quality in the region than abatement options in the catchment of Moreton Bay Regional Council. Willingness to pay studies suggest that residents in one part of SEQ are willing to pay for improvement in other parts of SEQ if it is more cost-effective (Binney 2010). This could provide the resources for areas that are failing water quality objectives and represent the most efficient abatement options (Binney and James 2011). However, this requires cooperation and coordination across Council areas and to link TWCMP rather than considering them in isolation.

APPENDIX 1: Pollution Status

Environmental Values and Water Quality Objectives and Report Cards

The ecosystem values and water quality objectives are defined and legislated by the Environmental Protection (Water) Policy 2009[6] for the Caboolture River and its tributaries (DERM 2010). The State Planning Policy and State Planning Guideline 4/10 Healthy Waterways (DERM 2010; DERM 2010) became effective in May 2011 and aims to ensure that development meets the water quality objectives and protects the Environmental Values of the Environmental Protection (Water) Policy 2009. Table 15 presents the Environmental Values for Caboolture River and its tributaries.

Table 15. Environmental Values for the Caboolture River and its tributaries (DERM 2010).

	Environmental values [1, 2, 3, 4, 5]													
Water	Aquatic ecosystems	Seagrass	Irrigation	Farm Supply/use	Stock water	Aquaculture	Human consumer	Oystering	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values
Caboolture River Lagoon Creek Wararba Creek Sheepstation Creek	✓	✓[6]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Burpengary Creek Little Burpengary Creek	✓	✓[6]	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
Coasts and beaches	✓	✓				✓	✓		✓	✓	✓			✓
Deception Bay	✓	✓				✓	✓	✓	✓	✓	✓			✓
Other tidal canals, constructed estuaries, marinas and boat harbours (not included in above waters)	✓						✓		✓	✓	✓			✓
Other estuarine tributaries (not included in above waters)	✓						✓		✓	✓	✓			✓
Other freshwater tributaries (not included in above waters)	✓		✓	✓	✓		✓		✓	✓	✓			✓
Other wetlands, lakes and reservoirs (not included in above waters)	✓						✓		✓	✓	✓			✓
Ground waters	✓		✓	✓	✓							✓		

Notes:
1. ✓ means the EV is selected for protection.
2. Blank indicates that the EV is not chosen for protection.
3. Seagrass is a component of the aquatic ecosystem EV. Oystering is a component of the human consumer EV.
4. Refer dictionary for further explanation of environmental values.
5. Refer to section 3 for water quality objectives applying to the EVs in this table.
6. Refers to the mouths of creeks

[6] This is the same legislation that prescribes Local Government Areas over a certain population to undertake Total Water Cycle Management Planning.

Figure 18. Caboolture River and tributaries with water types and high ecological value areas (DERM 2010).

Figure 18 highlights High Ecological Value Areas (HEVA) to be maintained including freshwater Areas PR1 (Pine Rivers) and CB1 (Upper Caboolture River and Wararba Creek waters) as well as marine waters of Area W2 (Western Bay including Deception Bay). Figure 1 also highlights High Ecological Value Areas to be achieved for Area a1281 (part of the Western Bay). These are important objectives that are affected by pollutant loads. The maintenance of HEVA suggests that current loads cannot be increased without the risk of deterioration of the ecosystem. The achievement of a HEVA suggests that pollutant loads must be reduced to improve the quality of the ecosystem.

The pollutants of nutrients and sediments effect a range of environmental values. However, this report focuses only on the physicochemical water quality objectives to protect aquatic ecosystem values. It should also be noted that nutrients and sediments do not cover all of the physicochemical water quality objectives (others include tubidity, chlorophyll a, dissolved oxygen, pH and secchi depth (to restore seagrass). Table 16 provides a summary of the nutrient and turbidity water quality objectives to protect aquatic ecosystem values for water types listing in Figure 18. There is a focus on maintaining existing water quality and seagrass health and a secondary focus on restoration. The WQO concentrations of the different pollutants vary depending on the type of water.

Table 16. Nutrient and sediment Water Quality Objectives to protect aquatic ecosystem environmental value (DERM 2010 – Tab 2).

Water Area/Type (Refer Plan WQ1422)	**Management Intent (Level of Protection)**	**Water Quality Objectives to Protect Aquatic Ecosystem EV**		
MARINE AND ESTUARINE WATERS		**SS (µg/L)**	**TN (µg/L)**	**TP (µg/L)**
Area HEVa1281 – Western Bay (part)	High ecological value		120 – 150 – 200	15 – 22 – 30
Area W2 - Western Bay, including Deception Bay	Moderately disturbed		<200	<30
Lower estuary	Moderately disturbed	<15	<200	<20
Mid estuary	Moderately disturbed	<20	<300	<25
Upper estuary	Moderately disturbed	<25	<450	<30
Tidal canals, constructed estuaries, marinas and boat harbours	Moderately disturbed	<20	<300	<25
Marine/estuarine waters with seagrass component chosen	Moderately disturbed	<10mg/L		
FRESHWATERS				
Area PR1 - Pine Rivers	High ecological value	Maintain existing water quality		
Area CB1 - upper Caboolture River and Waraba Creek Waters	High ecological value	Maintain existing water quality		
Upland freshwater	Moderately disturbed	<6	<250	<30
Lowland freshwater	Moderately disturbed	<6	<500	<50
Freshwater lakes/reservoirs	Moderately disturbed	No data	<350	<10

Figure 19 presents the key catchment characteristics and waterway health for Moreton Bay Regional Council catchments considered in the TWCMP. The catchments for Caboolture River and Burpengary Creek (which feeds into the estuary) are indicated by the solid black line. The figure is a combination of 2010 EHMP scores for waterway health with Key Catchment Characteristics from the TWCMP Strategy (where A= Excellent, B= Good, C = Fair, D= Poor and F = Fail) (BMT-WBM 2010) - Fig 3-1, Table 4-7. High Environmental Value (HEV) areas such as Deception Bay and Bramble Bay coincide with the lowest EHMP scores. In general, the health of the waterways deteriorates from ‘good’ to ‘fair’ in the upper catchments to ‘fair’ in the lower catchment and becomes ‘poor’ in the Bay near the mainland coast. The health of the bay then improves to ‘fair’ further from the mainland coast.

