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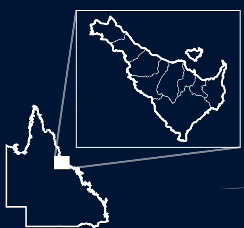
Options, Costs & Benefits Report for the Black Ross (Townsville) WQIP



Improving Water Quality from Creek to Coral

Australian Government

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1. Background

1.1 Linking Options with Benefits and Costs

The Black Ross (Townsville) Water Quality Improvement Plan was developed using a variety of information sources and synthesis reports prepared by the Creek to Coral team. This report brings together the information relevant to the costs and benefits associated with the identified options that have potential to improve water quality across the Townsville region. This is not a conventional economic cost benefit analysis but rather a summary of the reasoning used to link the science and the physical and social options with the benefits and costs to show the potential for achievement of water quality pollutant load reductions through a range of integrated programs and management actions.

1.2 WQIP Area

The total land area of the catchments that flow to Cleveland and Halifax Bays is 268,400 hectares (~2,700 square kilometers). This represents approximately 0.6% of the total area of the Great Barrier Reef (GBR) catchments. While not a large area in terms of the GBR catchment the Black Ross (Townsville) WQIP area is home to approximately 20% of the GBR catchment population.

1.3 Land Use

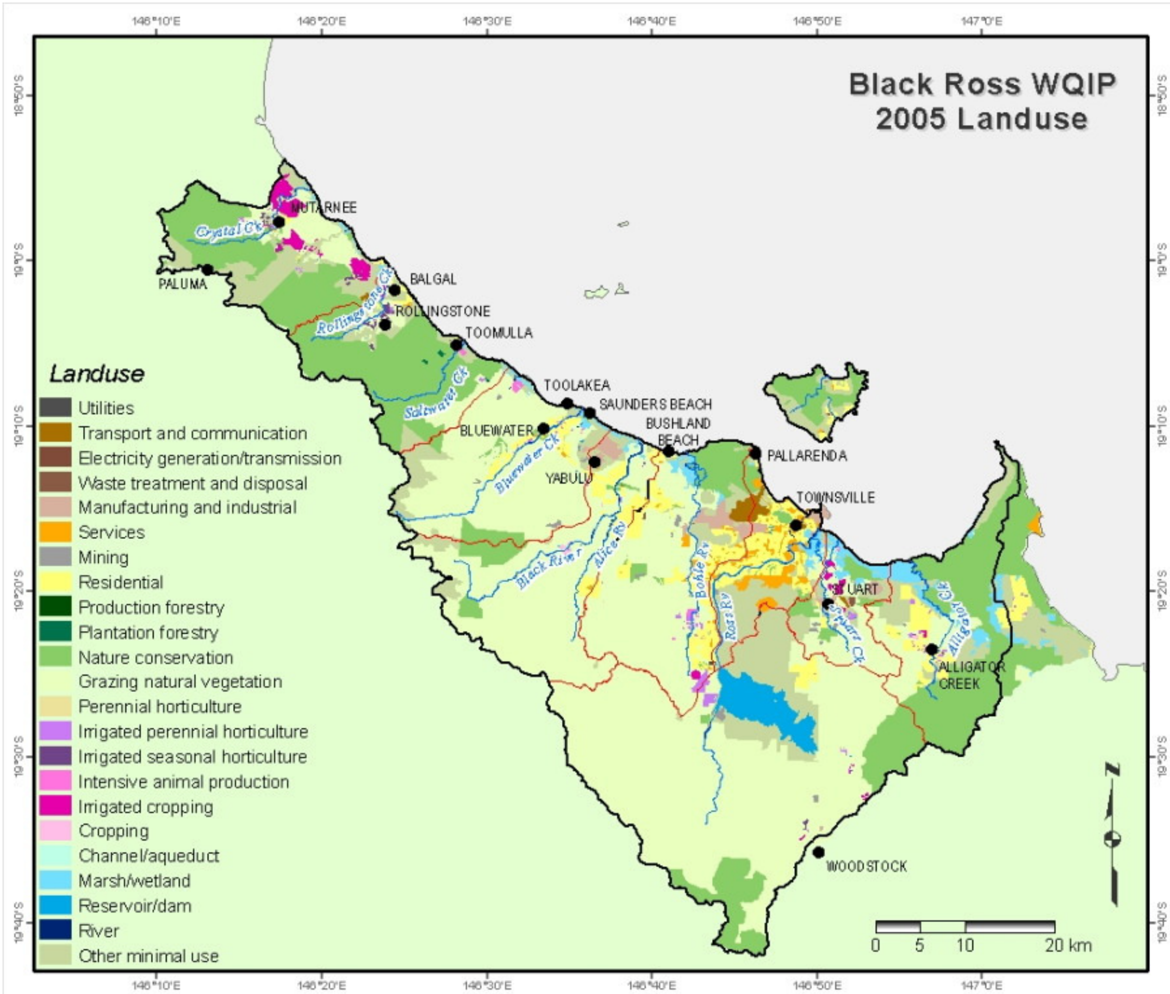
Creek to Coral, as part of the Coastal Catchments Initiative (CCI) project, updated the land use mapping from the Queensland Land Use Mapping Program (QLUMP) (DNRM 1999) to more closely reflect the present land use situation, particularly in the expanding urban area. The main land use categories and total areas for the Black Ross (Townsville) WQIP area are listed in Table 1.1. Secondary and tertiary land use groupings are illustrated in Figure 1.1.

Table 1.1 Principal Land Use Categories (2005)

Secondary and Tertiary Land Use	Main Land Use Groupings	Hectares	%
Nature conservation, Other minimal use	Conservation and natural areas	98,527	36.7
Grazing natural areas, Production forestry	Grazing	132,209	49.3
Residential	Rural residential	8,173	3.0
Cropping, Perennial horticulture, Plantation forestry, Irrigated cropping, Irrigated horticulture (perennial and seasonal), Intensive animal production.	Intensive agriculture	4,108	1.5
Residential, Manufacturing and industrial, Services, Utilities, Transport and communication, Waste treatment and disposal, Mining.	Urban	15,565	5.8
Channel/aqueduct, Marsh/wetland, Reservoir/dam, River.	Water and wetlands	9,819	3.7

A land use summary, by Black Ross WQIP sub basins, is provided in Table 1.2. A more detailed analysis of land use can be found in the report titled *Basins, Catchments and Receiving Waters of the Black Ross River Water Quality Improvement Plan Area* (Gunn and Manning 2009).

Figure 1.1 Black Ross WQIP Area Updated Land Use Map



Note: The 1999 QLUMP land use data was updated using 2004/2005 aerial photography provided by Townsville City Council, and SPOT satellite imagery provided by Burdekin Dry Tropics NRM (now NQ Dry Tropics).

1.4 Land Use and Water Quality Pollutants

Determining pollutant types, their source and discharge quantities underpins the Black Ross (Townsville) WQIP particularly as the pollutants emanating from urban areas are not typical of rural areas and agriculture based land uses.

Focused event water quality monitoring has been used in an attempt to differentiate between different land uses and the pollutant types and loads associated with those land uses. A full description of pollutant types and sources can be found in the report *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009).

Movement of sediment and nutrients in rainfall runoff is a normal component of natural weathering and erosion processes. Additional inputs of nutrients combined with land disturbance and inappropriate management practices often results in accelerated run off and erosion rates and the subsequent transport of sediment and nutrients to receiving waters in quantities above natural levels. It is the delivery of sediment and nutrients to receiving waters at elevated levels, and particularly nutrients in forms that are soluble/bioavailable, that creates threats to aquatic habitats and biodiversity and, in some cases, for human health.

Table 1.2 Land Use Summary by Sub Basin

Land Use	Crystal		Rollingstone		Bluewater		Black		Bohle		Lower Ross		Upper Ross		Stuart		Alligator		Magnetic Is	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Nature conservation	11,786	49.2	15,865	72.1	1,645	5.7	1,962	6.5	3,197	9.9	944	7.0	8,218	10.9	1,366	13.2	14,194	53.6	2,639	52.9
Other minimal use	7,365	30.7	2,863	13.0	3,133	10.8	1,962	6.5	2,053	6.4	4,584	34.0	7,461	9.9	1,704	16.4	3,663	13.8	1,924	38.6
Grazing natural vegetation	2,287	9.5	2,382	10.8	21,893	75.4	23,063	75.9	19,018	59.0	316	2.3	54,082	71.7	5,054	48.7	4,111	15.5		
Production forestry	1	0.0	2	0.0																
Plantation forestry			70	0.3																
Cropping	10	0.0	28	0.1			103	0.3	4	0.0							43	0.2		
Irrigated cropping	1,697	7.1	52	0.2			7	0.0	88	0.3			63	0.1	299	2.9	26	0.1		
Irrigated perennial horticulture	88	0.4	70	0.3	77	0.3	58	0.2	299	0.9			323	0.4	56	0.5	185	0.7		
Irrigated seasonal horticulture	178	0.7	215	1.0									35	0.0			15	0.1		
Perennial horticulture	4	0.0							10	0.0							3	0.0		
Intensive animal production			40	0.2	117	0.4			101	0.3					23	0.2				
Residential	171	0.7	253	1.1	1,473	5.1	2,081	6.9	4,755	14.8	4,046	30.0	647	0.9	191	1.8	2,439	9.2	383	7.7
Manufacturing and industrial					48	0.2	564	1.9	1007	3.1	381	2.8	11	0.0	353	3.4			5	0.1
Services	25	0.1	34	0.2	45	0.2	58	0.2	532	1.7	2,004	14.9	75	0.1	32	0.3			27	0.5
Transport and communication	85	0.4	15	0.1			7	0.0	485	1.5	416	3.1			68	0.7				
Utilities									21	0.1	9	0.1			2	0.0				
Waste treatment and disposal			5	0.0	4	0.0			17	0.1					62	0.6			13	0.3
Mining	4	0.0			177	0.6			110	0.3	21	0.2	173	0.2	116	1.1	11	0.0		
Channel / aquaduct					7	0.0														
Reservoir / dam	2	0.0	5	0.0	20	0.1	5	0.0	3	0.0	149	1.1	4,332	5.7	14	0.1				
River	61	0.3	10	0.0	58	0.2	343	1.1	16	0.0	91	0.7	27	0.0			43	0.2		
Marsh / wetland	205	0.9	96	0.4	341	1.2	165	0.5	514	1.6	515	3.8	12	0.0	1,033	10.0	1,755	6.6		
Total (hectares)	23,969		22,003		29,037		30,377		32,229		13,475		75,460		10,371		26,489		4,990	

Note: The dominant landuse for each sub basin is shaded in yellow, 2nd most dominant in blue, 3rd in green, and 4th in pink.

1.5 Water Quality Pollutant Load Modelling

Catchment modelling was used to augment the limited amount of information available for the Black Ross WQIP area relating to sediment and nutrient discharge loads at the end of catchments. The modelled pre-settlement (1850) end of catchment loads based on expected pollutants generated from undisturbed forested catchments is shown in Table 1.3. This is considered to be the natural background level of pollutants generated and is the ultimate baseline for comparing current and future loads from disturbed catchments.

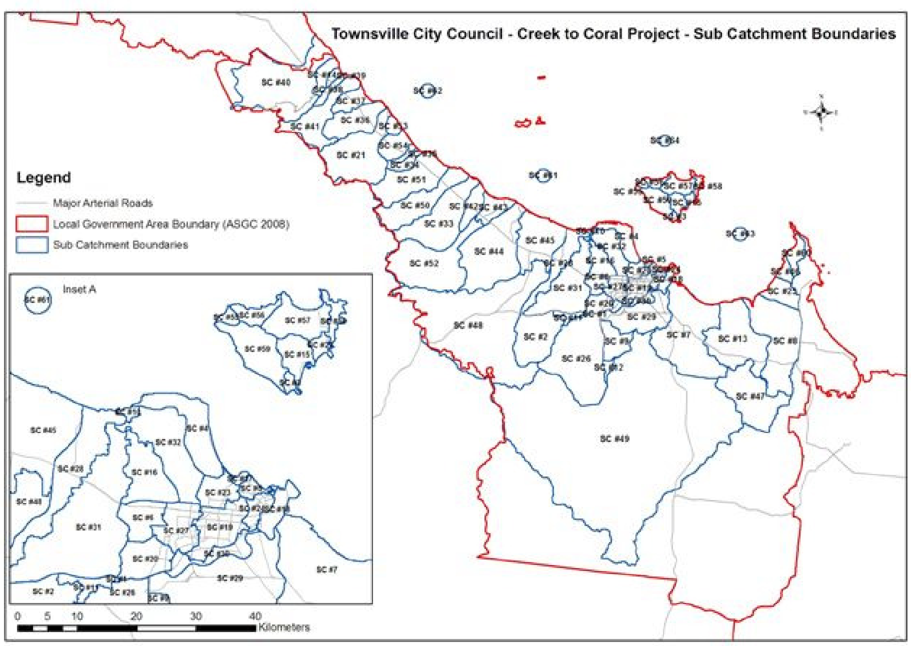
Table 1.3 Estimated End-of-Catchment Loads by Basin and Sub Basin at 1850

Sub Basin	No.	Area Hectares	Flow ML/year	TSS kg/year	TN kg/year	TP kg/year
Crystal Creek	1	22,629	241,419	967,949	45,919	4,693
Rollingstone Creek	2	21,822	145,337	581,003	27,628	2,943
Bluewater Creek	3	28,872	145,516	582,464	27,704	3,102
Black River	4	29,539	112,643	1,521,997	38,790	4,120
Black Basin total		102,861	644,915	3,653,413	140,041	14,859
Bohle River	5	33,194	119,673	1,955,625	46,633	4,895
Lower Ross River	6	13,244	46,692	760,268	18,181	1,909
Upper Ross River	7	74,929	198,331	3,119,235	77,433	7,962
Stuart Creek	8	11,024	37,986	609,968	14,793	1,538
Alligator Creek	9	27,490	110,086	1,902,587	42,778	4,621
Ross Basin total		159,882	512,769	8,347,683	199,817	20,925
Magnetic Island	10	4,815	26,755	107,077	5,088	518
Black Ross Total		267,559	1,184,438	12,108,173	344,945	36,302

Note: SB is sub basin. Alligator Creek sub basin has been grouped with the Ross River AWR Basin. It is part of the Haughton River AWR Basin.

The results of a significant number of smaller catchments (see Figure 1.2) have been combined to produce the aggregate results for each of the Black Ross WQIP sub basins in Table 1.3.

Figure 1.2 Modelled Catchment Units



This is not the first time that pre-settlement end of catchment pollutant discharge loads have been estimated (see Table 1.4) however it is the first detailed assessment specific to the Black Ross WQIP area.

Table 1.4 Pre settlement (1850) export loads

Study	Black Basin			Ross Basin			Black Ross WQIP		
	SS (kt/yr)	TN (t/yr)	TP (t/yr)	SS (kt/yr)	TN (t/yr)	TP (t/yr)	SS (kt/yr)	TN (t/yr)	TP (t/yr)
BMT WBM (2009)	3.7	140	15	8.3	200	21	12	340	36
Brodie et al (2001)	28	93	5	29	119	6	57	212	11
Brodie et al (2003)	30	77	11	20	39	5	50	116	16
NLWRA (2001)	27	200	27	30	269	38	57	469	65

Source: Brodie et al (2001), Brodie et al (2003), NLWRA and BMT WBM (2009).

Notes: NLWRA figures are based on their pre settlement to current export ratio for sediment of 1:3 for Black Basin and 1:2 for Ross Basin (http://www.anra.gov.au/topics/soils/erosion/qld/basin-ross-river-se.html) and for nutrients 1:2 for Black Basin and 1:1 for Ross Basin (http://www.anra.gov.au/topics/water/nutrients/qld/basin-ross-river.html)

The next stage was to use event mean concentrations results for receiving waters associated with various land uses as input to a catchment model (WaterCAST) to determine 'current' end of catchment loads. The event mean concentrations were derived from the event water quality monitoring undertaken by the ACTFR. A summary of the modelled diffuse source end of catchment loads for the sub basins in the Black Ross WQIP area, based on 2005 land use, is provided in Table 1.5.

The load estimates are based on diffuse source pollutants entering waterways in rainfall run-off at a 'set' areal rate from the various land uses. For a full explanation of the modelling methodology see the *Black and Ross River Water Quality Improvement Plan Catchment and Water Quality Modelling* report (BMT WBM 2010).

Table 1.5 Estimated End-of-Catchment Diffuse Source Loads by Basin and Sub Basin at 2005

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	kg/year	kg/year	kg/year
Crystal Creek	1	22,629	239,443	5,513,449	90,122	9,383
Rollingstone Creek	2	21,822	144,387	1,603,046	40,448	4,021
Bluewater Creek	3	28,872	145,698	2,806,946	92,700	4,641
Black River (no STP)	4	29,539	114,396	7,195,425	69,178	10,022
Black Basin total		102,861	643,925	17,118,866	292,448	28,067
Bohle River (no STP)	5	33,194	131,708	9,295,613	78,328	14,146
Lower Ross River	6	13,244	53,714	4,205,854	33,120	6,981
Upper Ross River	7	74,929	196,870	8,108,550	100,444	12,784
Stuart Creek (no STP)	8	11,024	47,483	1,650,930	18,956	2,959
Alligator Creek	9	27,490	104,834	2,104,936	42,716	4,811
Ross Basin total		159,882	534,608	25,365,882	273,565	41,680
Magnetic Island	10	4,815	27,390	342,217	6,286	944
Black Ross Total		267,559	1,205,923	42,826,965	572,299	70,690
Change from 1850			21,485	30,718,792	227,354	34,388
% increase from 1850			1.8	254	66	95

Note: Figures for the Upper Ross River Sub Basin indicate the loads entering Lake Ross behind the Ross River Dam. Figures for the Lower Ross River Sub Basin do not represent a true end of catchment load due to the impeding effect of the Ross River Dam and the lack of inclusion of flow events that result in the dam overtopping and spilling loads from the Upper Ross into the Lower Ross. Similarly the totals for the Ross Basin and Black Ross are not true end of catchment totals due to the trapping of the majority of the Upper Ross loads by the Ross River Dam.

Additional information including load discharge estimates by modelled catchment and Black Ross WQIP catchment is provided in Appendix B. A comparison of 'current' discharge load estimates from various studies is provided in Table 1.6. Point source pollution can also be factored into the load estimates using known discharge rates to waterways for contributing facilities.

Table 1.6 Comparison of End of Catchment Load Calculations

	Black Basin			Ross Basin			Black Ross WQIP Area		
Study	**SS (kt/yr)**	**TN (t/yr)**	**TP (t/yr)**	**SS (kt/yr)**	**TN (t/yr)**	**TP (t/yr)**	**SS (kt/yr)**	**TN (t/yr)**	**TP (t/yr)**
BMT WBM (2009)	17	292	28	25	274	42	42	566	70
[1]ACTFR (2008)	98	386	50	58	302	58	156	688	108
[2]ACTFR (2007)	61	140	31	53	273	49	114	412	80
Brodie et al (2003)	161	571	99	80	307	44	241	878	143
Furnas (2003)	140	319	62	180	411	81	320	730	143
Belperio (1983)	250			250			550		
Horn et al (1998)	67								
NLWRA (2001)	80	409	54	60	269	38	140	678	92
Moss et al (1992)							242	1,233	173

Source: Brodie et al (2003), Moss et al (1992), NLWRA (2001) and BMT WBM (2009).

Note: * Figures for Upper Ross River sub basin (75kt/yr) included in this total do not represent a true end of catchment discharge load due to the impeding effect of the Ross River Dam, therefore these figures are an over estimate. Areal estimates assumed by Moss et al - 838 kg/ha TSS, 4.3 kg/ha N and 0.6 kg/ha P.

[1] Based on calculations from ACTFR 2007/2008 event monitoring for Black River, Bohle River and Ross River catchments. Loads for basins were inferred using proportional inputs from modelled catchments (see Appendix B for assumptions).