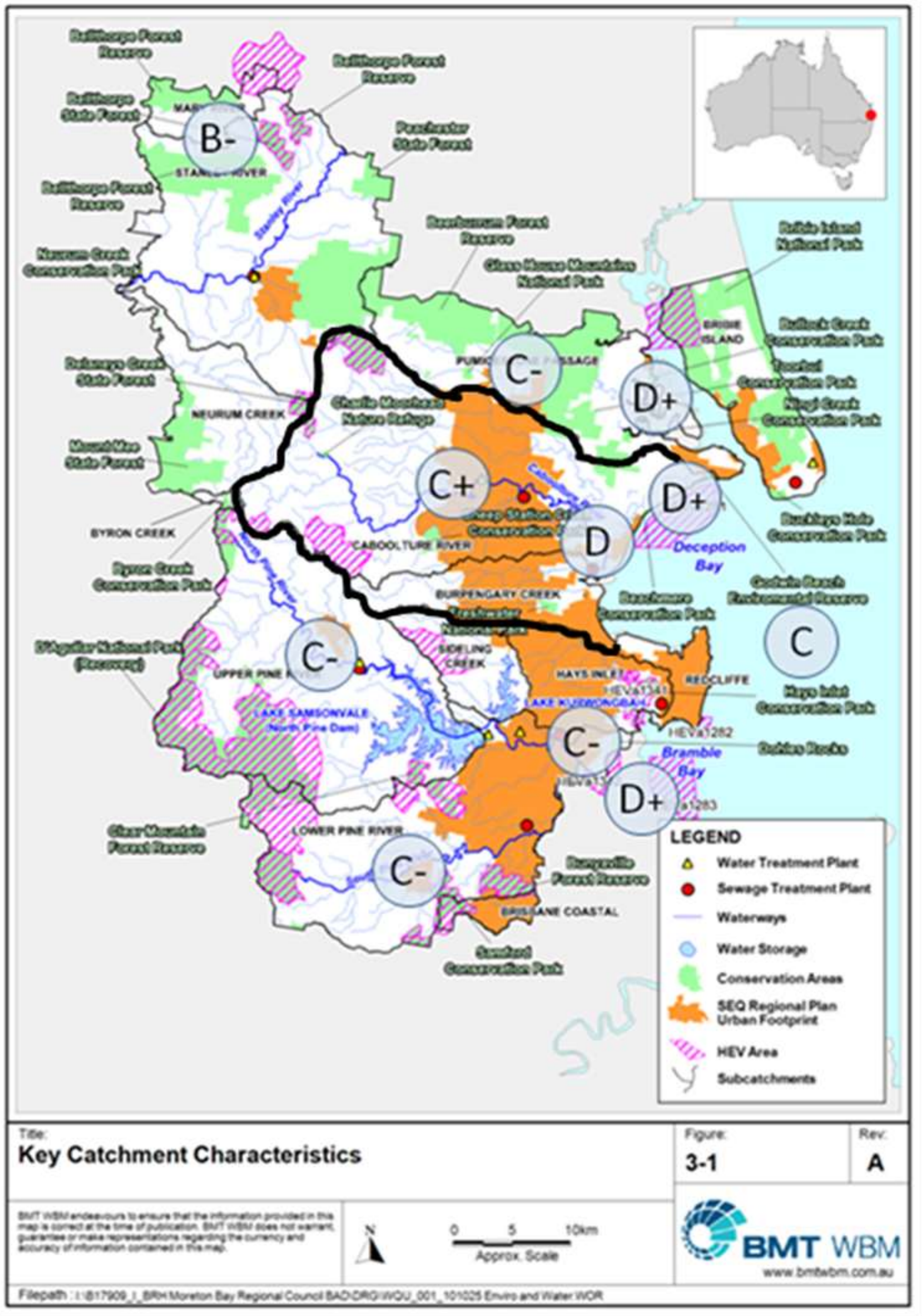

Figure 19. Key catchment characteristics and waterway health for Moreton Bay Regional Council catchments.

APPENDIX 2: TWCMP and Pollution Abatement Costs

Data from the WBM-BMT reports for the development of the TWCMP were used to calculate costs for pollution abatement. This information was used to construct the MACC and develop a cost for pollution abatement for Caboolture and CIGA. A number of other catchments in the TWCMP were also included in the following calculations although not included in the report. This information was retained for comparison as well as to facilitate further application of the approach to the TWCMP.

The following sections provide a summary of the pollution abatement costs. It should be noted that abatement costs in this report are not directly comparable to the 'levelised cost' for pollution in the BMT-WBM Total Water Cycle Management Plan. The BMT-WBM 'levelised cost' for pollution was calculated by dividing the option cost by the load reduction over the period of analysis *for each pollutant*. In addition, avoided costs such as the value of water from a scheme was not subtracted from the capital and operating costs. In summary, the primary purpose of the BMT-WBM calculations was to provide a levelised cost for water and to provide an indication of pollutant costs. In contrast, the following abatement costs sought only to provide an abatement cost for pollution and assumed the price of water based upon the price path for bulk water supply.

Future Development meets Queensland Development Code Requirements

Table 17 presents the capital and operating costs presented in the Draft TWCMP (BMT-WBM 2012 – Table 5-1), which were adjusted to consider the value of water and to allocate the remaining cost to TSS, TN and TP.

Table 17. Allocation of rainwater tank Present Value to water pollutants.

					Allocation of Pollutant NPV ($M2011)		
Catchment	**NPV ($M2011)**	**Potable Water Savings (ML/yr)**	**NPV Water ($M2011)**	**NPV Allocated to Pollutants ($M2011)**	**TSS**	**TN**	**TP**
Bribie Island	5.444	96	2.417	3.027	1.392	0.454	1.150
Pumicestone	0.890	16	0.403	0.487	0.224	0.073	0.185
Redcliffe	26.914	472	11.884	15.029	6.913	2.254	5.711
Caboolture	49.470	869	21.880	27.590	12.691	4.138	10.484
CIGA	28.342	1,064	26.790	1.552	0.714	0.233	0.590
Burpengary	25.01	440	1.108	13.992	6.436	2.099	5.317
Hays	55.668	977	24.560	31.068	14.291	4.660	11.806
Brisbane Coastal	1.690	30	0.755	0.935	0.430	0.140	0.355
Lower Pine	49.004	860	21.654	27.350	12.581	4.103	10.393
Upper Pine	1.402	25	0.629	0.773	0.355	0.116	0.294
Stanley	5.296	93	2.342	2.954	1.359	0.443	1.123
Total	**249.190**	**4942**	**124.434**	**124.756**	**57.388**	**18.713**	**47.407**

The capital cost for a 5 kL tank and the yield was similar to the review of rainwater tank costs. Assumed operating cost of $20/tank/year was lower than the assumed value in the review of $90/tank/year. However, this has a relatively small impact on costs and the cost-effectiveness calculated in the review was very similar to the Draft TWCMP once the value of water and costs were allocated between pollutants. There is a noticeable difference between the cost-effectiveness for pollution abatement in different parts of MBRC. For example, CIGA is an order of magnitude more cost-effective than most other catchments in MBRC (Table 18). This difference is important because CIGA rainwater tanks account for approximately one fifth of the total load reduction from rainwater tanks in MBRC.

Table 18. Rainwater tank pollutant load reduction and abatement cost-effectiveness.

Catchment	Reduction in load (t/20 years)			Abatement Cost-effectiveness ($AUD2011/tonne)		
	TSS	TN	TP	TSS	TN	TP
Bribie Island	38	3	0.24	36,427	130,458	4,792,156
Pumicestone	6	1	0.04	35,803	130,510	4,628,756
Redcliffe	189	17	1.22	36,579	131,068	4,681,213
Caboolture	347	32	2.24	36,532	130,882	4,680,435
CIGA	426	39	2.74	1,677	5,999	215,191
Burpengary	176	16	1.14	36,557	131,011	4,663,994
Hays	391	36	2.52	36,551	130,905	4,684,874
Brisbane Coastal	12	1	0.08	36,247	129,796	4,439,031
Lower Pine	344	31	2.22	36,573	131,491	4,681,556
Upper Pine	10	1	0.06	36,114	128,755	4,892,673
Stanley	37	3	0.24	36,531	131,106	4,677,581
Total	**1,976**	**180**	**0.24**			
Average				**29,036**	**104,056**	**3,721,141**

Water Sensitive Urban Design meets Best Practice Targets

Table 19. Pollutant load reduction.

	Reduction in Load (t/20 years)		
Catchment	**TSS**	**TN**	**TP**
Bribie	1,778	12.50	2.98
Brisbane Coastal	437	2.96	0.70
Burpengary	9,440	74.40	16.38
Caboolture	29,200	258.00	55.00
CIGA	106,400	524.00	143.20
Hays Inlet	22,560	198.00	44.20
Lower Pine	12,560	109.40	24.98
Pumicestone	15,500	133.80	27.58
Redcliffe	3,248	23.80	5.44
Stanley	1,254	9.46	2.16
Upper Pine	64	0.60	0.12
Total	**202,441**	**1,347**	**323**

Table 20. Allocation of WSUD-bioretention present value to water pollutants.

Catchment	NPV ($2011)	NPV minus Avoided Cost for TSS ($2011)	TN ($2011)	TP ($2011)
Bribie	3,621,500	3,242,786	907,980	2,334,806
Brisbane Coastal	810,800	717,804	200,985	516,819
Burpengary	20,155,900	18,145,180	5,080,650	13,064,530
Caboolture	62,474,200	56,254,600	15,751,288	40,503,312
CIGA	153,764,000	131,100,800	36,708,224	94,392,576
Hays Inlet	46,932,500	42,127,220	11,795,622	30,331,598
Lower Pine	27,683,000	25,007,720	7,002,162	18,005,558
Pumicestone	33,118,200	29,816,700	8,348,676	21,468,024
Redcliffe	6,788,200	6,096,376	1,706,985	4,389,391
Stanley	2,762,426	2,495,324	698,691	1,796,633
Upper Pine	138,100	124,396	34,831	89,565
Total	**358,248,826**	**315,128,906**	**88,236,094**	**226,892,812**

Table 21. WSUD-bioretention pollutant load reduction and abatement cost-effectiveness.