[2] Based on calculations from ACTFR 2006/2007 event monitoring for Bluewater Creek, Black River, Bohle River, Ross River and Alligator Creek catchments. Loads for basins were inferred using proportional inputs from modelled catchments.

Along with the pre-settlement and 2005 load estimates future growth scenarios were also modelled by BMT WBM (2009) based on predicted population growth coupled with known dwelling occupancy rates, known and anticipated urban expansion areas, planning scheme zonings, the Townsville-Thuringowa Strategy Plan and land use mapping. The resulting population and development growth estimates were translated to changes in land use, which were then used to estimate end of catchment loads for the following scenario horizons:

- 2012 - to measure point source load reductions from wastewater treatment plant upgrades,
- 2021 - achievable management practice adoption timeframe for diffuse sources, and
- 2045 – potentially measurable water quality outcomes.

Table 1.7 Projected Land Use Change 2005 to 2045

Land use	2005 (ha)	2005 %	2045 (ha)	2045 %	Change (ha)	% change
C and I	335	0	578	0	243	0.09
Urban	5,148	2	10,197	4	5,049	1.89
Urban 2	5,483	2.05	10,776	4.03	5,293	1.98
Rural Res	2,896	1	4,029	2	1,133	0.42
Greenspace	75,883	28	75,752	28	-131	-0.05
Agriculture	30,744	11	27,858	10	-2,886	-1.08
Grazing	152,553	57	149,144	56	-3,409	-1.27
Rural	183,297	69	177,002	66	-6,295	-2.35
Total	267,559		267,559			

Note: C and I is commercial and industrial, Rural Res is rural residential. Urban 2 is the sum of the C and I and Urban land use categories. Rural is the sum of the Agriculture and Grazing land use categories. The sum of all land use is 267,559 hectares. 2005 %, 2045 % and % change is relative to the total area of the Black Ross WQIP area i.e. 267,559 hectares.

The projected land use changes that would lead to potential end of catchment load increases with the 'business as usual' (BAU) scenario are summarised in Table 1.7. As could be expected with population growth the urban and rural residential areas are expanding and rural areas are correspondingly decreasing.

Change in hectares between 2005 and 2045 for the various land use categories for each of the Black Ross WQIP sub basins is displayed in Table 1.8 along with the percentage of land use change in each sub basin relative to the total Black Ross WQIP area.

Table 1.8 Land Use Change by Sub Basin and Black Ross WQIP Area

Sub basin	C and I		Urban		Rural Res		Green Space		Agriculture		Grazing	
	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR
Crystal	1.5	0.6	76	1.5	0	0.0	0	0.0	-74	-2.6	-4	-0.1
Rollingstone	1.1	0.5	177	3.5	23	2.0	0	0.0	-37	-1.3	-164	-4.8
Bluewater	1.0	0.4	41	0.8	193	17.0	0	0.0	-3	-0.1	-232	-6.8
Black	1.8	0.7	248	4.9	137	12.1	0	0.0	-49	-1.7	-339	-9.9
Bohle	130.6	53.6	2,660	52.7	356	31.4	0	0.0	-916	-31.8	-2,230	-65.4
Lower Ross	101.4	41.6	1,559	30.9	1	0.1	-68	-52.1	-1,493	-51.7	-99	-2.9
Upper Ross	0.0	0.0	13	0.3	97	8.6	0	0.0	-6	-0.2	-104	-3.0
Stuart	3.9	1.6	13	0.3	13	1.1	0	0.0	-13	-0.5	-17	-0.5
Alligator	0.6	0.2	0	0.0	302	26.6	0	0.0	-293	-10.2	-9	-0.3
Magnetic Is.	1.8	0.7	262	5.2	12	1.1	-63	-48.1	0	0.0	-213	-6.2
Black Basin	5.5	2.2	543	10.7	353	31.2	0	0.0	-163	-5.7	-738	-21.6
Ross Basin	236.5	97.0	4,245	84.1	768	67.8	-68	-52.1	-2,722	-94.3	-2,458	-72.1
Black Ross	243.7	100	5,049	100	1,133	100	-131	-100	-2,886	-100	-3,409	-100

Note: C and I is commercial and industrial and Rural Res is rural residential. % BR is the percentage change in the land use for each sub basin relative to the total change for that land use across the whole Black Ross WQIP area.

The most noticeable increases for commercial and industrial, and urban land use is in the Bohle and Lower Ross sub basins while rural residential expansion is predicted for the Bluewater, Black, Bohle, Upper Ross and Alligator sub basins.

The 2045 diffuse source pollutants scenario was then modelled using the projected land use change data. The 2021 scenario was subsequently interpolated assuming a straight-line load increase from 2005 to 2045. Projected increases in diffuse source pollutant loads at 2021 (interpolated) and 2045 as a result of population increase and subsequent land use change, with no additional water quality improvement management interventions in place, are shown in Table 1.9 and Table 1.10 respectively.

Modelling end of catchment loads under different land use and management scenarios is one of the primary predictive tools used at the catchment scale to determine potential improvements in water quality through the introduction of different management practices. With the base case (2005) loads and potential future diffuse source load increases calculated (2021 and 2045) various scenarios were then run through the model to calculate the 'new' loads and proportional water quality benefits associated with a particular management practice, or practices. The management practice scenarios modelled for the Black Ross WQIP were:

1. Water sensitive urban design (WSUD) applied to all new (Greenfield) development;
2. WSUD measures applied to all urban areas (new and established); and
3. Best management practice principles applied to rural areas i.e. grazing and intensive agriculture.

(Note: Management practice scenario 1 is a sub set of management practice scenario 2)

Table 1.9 Modelled End-of-Catchment Diffuse Source Loads by WQIP Sub Basin at 2021

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	kg/year	kg/year	kg/year
Crystal Creek	1	22,629	239,283	6,515,695	97,966	10,352
Rollingstone Creek	2	21,822	144,635	2,168,745	45,643	4,572
Bluewater Creek	3	28,872	145,245	2,807,092	95,213	4,515
Black River (no STP)	4	29,539	114,411	7,408,731	70,669	10,246
Black Basin totals		102,861	643,574	18,900,263	309,491	29,686
Bohle River (no STPs)	5	33,194	132,384	9,494,820	78,326	14,225
Lower Ross River	6	13,244	54,146	5,081,431	36,718	7,766
Upper Ross River	7	74,929	196,578	10,153,950	110,232	14,741
Stuart Creek (no STP)	8	11,024	47,483	2,429,643	23,559	3,777
Alligator Creek	9	27,490	104,410	3,792,099	53,248	6,586
Ross Basin totals		159,882	535,001	30,951,942	302,083	47,094
Magnetic Island	10	4,815	27,430	399,459	6,383	1,000
Black Ross Total		267,559	1,206,004	50,251,665	617,957	77,780
Change from 1850				38,143,492	273,011	41,478
% increase from 1850				315	79	114
Change from 2005				7,424,700	45,657	7,090
% increase from 2005				17	8	10

Note: Change from 1850 represents the increase of pollutants generated above modelled background levels (1850) to 2021. Change from 2005 represents the modelled increase in pollutant loads from 2005 to 2021 with no management intervention.

Table 1.10 Estimated End-of-Catchment Loads by Basin and Sub Basin at 2045

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	kg/year	kg/year	kg/year
Crystal Creek	1	22,629	239,042	8,019,064	109,732	11,806
Rollingstone Creek	2	21,822	14,5008	3,017,294	53,436	5,400
Bluewater Creek	3	28,872	144,566	2,807,312	98,983	4,327
Black River (no STP)	4	29,539	114,433	7,728,690	72,904	10,581
Black Basin		102,861	643,048	21,572,359	335,055	32,115
Bohle River (no STPs)	5	33,194	133,397	9,793,631	78,322	14,343
Lower Ross River	6	13,244	54,795	6,394,797	42,114	8,943
Upper Ross River	7	74,929	196,139	13,222,050	124,916	17,678
Stuart Creek (no STP)	8	11,024	47,483	3,597,713	30,462	5,004
Alligator Creek	9	27,490	103,775	6,322,843	69,047	9,248
Ross Basin		159,882	535,589	39,331,033	344,860	55,216
Magnetic Island	10	4,815	27,489	485,322	6,527	1,084
Black Ross Total		267,559	1,206,126	61,388,714	686,442	88,416
Change from 1850			21,688	49,280,542	341,497	52,114
% increase from 1850			1.8	407	99	144
Change from 2005			202	18,561,749	114,143	17,726
% increase from 2005			0.0	43	19.9	25.1

Note: Change from 1850 represents the increase of pollutants generated above modelled background levels (1850) to 2045. Change from 2005 represents the modelled increase in pollutant loads from 2005 to 2045 with no management intervention.

Potential sediment, nitrogen and phosphorus load reductions at 2021 (interpolated), and 2045, if the management practice scenarios are implemented across the entire Black Ross WQIP land use area, are shown in Table 1.11 and Table 1.12 respectively. More detailed examples of potential load reduction figures as a result of management practice adoption are provided in Appendix B.

Potential load reductions for TSS, TN and TP are graphically illustrated in Figure 1.3, Figure 1.4 and Figure 1.5 respectively.

Table 1.11 Potential Diffuse Load Reductions with 100% Management Practice Adoption at 2021

Basin	2005 BAU	2005 to 2021 Increase		2021 BAU	All Urban WSUD			Rural BMP			All Change	
					Treated	Change		Treated	Change			
	t/year	t/year	%	t/year	t/year	t/year	%	t/year	t/year	%	t/year	% BAU
Total suspended solids (TSS)												
Black Basin	17,119	1,781	10	18,900	18,589	311	1.6	14,763	4,137	22	4,448	23.5
Ross Basin	25,366	5,586	22	30,952	28,876	2,076	6.7	24,600	6,352	21	8,428	27.2
Black Ross Total	42,827	7,425	17	50,252	47,756	2,495	5.0	39,763	10,489	21	12,984	25.8
Total nitrogen (TN)												
Black Basin	292	17	6	310	309	0.6	0.2	296	13.6	4.4	14	4.6
Ross Basin	274	29	10	302	298	4.0	1.3	291	11.2	3.7	15	5.0
Black Ross Total	572	46	8	618	613	4.8	0.8	593	24.8	4.0	30	4.8
Total phosphorus (TP)												
Black Basin	28	2	6	30	29.4	0.32	1.1	28.7	0.99	3.3	1	4.4
Ross Basin	42	5	13	47	44.8	2.26	4.8	45.5	1.58	3.4	4	8.2
Black Ross Total	71	7	10	78	75.1	2.71	3.5	75.2	2.57	3.3	5	6.8

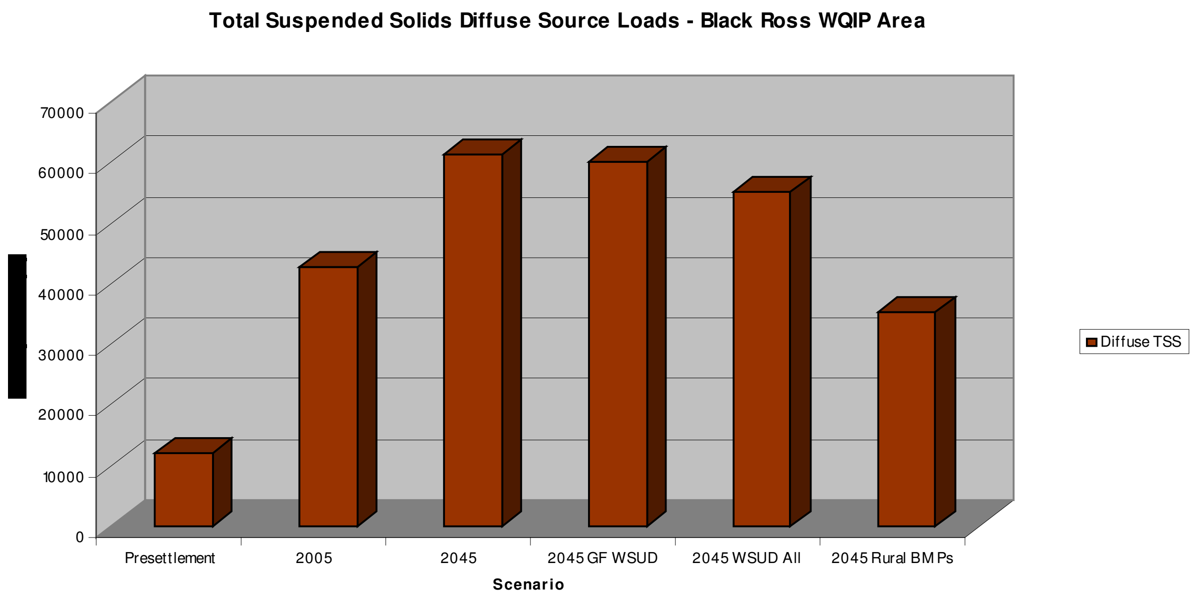
Note: BAU is business as usual. WSUD is water sensitive urban design. All Urban WSUD is the total of Existing Urban WSUD and Greenfield WSUD. Greenfield WSUD is new urban development outside already existing urban areas. BMP is best management practice. All is the sum of All Urban WSUD and Rural BMP. Figures have been rounded to the nearest whole number.

Table 1.12 Potential Diffuse Load Reductions with 100% Management Practice Adoption at 2045

Basin	2005 BAU	2005 to 2045 Increase		2045 BAU	All Urban WSUD			Rural BMP			All Change	
					Treated	Change		Treated	Change			
	t/year	t/year	%	t/year	t/year	t/year	%	t/year	t/year	%	t/year	% BAU
Total suspended solids (TSS)												
Black Basin	17,119	4,453	26.0	21,572	20,795	777	3.6	11,229	10,343	47.9	11,120	51.5
Ross Basin	25,366	13,965	55.1	39,331	34,141	5,190	13.2	23,452	15,879	40.4	21,069	53.6
Black Ross Total	42,827	18,562	43.3	61,389	55,150	6,239	10.2	35,166	26,223	42.7	32,462	52.9
Total nitrogen (TN)												
Black Basin	292	43	14.8	335.1	333.6	1.5	0.5	300.9	34.2	10.2	36	10.7
Ross Basin	274	71	25.9	344.9	334.8	10.1	2.9	316.9	28.0	8.1	38	11.0
Black Ross Total	572	114	19.9	686.0	674.4	11.6	1.7	624.4	61.6	9.0	73	10.7
Total phosphorus (TP)												
Black Basin	28	4	14.6	32.1	31.3	0.8	2.5	29.6	2.5	7.7	3	10.3
Ross Basin	42	13	31.4	55.2	49.6	5.6	10.2	51.3	3.9	7.1	10	17.2
Black Ross Total	71	17	24.5	88.4	81.6	6.8	7.7	82.0	6.4	7.3	13	14.9

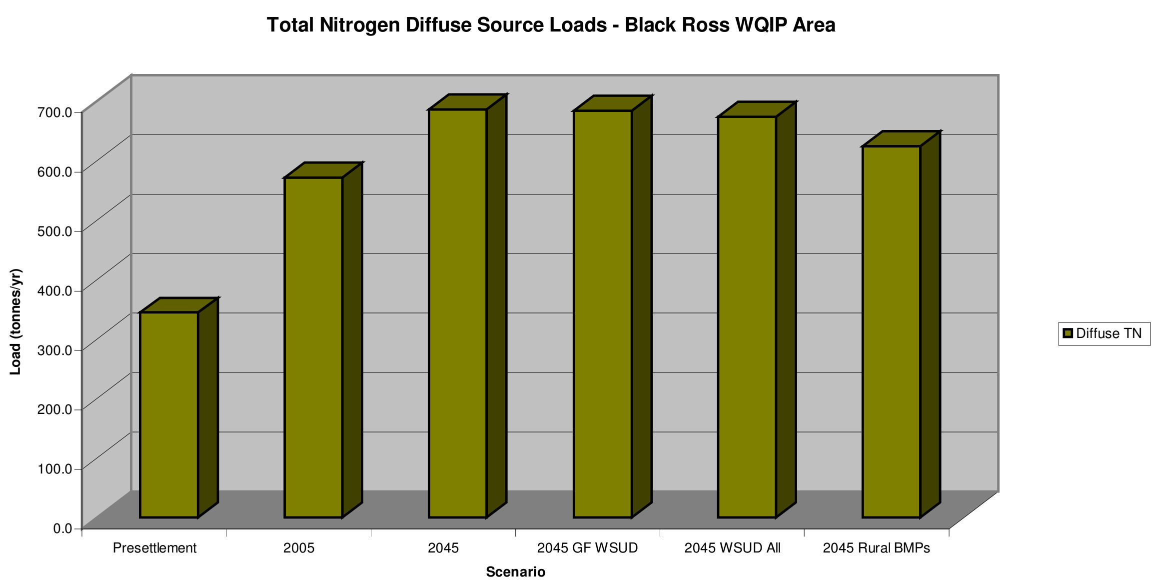
Note: Notes from Table 1.11 apply to this table.

Figure 1.3 Potential TSS Diffuse Source Load Reductions by Scenario



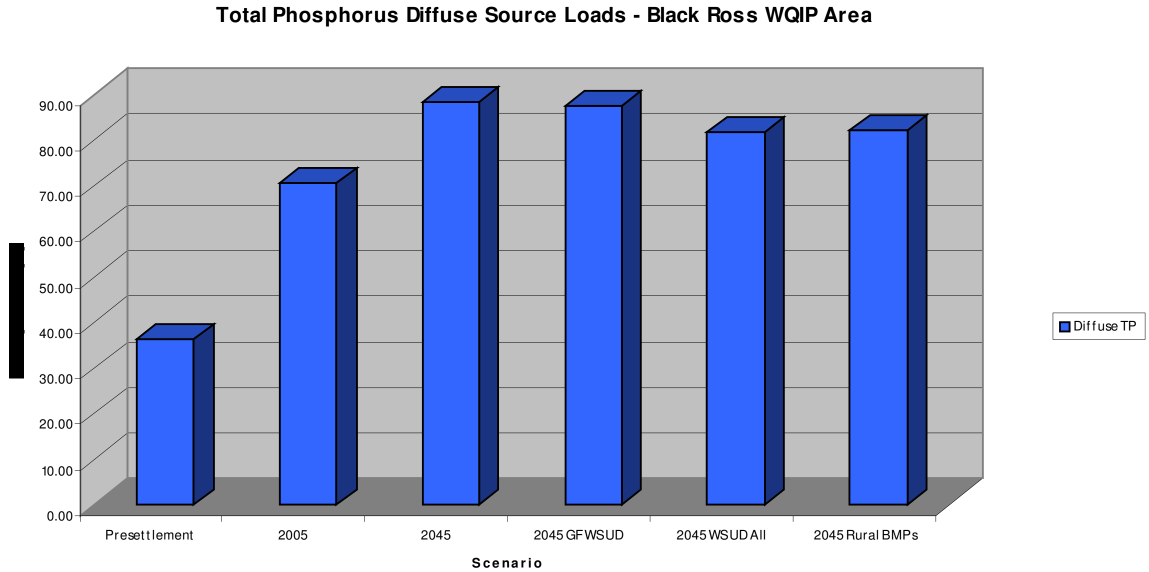
Source: BMT WBM (modelling spreadsheet 20090612)

Figure 1.4 Potential TN Diffuse Source Load Reductions by Scenario



Source: BMT WBM (modelling spreadsheet 20090612)

Figure 1.5 Potential TP Diffuse Source Load Reductions by Scenario



Source: BMT WBM (modelling spreadsheet 20090612)

Potential improvements can be related to the cost of management interventions to derive comparative costs for basins, catchments and waterways to improve water quality. If there is adequate information available this use of modelling results can assist with the prioritisation of areas where maximum benefit can be attained for the least cost per tonne of pollutant. Realistic targets can then be set based on achievable outcomes with available resources. Costs associated with the modelled management practice scenarios along with other management options are examined later in this report.

Figure 1.6 Managed Landscapes to Protect the Reef

2. Urban Management Options, Costs and Benefits

2.1 Introduction

Management options were identified that have the potential to reduce end of catchment pollutant loads and improve water quality within the Black Ross WQIP area.