	Abatement Cost-Effectiveness ($AUD2011/tonne)	
Catchment	**TN**	**TP**
Bribie	72,638	783,492
Brisbane Coastal	67,900	738,313
Burpengary	68,288	797,590
Caboolture	61,052	736,424
CIGA	70,054	659,166
Hays Inlet	59,574	686,235
Lower Pine	64,005	720,799
Pumicestone	62,397	778,391
Redcliffe	71,722	806,873
Stanley	73,857	831,775
Upper Pine	58,051	746,373
Total	**66,322**	**753,221**

Increased Enforcement and Implementation of Erosion and Sediment Control on Development Sites

Table 22. Development site sediment load reduction and abatement cost-effectiveness.

Catchment	NPV ($2011)	TSS Reduction (t/20 years)	TSS Abatement Cost-Effectiveness ($/tonne)
Bribie Island	$1,296	266	$4.87
Pumicestone Passage	$7,418	1,530	$4.85
Redcliffe	1679	310	$5.42
Caboolture River	$19,722	3,412	$5.78
Burpengary Creek	$4,709	956	$4.93
Hays Inlet	$14,893	2,344	$6.35
Brisbane Coastal	$299	38	$7.87
Lower Pine River	$8,244	1,296	$6.36
Upper Pine River	$22	5	$4.78
Stanley River	$618	122	$5.07
CIGA	$12,691	6,260	$2.03
Total	$71,591	16,539	
Average			**$4.33**

Riparian Revegetation for 3rd and 4th Order Streams

Table 23. Riparian revegetation of 3rd and 4th order streams sediment load reduction and abatement cost-effectiveness.

Catchment	Total Revegetation Area (ha)	NPV ($M2011)	Total Sediment Load Reduction (t/20years)	Abatement Cost-Effectiveness ($/t)
Pumicestone	32	4.8	10,440	460
Caboolture	100	15.0	35,200	426
CIGA	24	3.6	11,978	301
Burpengary	54	8.0	82,180	97
Hays	12	1.8	6,194	291
Sideling	2	0.3	705	426
Lower Pine	65	9.8	13,005	754
Upper Pine	56	8.3	13,958	595
Stanley	58	8.6	15,910	541
Total	**403**	**60.2**	**189,570**	
Average				**318**

Rural BMP – Stock Exclusion and Revegetation of 1st and 2nd Order Streams

Table 24. Stock exclusion and revegetation of 1st and 2nd order streams sediment load reduction and abatement cost-effectiveness.

Catchment	Total Revegetation Area (ha)	NPV ($M2011)	Total Sediment Load Reduction (t/20years)	Abatement Cost-effectiveness ($/t)
Pumicestone	83	15.14	19,415	780
Caboolture	254	46.205	57,995	797
Burpengary	43	7.76	9,845	788
Sideling	19	3.51	6,690	525
Lower Pine	8	1.52	5,952	255
Upper Pine	105	19.08	27,137	703
Stanley	191	34.72	36,059	963
Total	**703**	**127.93**	**163,093**	
Average				**784**

Buffer Strips

Table 25. Allocation of buffer strip present value to water pollutants.

Catchment	NPV ($2011)	TSS ($2011)	TN ($2011)	TP ($2011)
Pumicestone	521,200	239,752	78,180	198,056
Caboolture	187,400	86,204	28,110	71,212
Sideling	68,600	31,556	10,290	26,068
Lower Pine	1,296,500	596,390	194,475	492,670
Upper Pine	3,452,500	1,588,150	517,875	1,311,950
Stanley	1,440,100	662,446	216,015	547,238
Total	**6,966,300**	**3,204,498**	**1,044,945**	**2,647,194**

Table 26. Buffer strip pollutant load reduction and abatement cost-effectiveness.

	Load Reduction (t/20years)			Abatement Cost-Effectiveness ($AUD2011/tonne)		
Catchment	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**
Pumicestone	1,650	11	2	145	7,133	105,349
Caboolture	246	1	0	350	31,943	445,075
Sideling	158	1	0	200	10,290	144822
Lower Pine	2,170	14	3	275	13,562	185,214
Upper Pine	11,188	71	13	142	7,319	99,844
Stanley	6,332	148	8	105	1,461	67,896
Total	**21,743**	**246**	**26**			
Average				**147**	**4,251**	**101,503**

Recycled Water to Agricultural Users

Note that the value of water was based upon the water charges to agricultural users. Pollution costs were initially allocated to TSS, TN and TP. However, TSS abatement cost-effectiveness was many magnitudes higher than other sediment abatement measures and the amount of abatement available was relatively small. Consequently, it was assumed that recycled water would be used as an abatement measure for nutrients but not for sediments.

Table 27. Allocation of recycled water to agricultural users present value to water pollutants.

Catchment	NPV ($M2011)	Water Savings (ML/yr)	NPV Water ($2011)	NPV Allocated to Pollutants ($M2011)	TSS ($2011)	TN ($M2011)	TP ($M2011)
Caboolture Catchment (Wamuran Scheme)	14.90	2,920	132,597	14.77	0	4.18	10.59
Stanley Catchment (Woodford Scheme)	2.04			2.04	0	0.58	1.46
Total				**16.81**	**0**	**4.76**	**12.05**

Table 28. Recycled water to agricultural users pollutant load reduction and abatement cost-effectiveness.