Management options for urban areas are discussed in this section with management options for peri-urban and rural land uses discussed in the sections 3 and 4 respectively. Enabling options and management actions that cut across land use and catchment boundaries are discussed in section 5.

Potential savings are discussed in terms of 'standard' and 'environmental' infrastructure and maintenance, soft system methodologies and 'hard' system infrastructure installation.

The management action options that can make a significant difference to water quality in the urban environment have first been separated into two primary categories i.e. point sources and diffuse sources.

2.2 Point Sources

As identified in the report titled *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009), the only significant urban point sources directly and continuously affecting water quality are the wastewater treatment plants (WWTPs), now sometimes referred to as water purification plants (WPPs).

The former Thuringowa City and Townsville City WWTPs have been the subject of studies to determine the most appropriate methods of wastewater treatment in line with projected population growth, current system capacity and regulatory requirements under the *Environmental Protection Act 1994*. System upgrades and expansion were proposed for both the smaller and larger plants. The main upgrade of the Cleveland Bay WWTP has been completed with bioavailable nutrient emissions already reduced (see Gunn and Barker 2009).

Following the Council amalgamation in 2008 a revised 'regional' wastewater treatment strategy was prepared combining the two former wastewater networks. The previous decentralised treatment approach was compared to a centralised treatment approach and the centralised approach was found to have a range of economic benefits in terms of capital costs, maintenance and life cycle costs. Council adopted the centralised approach in July 2008 (see Appendix C and also Gunn and Barker (2009) for more detail).

Based on the proposed upgrades in the *Wastewater Upgrade Program Planning Report* (Maunsell Australia 2008), population growth figures and projected resulting pollutant discharge rates over time, estimates of the discharge loads of nitrogen and phosphorus from all WWTPs in the Black Ross WQIP area were made using catchment modelling (WaterCAST). Point source load change from WWTPs over time is shown in Table 2.1 with associated population projections listed in Table 2.2.

Table 2.1 Point Source Loads Over Time

Years	Total Flows (ML/day)	Total TSS loads (t/yr)	Total TN loads (t/yr)	Total TP loads (t/yr)
Pre 2006	41.54	91.03	296.32	72.08
2008	41.54	91.03	157.41	33.83
2010	43.24	94.77	163.29	36.68
2012	48.43	106.14	70.02	23.92
2021	55.65	121.97	92.10	28.67
2045	74.43	163.12	124.64	37.06

Note: Loads are in tonnes per year. Flows are daily discharge flows based on expected population growth. Cleveland Bay WWTP upgrades are in place by 2008. All other WWTP upgrades are assumed to be in place by 2012. Upgrades are based on reduction of nutrient concentrations.

Table 2.2 Long Term Population Projections

Year	Projections			Population change	
	Low	Medium	High	Five years to 30 June	Average annual change
2011	187,441	191,329	196,145	2011	3.0%
2016	210,078	218,660	229,941	2016	2.7%
2021	226,401	239,619	257,722	2021	1.8%
2026	238,451	255,986	280,736	2026	1.3%
2031	248,287	270,500	302,044	2031	1.1%
2045*	[289,381]	315,270	[352,035]		

Notes: (Source Cardiff 2009) * A 1.1% growth rate for the medium forecast was used to project the growth beyond the life of the current Planning Scheme(s) i.e. beyond PIFU 2031 projections above. The same growth rate was applied to the Low and High projections [in brackets] to give an idea of the potential population range at 2045, highlighting some of the uncertainty in long-term projections.

The initial nutrient load reduction (pre 2006 to 2008) follows the upgrade of the Cleveland Bay WWTP facility with the subsequent decrease (2010 to 2012) attributed to upgrading the remaining WWTPs. Loads then increase from 2012 in line with projected (medium) population growth (see Table 2.2).

Graphical representation of decreases as a result of upgrades and subsequent increases due to population growth are shown in Figure 2.1 and Figure 2.2 for nitrogen and phosphorus respectively.

Figure 2.1 Point Source Nitrogen Load Over Time

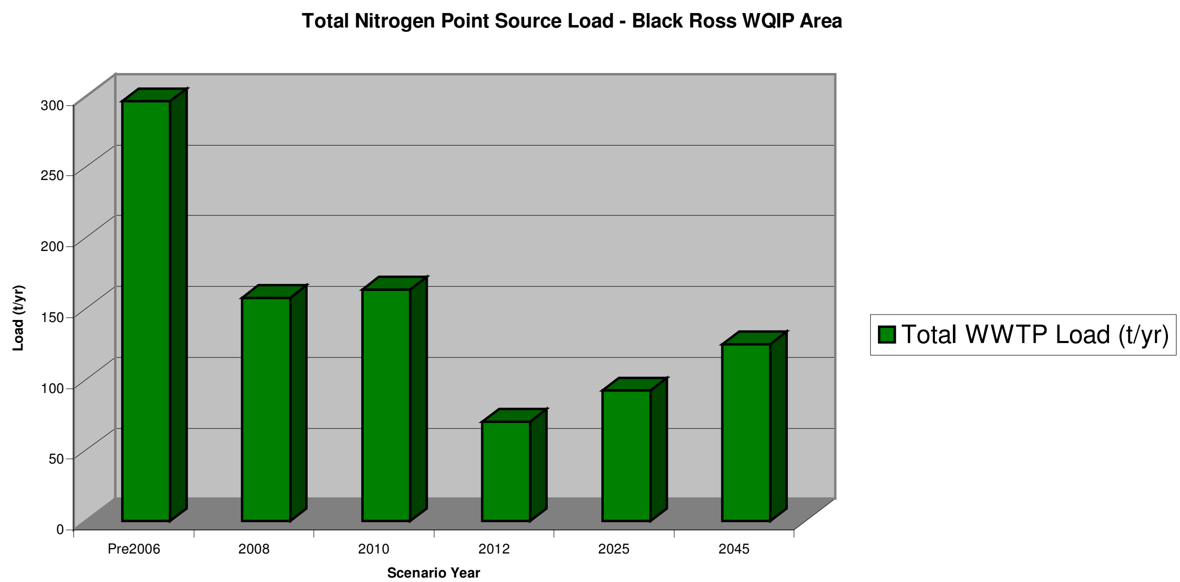
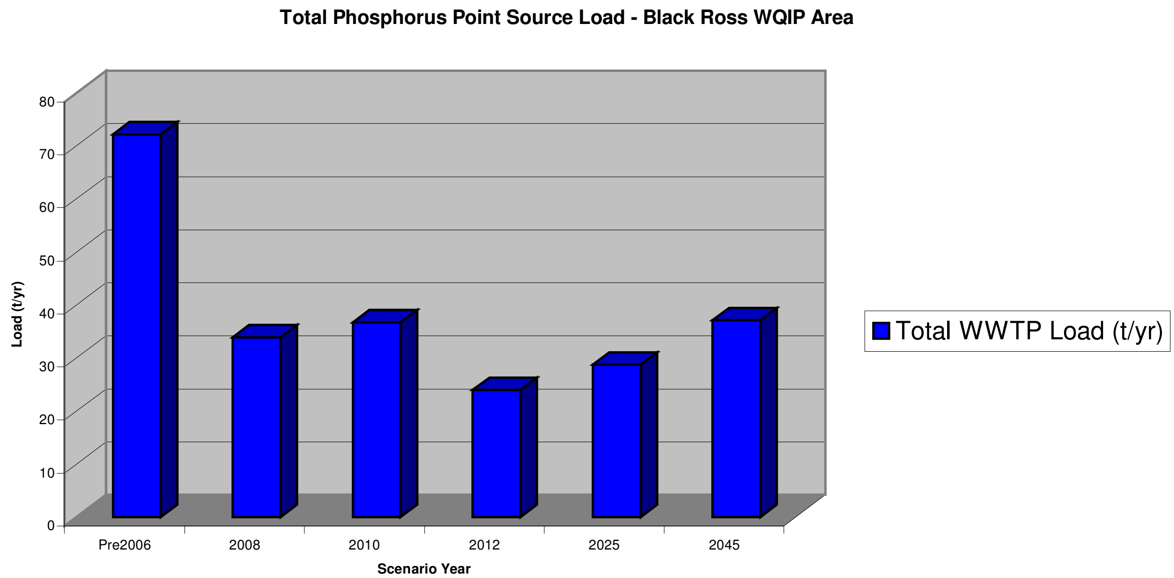


Figure 2.2 Point Source Phosphorus Load Over Time



After a $65 million upgrade, the state of the art Cleveland Bay Wastewater Treatment Facility is now the largest of its kind in the southern hemisphere, using high tech filters to turn effluent into high quality water. The facility`s centrepiece consists of membrane bioreactor technology that treats the wastewater to a very high standard by filtering out small particles that conventional treatment is unable to remove.

The facility has the capacity to process 29 million litres of wastewater every day and is currently processing 23 megalitres of effluent a day i.e. 60 per cent of the city`s sewage, and delivering a massive reduction in the level of nitrogen and phosphorous being discharged into Cleveland Bay. The plant has reduced the amount of nutrient discharge into the environment by around 140 tonnes per annum. The amount of nitrogen discharge has been reduced from 138 tonnes a year to 30 tonnes, and the amount of phosphorus has been slashed from 43 tonnes to just eight tonnes.

Further enhancing the sustainability of the plant is a biosolids facility that`s turning sewage sludge into a soil conditioner. The product is being used for pasture improvement, with the potential to be sold to the wider agricultural sector.

Infrastructure that can produce recycled wastewater for civic and commercial purposes has also been incorporated into the facility, meaning with further investment there is real potential for the future in terms of reuse options. Through reuse, this treatment plant could eventually cut Townsville`s use of potable water by about 15 per cent every day.

Options to further decrease point source pollutant loads, after the WWTP upgrades, revolve around either decreasing the concentration of pollutants in treated discharge, or decreasing the discharge volume to receiving waters. Both options are discussed below.

2.2.1 Reducing concentrations

If loads are to be reduced while the volume of discharge from WWTPs is increasing due to population growth then the concentrations need to be reduced accordingly (load is a product of the concentration and the discharge volume).

To date the upgrades to the WWTPs have been based on reducing the concentration of nutrients, especially bioavailable nutrients, in the treated discharge, which has resulted in a reduction in discharge volumes. While it is relatively inexpensive to reduce concentrations up to a certain level of treatment subsequent reductions of nutrient concentrations become prohibitively more expensive per tonne of nutrient load reduction.

2.2.2 Reducing discharge volume

Reducing loads while maintaining the same treatment process with the same nutrient concentrations in treated discharge requires a reduction in the volume of discharge to receiving waters. The most practical way to achieve this reduction is by reuse of the treated wastewater and/or land-based disposal. Wastewater reuse schemes are not a new idea with the output from the WWTPs on Magnetic Island already being reused for irrigation purposes resulting in zero discharge to receiving waters. The costs associated with the reuse schemes can be prohibitive especially if the reuse application is a considerable distance from the WWTP and significant infrastructure needs to be constructed.

As the exact costs of removing phosphorus and nitrogen cannot be apportioned the total costs of WWTP upgrades and annual operating costs have been applied to phosphorus and nitrogen separately. Using this approach the results of reducing pollutants entering waterways from point sources (WWTPs) are shown in Table 2.3.

Table 2.3 WWTP Costs of TP and TN Removal

Upgrades	Cost of upgrade	*Load Reduction	$/kg of capital cost	Annual operating cost	$/kg of annual operating cost	$/kg total annual cost
Cleveland Bay WWTP (2006)	$65m	TP: 35 t/yr TN: 108 t/yr	TP: $ 1,857 (93) TN: $ 602 (30)	$4.35m	TP: $ 124 TN: $ 40	TP: $ 217 TN: $ 70
Other WWTPs (2012)	$189.4m	TP: 48.16 t/yr TN: 226.3 t/yr	TP: $ 3,933 (197) TN: $ 837 (42)	$3.41m	TP: $ 71 TN: $ 15	TP: $ 268 TN: $ 57
Reuse (2021)[1]	$32.9m	TP: 5.8 t/yr TN: 12.0 t/yr	TP: $ 32,655 (816) TN: $ 15,757 (394)	[2]$1m	TP: $ 172 TN: $ 83	TP: $ 988 TN: $ 477

Notes: * Load Reduction is based on the first full year of operation of the upgraded WWTPs using estimated treatment rates and discharge figures at the time of upgrade.

"$/kg of capital cost" - WWTP upgrade costs have been applied equally to TP and TN load reductions e.g. $65m divided by 35t TP and $65m divided by 108t TN. Similarly "$/kg of annual operating cost" is the annual operating cost of the plant/s divided by the annual load reduction of TP and TN.

"$/kg total annual cost" is based on an effective plant life of 20 years with the "$/kg of capital cost" divided by 20 (shown in brackets in $/kg of capital cost column) and added to the "$/kg of annual operating cost".

No adjustment has been made for the expected increase in volumes to be treated resulting from increased population. This is expected to increase annual operating costs however the treatment costs per kilogram of load reduction are not expected to change significantly. The "$/kg total annual cost" may decrease marginally as a result of the load reduction increase in relation to the capital cost of the upgrades.

Annual operating cost does not include administration and management costs.

[1] the 2021 upgrade is based on a reuse option at Cleveland Bay WWTP. Calculations use the same principles as applied to the WWTPs with an effective plant life of 40 years.

[2] Annual operating costs are an estimate only and may vary by ± 50%.

In an attempt to gain a closer approximation of the cost for the 'separate' removal of phosphorus and nitrogen another set of calculations were based on the total pollutant reduction figure (tonnes of phosphorus plus tonnes of nitrogen) and again applied to capital costs and operating costs (see Table 2.4).

Costs for phosphorus and nitrogen reduction were then calculated on a pro rata basis to arrive at an annual capital cost, annual operating cost and total annual cost (see Table 2.5).

Table 2.4 WWTP Cost of Nutrient Reduction

Upgrades	Cost of upgrade	*Load Reduction	$/kg of capital cost	Annual operating cost	$/kg of annual operating cost	$/kg total annual cost
Cleveland Bay WWTP (2006)	$65m	143 t/yr	$ 455 (23)	$4.35m	$ 30	$ 53
Other WWTPs (2012)	$189.4m	274 t/yr	$ 691 (35)	$3.41m	$12	$ 47
Reuse (2021)[1]	$32.9m	17.8 t/yr	$ 1,848 (46)	[2]$1m	$ 56	$ 102

Notes: * Load Reduction is the total combined tonnage reduction for TP and TN based on the first full year of operation of the upgraded WWTPs using estimated treatment rates and discharge figures at the time of upgrade.
"$/kg of capital cost" - WWTP upgrade costs have been applied to total nutrient load reductions.
Similarly "$/kg of annual operating cost" is the annual operating cost of the plant/s divided by the annual total nutrient load reduction.
[The remainder of the notes from Table 2.3 also apply to this table]

Table 2.5 Pro Rata Costs for Phosphorus and Nitrogen

Upgrades	Cost of upgrade	*Load Reduction	Pro rata capital cost (annual)	Annual operating cost	Pro rata annual operating cost	Pro rata total annual cost
Cleveland Bay WWTP (2006)	$65m	TP: 35 t/yr TN: 108 t/yr	TP: $15.9m ($0.8m) TN: $49.1m ($2.5m)	$4.35m	TP: $1.07m TN: $3.28m	TP: $1.87m TN: $5.78m
Other WWTPs (2012)	$189.4m	TP: 48 t/yr TN: 226 t/yr	TP: $33.15m ($1.7m) TN: $156.25m ($7.8m)	$3.41m	TP: $0.6m TN: $2.81m	TP: $2.3m TN: $10.6m
Reuse (2021)[1]	$32.9m	TP: 5.8 t/yr TN: 12 t/yr	TP: $10.73m ($0.3m) TN: $22.17m ($0.6)	[2]$1m	TP: $0.33m TN: $0.67m	TP: $0.63m TN: $1.27m

Notes: * Load Reduction is based on the first full year of operation of the upgraded WWTPs using estimated treatment rates and discharge figures at the time of upgrade. WWTP plant life assumed to be 20 years for annual capital cost.
[1] the 2021 upgrade is based on a reuse option at Cleveland Bay WWTP. Reuse plant life assumed to be 40 years for annual capital cost. [2] Annual operating costs are an estimate only and may vary by $\pm$ 50%.

2.2.3 Point and diffuse source pollutant contributions

The relative nutrient load contributions, derived from modelling results, from point and diffuse pollutant sources are illustrated in Figure 2.3 for nitrogen and Figure 2.4 for phosphorus for the 'business as usual' scenario. Sediment loads are principally derived from diffuse sources with the point source contribution being negligible and as such sediment has not been considered in the combined calculations.

The reduced nutrient loads from point sources at 2045 compared to 2005 are a direct result of WWTP upgrades. Point source loads increase after 2012 as a result of population increase (see Figure 2.1 and Figure 2.2). The increase in diffuse source loads across the Black Ross WQIP is also a function of population increase and is principally due to the conversion of rural and peri-urban land uses to urban land uses, which have a greater nutrient generation rate per hectare than the former land uses.

As can be seen from the graphs the contribution of nutrients from diffuse sources and urban point sources is significant compared to pre-settlement contributions. The graphs also imply the potential range of water quality improvement for the Black Ross (Townsville) WQIP area if appropriate management actions are applied to pollutant generation activities for point sources and diffuse sources.

Figure 2.3 Diffuse and Point Source Nitrogen Contributions

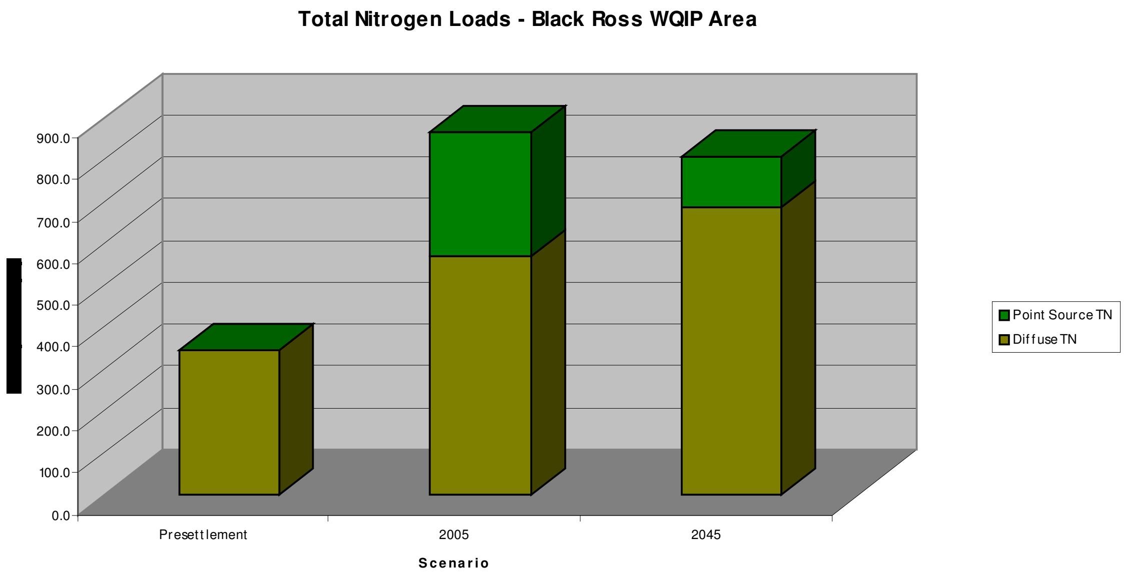
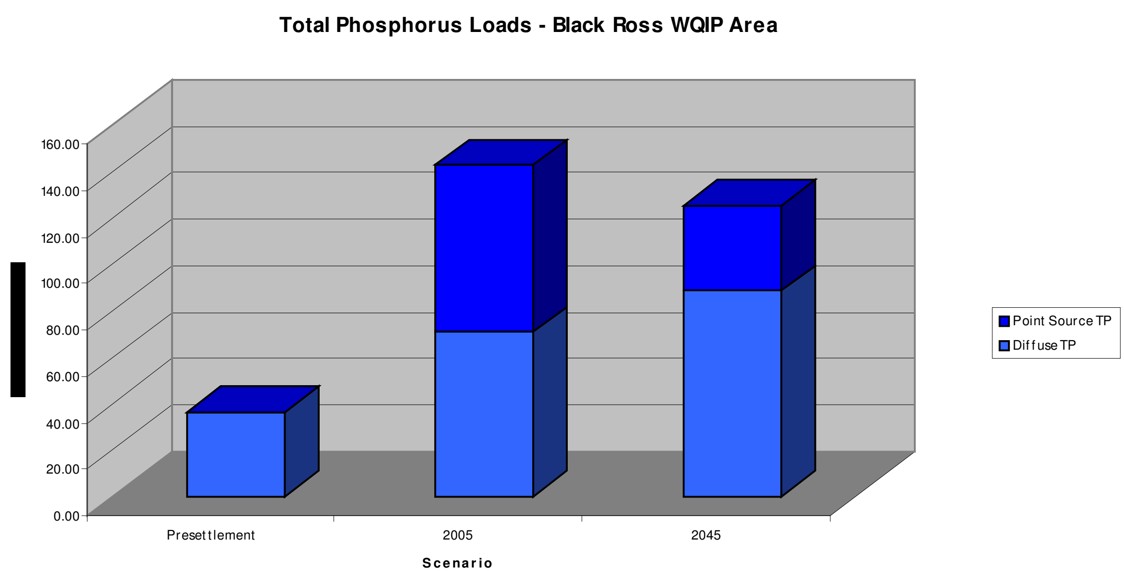


Figure 2.4 Diffuse and Point Source Phosphorus Contributions



Source: BMT WBM (modelling spreadsheet 20090612)

2.3 Urban Diffuse Management Options

Diffuse source pollutants are generally more difficult to address than point source pollutants as there is a broader range of environmental and social factors and the water quality issues are not as easy to define as for point sources. Additionally, water quality pollutant issues are fundamentally different for developing (Greenfield or new development) and mature urban areas (Brownfield or existing urban areas) (see Gunn and Barker 2009). When progressing from the identification of urban water quality issues to water quality improvement management options and subsequently selecting appropriate management actions the following are some of the factors that need to be taken into consideration:

- The issues associated with the stage of development i.e. Greenfield or Brownfield,
- Our confidence of expected outcomes and benefits from particular management interventions;
- Relative cost of improvements per tonne of load reduction;
- Establishment, maintenance and lifecycle costs;
- Compliance and monitoring costs;
- The current capacity to implement new management practices and systems;
- The issues associated with established urban land use types, including;
    - Our level of certainty about the extent of the issue;
    - Relationships between point source and diffuse source,
    - Sewered and unsewered (parts of Magnetic Island and peri-urban areas),
    - Structural and non-structural measures (also relevant to Greenfield sites),
    - Stormwater systems and natural drainage characteristics.
- Information requirements to determine priority actions and priority areas (outside those already known);
- Adoption of a treatment train approach, as appropriate to the situation, with the general principle of treating the issue at the source as the first priority;
- Existing programs and projects (environmental and social) and potential for integration;
- Recognition of the need for people-based solutions to environmental issues.

Selected management actions then need to be designed to incorporate measures and feedback loops to inform the adaptive management process and result in continual improvement including through:

- An integrated water quality monitoring and modelling strategy;
- Models that link physical and social parameters such as Bayesian Belief Networks (BBN) incorporating Social Learning;
- Developing and testing a simplified process for measuring outcomes e.g. ABCD management practice framework;
- Incorporating behaviour change research into case studies and pilot schemes as a precursor to full-scale engagement, and knowledge and skills transfer program development e.g.Community Based Social Marketing (CBSM), Thematic Interpretation and Collective Social Learning (CSL).

Development of a comprehensive communication strategy is also necessary to ensure the objectives; actions and outcomes are readily available to the Black Ross (Townsville) WQIP community, sponsor organisations and associated audiences, and to facilitate the effective implementation of selected management actions and associated programs.

Water quality improvement management options for urban diffuse pollutants are discussed below in terms of the principal ‘program’ categories which have been derived by linking the issues to the potential actions in the context of the factors outlined above.

2.4 Developing Areas

Developing areas generally involve a change from a less intensive to a more intensive land use. The period of transition is usually characterised by physical disturbance to the development area and can include disturbance to connecting and/or surrounding areas if additional infrastructure is required to service the developing area e.g. roads, electricity and wastewater disposal.

Management options to reduce water quality pollution from developing areas relates primarily to the reduction of impacts from the disturbance of terrestrial areas associated with the land development and construction phases.

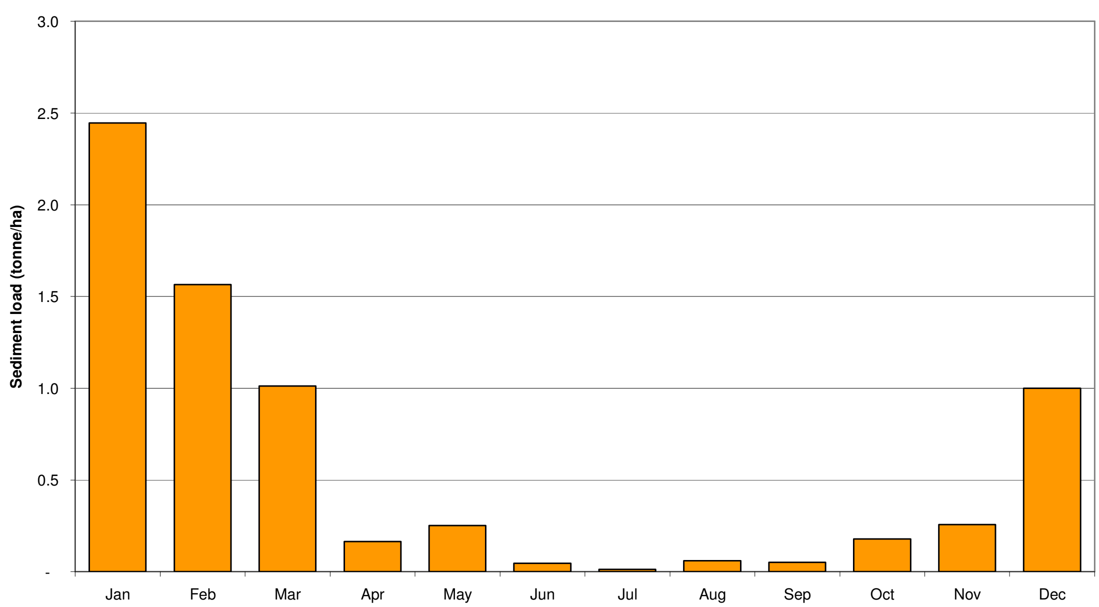
2.4.1 Erosion and sediment control

Sediment is the primary pollutant associated with developing urban areas as a result of vegetation clearing, earthmoving activities (excavation and fill), and general land disturbance. Rainfall is the predominant erosive force impacting exposed soils in the Townsville region. Wind plays a minor role in soil erosion and does not require additional management options.

The majority of rainfall in the dry tropics falls during the wet season between December and March with an average of six tonne/hectare/year of sediments generated and delivered to waterways during this period. This is approximately 86% of the mean annual load from exposed soils, with four tonne (57% of the mean annual load) generated in January and February alone.

The average rate of sediment load generated during construction from a Greenfield development site in the Townsville region during an 'average' year is illustrated in Figure 2.5.

Figure 2.5 Sediment Generated from Bare Ground During Construction



Note: Figures generated by Creek to Coral (A. McHarg) using MUSIC model and local rainfall data.

An estimated 7 tonne/hectare/year of sediment is generated from exposed soil during the initial stages of land development. This is 63 times greater than the sediment load delivered to waterways from developed urban areas and over 100 times greater than the amount generated from developed urban areas with water sensitive urban design (WSUD) measures in place.

Based on this information it can be seen that erosion prevention is the key to reducing the volume of sediment, and associated nutrients, entering waterways during the land development and construction stages of urban development. Preventing sediment movement is the secondary option and should only be necessary if erosion prevention measures are inadequate.

Figure 2.7 illustrates the relationship between erosion and sediment control measures for developing areas as well as comparative sediment generation rates from mature land uses. It would appear from the modelled estimates shown in the graph that there is little likelihood of reducing total suspended solids (TSS) loads from Townsville development sites with exposed soils using conventional erosion and sediment control methods.

2.4.2 Current erosion and sediment control measures

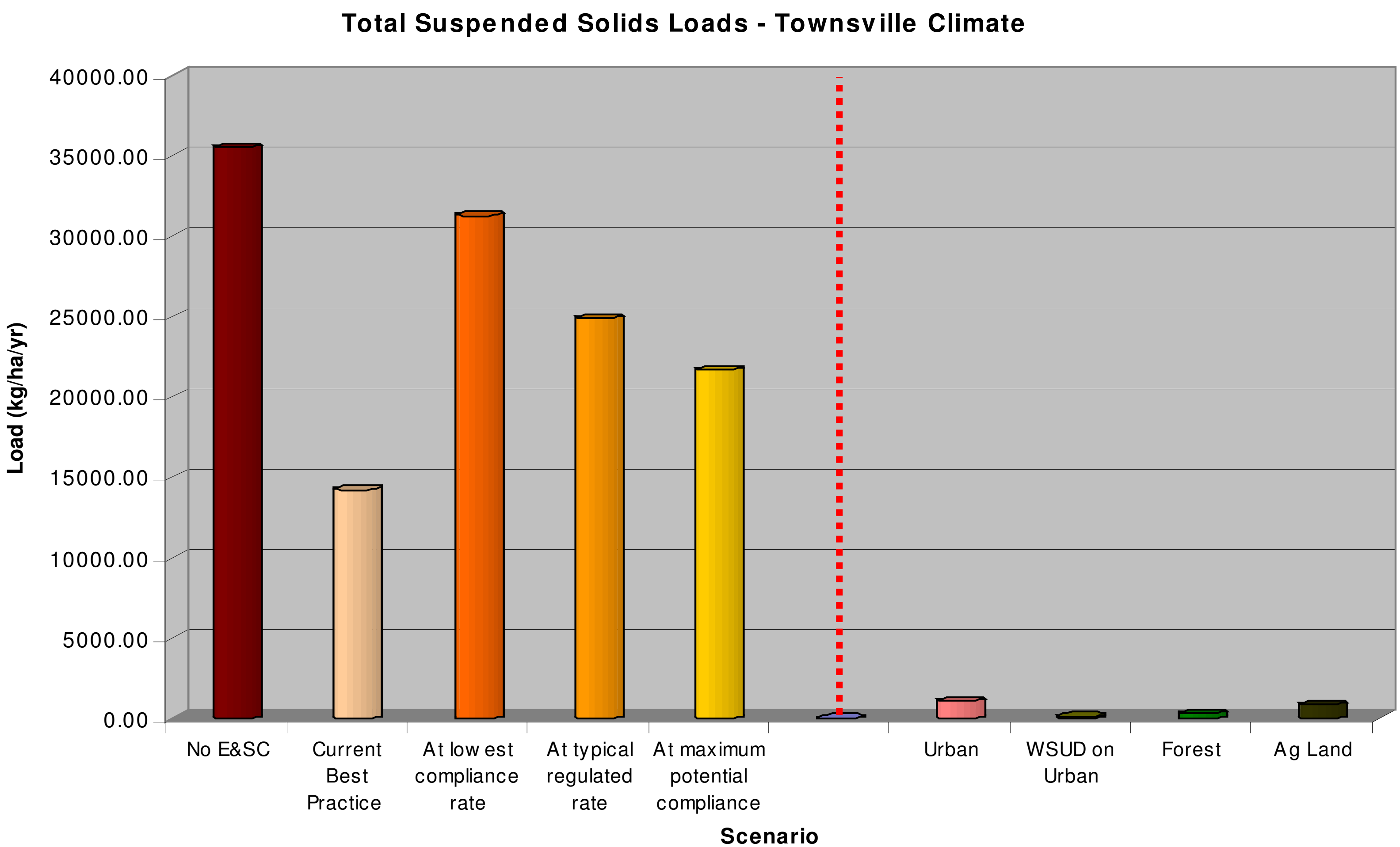
Current erosion and sediment control (ESC) measures are included in the operative planning schemes for the former Townsville and Thuringowa City areas, which flow through to the development assessment process. Additionally Townsville City Council has facilitated the development of a soil erosion and sediment control-training course that has been held periodically in Townsville since 2003. Successful completion of the course enables course participants to be acknowledged as accredited providers of Erosion and Sediment Control Plans for development assessment purposes in Townsville.

More recently local government in general has been devolved the responsibility under the *Environmental Protection Act 1994* (EP Act) for regulating stormwater quality in the urban environment. This includes the power to take legal action against entities that fail to meet their obligations under the EP Act and subordinate legislation e.g. *Environmental Protection (Water) Policy 2009*.

From the modelled results (see Figure 2.7) it appears that even at maximum potential compliance with <u>existing</u> erosion and sediment control measures the estimated sediment load reduction is still only in the order of 35-40%. To improve water quality outcomes associated with developing areas it is obvious that new measures and ways of doing business need to be introduced to reduce erosion from land development and construction sites.

Figure 2.6 Uncontrolled Erosion and Sediment Movement

Figure 2.7 Comparative Sediment Loads and Land Use



Source: Tony Weber (BMT WBM).

Note: Loads on the left half of the graph are indicative of developing areas. Comparisons of sediment generation rates for developed land uses are shown on the right half of the graph.

2.4.3 Erosion and sediment control options

Given that there are erosion and sediment control (ESC) measures already in place the first option would be to review the existing measures and their effectiveness. The review could include:

- In relation to existing Planning Scheme and associated provisions;
  - References to erosion and sediment control in the two Planning Schemes,
  - References to erosion and sediment control in planning policies,
  - Other references to erosion and sediment control in Council policies and operational plans,
  - Triggers and mechanisms for incorporating erosion and sediment control measures in the development assessment process and subsequent development approval conditions,
  - The relevance and effectiveness of erosion and sediment control measures included in development approval conditions,
  - Provisions for monitoring compliance with erosion and sediment control measures included in development approval conditions,
  - Compliance rate with development approval conditions,
  - Current enforcement measures,
  - Capacity of Council's development assessment staff to assess erosion and sediment control plans and associated technical issues,
  - Relationship between Council policies and plans and relevant State legislation, in particular the EP Act and EP (Water) Policy,
  - Relationship between Council policies and plans and relevant Commonwealth legislation, in particular the Environmental Protection and Biodiversity Conservation Act (EPBC Act),
  - Council's regulatory obligations in relation to State and Commonwealth legislation and current deemed compliance relative to existing measures in place.
- In relation to the TCC Erosion and Sediment Control Course;
  - The course structure and content with regard to recent innovations and advances in erosion and sediment control e.g. Best Practice Erosion and Sediment Control (IECA Australasia 2008),
  - The relevance of the course to development industry professionals,
  - The number of development industry professionals who have completed the course and are accredited through TCC,
  - The marketing strategy used to promote the course,
  - The relationship between the course and the development assessment process,
  - Linkages with stormwater management processes and water quality,
  - Implications for water sensitive urban design (WSUD) measures during construction.

Depending on findings of the review of existing erosion and sediment control measures, there is a range of management options that could be implemented to improve water quality including the preparation of a generic framework for erosion and sediment control plans to be administered through Townsville's development assessment process and a compliance emphasis based on water quality.

Of particular interest in this respect is an ESC compliance pilot program being conducted by the Sunshine Coast Regional Council and DERM. Such options need to be investigated as part of the exploration of the most effective options for reducing erosion in Townsville's developing urban and peri-urban environments.

2.4.4 Site based stormwater management planning

Closely aligned with erosion and sediment control measures, the preparation and implementation of site based stormwater management plans is another key to reducing the volume of sediment entering waterways during the land development and construction stages of urban growth. Again there are stormwater management provisions included in the operative planning schemes for the former Townsville and Thuringowa City areas, which flow through to the development assessment process.

As with the erosion and sediment control options a review of the range and effectiveness of existing stormwater management provisions, and the linkages to sediment control measures, would be the initial task prior to the development and advancement of additional options. Site based stormwater managament matters that require investigation include the protection of stormwater flow paths from erosion and the integration of stormwater management plans and erosion and sediment control plans.

2.5 Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an holistic approach to the planning and design of urban development that aims to minimise negative impacts (pollutants and flow) on the natural water cycle and protect the health of aquatic ecosystems over the long term.

WSUD operates at the normal development scale in terms of stormwater management and at the broader strategic level in terms of promoting the integration of stormwater management, water supply and wastewater management in a total water cycle management framework.

2.5.1 WSUD in Townsville

The WSUD stormwater management option has been shown to be effective in reducing water quality pollutant concentrations and loads in other parts of Australia (and the world), and was therefore seen as a logical management intervention for the urban component of the Black Ross WQIP area. As such Creek to Coral commissioned the development of stormwater WSUD products specifically for the Townsville region, with funding assistance from the CCI project.

The draft WSUD products developed to date are listed in Table 2.6.

Table 2.6 WSUD Guidelines for the Townsville Dry Tropics

WSUD Strategy Roadmap
To assist with the adoption of WSUD a web based navigation tool has been developed called the "*WSUD Strategy Roadmap*". The Roadmap has been designed to assist the development industry access information and resources relevant to the application of WSUD in the Coastal Dry Tropics including links to 'locally relevant' WSUD Fact Sheets (see below), WSUD Objectives and Technical Design Guidelines (for civil and landscape designers). Links to additional references not specific to the Coastal Dry Tropics are also provided along with comments on the relevance of these references and caveats on their use in the Coastal Dry Tropics.
Factsheets
Factsheet 1 - Concepts and Terms Factsheet 2 - WSUD in the Dry Tropics Factsheet 3 - Site Planning and Urban Design Factsheet 4 - Industrial and Commercial Sites Factsheet 5 - Carparks Factsheet 6 - Porous Pavement Factsheet 7 - Best Management Practices
Water Sensitive Urban Design - Design Objectives for the Dry Tropics
Water Sensitive Urban Design Technical Design Guidelines for the Coastal Dry Tropics

The incorporation of WSUD into all new developments is seen as the key to reducing pollutant outputs, especially nutrients, from established urban areas. To achieve this WSUD needs to be included at the development conceptualisation stage. Introduction of the WSUD products into the Townsville region's development assessment processes is therefore an integral implementation component of the Black Ross WQIP for developing urban areas.

While Townsville is preparing for the introduction of the local WSUD guidelines, a set of default WSUD stormwater management guidelines, the Australian Runoff Quality (ARQ) guidelines, were adopted by Townsville City Council in July 2008. The former Thuringowa City Council had already included the ARQ guidelines in their Planning Scheme as part of the conditions of development.

The development of the WSUD guidelines has been the ‘easy’ part of the process. Increasing industry awareness and acceptance, as well as providing adequate training for Council staff tasked with assessing development applications are two key elements for the successful adoption of WSUD principles and subsequent long-term urban water quality improvements.

Additional material needs to be developed or adapted for the Townsville region to assist the development and construction industry with WSUD uptake including:

- Concept Design Guidelines;
- Construction and Establishment Guideline;
- Asset Management Guideline;
- Deemed to Comply and Standard Drawings; and
- A MUSIC Auditing Tool (to assist with the development assessment process).

Management and maintenance issues need to be addressed as part of the WSUD introduction and implementation processes so that there are no expectations that Council will be responsible for the maintenance of poorly designed WSUD measures.

2.5.2 Water Quality and WSUD ‘drivers’ in Queensland

Amendments to Queensland water quality legislation along with the release of a draft State Planning Policy (SPP) for Healthy Waters raised the profile of water quality and urban stormwater management, incorporating WSUD, in Queensland in 2009. A summary of the legislation and policy changes, particularly with regard to WSUD and the Black Ross WQIP, are included in Appendix D. The key points are discussed in section 5.4. The main pieces of legislation are listed below:

- Draft SPP Healthy Waters and associated documents including *Urban Stormwater - Queensland Best Practice Environmental Management* (USBPEM) *Guidelines* (DERM 2009);
- The revised *Environmental Protection Water Policy 2009* (Water EPP), which is subordinate legislation under the *Environmental Protection Act 1994*;
- The Draft Queensland Coastal Plan 2009 consisting of the Draft State Planning Policy Coastal Protection and Draft State Policy Coastal Management. Supporting guideline documents* include;
    - Draft State Planning Policy Guideline Coastal Protection,
    - Draft State Policy Guideline Coastal Management,
    - Draft Guideline Coastal Hazards.