	Load Reduction (t/20years)			Abatement Cost-Effectiveness ($/tonne)	
Catchment	**TSS**	**TN**	**TP**	**TN**	**TP**
Caboolture Catchment (Wamuran Scheme)	117	146	18	28,634	604,499
Stanley Catchment (Woodford Scheme)	6	15	3	39,761	504,334
Total	**123**	**161**	**20**		
Average				**29,641**	**590,274**

Waste Water Reuse for Dual Reticulation and Public Open Space Irrigation

Pollution reductions for recycled water assumed by WBM were based upon reducing the median STP discharge to a zero emission. The reduction in concentration was then multiplied by the volume of water supplied by the scheme to calculate a load reduction. For example, the Caboolture South STP had a median discharge concentration of 2, 2.5, 0.3 mg/L of TSS, TN and TP respectively.

However, the biggest influence on the cost of pollution abatement from wastewater reuse was the value of the water produced by the system. The present value of water based on the price path for bulk water with a 5.5% discount rate was greater than the present value of a number of options. This was reflected in the low levelised water cost for these schemes reported by BMT-WBM. The allocation to pollution abatement was sensitive to the discount rate. A 3% discount rate gave a present value of water greater than the discounted capital and operating costs of even more schemes.

The negative cost allocation for abatement suggests a cost saving and prioritisation of these schemes. However, when expressed on a catchment level with a number of other options there was no net cost saving.

Table 29. Allocation of present value for dual reticulation and public open space irrigation to water pollutants.

Catchment	STP	Demand	NPV ($M2011)	Potable Water Savings (ML/year)	Total Water Savings (Ml/yr)	NPV Water Savings ($M2011)	NPV Allocated to Pollutants ($M2011)
Caboolture Catchment assuming Wamuran Scheme is NOT implemented							
	South Caboolture STP						
		North East Business Park	23.1	717	847	21.33	1.77
		Narangba East LDAP	9.0	257	388	9.77	-0.77
		Burpengary East LAP	3.4	105	144	3.63	-0.23
		Morayfield Burpengary	23.8	671	1,039	26.16	-2.36
		Burpengary East STP					
		Narangba Industrial Estate	22.4	548	548	13.80	8.60
		Total Caboolture Catchment	81.6	2,297	2,966	74.68	6.92
Caboolture Catchment Assuming Wamuran Scheme is implemented and A+ water from Caboolture South NOT available for use							
	Burpengary East STP						
		Narangba Industrial Estate	22.4	717	548	13.80	8.60
		North East Business Park	32.0	257	847	21.33	10.67
		Narangba East LDAP	14.6	105	388	9.77	4.83
		Burpengary East LAP	5.5	671	144	3.63	1.87
		Morayfield Burpengary	38.8	548	1,039	26.16	12.64
		Total Caboolture Catchment	113.3	2,297	2,966	74.68	38.62
Lower Pine							
	Murrumba Downs STP						
		Northern Growth Corridor (POS/Industrial only)	51.5	621	1,460	36.76	14.74
		Northern Growth Corridor (POS/Industrial and addition 4ML/day)	57.8	621	1,716	43.21	14.59
	Brendale STP						
		Brendale	12.9	365	365	9.19	3.71
		Total Lower Pine Catchment	70.7	986	2,081	52.40	18.30
Hays Inlet							
	Redcliffe STP						
		Ray Frawley Fields Clontarf	2.00	53	67	1.69	0.31
		Redcliffe Reuse Scheme	17.60	100	600	15.11	2.49
		Total	19.50	153	667	16.79	2.71
Caboolture							
	New STP Caboolture Identified Growth Area (CIGA)						
		CIGA	37.00	1,688	2,924	73.62	-36.62

Table 30. Dual reticulation and public open space irrigation pollutant load reduction and abatement cost-effectiveness.

Catchment	STP	Demand	Pollution Reduction (t/20yr)			Abatement Cost-effectiveness ($/t)	
			TSS	TN	TP	TN	TP
Caboolture Catchment assuming Wamuran Scheme is NOT implemented							
	South Caboolture STP						
		North East Business Park	34	42	5.1	11,855	250,304
		Narangba East LDAP	16	19	2.3	-11,213	-235,751
		Burpengary East LAP	6	7	0.9	-8,874	-188,218
		Morayfield Burpengary	42	52	6.2	-12,859	-271,267
		Burpengary East STP					
		Narangba Industrial Estate	22	33	3.3	74,088	1,880,318
		Total Caboolture Catchment	119	154	17.8	12,734	278,711
Caboolture Catchment		Assuming Wamuram Scheme is implemented and A+ water from Caboolture South NOT available for use					
	Burpengary East STP						
		Narangba Industrial Estate	22	33	3.3	74,088	1,880,318
		North East Business Park	34	51	5.1	59,464	1,506,432
		Narangba East LDAP	16	23	2.3	58,676	1,480,102
		Burpengary East LAP	6	9	0.9	61,394	1,562,550
		Morayfield Burpengary	42	62	6.2	57,362	1,452,245
		Total Caboolture Catchment	119	178	17.8	61,418	1,555,582
Lower Pine							
	Murrumba Downs STP						
		Northern Growth Corridor (POS/Industrial only)	58	88	14.6	47,618	723,797
		Northern Growth Corridor (POS/Industrial and addition 4ML/day)	69	103	17.2	40,121	609,726
	Brendale STP						
		Brendale	15	18	3.7	57,498	726,717
		Total Lower Pine Catchment	83	121	20.8	42,746	630,898
Hays Inlet							
	Redcliffe STP						
		Ray Frawley Fields Clontarf	3	7	0.1	13,262	1,603,033
		Redcliffe Reuse Scheme	24	60	1.2	11,758	1,489,323
		Total	27	67	1.3	11,484	1,447,697
Caboolture							
	New STP Caboolture Identified Growth Area (CIGA)						
		CIGA	117	146	17.54	-70,906	-1,497,040

Recycled Water to Urban Users Option 2: Public Open Space Irrigation only (Class A)

The value of water again determines whether the abatement option is a cost or a saving. It appears that it is more cost-effective to use the water from South Caboolture STP for recycling to urban water demands rather than agricultural uses in the Wamuran Scheme because the value of the water is higher and provides and provides very cost-effective pollution abatement (at low or negative cost for abatement assuming bulk water value for recycled water). It also appears to be more cost-effective to irrigate Public Open Space only rather than couple it together with Dual Reticulation. However, this assumes that both water demands offset bulk water supplies. It this is not the case then the value of POS irrigation may be less and dual reticulation may be more cost-effective.