  (Note: * Includes the previously prepared Guideline EPA Best Practice Urban Stormwater Management – Erosion and Sediment Control referred to in the Healthy Waters SPP.)
- The *Sustainable Planning Act 2009* was assented to on 22 September 2009. It will replace the *Integrated Panning Act 1997* (IPA) and will come into effect later in 2009;
- The *Great Barrier Reef Protection Amendment Act 2009* amends the *Environmental Protection Act 1994* and *Integrated Planning Act 1997*, with the intent of reducing the impact of agricultural activities on the quality of water entering the reef;
- *Water Supply (Safety and Reliability) Act 2008*, in place previously with connection to new policy;
- The *Vegetation Management and Other Legislation Amendment Act 2009,* amongst other things, repeals the *Vegetation Management (Regrowth Clearing Moratorium) Act 2009* (Regrowth Act). The Regrowth Act applies to all native vegetation within 50 metres of a regrowth watercourse in the priority Great Barrier Reef catchments of Burdekin, Mackay Whitsunday and Wet Tropics.

In addition to the legislative changes a revised version of the Reef Water Quality Protection Plan (for the Great Barrier Reef World Heritage Area and adjacent catchments) was released in 2009. While not directly applicable to urban areas Reef Plan will have implications for stormwater management in Townsville's peri-urban and rural areas, as part of the broader stormwater management activities outlined in the Black Ross WQIP.

2.6 WSUD Costs and Benefits

Does WSUD add significantly to the cost of development? There are a number of frequently asked questions about WSUD, which often focus on the costs associated with construction and maintenance of WSUD measures. The benefits associated with WSUD are often overlooked including the role that appropriate WSUD can play in reducing degradation to natural waterways and wetlands, assist with flood mitigation and improve neighbourhood amenity. Perhaps we also need to be asking questions such as; What is the ecosystem service cost of not implementing WSUD?

To help answer some of the 'financial' questions associated with WSUD, Water by Design (a program of the South East Queensland Healthy Waterways Partnership) has developed a draft report titled *Water Sensitive Urban Design to meet the proposed stormwater management objectives in Queensland: A Business Case* (Water by Design 2009). The WSUD Business Case report was developed with financial assistance from the State of Queensland acting through the Department of Environment and Resource Management (DERM). Selected sections of the report, especially those relevant to Townsville, are included in Appendix E.

Water by Design developed six WSUD case studies, for four Queensland regions (Brisbane, Mackay, Townsville and Cairns), representing typical developments that will be subject to the requirements of the draft SPP Healthy Waters. A summary of the case studies is provided in Table 2.7.

Table 2.7 WSUD Case Studies Summary

No.	Development type	Key elements
1	Residential greenfield (large scale) on sloping topography (5% gradient or greater)	• 76 ha of detached residential (within a 1,000ha staged development) • 951 detached houses (400–700 m^2/lot) • 5.5 ha of active and passive parkland • 8.75 ha drainage and restored waterway (vegetated) • 47% impervious surfaces on site.
2	Residential greenfield (small / medium scale) on flat topography	• 6.4 ha of detached residential (within a 100ha staged development) • 84 detached houses (400–500m2 p/lot) • 56% impervious surfaces on site.
3	Residential townhouse development	• 0.67 ha of attached residential • 25 townhouse dwellings • 61% impervious surfaces on site • 15% pervious landscaped areas on site.
4	Urban renewal development	• Conversion of 14 ha of light industrial area to high-density residential • 7 ha high rise residential towers (25 separate buildings) • 5 ha five-storey residential apartment buildings • 2000 + dwellings (units and apartments) • 40 m-wide road reserve and substantial promenades • 81% impervious surfaces on site.
5	Commercial development	• 0.42 ha neighbourhood shopping centre • Two buildings separated by a central arcade • 15-20 ground-level shops • 95-98% impervious surfaces on site.
6	Industrial development	• 1.0 ha factory and warehouse • Single building surrounded by driveway and car park (100 spaces) • 86% impervious surfaces on site.

One of the objectives of the WSUD Business Case was to determine what additional costs, if any, were associated with meeting the stormwater management objectives proposed in the draft SPP Healthy Waters.

The method used to determine any additional costs associated with WSUD was to compare the costs of a 'Base Case' i.e. development that complies with current mandatory State Government policy and legislation, with the costs and benefits of a 'WSUD Case' i.e. incorporating measures required to meet the proposed stormwater management objectives. For full details of the method used, including the cost benefit comparison framework, see Water by Design (2009).

The Base Case development assumes:

- Conventional stormwater drainage management;
- Flood management (flood detention storage);
- Compliance with the Queensland Development Code by using rainwater tanks.

The WSUD Case development assumes:

- As per Base Case;
- WSUD elements (e.g. bioretention systems, etc.) to meet the stormwater management objectives. (Water by Design 2009, pp.3-7 and 3-8)

The results for Townsville have been recalculated for the first three of the case studies to reflect the local Base Case, which is exclusive of rainwater tanks. Townsville has an exemption from the requirements of the Queensland Development Code to install rainwater tanks for new developments. As such the cost of rainwater tanks has been excluded from the Base Case and WSUD Case, and the size of bioretention systems has been increased to compensate for the WSUD benefits that would have been gained from the rainwater tanks. Case Study 4 includes options with and without rainwater tanks, and consequently the option without rainwater tanks (4B) has been adopted for this cost and benefit comparison.

Case studies 5 and 6 are a commercial and an industrial development respectively. Due to the variable nature of this style of development, the lower percentage cost associated with rainwater tanks in relation to the total WSUD cost and potential advantages of including rainwater tanks in this type of development, the Base Case and WSUD Case remain unaltered.

A summary of the costs and benefits associated with the WSUD case studies for Townsville are provided below.

Figure 2.8 Townsville Light Industrial Area

2.6.1 Quantifiable costs

The quantifiable WSUD costs associated with achieving the new stormwater objectives proposed in the SPP Healthy Waters are displayed in Table 2.8. The residential and urban renewal developments are based on the Townsville scenario without rainwater tanks as part of the Base Case and WSUD treatment train. While the incremental cost of the WSUD Case has increased as a result of increased bioretention system size the Overall WSUD Case cost is reduced substantially as a result of the removal of rainwater tanks and the associated capital and maintenance costs.

Table 2.8 WSUD Case Study Acquisition, Maintenance and Lifecycle Costs for Townsville

Case Study Description		Capital Costs		Annual Maintenance		Lifecycle (LC) Cost		Annualised LC Cost[2]	
		$ / lot*	$ / ha	$ / lot*	$ / ha	$ / lot*	$ / ha	$/lot/yr	$/ha/yr
1[1]	Residential greenfield (large scale) on sloping site	2,955	37,100	37	455	4,136	51,927	166	2,077
2[1]	Residential greenfield (small / medium scale) on flat site	3,486	46,189	35	455	4,735	62,739	190	2,510
3[1]	Residential townhouse development	1,143	42,889	12	423	1,552	58,258	62	2,330
4B	Urban renewal development	370	52,800	4	520	500	71,720	20	2,869
5	Commercial development**	11,498	54,750	100	490	15,430	73,485	617	2,939
6	Industrial development**	49,500	49,500	490	490	67,235	67,235	2,690	2,690

Notes: Information was sourced primarily from Table 5-1 (Water by Design 2009, p.5-19) and Table 5-2 (Water by Design 2009, p.5-20).

Figures represent the incremental cost of going from the Base Case to the WSUD Case i.e. the additional cost of achieving the new stormwater objectives.

* Lot refers to household or dwelling.

** Per lot estimates for industrial and commercial cases are dependent on lot numbers and sizes which vary considerably.

[1] recalculated WSUD Case for Townsville without rainwater tanks and with enlarged bioretention systems to compensate for the water quality benefits associated with rainwater tanks.

[2] a 25 year life cycle is assumed

2.6.2 Pollutant load benefits

Table 2.9 Pollutant load reductions costs and benefits for Townsville (no rainwater tanks)

Case Study Description		TN removed by WSUD (kg/ha/yr)	Equivalent annual TN removal treatment costs¹ ($/kg/year)	Annualised life cycle cost of WSUD² ($/ha/year)	WSUD TN removal cost ($/kg/year)	WSUD TN removal cost vs equivalent TN removal treatment cost
1	Residential greenfield	6.2	3,193	2,077	335	13%
2	Residential greenfield	6.6	3,399	2,510	381	14%
3	Residential townhouse	7.3	3,760	2,330	320	12%
4B	Urban renewal	7.9	4,069	2,869	364	14%
5	Commercial	13.8	7,107	3,175*	230	3%
6	Industrial	9.2	4,738	2,904*	316	7%

Notes: Original information was sourced primarily from Table 5-3 (Water by Design 2009, p.5-23)

"TN removed by WSUD" column – TN removed by bioretention systems after bioretention system size increase to compensate for removing rainwater tanks from the treatment train.

"Equivalent annual TN removal treatment costs" column – recalculated cost including the TN removed with increased bioretention system size i.e. includes TN formerly removed by rainwater tanks.

"Annualised lifecycle cost of WSUD" column - Annualised lifecycle cost of WSUD recalculated for Townsville without rainwater tanks, and with larger bioretention systems.

"WSUD TN removal cost" is based the annual cost based on the annual lifecycle cost of WSUD.

¹ A levelised annual treatment cost of $ 515,000 per tonne (the average of the $ 180,000 to $ 850,000 range as presented above) of total nitrogen (TN) removed has been used in this calculation. The estimates were originally calculated to provide estimates for efficient pricing of wastewater services and it is recognised that there are inherent limitations with adopting this data for this calculation, however this data represents the best estimate available.

² The incremental costs of WSUD compared to the base case. The life cycle of the WSUD elements has been modelled as 25 years.

* the annualised lifecycle cost for Case Studies 5 and 6 was adjusted upwards by 8% to compensate for not calculating the increased cost of bioretention systems which would result in the increased TN removal figures used to calculate the $/kg/yr cost of TN removal.

"WSUD TN removal vs TN treatment costs" is the annual WSUD TN removal cost expressed as a percentage of the equivalent TN (point source) removal treatment cost.

Table 2.10 Rainwater Tank Nitrogen Removal Cost

Case Study Description		TN removed by RWT (kg/yr)	Total lifecycle cost of RWT	Annualised life cycle cost of RWT ($/year)	RWT TN removal cost ($/kg/year)	WSUD TN removal cost vs RWT TN removal cost
1	Residential greenfield	82	$4,214,208	168,568	2,056	16%
2	Residential greenfield	8	$372,233	14,889	1,861	20%
3	Residential townhouse	1.31	$96,998	3,880	2,985	11%
4A	Urban renewal	28	$645,062	25,802	922	40%
5	Commercial	0.4	$12,110	484	1211	19%
6	Industrial	0.6	$8,800	352	587	54%

Notes: RWT is rainwater tanks

"RWT TN removal cost" is based on the annual lifecycle cost of RWTs. The life cycle of RWTs has been modelled as 25 years.

"WSUD TN removal vs RWT TN removal costs" is the annual WSUD TN removal cost expressed as a percentage of the rainwater tank TN removal cost.

2.6.3 Avoided cost of waterway rectification / maintenance benefits

Lifecycle costs for waterway rehabilitation works were calculated along with capital cost ranges and annual maintenance costs for Case Study 1 for Townsville by converting rehabilitation costs per metre of stream to unit rates per square metre of development. Waterway rehabilitation works (potential avoided cost) are presented comparatively as a cost per lot and a cost per hectare of the development site, with the lifecycle costs of both water rehabilitation and WSUD. The stream length is 1,000m for the 75.75ha development.

Table 2.11 Avoided cost of Waterway Rectification / Maintenance

Waterway rehabilitation works*						WSUD Lifecycle Cost ($/ha)
Lifecycle cost		Capital cost[3]		Maintenance costs[3]		
($/lot)	($/ha of catchment)	$ per lot	$/ha of site	$/yr per lot	$/ha/yr of site	
638-4,780 (2,709)[1]	8,000 - 60,000 (34,000)	210-3,155 (1,682)	2,640-39,604 (21,122)	27	330	51,927[2]

Notes: Information was sourced primarily from Table 5-4 (Water by Design 2009, p.5-24)

Averages are shown in (brackets).

[1] $/lot lifecycle cost range is for Townsville Case Study 1 using Total Lifecycle cost of waterway rehabilitation works per kilometre of stream length ranging between $606,000 and $4,545,000 (Average $2,575,890).

[2] recalculated based on no rainwater tanks and larger bioretention systems to compensate.

[3] Capital cost range used $200,000 to $3,000,000. Annual maintenance cost rates used - $25/m of stream.

* in reality, local authorities will not always complete waterway rectification when WSUD is not adopted, so the true avoided costs are likely to be at the lower end of this range on average.

The Case Study 1 example shows that while the lifecycle costs of the WSUD treatment are likely to be higher than the costs of the waterway rehabilitation works the value of the benefit is still significant i.e. 65% of the WSUD costs. (Water by Design 2009, p.5-24).

2.6.4 Property value benefits

Table 2.12 Property Premiums Associated with WSUD (With and without rainwater tanks)

Case Study		Property premiums associated with WSUD ($ / hectare)	Capital Costs of WSUD Measures ($ / hectare)	
			With tanks	Without tanks*
1	Residential greenfield [1] (sloping)	11,000 – 44,000 (27,500)	34,450	37,100
2	Residential greenfield [1] (flat)	11,000 – 44,000 (27,500)	42,890	46,189
3	Residential townhouse [2]	35,000 – 70,000 (52,500)	39,590	42,889
4	Urban renewal [3] (no tanks)	175,000 – 350,000 (262,500)	49,500	49,500

Notes: Information was sourced primarily from Table 5-5 (Water by Design 2009, p.5-25)

It was not considered possible to quantify this benefit for commercial development within the scope of the Water by Design assessment (Case Study 5). It is not clear how this benefit would impact on industrial sites and this was therefore not calculated (Case Study 6).

* recalculated capital costs based on no rainwater tanks and correspondingly larger bioretention systems to compensate.

[1] Using an average house price of $400,000 and 11 dwellings per hectare with a benefit value in the range of 0.25% to 1%.

[2] Using an average townhouse price of $350,000 and 40 dwellings per hectare with a benefit value in the range of 0.25% to 0.5%.

[3] Using an average unit price of $350,000 and 200 dwellings per hectare with a benefit value in the range of 0.25% to 0.5%.

2.6.5 Benefits of avoided development costs

The potential reduction in drainage and earthworks costs (avoided) associated with adopting WSUD for flat sites i.e. Case Studies 2, 4 and 6, are shown in Table 2.13.

Table 2.13 Potential avoided development costs associated with WSUD on flat sites

Case Study Description		Avoided capital cost[1] ($/ha)	Acquisition (capital) costs of WSUD ($/ha)	% Avoided capital cost of WSUD capital cost	Avoided annualised lifecycle cost ($/ha)	Annualised life cycle cost of WSUD* ($/ha/yr)
2	Residential greenfield (flat)	36,000	46,190	78%	1,365	2,510
4A	Urban renewal	36,000	49,500	73%	1,365	2,689
4B	Urban renewal (no tanks)	36,000	52,800	68%	1,365	2,869
6	Industrial	36,000	49,500	73%	1,365	2,690

Notes: Information was sourced primarily from Table 5-6 (Water by Design 2009, p.5-26) and recalculated for Townsville i.e. no rainwater tanks.

*The life cycle of the WSUD elements has been modelled as 25 years.

Avoided annualised lifecycle cost as a percentage of WSUD annualised lifecycle cost = for CS2 54%, CS4A 51%, CS4B 48%, and CS6 51%.

[1] based on $11,000 per hectare reduction by substituting at-surface drainage i.e. kerb/channel and swales, for pit and pipe drainage, and reduction in fill requirements ($10 per m³ at a minimum of 0.25 metres additional fill across the site) associated with pit and pipe drainage.

2.6.6 Unquantifiable benefits

"*There are also many unquantifiable benefits that are hugely important. The combined markets of recreational and commercial fishing, tourism and the seafood Industry are worth billions of dollars each year to the Queensland economy. A reduction in water quality and the health of Queensland's waterways will directly affect each of these industries. Achieving the stormwater management objectives with WSUD provides an opportunity to assist to maintain or enhance the water quality in Queensland's water bodies in or near urban areas. The unquantifiable benefits are potentially worth millions of dollars each year.*

Additionally, there are benefits, which are unable to be quantified, and these include ecological benefits such as option, existence and bequest values. These benefits refer to the impact on the ecological health of affected local and/or regional ecosystems, the impact of the value of having healthy aquatic and riparian ecosystems for potential use in the future, and the impact of the value of providing healthy aquatic and riparian ecosystems for future generations. Arguably these are ecological functions that are vital to protect. Employing WSUD in urban areas to maintain or enhance these values provides a clear benefit."

The unquantified benefits identified by Water by Design (2009) for the various case studies are listed in Table 2.14.

Table 2.14 Unquantified Benefits of WSUD

Unquantified Benefit Description	CS1 and 2	CS3 and 4B	CS5 and 6
Protection of the numerous values associated with healthy downstream waterways:			
• Ecosystem services (which may include some of the benefits below)	√	√	√
• Recreational and commercial fishing	√	√	√
• Tourism	√	√	√
• Seafood Industry	√	√	√
• Option, Existence and Bequest values	√	√	√
• Community amenity at local and regional scale (i.e. connection to water cycle)	√		
Minor benefits:			
• Increased rate of sales in developments with landscaped WSUD features	√	√	
• Increased local streetscape and parkland amenity	√	√	√
• Shading and urban cooling (potentially reducing energy consumption)	√	√	√
• Some direct and indirect aspects of implementing WSUD will result in changes to the configuration of development that will enhance open space	√	√	
• Education and research	√		
• Enhanced streetscape likely to deliver premium on rents received by landlords (related to increased patronage for retail and service businesses			√

Notes: Information was sourced from Table 5-7 (Water by Design 2009, p.5-28), Table 5-8 (Water by Design 2009, p.5-29), and Table 5-9 (Water by Design 2009, p.5-30). CS is case study.
A √ indicates that the unquantified benefit was identified as being applicable to the case studies.

"*Therefore, considering all the costs and all the potential benefits of applying WSUD to achieve the new storm water management objectives, **it is clear that the benefits are likely to outweigh the costs***" (Water by Design 2009, p.5-28), for all of the case studies examined.

2.6.7 Rainwater tank, bioretention system and detention storage relationships

"Detention storage detains or retards the 1-year ARI flow for the waterway stability objective. The waterway stability objective will not apply in many development situations and detention storage will not be required. Where the waterway stability objective does apply, it is likely flood storage will also be required and the waterway stability detention storage will be integrated into the flood storage at minimal cost. Therefore the cost of the detention storage does not form part of the WSUD Case costs." (Water by Design 2009, p.vi)

As flood mitigation in Townsville is a significant cost associated with urban stormwater management it was considered that the relationship between detention storage, WSUD measures, rainwater tanks and flood mitigation should be more closely examined.

While flood mitigation is about safeguarding the community by reducing the potential damage to property and infrastructure the SPP Healthy Waters has additional objectives associated with the protection of natural assets, including high ecological value (HEV) waters.

Design objectives for management of stormwater quality and flow during the construction phase of development aim to protect water environmental values (EVs) by minimising hydrologic impacts and contaminants in runoff. The stormwater design objective for drainage and flow management during construction is:

"*Take all reasonable and practicable measures to minimise changes to the natural waterway hydraulics and hydrology from:*

- *Peak flow for the 1–year and 100–year ARI event (respectively for aquatic habitat and flood protection);*
- *Run-off frequency and volumes entering receiving waters;*
- *Uncontrolled release of contaminated stormwater*." (Source: BPEM 2009, Table 1a, p.4)

The stormwater management design objectives for the construction phase are generally addressed through the development and implementation of site-based management plans incorporating erosion and sediment control and stormwater management. While important in their own right the construction phase stormwater design objectives are not directly relevant to our examination of longer-term flood mitigation and the relationship with WSUD measures.

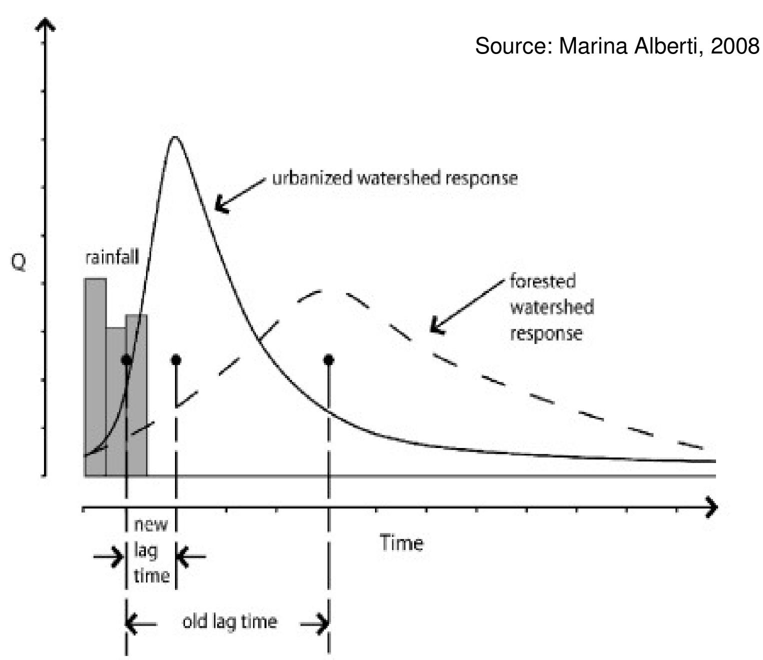
Stormwater management design objectives for the operational (post construction) phase of development are the most relevant to WSUD and flood mitigation interrelationships. "*Stormwater quantity management for waterway health enhancement focuses on the management of frequent urban stormwater flows that cause disturbance to aquatic habitats and aquatic ecosystem health, and on waterway geomorphic stability*" is distinct from flood management, "*which is concerned with the management of less frequent, more extreme stormwater flows that cause nuisance flooding and potential flood damage*". (Source: BPEM 2009, p.5). This would suggest that flood management measures could also work to achieve stormwater flow management design objectives.

The aim of two flow management design objectives is:

- ***Frequent flow*** - to protect in-stream ecosystems from the significant effects of increased run-off frequency and hydraulic disturbance, by capturing the initial portion of run-off from impervious areas;
- ***Waterway stability*** - to prevent accelerated in-stream erosion downstream of urban areas by controlling the magnitude and duration of erosion-generation and sediment-transporting flows

Flow management issues are generally associated with the increase in impervious areas resulting from urban development. Depending on the development type, impervious areas can increase by 40 – 90%. As a consequence there is less infiltration into the soil and watertables, and an increase in the volume and frequency of run-off (see Figure 2.9).

Figure 2.9 Urban Altered Hydrograph



Small rainfall events that would not generate run-off in undeveloped areas result in run-off in urban areas due to the impervious surfaces. Flow management design objectives aim to 'return' hydrological conditions to pre-development conditions through detention of flow to more closely resemble a 'normal' hydrograph.

The flow management design objectives are listed in the text box below.

Frequent flow

Capture and manage the following design run-off capture depth (mm/day) from all impervious surfaces of the proposed development:

- with a total fraction impervious 0% to 40%: Capture at least first 10 mm of run-off from impervious surfaces
- with a total fraction impervious >40%: Capture at least first 15 mm of run-off from impervious surfaces.

Note: Run-off capture capacity needs to be replenished within 24 hours of the run-off event.
Capturing and managing the first 20 mm of surface run-off from impervious surfaces would achieve very close to 'predeveloped' catchment hydrology.
Compliance with this objective may be easily demonstrated by providing a total stormwater capture volume (m^3) calculated as: **Capture volume (m^3) = Impervious area (m^2) x target design run-off capture depth (m)**
There may be opportunity to incorporate the required capture volume within stormwater quality treatment measures.

Waterway stability

Limit the post-development peak 1 year average recurrence interval (ARI) event discharge within the receiving waterway to the predevelopment peak 1 year ARI event discharge.

Note: Compliance with this design objective can be demonstrated using a run-off routing model.

(Source: BPEM 2009, p.7).

A preliminary summary of the cost relationships between rainwater tanks, bioretention systems and detention storages has been compiled for the urban residential case studies from the WSUD Business Case (Water by Design 2009) (see Table 2.15 for lifecycle cost, Table 2.16 for acquisition costs and Table 2.17 for maintenance costs). The costs relationships are based on Option B from case study 4, where the rainwater tanks were removed from the treatment train and the bioretention systems were increased correspondingly to compensate for the rainwater tank removal. Option B was calculated for the other case studies to reflect the Townsville scenario. See Appendix E for more detail.

Table 2.15 Option B lifecycle costs

Element	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Rainwater tanks	$4,214,208	$372,233	$96,998	$645,062
Bioretention cost increase[1]	$280,962	$28,412	$2,985	$62,755
Bioretention capacity increase	8.2%	7.8%	8.1%	4.6%
Bioret. cost increase vs RWT cost[2]	6.7%	7.6%	3%	10%
Cost saving without rainwater tanks	$3,933,246	$343,821	$94,013	$582,307
Detention storage cost reduction [3]	$18,204	$3,915	$965	$50,430
Detention storage size decrease	5%	2.2%	3.4%	15%
Total cost reduction	$3,951,450	$347,736	$94,978	$632,737

Note: [1] Added cost of bioretention systems to compensate for the removal of rainwater tanks.
[2]The cost increase due to bioretention systems as a percentage of the cost of rainwater tanks.
[3] based on a size reduction possible because of the increase in bioretention system detention volume.
"Cost saving without rainwater tanks" is the cost of rainwater tanks minus the cost of bioretention capacity increase.
"Total cost reduction" is "Cost saving without rainwater tanks" plus "Detention storage cost reduction" and represents the cost reduction achieved when rainwater tanks are removed from the WSUD case studies i.e. Townsville scenario.

Table 2.16 Option B acquisition costs

Element	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Rainwater tanks	$2,853,000	$252,000	$62,500	$500,000
Bioretention cost increase[1]	$200,738	$20,917	$2,197	$46,200
Bioretention capacity increase	8.2%	7.8%	8.1%	4.6%
Bioret. cost increase vs RWT cost[2]	7.0%	8.3%	3.5%	9.2%
Cost saving without rainwater tanks	$2,652,262	$231,083	$60,303	$453,800
Detention storage cost reduction[3]	$10,624	$3,271	$834	$43,800
Detention storage size decrease	5%	2.2%	3.4%	15%
(Option B) Total cost reduction	$2,622,886	$234,354	$61,137	$497,600

Note: Table notes from lifecycle cost table also apply this table.

Table 2.17 Option B maintenance costs*

Element	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Rainwater tanks	$85,590	$7,560	$2,250	$7,500
Bioretention cost increase[1]	$2,462	$206	$12	$455
Bioretention capacity increase	8.2%	7.8%	8.1%	4.6%
Bioret. cost increase vs RWT cost[2]	2.9%	2.7%	0.5%	6.1%
Cost saving without rainwater tanks	$83,128	$7,354	$2,238	$7,045
Detention storage cost reduction[3]	$425	$22	$3	$146
Detention storage size decrease	5%	2.2%	3.4%	15%
(Option B) Total cost reduction	$83,553	$7,376	$2,241	$7,191

Note: Table notes from lifecycle cost table also apply this table. * based on annual maintenance costs for the entire development site.

As mentioned the cost relationships are associated with the increase in bioretention system detention storage when rainwater tanks are removed from the WSUD treatment train (Option B). The actual relationship between detention storage for flood mitigation and detention storage in WSUD treatment trains needs to be analysed for real development situations in Townsville to garner meaningful cost and benefit information.

This will require the calculation of base case flood mitigation detention storage volumes and costs, with no rainwater tanks and no WSUD treatment train measures. The costs and volumes can then be compared to the WSUD case to establish any costs and benefits associated with flood mitigation as a result of WSUD treatment measures being included in the development scenario.

2.6.8 Priority infrastructure plans

Priority Infrastructure Plans (PIP) for trunk infrastructure need to be prepared by local government as a requirement of the *Sustainable Planning Act 2009*. Desired Service Standards (DSS) identify the level of service provided by particular types of infrastructure within the PIP. TCC will need to review the DSS for both the former Thuringowa and Townsville City Councils to develop new DSS that reflect the range of legislative requirements introduced since the old DSS were prepared.

The connection between flood mitigation, water quality and waterway management as components of overall stormwater management is highly relevant in terms of the DSS and PIP. Determining the relationships between these components of stormwater management seems to be an integral part of priority infrastructure planning and results would also assist the development industry with the design and construction of conjoint flood mitigation and water quality WSUD measures in new developments. This would ensure consistency with Council's strategic intent for stormwater management and the total water cycle management plan which is a requirement of the *Environmental Protection (Water) Policy 2009*. The first step is to scope the WSUD flood mitigation project requirements and ensure its integration with other stormwater management components.

2.7 Developed Areas

Water quality issues associated with the disturbance created during the development and construction stages are different to those associated with developed areas. Developed urban areas have less soil exposed to erosion and hence the acute sediment loads generated by developing areas are not a critical issue in developed areas. However, sediment generated from developed urban areas is still above natural levels of sediment generation, as are nutrient generation rates.

Management options for water quality improvement in developed urban areas relate to reduction of pollutants at the source (as with developing areas), as well as planning for and incorporation of treatment train measures throughout the urban landscape.

2.7.1 Coastal Dry Tropics Guide for Urban Water Management

The original concept was to develop the guide as part of the CCI project. It was obvious however that a significant amount of foundation work was required to develop such a guide and as part of the adaptive management strategy approach used while developing the Black Ross WQIP, it was deemed a more appropriate use of the funds to contribute to some of the foundation products. This included the development of the Townsville WSUD guidelines, and associated products, with Creek to Coral WQIP partners. Development of the Coastal Dry Tropics Guide for Urban Water Management (the Guide) became one of the implementation actions of the Black Ross WQIP.

Proposed content of the Coastal Dry Tropics Guide for Urban Water Management included:

- Total Water Cycle Management concepts within a catchment management framework;
- Hydrology and hydraulic considerations;
- Geology, soils and geomorphic features and influences;
- Aquatic ecosystem health concepts;
- Ecosystem services and their relevance;
- Other relevant findings and components associated with preparation of the Black Ross WQIP e.g. Stormwater Quality Improvement Devices (SQID) case studies report;
- The WSUD Guidelines and products (for stormwater);
- Potable water demand management principles and strategies;
- Wastewater treatment and reuse options and benfits;
- Asset Maintenance/Management Plans;
- Erosion and sediment control components;
- Stormwater management principles and USQMP;
- Waterway management planning framework and principles;
- Linkages to other programs such as Creekwatch and Dry Tropics Watersmart.

Before the WQIP was finalised the Environmental Protection (Water) Policy was revised to include a requirement for local government to prepare a total water cycle management plan incorporating an urban stormwater quality management plan. The Guide was essentially superceded by this mandatory requirement to prepare a total water cycle management plan. Rather than preparing the Guide efforts will be redirected into the preparation of a total water cycle management plan incorporating all the features listed above.

2.8 Urban Stormwater Quality Management

Both the former Townsville and Thuringowa City Councils prepared Urban Stormwater Quality Management Plans (USQMPs) during the latter half of the 1990s. Technically USQMPs only apply to areas with constructed stormwater systems. A Stormwater Quality Management Framework for Townsville was prepared for Citiworks (former Townsville City Council) in 2006 (Earth Environmental) and this was to be used to expand the stormwater quality management process beyond the constructed stormwater systems to incorporate natural stormwater drainage features and peri-urban areas.

It was initially proposed that one of the main urban stormwater quality management actions in the WQIP would be the integration of the two USQMPs to produce a single USQMP to cover the new local government area. Recent changes to policy and legislation has changed the requirements with respect to USQMPs (see section 5.4) and a more integrated approach is now required to incorporate USQMPs in the total water cycle management framework.

Consequently the USQMP options associated with the new and amended legislation have been examined in conjunction with total water cycle management planning and revised actions, costs and timeframes are proposed for the Black Ross WQIP. A brief summary of the legislative requirements is included below, with implications and options to meet the new regulatory regime.

2.8.1 Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy 1997* (Water EPP) was the key piece of subordinate legislation under the *Environment Protection Act 1994* dealing with urban stormwater quality management and the preparation of USQMPs by local government. The Water EPP was revised in 2009 with a major change being the requirement for local governments with populations of 10,000 people or more to develop and implement a total water cycle management plan for its local government area. Total water cycle management plans (TWCMP) are inclusive of the former USQMPs and sewage management plans (SMPs). The sewage management component of the TWCMP must include provisions about; effluent management, waste water recycling, sewerage system overflows and biosolids management, for each waste water treatment plant in its local government area.

According to the Water EPP 2009, a local government's TWCMP must include provisions about the collection, treatment and recycling of waste water, stormwater, ground water and other water sources; and the integration of water use in its area.

When developing and implementing the plan local government must have regard to guidelines published by the department about water cycle management, and any regional water security program made under the *Water Act 2000* (section 360M) applying to its local government area.

Components to be considered as part the TWCMP are:

(a) a strategy for demand management for water in its local government area; and
(b) ways to increase recycling of waste water and stormwater for purposes including, for example, industrial or agricultural purposes; and
(c) ways to use recycled waste water; and
(d) opportunities for stormwater harvesting for use as a water source; and
(e) the impacts of existing and future land use in the area on water cycle management, including the following—
  (i) impacts of the use on the natural flow of waters;
  (ii) impacts of the use on water quality objectives for waters;
  (iii) the risks to drinking water supplies caused by the use; and
(f) a forecast of the water supply requirements for the area.

Along with the inclusion of the components listed above the TWCMP must also include provisions about stormwater quality management to improve the quality and flow of stormwater in ways that protect the environmental values of waters affected by the local government's urban stormwater system. This is the 'old' USQMP component of the previous Water EPP (1997).

If a local government is required to develop a TWCMP, or other environmental plan (apart from a trade waste management plan), it must develop and start implementing the plan within two years after the commencement of the Water EPP 2009 (August 2009). The plan is to be reviewed and revised after five years.

A local government may comply with the requirement to develop and implement an environmental plan by using and implementing a plan prepared by it that complies with the Water EPP 2009.

The Water EPP also provides an option for developing and implementing a healthy waters management plan, in conjunction with DERM. Healthy waters management plans (HWMP) are similar in many respects to WQIPs and catchment management plans. HWMPs take a broader view of stormwater quality management than just the urban context, as with the Black Ross (Townsville) WQIP developed by Creek to Coral.

For Townsville, a HWMP would potentially focus on specific issues and tasks, which were not explored in the Black Ross WQIP, due to the weight the Commonwealth placed on determining end of catchment load targets. This could include any threats to water-dependent ecosystems including matters that may adversely affect the use of the water as a supply of drinking water. This would be particularly relevant to the management of the upper Ross River catchment.

2.8.2 Draft State Planning Policy Healthy Waters

The draft State Planning Policy Healthy Waters (Healthy Waters SPP) was released in September 2009. The main 'reference' document of the Healthy Waters SPP is the Urban Stormwater - Queensland Best Practice Environmental Management (USBPEM) Guidelines (DERM 2009). The principles enunciated in the USBPEM Guideline also underpin the Black Ross WQIP, with many of the urban-based water quality improvement actions proposed as part of the WQIP implementation phase being confirmed. A cross-Council integrated approach to the implementation of relevant Black Ross WQIP actions will assist Townsville City Council comply with the draft Healthy Waters SPP and the Water EPP.

The relationship between the Black Ross WQIP, Section 3.3 of the draft Healthy Waters SPP (how the aims of the Healthy Waters SPP can be met through a planning scheme) and the various elements of the BPEM Guideline are mentioned briefly in Table 2.18. Additional detail and extracts from the BPEM Guideline are provided in Appendix D.

Table 2.18 Healthy Waters SPP Relative to Black Ross WQIP

<table>
<tr><th>SPP</th><th>SPP Achievement in Planning Scheme and Black Ross WQIP Relevance</th></tr>
<tr><td>a</td><td>Land allocated or zoned for urban or future urban purposes is compatible with natural drainage, erosion potential, watertable levels and landscape features
(BPEM Chapter 4 – Land use planning, and urban capability/suitability mapping and planning accompanied by the use of 'zones', overlays and associated provisions)</td></tr>
<tr><td colspan="2">Mapping and prioritisation of environmental assets, environmental infrastructure and environmental constraints is considered to be a fundamental step in determining the most appropriate water quality improvement actions. Collation of data and preliminary mapping was completed to inform the WQIP and could be used to inform the construction of a land use suitability layer showing the location of areas required for environmental infrastructure to inform the new TCC planning scheme, and future regional plans.
Along with water quality and water related issues and hazards this layer could take into account a number of factors including; delineation of local and regional biodiversity areas (using a 3-5 tier prioritisation process), waterways and wetlands, climate change (sea level rise/storm surge/flood plain management), landscape features and amenity. There are also links with the Draft Queensland Coastal Plan as environmental infrastructure will be required to ensure sea level rise and storm surge are taken into account.</td></tr>
<tr><td>b</td><td>The measures required by development to protect water EVs are clearly identified
(BPEM Chapter 3 – Stormwater Management Planning, Chapter 5 – Water Sensitive Urban Design, Chapter 6 – Source Controls and Chapter 7 – Structural Control Methods)</td></tr>
<tr><td colspan="2">EVs and WQOs were identified at the landscape scale as part of the preparation of the Black Ross WQIP. Measures to protect the EVs have also been proposed. Some measures are proven e.g. WSUD, while others need to be tested to ensure their effectiveness.
TCC already has some policies and guidelines in place that assist with the definition of measures required by development. It is proposed that these policies and guidelines be reviewed, revised and integrated as appropriate with the development of the amalgamated TCC USQMP/TWCMP and the new TCC planning scheme. It is assumed that the USQMP process will define the measures required by development to protect water EVs, and that these will then be incorporated into the planning scheme.</td></tr>
</table>

c	Areas that drain directly into waters mapped as being of HEV are not allocated or zoned for urban or future urban purposes unless relevant WQOs can be achieved (BPEM Chapter 4 – Land use planning, and urban capability/suitability mapping and planning accompanied by use of 'zones', overlays and associated provisions)
HEV areas were identified at the regional landscape scale as part of the WQIP development process. This involved considerable input from DERM and the GBRMPA, technical experts and community consultation. A draft map of HEV waters now exists for the Black Ross WQIP area i.e. the coastal catchments from Crystal Creek to Cape Cleveland. This process will need to be extended to include the rest of the Townsville City local government area i.e. parts of the Haughton catchment and streams that flow to Bowling Green Bay. These areas were included in the Burdekin WQIP area and the results can be used as draft HEV areas for Townsville. A more detailed delineation process will also be required for urban areas to ensure that locally important HEV areas are identified. This is another task involved in the preparation of an amalgamated USQMP for Townsville. A draft set of WQOs has been developed for the Black Ross WQIP area and these can be used in conjunction with the identified HEV areas to generate a draft set of 'zonings' for land use associated with HEV areas. Again preparation of the USQMP will confirm and refine these areas, and assist with determining the appropriate type and scale of development for environmentally sensitive areas associated with HEV waters. Options include 'exclusion' areas and buffer zones associated with HEV waters and prescribed solutions to meet WQOs associated with development areas that drain to HEV waters e.g. ESC Plans and WSUD.	
d	The local planning instrument is in accordance with any USQMP relevant to the area (BPEM Chapter 3 – Describes the process for developing a USQMP, including incorporation of WSUD principles and structural control methods, erosion and sediment control and stormwater management for the development stages)
The need to amalgamate the 'pieces' of USQMPs previously prepared for the former Thuringowa and Townsville local government areas was identified during preparation of the Black Ross WQIP. Scoping the tasks required to prepare an amalgamated USQMP was flagged as an implementation action of the WQIP. The initial scoping has been brought forward and is included in this Options report (see 2.8.3).	
e	The local planning instrument is in accordance with any WMP relevant to the area
Waste Management Plans (WMPs) were not identified as part of the WQIP preparation process. These will however be considered in the more specific process for developing the USQMP and the TWCMP.	
f	Waste-disposal facilities are not located in areas with highly permeable soils or a high groundwater table (BPEM Chapter 6 – Source Controls)
The WQIP dealt with surface water and did not consider groundwater impacts except in a superficial way. This will be a function of land use planning and constraints mapping presumably associated with the designation of community infrastructure, either as part of a broad scale land use suitability study for the new planning scheme or as part of a specific study to inform a regional waste management strategy or similar process. This has been noted and will be considered when developing the USQMP and the TWCMP as part of the review of Council activities and their impact on water quality.	
g	The local planning instrument ensures development to which this draft Policy applies is assessable or self-assessable
This is not addressed through the WQIP and is an action relevant to the preparation of the planning scheme.	
h	The code set out at Annex 1 is incorporated in the local planning instrument in a way that provides for the same or better water quality management outcomes as that code
The Black Ross WQIP helped inform some of the components referred to in the code in Annex 1 of the draft SPP, and in particular the design objectives referred to in Chapter 2 of the BPEM Guidelines. Creek to Coral (TCC-ISS) in collaboration with TCC planning and development staff involved in preparing the planning scheme would ensure that the SPP outcomes are appropriately incorporated in the planning scheme using Black Ross WQIP products and outputs, knowledge and ongoing investigations, including the preparation and outputs of the amalgamated USQMP.	
i	The local planning instrument states that the information that may be requested for assessing development to which the draft Policy applies will include matters in accordance with the Urban Stormwater - Queensland BPEM Guidelines, and best practice waste water management, and best practice environmental management of non-tidal artificial waterways