Table 31. Allocation of present value for public open space irrigation only to water pollutants.

Catchment	STP	Demand	NPV ($M2011)	Potable Water Savings (ML/year)	Total Water Savings (Ml/yr)	NPV Water Savings ($M2011)	NPV Allocated to Pollutants ($M2011)
Caboolture Catchment assuming Wamuran Scheme is NOT implemented							
	South Caboolture STP						
		North East Business Park	10	235	365	9	1.11
		Narangba East LDAP	4	51	183	5	-1.11
		Burpengary East LAP	1	21	60	2	-0.31
		Morayfield Burpengary	10	143	511	13	-3.07
		Total Caboolture Catchment	25	450	1119	28	-3.38
Caboolture Catchment		Assuming Wamuran Scheme is implemented and A+ water from Caboolture South NOT available for use					
	Burpengary East STP						
		North East Business Park	12	235	365	9	3.11
		Narangba East LDAP	6	51	183	5	1.59
		Burpengary East LAP	2	21	60	2	0.49
		Morayfield Burpengary	17	143	511	13	4.33
		Total Caboolture Catchment	38	450	1119	28	9.52
Lower Pine							
	Murrumba Downs STP						
		Northern Growth Corridor (POS/Industrial only)	52	621	1460	37	14.74
		Northern Growth Corridor (POS/Industrial and addition 4ML/day)	58	621	1716	43	14.59
	Brendale STP						
		Brendale	6	183	183	5	1.19
		Total Lower Pine Catchment	64	803	1898	48	15.81
Hays Inlet							
	Redcliffe STP						
		Ray Frawley Fields Clontarf	2	53	67	2	0.31
		Redcliffe Reuse Scheme	18	100	600	15	2.49
		Total	20	153	667	17	2.71
Caboolture							
	New STP Caboolture Identified Growth Area (CIGA)						
		CIGA	29	671	1908	48	-19.44

Table 32. Public open space irrigation only pollutant load reduction and abatement cost-effectiveness.

			Pollution Reduction (t/20yr)			Abatement Cost-Effectiveness ($/t)	
Catchment	**STP**	**Demand**	**TSS**	**TN**	**TP**	**TN**	**TP**
Caboolture Catchment assuming Wamuran Scheme is NOT implemented							
	South Caboolture STP						
		North East Business Park	14.60	18.26	2.20	17,200	361,651
		Narangba East LDAP	7.30	9.12	1.10	-34,376	-722,026
		Burpengary East LAP	2.42	3.02	0.36	-29,120	-618,863
		Morayfield Burpengary	20.44	25.56	3.06	-33,954	-718,486
		Total Caboolture Catchment	44.76	55.94	6.72	-17,076	-360,112
Caboolture Catchment		Assuming Wamuram Scheme is implemented and A+ water from Caboolture South NOT available for use					
	Burpengary East STP						
		North East Business Park	14.60	21.90	2.20	40,187	1,013,453
		Narangba East LDAP	7.30	10.96	1.10	41,117	1,037,837
		Burpengary East LAP	2.42	3.62	0.36	38,252	974,428
		Morayfield Burpengary	20.44	30.66	3.06	40,003	1,015,390
		Total Caboolture Catchment	44.76	67.12	6.72	40,162	1,016,236
Lower Pine							
	Murrumba Downs STP						
		Northern Growth Corridor (POS/Industrial only)	58.40	87.60	14.60	47,618	723,797
		Northern Growth Corridor (POS/Industrial and addition 4ML/day)	68.62	102.94	17.16	40,121	609,726
	Brendale STP						
		Brendale	7.3	9.12	1.82	36,999	469,686
		Total Lower Pine Catchment	75.92	112.06	18.98	39,931	597,249
Hays Inlet							
	Redcliffe STP						
		Ray Frawley Fields Clontarf	2.66	6.68	0.14	13,262	1,603,033
		Redcliffe Reuse Scheme	24	60	1.20	11,758	1,489,323
		Total	26.66	66.68	1.34	11,484	1,447,697
Caboolture							
	New STP Caboolture Identified Growth Area (CIGA)						
		CIGA	76.3	95.38	11.44	-57,688	- 1,218,451

Water Sensitive Urban Design Retrofit to Existing Areas

Table 33. Pollutant load reduction.

	Reduction in Pollutant Loads		
Catchment	**TSS (t/20 year)**	**TN (t/20year)**	**TP (t/20year)**
Pumicestone	2,120	11	4
Caboolture	32,000	160	56
Burpengary	14,600	62	26
Hays Inlet	5,020	24	9
Brisbane Coastal	2,580	10	4
Lower Pine	25,600	114	44
Total	**81,920**	**381**	**142**

Table 34. Allocation of present value for WSUD retrofit to water pollutants.

			Allocation of Pollution Costs	
Catchment	**NPV ($M2011)**	**NPV - TSS avoided cost ($M2011)**	**TN ($M2011)**	**TP ($M2011)**
Pumicestone	$4.529	4.077	1.142	2.936
Caboolture	$45.705	38.889	10.889	28.0
Burpengary	$22.151	19.041	5.331	13.71
Hays Inlet	$8.841	7.772	2.176	5.596
Brisbane Coastal	$3.867	3.318	0.929	2.389
Lower Pine	$38.332	32.879	9.206	23.673
Total	**$123.426**			

Table 35. WSUD retrofit load reduction and abatement cost-effectiveness.

Catchment	**TN**	**TP**
Pumicestone	103,787	733,921
Caboolture	68,055	499,996
Burpengary	85,993	523,270
Hays Inlet	90,673	658,329
Brisbane Coastal	92,911	612,602
Lower Pine	80,756	542,961
Average	**87,029**	**595,180**

Water Sensitive Urban Design to Achieve No Worsening of Pollutant Loads

Only the catchments that hadn't already met the 'no worsening' of pollutant load were included.

Table 36. Pollutant load reduction.

Catchment	TSS (t/20 year)	TN (t/20year)	TP (t/20year)
Caboolture	30,180	278	57
Hays Inlet	24,580	240	50
Pumicestone	16,160	147	29
Upper Pine	70	0.7	0.1
Total	**70,990**	**666**	**136**

Table 37. Allocation of present value for 'WSUD to achieve no worsening of pollutant loads'.

			Allocation of Pollution Costs		
Catchment	**NPV ($M2011)**	**NPV - TSS Avoided Cost ($M2011)**	**TSS ($M2011)**	**TN ($M2011)**	**TP ($M2011)**
Caboolture	73.624	67.195	0	18.815	48.381
Hays Inlet	82.822	77.586	0	21.724	55.862
Pumicestone	41.398	37.956	0	10.628	27.328
Upper Pine	0.22	0.205	0	0.057	0.147
Total	**198.063**	**182.942**	**0**	**51.224**	**131.718**

Table 38. WSUD to achieve no worsening of pollutant loads' load reduction and abatement cost-effectiveness.

	Abatement Cost-Effectiveness ($AUD2011/tonne)	
Catchment	**TN**	**TP**
Caboolture	67,679	842,868
Hays Inlet	90,442	1,128,528
Pumicestone	72,395	936,534
Upper Pine	79,626	1,053,007
Average	**76,945**	**966,952**

Stormwater Harvesting

Note CIGA relatively cost-effective due to the relatively large water savings compared to stormwater harvesting in other catchments. This also affects the average cost-effectiveness across all catchments.

Table 39. Allocation of present value for stormwater harvesting to water pollutants.

						Allocation of Pollutant NPV ($M2011)		
Catchment	**NPV ($M2011)**	**Potable Water Savings (ML/year)**	**Total Water Savings (Ml/yr)**	**NPV Water Savings ($M2011)**	**NPV Alocated to Pollutants ($M2011)**	**TSS**	**TN**	**TP**
Pumicestone	49	385	499	12.6	37	17	6	14
CIGA	69	1,232	2,161	54.4	14	7	2	6
Caboolture	28	184	239	6.0	22	10	3	8
Burpengary	27	178	254	6.4	20	9	3	8
Hays Inlet	25	246	246	6.2	19	9	3	7
Lower Pine	27	197	257	6.5	20	9	3	8
Total	**225**	**2,422**	**3,656**	**92**	**133**	**61**	**20**	**50**

Table 40. Stormwater harvesting pollutant load reduction and abatement cost-effectiveness.

	Pollution Reduction (t/20yr)			Abatement Cost-Effectiveness ($/t)		
Catchment	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**
Pumicestone	1,508	18	3	11,250	304,522	4,144,868
CIGA	6,526	79	15	1,021	27,628	375,552
Caboolture	723	8.7	1.6	13,962	377,594	5,148,957
Burpengary	768	9.3	1.7	12,086	326,770	4,456,732
Hays Inlet	742	8.9	1.7	11,756	318,153	4,340,674
Lower Pine	776	9.3	1.7	12,103	327,695	4,456,154
Total	**11,042**	**133**	**25**			
Average				**5,534**	**149,736**	**2,037,181**

Purified Recycled Water

Table 41. Allocation of present value for purified recycled water to water pollutants.

					Allocation of Pollutant NPV ($M2011)	
Catchment	**NPV (Million$2011)**	**Total Water Savings (Ml/yr)**	**NPV Water Savings (Million$2011)**	**NPV Allocated to Pollutants (Million$2011)**	**TN**	**TP**
Lower Pine	449	15,197	383	66	19	48
CIGA	81	3,626	91	-10	-2.9	-7.2
Total	**530**	**18,823**	**474**	**56**	**16**	**40**

Table 42. Purified recycled water pollutant load reduction and abatement cost-effectiveness.

	Pollution Reduction (t/20yr)			Abatement Cost-Effectiveness ($/t)		
Catchment	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**
Lower Pine	319	402	145		46,674	326,895
CIGA	155	97	19		-29,575	-387,612
Total	**474**	**498**	**164**			
Average					**31,889**	**245,511**

Retrofit of Rainwater Tanks in Existing Urban Areas

Table 43. Allocation of present value for retrofit of rainwater tank to water pollutants.