<table>
<tr><td colspan="2">As for item h, Creek to Coral (TCC-ISS) in collaboration with TCC planning and development staff would ensure the information requested as part of the development assessment process appropriately reflects the intent of the SPP with respect to the BPEM Guidelines and local derivations developed as part of the Black Ross WQIP. The Queensland BPEM Guidelines can be used as an interim measure while local BPEM guidelines are being developed, including additional components of the WSUD suite of tools. As with the BPEM guidelines the Black Ross WQIP recognises the water quality issues associated with different land uses, geophysical and biophysical features, and stages of development and has tailored water quality improvement responses appropriately.
The BPEM Guidelines will also be used as the basis for the development of the amalgamated USQMP for Townsville, which will include all the relevant measures and actions from the Black Ross WQIP.</td></tr>
<tr><td>j</td><td>The local planning instrument identifies nutrient hazardous areas and ensures development in these areas is located, designed, constructed and operated to avoid the mobilisation and release of nutrients of concern for coastal algal blooms</td></tr>
<tr><td colspan="2">At present coarse scale hazard maps have only been produced for South East Queensland as per Implementing Polices and Plans for Managing Nutrients of Concern for Coastal Algal Blooms in Queensland (Ahern 2009). Course scale modelling has been prepared for the Black Ross WQIP and could be used as the basis for coarse scale hazard maps for the Townsville region using the water quality data base and background reports prepared to support the development of the WQIP. Creek to Coral could collate the available information to provide a preliminary nutrient hazard map equivalent to the coarse scale hazard maps.
The northern extent of the Black Ross WQIP area/ Townsville City local government area is within the Wet Tropics Coastal Nutrient Management Zone, and is part of an agricultural land use management program to reduce the load of water borne nutrients discharged to the marine waters of the Great Barrier Reef. There may be some mapping available from this program through the former Department of Primary Industries and Fisheries (DPIF) (now part of the Department of Employment, Economic Development and Innovation (DEEDI)).</td></tr>
</table>

Note: Letters in SPP column correspond to the listing in section 3.3 of the draft Healthy Waters SPP. See definitions from the draft SPP and additional commentary in Appendix D. Section 3 of the draft SPP Guideline provides further information on how to achieve the draft Policy outcome through a local planning instrument (see Appendix D)

In practice the USQMP component of the TWCMP could be the delivery vehicle for most of the requirements of the draft Healthy Waters SPP. The previous process for developing USQMPs was more limited in its scope and would not deliver the outcomes outlined in the Water EPP 2009, and the draft Healthy Waters SPP. Considerable work will be required to transform existing USQMP elements into the new framework for TWCMPs.

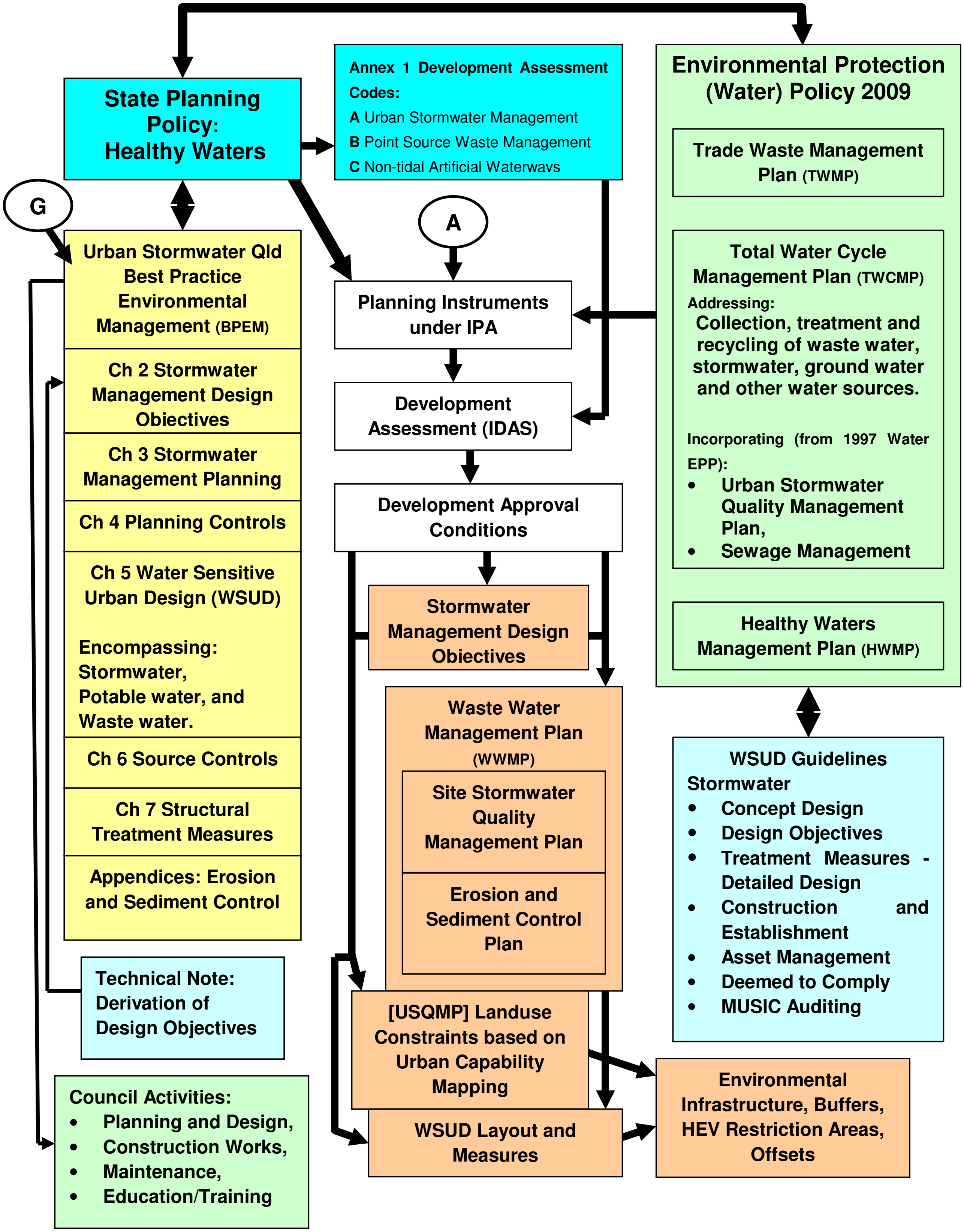
The Black Ross WQIP is reasonably well aligned with the framework and concepts for stormwater management expressed in the TWCMP. As such there are a number of elements that can be translated across, adapted and used as a platform for the development of the TWCMP (see Table 2.18). The main collaborative effort required between Creek to Coral and TCC's planning and development team members is the development of the interface between the USQMP elements and the new TCC planning scheme.

The 'updated' USQMP development process is described in the USBPEM Guidelines prepared for the draft Healthy Waters SPP. This has been referred to in determining the options associated with developing the 'new' USQMP for Townsville. The main components of the USBPEM guide, including USQMP components, are summarised in Appendix D.

Through the preparation of the TWCMP and USQMP TCC can internally review and improve its management systems and processes and make linkages with the development assessment process. This could include measures to ensure that urban stormwater treatment devices and WSUD treatment trains are appropriately designed and constructed so that when they are handed over to Council they will perform the function they were designed for without additional, or onerous, costs to Council.

The components of and interrelationship between the Healthy Waters SPP and the Water EPP 2009 are illustrated in Figure 2.10.

Figure 2.10 SPP and EPP Planning Connections



Note: A indicates additional policy and legislative input to planning instruments e.g. Coastal Plan. G indicates additional guidelines and reference documents constituting best practice for stormwater management.

2.8.3 TWCMP and USQMP options

To achieve anything resembling total water cycle management in the urban and peri-urban environment involves the inclusion of both water supply and wastewater treatment with the stormwater management components (WSUD and USQMP). The starting point may be the development of an Integrated Water Management Policy as an overarching document that encapsulates Total Water Cycle Management and WSUD principles and includes:

- Potable water (including transport and treatment energy requirements and greenhouse emissions, infrastructure, ecosystem impacts, social and economic costs, and hydrological and hydraulic impacts);
- Wastewater (including point source treatment implications, impacts and costs, recycling options including reduction of demand for potable supplies, septic system impacts and costs, greywater reuse in the Townsville context, trade waste disposal, and alternative wastewater management and recycling systems);
- Stormwater and drainage management (including USQMP, WSUD, floodplain studies, flood mitigation measures and climate change risk management);
- Community based education and involvement.

The main components to be considered when developing a USQMP, as part of the TWCMP, include:

(a) identifying urban stormwater quality management needs for developed and developing areas that are consistent with the local government's priority infrastructure plan under the Integrated Planning Act; and
(b) the opportunities for stormwater harvesting, recycling or re-use; and
(c) incorporating water sensitive urban design in developed areas within a stated period; and
(d) managing urban stormwater quality and flows for development in the local government's area, having regard to the following documents -
    (i) any site specific documents;
    (ii) the QWQ guidelines;
    (iii) relevant guidelines published by the department about stormwater quality (and especially the USBPEM guidelines prepared for the draft Healthy Waters SPP); and
(e) monitoring and reporting processes for stormwater quality management.

The option for the preparation of a TWCMP and USQMP to comply with the requirements of the updated Water EPP and the draft Healthy Waters SPP, assuming it will become a SPP under the *Sustainable Planning Act 2009* is based on the framework and outline in the USBPEM guidelines (see Appendix D and F for additional detail). The scope and component tasks of the TWCMP and USQMP are shown in the text boxes below.

Figure 2.12 USQMP is Not Just Pipes

Total Water Cycle Management Plan Framework

The main tasks associated with the preparation of a TWCMP are:

- Convene the steering group to;
  - Agree on the desired objectives and outcomes for the project,
  - Define the administrative structure that will be used to coordinate the project,
  - Appoint a project manager and support staff (including technical working group/s),
  - Prepare a workplan including management and communications strategy (does not need to be complex and defines coordination meetings / timeframes, key contacts, roles and responsibilities etc) to coordinate TWCMP preparation.

- Review of existing 'water' plans and policies to determine;
  - the connections and relationships between them,
  - their applicability to the TWCMP,
  - the actions required to meet EPP Water 2009 TWCMP requirements i.e. to adapt existing plans or prepare new plans.

- Prepare a TWCMP framework incorporating component plans and integrative processes;

- Scope the activities and prepare a workplan framework for TWCMP component plan adaptation and/or preparation;

- Identify common requirements of TWCMP components e.g. population growth estimates and land use mapping, and allocate responsibilities for actions and define timeframes;

- Allocate resources for TWCMP component preparation, including common components;

- Prepare TWCMP components as per allocations and in conjunction with TWCMP coordination strategy.

Figure 2.13 Woolcock Street Drainage in a Tidal Setting

USQMP Scope for Townsville[1]

Stage 1 Preliminary Activities

Step 1 Initial scoping of the project

- Identify the main drivers and requirements i.e. policy and legislation (EPP Water and draft SPP Healthy Waters);
- Prepare a draft project scope or framework to take the actions required to comply with 'new' requirements (this document).

Step 2 Confirming support for USQMP development

- Agree on the desired objectives and outcomes for the project;
- Define the administrative structure that will be used to coordinate the project;
- Appoint a project manager and support staff (including steering group/technical working group composition);
- Develop the action plan (based on the project scope) and budget for the planned life of the project including adaptive planning and management strategy, communication strategy and reporting protocols.

Step 3 Information gathering and collation

- Define the connections between the main drivers and legislative requirements and other 'external' policies and programs i.e. look for opportunities to integrate USQMP activities with other requirements to be more effective with resource use;
- Identify and access existing Council policy, programs, projects, studies, management plans, maintenance activities relevant to the drivers and requirements;
- Collate and reference the material using a spreadsheet database;
- Undertake a summary review of collated material and note;
    - Any points of clarification required,
    - Other reference material identified and not accessed,
    - The material that is most relevant to the development of the USQMP and TWCMP,
    - Existing Council activities that go some way to meet the requirements of the USQMP,
- Contact relevant people to access additional reference material, clarify ambiguous material and discuss projects and programs as necessary to gain a bigger picture of activities connected to urban stormwater management and the total water cycle management and may include;
    - Face to face consultation with staff from TCC departments, DERM, GBRMPA, NQ Dry Tropics,
    - Focus group and/or Technical Working Group meetings with key Council personnel and appropriate external stakeholders,
- Undertake a comprehensive review of the reference material most relevant to the USQMP and TWCMP (including studies underway and planned) to;
    - Identify studies, mapping, modelling, activities and other existing elements that can be adopted or adapted as part of the USQMP, or to inform the development of the USQMP and TWCMP including material that,
        - ❑ Defines the biophysical elements of the study area,
        - ❑ Identifies Townsville's natural assets,
        - ❑ Identifies land use and development growth patterns,
        - ❑ Predicts future population growth and developing areas,
        - ❑ Defines the stormwater infrastructure associated with built environments,
        - ❑ Identifies stormwater management issues in Townsville,
        - ❑ Identifies stormwater pollutant types, sources and levels,
        - ❑ Provides management options for urban stormwater,
        - ❑ Provides examples of WSUD in Townsville,
        - ❑ Describes current and planned stormwater management activities,
        - ❑ Assesses and/or describes the condition of natural assets,
        - ❑ Assesses and/or describes the effectiveness of stormwater management measures and infrastructure,
        - ❑ Provides an indication of the likely stormwater quality improvements associated with management measures e.g. from modelling,
        - ❑ Climate change implications
- Review available GIS layers and update land use data i.e. to most recent aerial photography or SPOT imagery (has been completed to 2005 by Creek to Coral for the Townsville WQIP area);
- Delineate catchments and waterways, associated stormwater systems and receiving waters, which might include open waterways, wetlands, lakes and coastal waters;
- Based on the above, define draft functional management units;
- Collate all available water quality data in a database, or adapt existing database/s;

- Identify any unmet information requirements for catchment and water quality modelling e.g. additional event WQ monitoring required;
- Act to fill catchment and water quality modelling information requirements as a matter of priority;
- Document issues associated with land use types (residential, commercial, industrial, parks and open space) and development stage i.e. undeveloped, developed or developing;
- Document activities and management practices associated with land use types and development stage that have the potential to impact stormwater quality. Along with the identification of generic activities associated with natural areas, formal parks, residential, commercial and industrial land uses this will also require a review of Council activities (see Step 4);
- Consultation, including workshops, as required to review and confirm land use types, management activities, development stage, growth areas and development trends i.e. to determine water quality pressures and hazards;
- Water quality modelling to confirm high risk areas;

Step 4 Review of management practices and processes

- Prepare an action plan to review management practices and processes (It is suggested that the action plan to review management practices and processes be developed by the Technical Working Group assigned to assist with the development of the USQMP and TWCMP).

(see Appendix F for more detail)

Stage 2 Risk assessment

Step 1 Compilation of available data to determine draft Environmental Values (human use and aquatic ecosystem) for waterways and waterbodies impacted by urban stormwater

The levels of aquatic ecosystem protection need to be determined as either high ecological value (HEV), slightly disturbed (SD), moderately disturbed (MD) or highly disturbed (HD).

Step 2 Identification of appropriate WQOs for corresponding EVs

- As an interim measure use WQOs adopted for the Townsville WQIP;
- Longer term - WQ monitoring to establish local WQ guidelines to determine local WQOs (in consultation with DERM. Actions to be planned with DERM).

Step 3 Comparison of water quality data with WQOs

- Update the water quality (WQ) monitoring database developed by Creek to Coral for the Townsville WQIP, including confirmation (GPS) of monitoring site locations;
- Extract site specific 'reports' based on recent data and compare to historic data if available;
- Place site WQ reports into the report card format;
- Compare site WQ reports to the WQOs for associated functional management units, waterways and catchments where data is available;
- Identify waterways where WQ data is not readily available to assess current condition against WQOs;
- Investigate the possible integration of data collected as part of the development assessment approval process with the Creek to Coral WQ database.

Step 4 Identify threats to receiving waters from stormwater

- Document major site-specific and transient activities with potential to damage receiving water EVs for each catchment, waterway and, where possible, functional management unit using information collated and reviewed in Stage 1 including;
    - Townsville WQIP reports e.g. Pollutants and Sources Report,
    - Former CoT and TCC USQMPs,
    - Technical Working Group consultation

- Stakeholder consultation.

Step 5 Rate threats to EVs

- Review information from Stage 1 for relevant material;
- Estimate the pollutant load generated and the frequency of occurrence e.g. modelling;
- Review any measured impact of threats / activities on receiving environments e.g. WQ monitoring data and incident reports;
- Where quantitative information is not available use informed assessment e.g. professional judgment and experience, local knowledge, history of spills, complaints, age of infrastructure etc;
- Consult with the Technical Working Group (Council), State agencies (DERM), regional NRM body and others as appropriate;
- Document the findings and rate threats on a three or five point scale.

Step 6 Site assessments

- Identify areas where additional information is required;
- Review and pilot site assessment process prepared for SQMF (Gunn 2006);
- Conduct site assessments;
- Compile results and cross reference / add to previous findings.

Step 7 Risk assessment

- Document values and threats for each functional management unit, waterway and catchment using information from Stages 1 and 2;
- Calculate potential risks by multiplying the threat by the value i.e. threat x value = risk.

Step 8 Stakeholder workshop/s to review findings and amend EVs and threat ratings

Step 9 Follow up and resolve any significant disagreements

Stage 3 Development of USQMP Management Options and Actions

The USQMP will provide actions and strategies to be undertaken by Townsville City Council, and its partners as appropriate, to meet the agreed objectives and values identified and confirmed in Stage 2.