					Allocation of Pollutant NPV ($M2011)		
Catchment	**NPV ($M2011)**	**Potable Water Savings (ML/yr)**	**NPV Water ($M2011)**	**NPV ($M2011)**	**TSS**	**TN**	**TP**
Bribie Island	14.298	251	6.320	7.978	3.670	1.197	3.032
Redcliffe	41.425	727	18.305	23.120	10.635	3.468	8.785
Brisbane Coastal	18.861	331	8.334	10.527	4.842	1.579	4.0
Pumicestone	9.526	167	4.205	5.321	2.448	0.798	2.022
Total	**84.110**	**1476**	**37.164**	**46.946**	**21.595**	**7.042**	**17.839**

Table 44. Retrofit of rainwater tanks pollutant load reduction and batement cost-effectiveness.

	Reduction in Load (t/20 years)			Abatement Cost-Effectiveness ($AUD2011/tonne)		
Catchment	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**
Bribie Island	100	9	0.6	36,553	130,932	4,736,994
Redcliffe	291	26	1.9	36,559	130,965	4,673,118
Brisbane Coastal	132	12	0.9	36,562	130,928	4,651,280
Pumicestone	67	6	0.4	36,588	131,280	4,595,601
Total	**591**	**54**	**3.8**	**36,562**	**130,986**	**4,669,975**
Average				**36,562**	**130,986**	**4,669,975**

APPENDIX 3: Distance to Target Approach for Allocating of Costs between Pollutants for Each Abatement Option

A number of abatement options focus on reducing a particular pollutant. For example, water recycling reduces nutrients and the reduction of suspended solids is very small. Applying a general allocation rule which allocates half of the costs of water recycling to suspended solids would make the costs allocated to nutrient abatement much lower and distort the comparison of cost-effectiveness estimates. The following approach provides a method of allocation that considers the relative contribution of each abatement option towards the load reduction targets as a method of allocating its abatement costs.

Equation 1. Adding individual abatement options to achieve a predetermined load reduction target

$$R_{TN} = \sum_{1}^{i} r_{TNi}$$

$$R_{TP} = \sum_{1}^{i} r_{TPi}$$

$$R_{TSS} = \sum_{1}^{i} r_{TSSi}$$

Where:

r_{TNi} r_{TPi} r_{TSSi} = abatement options for Total Nitrogen, Total Phosphorus and Total Suspended Solids respectively

$R_{TN} R_{TP} R_{TSS}$ = load reduction targets for Total Nitrogen, Total Phosphorus and Total Suspended Solids respectively

Equation 2. Considering the relative contribution of an individual abatement option towards a load reduction target

Each term in the following sum captures the relative contribution towards the load reduction target for each pollutant for an abatement option. For example:

$$c = \frac{r_{TNi}}{R_{TN}}$$

Where:

c = $contribution\ towards\ TN\ target\ for\ abatement\ option\ i$

The following sum α is unlikely to equal 1 and needs to be scaled to provide an allocation for 100% of project costs.

$$\alpha_i = \frac{r_{TNi}}{R_{TN}} + \frac{r_{TPi}}{R_{TP}} + \frac{r_{TSSi}}{R_{TSS}}$$

Where:

α_i = the sum of the contributions for each pollutant reduction towards a predetermined target for an abatement option

Normalising the contributions to provide an allocation for costs and benefits based upon the contribution of each abatement option to the water quality pollution reduction targets

$$A_{TNi} = \frac{1}{\alpha_i} * \frac{r_{TNi}}{R_{TN}}$$

$$A_{TPi} = \frac{1}{\alpha_i} * \frac{r_{TPi}}{R_{TP}}$$

$$A_{TSSi} = \frac{1}{\alpha_i} * \frac{r_{TSSi}}{R_{TSS}}$$

Where:

A_{TNi} = the allocation of costs and benefits to Total Nitrogen for the abatement option

A_{TPi} = the allocation of costs and benefits to Total Phosphorus for the abatement option

A_{TSSi} = the allocation of costs and benefits to Total Suspended Solids for the abatement option

Note that the sum of the allocations is equal to one ie: $A_{TNi} + A_{TPi} + A_{TSSi} = 1$

$$A_{TNi} + A_{TPi} + A_{TSSi} = \frac{1}{\alpha_i} * \frac{r_{TNi}}{R_{TN}} + \frac{1}{\alpha_i} * \frac{r_{TPi}}{R_{TP}} + \frac{1}{\alpha_i} * \frac{r_{TSSi}}{R_{TSS}} = \frac{1}{\alpha_i}\left[\frac{r_{TNi}}{R_{TN}} + \frac{r_{TPi}}{R_{TP}} + \frac{r_{TSSi}}{R_{TSS}}\right] = \frac{1}{\alpha_i}.\alpha_i = 1$$

Example:

	TSS	TN	TP	
Load reduction from WSUD (r)	202,441	1,347	323	
load reduction target for catchment (R)	85,126	2,002	369	
Contribution towards target (r/R)	2.38	0.67	0.88	
α				3.9263
Allocation (A)	0.61	0.17	0.22	
Alternative allocation assuming no contribution to sediment load reduction (r/R)		0.67	0.88	
α				1.55
Allocation (A)		0.43	0.57	

This example illustrates the possible need for an additional rule for developing the allocation. Although WSUD can potentially meet the load reduction target a number of times over based on the Draft TWCMP, it does not appear in the MACC for TSS. This was because sediment abatement in the catchment was much more cost-effective. If more cost-effective abatement options for sediments were adopted then there would be no need for WSUD sediment abatement and there would be no remaining target and no allocation for WSUD sediment abatement. In this case, 43% and 57% of abatement costs would be allocated to TN and TP respectively.

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