Step 1 Identify the range of available management options to address issues / threats identified in Stage 2

Step 2 Align potential management options with functional management units, waterways and catchments as appropriate

- Identify the options that could be used to address the priority issues associated with each functional management unit, waterway and catchment;
- Identify resource and funding requirements for the various options;
- Identify impediments and opportunities associated with the options;
- Use a decision support matrix, or similar process, as an initial filter to identify the most practical options;
- Prepare strategies and draft catchment-based action plans incorporating the most practical options identified (this may include the preparation of a Waterway Action Plan or Catchment Management Plan for priority areas).

Step 3 Evaluate cost effectiveness of options and prioritise management actions

- Develop a cost-effectiveness index to assist with prioritisation of management actions and sequencing / timeframe;
- Identify resource and funding requirements for the various options, strategies and plans;

- Identification and assessment of the social, economic and environmental implications of implementation including alignment with Council's priority infrastructure plan;
- Develop the plan based on information gathered which may include the need to;
    - assess the cost-effectiveness of potential control techniques,
    - rank control measures in order of cost-effectiveness,
    - review alternative catchment land use and management techniques and point source control scenarios. Model various water quality outcomes until a satisfactory balance is achieved between development and required environmental objectives, having regard to social and economic implications.

Step 4 Document USQ Strategies and Management Actions

- Incorporate option analysis findings, stormwater quality protection and improvement strategies, management actions (including development of area-specific action plans), estimated timeframes and assumed responsibilities in the USQMP report;
- Review Council planning and development approval requirements and prepare a strategy to align USQMP actions with development assessment processes including;
    - land use and capability mapping with appropriate zoning for protection of EVs including;
        - present and future land use,
        - environmental and other constraints,
        - land use capability (physical components),
        - land use suitability (incorporating socio-economic components),
        - riparian condition and buffering capacity,
        - a waterway and wetland overlay showing HEV areas,
        - environmentally sensitive areas,
        - water quality and flow hazards and threats,
        - land to be set aside for drainage corridors and pollution control infrastructure.
    - planning scheme provisions and development assessment conditions consistent with water quality and waterway protection (best practice land management and pollution control),
    - monitoring, auditing and enforcement,
    - a cost strategy apportioning priority infrastructure charges for stormwater management, waterway and WSUD infrastructure maintenance, and water quality monitoring.
- Investigate opportunities for stormwater harvesting, recycling and reuse;
- Integrate findings into other components of the TWCMP e.g. sewage management, and other Council programs and planning processes e.g. Corporate Plan;
- Develop waterway action plans addressing specific waterways (or reaches) and achievement of specific water quality objectives;
- Prepare a communication strategy incorporating reporting components and education, awareness, training and behaviour change programs;
- Prepare a monitoring, evaluation and review strategy incorporating adaptive management capability;
- Secure stakeholder and community input and review and amend the plan if necessary;
- Secure necessary funding required to implement strategies.

Step 5 Prepare an Implementation Plan

The implementation plan should specify:

- Priority actions,
- Funding and resources,
- Responsibilities,
- Timeframes,
- Reporting requirements and processes,
- Monitoring, evaluation and review processes,
- Communication approach and processes.

Additional information on TWCMPs and USQMPs is provided in Appendix F.

2.8.4 Urban stormwater treatment trains

Preliminary water quality monitoring results suggest the light industrial and commercial areas of the urban footprint are contributing above average levels of pollutants to waterways. Installation of stormwater treatment train measures to improve water quality entering receiving waters from light industrial and commercial areas is a key option as a component of USQMP implementation. Priority areas will be identified during the preparation of the integrated Townsville USQMP.

Existing projects and improvements in known areas will continue in the interim e.g. Louisa Creek rehabilitation.

2.8.5 WSUD retrofit

Another option associated with WSUD is planning for and retrofitting measures into already developed areas and redevelopment sites. Creek to Coral will work with TCC departments to plan the installation of WSUD measures to improve water quality leaving established Council properties and especially those areas in close proximity to environmentally significant areas e.g. Rowes Bay Depot and nearby wetlands.

Retrofitting WSUD measures into existing developed landscapes and redevelopment sites will be enhanced through the demonstration of possible solutions on Council properties, including public greenspace areas e.g. the Lakes and associated open space. Again this is another option associated with the USQMP and TWCMP, with priority sites to be identified during the USQMP preparation.

2.9 On-ground Works and Pilot Programs - Road Testing the Waters

This is where on ground action is taken for areas that we know will result in improvements for water quality. Studies proposed in the enabling actions section (especially section 5.8) will contribute to action learning about natural asset condition to assist with ongoing prioritisation of areas for focused action to achieve effective outcomes as part of the adaptive management approach to water quality improvement.

2.9.1 Riparian rehabilitation

Riparian rehabilitation works is an option with the potential to reduce the likelihood of erosion and improve the filtering effect of waterway ‘buffer’ zones. This may require initial stabilisation of erosion prone areas including earthworks and installation of erosion prevention measures e.g. matting. Establishment of native vegetation is the preferred long-term option for bank and riparian zone stabilisation, and sediment and nutrient filtering, as it will also contribute to biodiversity outcomes.

Initial works can be undertaken where there is consensus (expert advice and community support) on the likely water quality benefits associated with ‘no regrets’ areas. A prioritisation process associated with more detailed condition assessment studies will guide the location of future works (see section 5.6.2).

2.9.2 Wetland restoration and construction

Wetlands can be highly productive natural filtering systems in the tropics as long as they are not overwhelmed by excessive sediment, pesticide and nutrient inputs. Improving the capacity of wetlands to function as ‘natural’ filtering mechanisms can be achieved by restoring existing wetlands and, where appropriate, constructing additional wetlands, or wetland components e.g. sediment retention ponds, to complement and/or buffer natural systems. The priority areas need to be defined by condition assessment studies and subsequent prioritisation of sites (see section 5.6.2). As with riparian rehabilitation works there will be some ‘obvious’ sites determined from previous studies and consultation where immediate action will result in water quality improvement outcomes.

2.9.3 Aquatic ecosystem health

Management interventions for aquatic ecosystem health may have water quality benefits as well as known biodiversity and aquatic habitat benefits. This is in addition to the interventions that relate primarily to physico-chemical water quality condition.

In general terms management interventions that improve the rating of report card indicators will improve aquatic ecosystem health. Indicator areas not fully addressed so far include; freshwater fish, aquatic invertebrates, aquatic vegetation, riparian vegetation and channel and floodplain features.

Figure 2.14 Townsville has a Variety of Aquatic Ecosystems

Until there is sufficient information to assess the condition of our waterways and waterbodies the benefits of protection and rehabilitation efforts will be based largely on expert opinion and community consultation. The addition of systematic condition assessment information will greatly assist the prioritisation of sites for management intervention and provide a baseline to measure progress.

Figure 2.15 Aquatic Habitat in the Urban Landscape

3. Peri-urban Management Options, Costs and Benefits

3.1 Peri-urban and Rural Residential Management Options

The interface between the established urban areas and rural agricultural areas is a special case requiring a separate set of management options to address the issues that are particular to this land use 'ecotone'. The peri-urban landscape generally consists of blocks that may be too small to be financially productive in terms of agricultural production and are too widely spread to warrant the establishment of urban style infrastructure e.g. stormwater systems and wastewater management.

Current science knowledge of peri-urban contributions to water quality issues is limited, however the general catchment management issues associated with the peri-urban landscape are apparent and need to be addressed in an integrated manner. Peri-urban areas can be considered to be relatively heavily populated 'rural' areas with a limited areal extent. The limited areal extent makes the extension task less difficult as the audience is relatively concentrated while the larger disparate population makes the engagement task more complex.

Regardless of the limited knowledge associated with Townsville's peri-urban areas increasing the capacity of peri-urban landholders to manage this part of the landscape is a critical action for overall catchment health. A number of foundation activities will be required before a set of management actions can be developed to address the identified issues.

There is significant potential for collaboration on peri-urban projects with James Cook University, CSIRO/LWA, Griffith University (Daryl Low Choy), NQ Dry Tropics and Terrain, as this is an area that has not been seriously investigated and addressed to date.

NQ Dry Tropics is currently rolling out the Healthy Habitat project, which aims at reducing critical threats to endangered habitats in the peri-urban and semi-rural areas adjacent to Townsville. NQ Dry Tropics is already working with Townsville City Council on weed control issues and the development of a complementary subsidy arrangement for land holders. Creek to Coral has discussed the possibility of combining the Black Ross (Townsville) WQIP peri-urban options with the Healthy Habitat project and reached agreement in principle on an integrated effort. In the event that a Caring for Our Country funding proposal submitted by Creek to Coral is successful, NQ Dry Tropics will provide Creek to Coral with information from their Healthy Habitat project, including mapping products, demographic information, critical habitat threat abatement management practices and landholder engagement techniques. Creek to Coral will provide reciprocal input to any extension of the Healthy Habitat project.

From Creek to Coral's perspective the main task associated with the Dry Tropics peri-urban environment is to develop a set of catchment management guidelines that will address the range of issues associated with this land use zone. This will involve enabling actions including behaviour change investigations and development of a program to facilitate management practice uptake.

Subject to funding for both parties, NQ Dry Tropics may assist Creek to Coral to develop a peri-urban sustainable management guideline delivery program and be a partner in delivery of the program across the wider Townsville region peri-urban areas.

Due to the uncertainty of the final measures that will need to be implemented as part of any peri-urban sustainable management program the foundation activities need to be built into the proposed activities. Costs of the foundation activities have been estimated however the longer term implementation actions cannot be defined with any reliability until the initial work has been completed and the benefits are established in relation to the costs of the implementation options.

The proposed foundation actions for peri-urban areas are listed in Table 3.1. As can be seen the main implementation options will be developed as a component of the initial actions. As with other elements of the Black Ross WQIP the peri-urban option focuses on addressing issues at the source through behaviour change.

Table 3.1 Peri-urban Foundation Actions

Action	Description
1	Delineate key peri-urban areas through internal/external stakeholder focus group meeting/s and aerial photograph and cadastral interpretation to develop a GIS layer
2	Identify and prioritise catchment management, water quality and socio-economic issues associated with peri-urban areas
3	Develop biophysical BMP guidelines for peri-urban areas (soil, land, water and biodiversity management) incorporating fire management for catchment health and water quality
4	Refine the ABCD framework for peri-urban areas in line with BMP guidelines
5	Undertake behaviour change studies (Thematic Interpretation and/or Community Based Social Marketing) in selected catchments e.g. Alligator Creek, Stuart Creek, Ross River, Bohle River, Black River and Bluewater Creek, to determine the most effective programs for water quality and catchment management initiatives (does not include Ross Dam catchment study)
6	Develop and cost programs based on results of studies
7	Incorporate social findings in biophysical BMP guidelines and ABCD framework
8	Implement peri-urban land and water management program
9	Ross River Dam water resource catchment management actions: • Integrate the dam catchment water quality monitoring program with the Black Ross (Townsville) WQIP WQ Monitoring and Modelling Strategy; • Review planning scheme provisions in terms of what has worked and what needs to be amended for the information of the new planning scheme for Townsville City; • Catchment planning for water quality improvement in higher risk land use areas/sub catchments; • Include Oak Valley in peri-urban management actions and subject to a combination of appropriate management interventions; • Include Ross River Dam catchment peri-urban areas in the development of the peri-urban BMP guidelines as a specific case study; • Partner with NQ Dry Tropics to extend grazing Reef Rescue BMP incentives to the larger grazing properties of the Upper Ross River Sub Basin; • Review previous catchment plans and studies and provide further recommendations for catchment management and WQIP actions; • Conduct CBSM / Thematic Communication and Social Learning studies for implementation of peri-urban BMP in dam catchment communities e.g. Oak Valley; • Develop an extension program based on behaviour change findings and the peri-urban BMP guidelines; • Gather support, develop partnerships, source funding and implement the program.

3.1.1 Ross River Dam catchment

The Upper Ross River Sub Basin is the catchment of the Ross River Dam and as such requires special management consideration. As the sub basin contains significant peri-urban areas with the potential to impact the water supply it has been included in the peri-urban section.

Historically the former NQ Water was responsible for the supply of potable water to the Townsville urban areas including the management of the Ross River Dam, Black Weir, Paluma Dam and associated infrastructure. Since the amalgamation of Thuringowa and Townsville City Councils this role has become the responsibility the water group within Townsville City Council.

The management of the catchment is essentially left to the individual landholders within the catchment. At present development within the Upper Ross River Sub Basin is subject to the respective planning schemes of the former Townsville and Thuringowa City Councils as a Water Resource Catchment.

NQ Water took an active role in the management of the dam catchment in its advisory capacity to the former Councils and through the commissioning of various studies and reports relevant to catchment management and water quality protection including:

- A *Catchment Management Plan Report* (Maunsell McIntyre 2000) - essentially a risk management assessment and catchment management scoping/strategy document which subsequently became the *Ross River Dam Catchment Water Quality Strategy (*Maunsell McIntyre 2001);
- The *Ross River Dam Catchment: Land Use Management Framework Report* (GHD 2002) – principally concerned with informing the development of new Planning Schemes (under the Integrated Planning Act 1997) to include development assessment provisions that would provide a greater level of protection to the dam catchment from future development; and (more recently)
- The *Ross River Dam Catchment Water Quality Monitoring Plan* (GHD 2006).

NQ Water also took responsibility for the management of aquatic weeds in the weir pools below the dam i.e. Black Weir, Gleesons Weir and Aplin Weir. Again NQ Water commissioned studies and reports in relation to the aquatic weed issue (Maunsell McIntyre 2001 and Maunsell 2002). The weir pools are part of the Lower Ross River Sub Basin and have their own sub catchments. These areas will be subject to urban management considerations.

In general terms management actions for the Upper Ross River Sub Basin will align with those of other rural areas in the Black Ross (Townsville) WQIP area with respect to grazing and intensive agriculture land uses. Additional management strategies specific to the peri-urban land use in the sub basin and relevant to the water resource catchment are listed in Table 3.1 (above).

Figure 3.1 Ross River Dam Western Wall

4. Rural Management Options, Costs and Benefits

4.1 Rural

The focus of the Mackay Whitsunday and Burdekin WQIPs revolves around rural land use whereas the focus of the Black Ross (Townsville) WQIP is on urban and peri-urban areas. Rather than duplicating effort it is assumed that the associated costs and benefits from these rural based WQIPs have been assessed and found to be feasible. The rural management options from these neighbouring WQIP areas have been adopted for the Black Ross WQIP, where applicable. The main proviso is that the programs of the neighbouring WQIP areas may benefit from behaviour change studies prior to the development of any delivery strategies under the Reef Plan and Reef Rescue program. This could significantly enhance the likelihood of uptake of water quality improvement management practices.

4.2 Rural Management Options

Rural areas include all forms of agricultural land use as well as a significant proportion of conservation, natural and minimum use areas (see Table 1.1). Grazing land use accounts for approximately 50% of the Black Ross WQIP area followed by natural areas/minimal use at 37%. Intensive agriculture accounts for 1.5% of the WQIP area and is located predominantly in the Crystal Creek Sub Basin.

It is considered that natural/minimal use areas are relatively undisturbed and contribute natural, or background, levels of pollutants to waterways. Management intervention for water quality load reduction in natural areas is therefore not considered a requisite in the WQIP.

The two rural land uses shown in various studies to contribute pollutants to waterways above background levels are grazing and intensive agriculture (cane growing and horticulture). Management options for these two land uses are considered further below along with a special rural land use servicing urban areas i.e. water supply catchment. It is anticipated that there will be a significant amount of overlap between rural and peri-urban management options. Some indicative costs associated with rural management measures are provided in Appendix I.

4.2.1 Grazing

NQ Dry Tropics (formerly Burdekin Dry Tropics NRM), during the development of their WQIP, did a considerable amount of work to identify grazing best management practice (BMP) for the Burdekin rangelands, in consultation with the grazing industry.

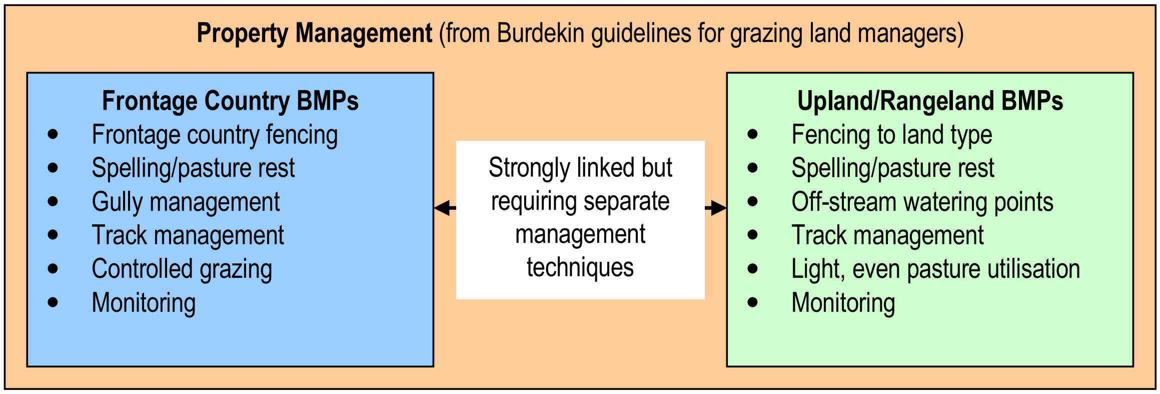
Grazing recommendations and measures developed for the Burdekin WQIP will be adopted by the Black Ross WQIP where appropriate. While the general grazing BMP principles for the Burdekin rangelands apply to the 'dry' catchments of the Black Ross WQIP area there are wetter catchments in the coastal areas (especially the northern end of the Black River Basin) where some modification to the BMP may be required to suit local conditions.

Costs associated with the delivery of the grazing component of the Black Ross WQIP have not been estimated in detail as there is no funding currently available to implement the actions outside selected Great Barrier Reef catchments included in the Caring for Our Country Reef Rescue program.

Regardless of the funding constraints Creek to Coral will work with NQ Dry Tropics in a coordinated approach across the two WQIP areas i.e. Burdekin Dry Tropics region, to assist with foundation activities, and the development and delivery of the awareness and capacity building actions (behaviour change support) designed to enable land managers to adopt recommended BMP for water quality improvement. The main components of the Burdekin grazing BMP for water quality improvement are shown in Figure 4.1.

It should be noted that the grazing BMP uses a pasture condition assessment ABCD framework that is different to the ABCD management practice framework developed through the Mackay Whitsunday WQIP to assist with monitoring the uptake of recommended management practices. The two should not be confused.

Figure 4.1 Main Grazing BMP Components



Source: Managing for water quality within grazing lands of the Burdekin Catchment: Guidelines for land managers (Coughlin et al 2008).

4.2.2 Intensive agriculture

The majority of intensive agriculture in the Black Ross WQIP (sugar cane production and horticulture) takes place in the Crystal Creek Sub Basin. While within the Burdekin Dry Tropics region the climatic conditions and vegetation assemblages of the Crystal Creek Sub Basin more closely resemble those of the Wet Tropics, or the Central Queensland Coast bioregions (part of the Mackay Whitsunday NRM region). The harvested sugarcane is transported to Ingham sugar mills for crushing and the agronomic extension support for the industry would also come from the Herbert sugar region.

While NQ Dry Tropics has a recommended suite of best management practices to improve the quality of water leaving sugar cane farms in the Burdekin region these may not be the most appropriate for the northern catchments of the Black Ross WQIP area. This is premised on two main factors i.e. climate and irrigation practices. The climate has already been mentioned and this also contributes to the irrigation regime. Being a wet tropical climate there is less need for irrigation and it is assumed that the majority of the water input for the sugar cane crop is from rainfall with irrigation being a supplementary measure. This type of irrigation regime is more characteristic of the Ingham and Mackay Whitsunday regions than the Burdekin delta and coastal plains where furrow irrigation is widespread and in most situations is the dominant form of water application.

Even though the approach adopted in the Burdekin WQIP and Mackay Whitsunday WQIP is not exactly the same the BMPs/management interventions to improve water quality are similar, with variations to suit climatic differences and irrigation regimes.

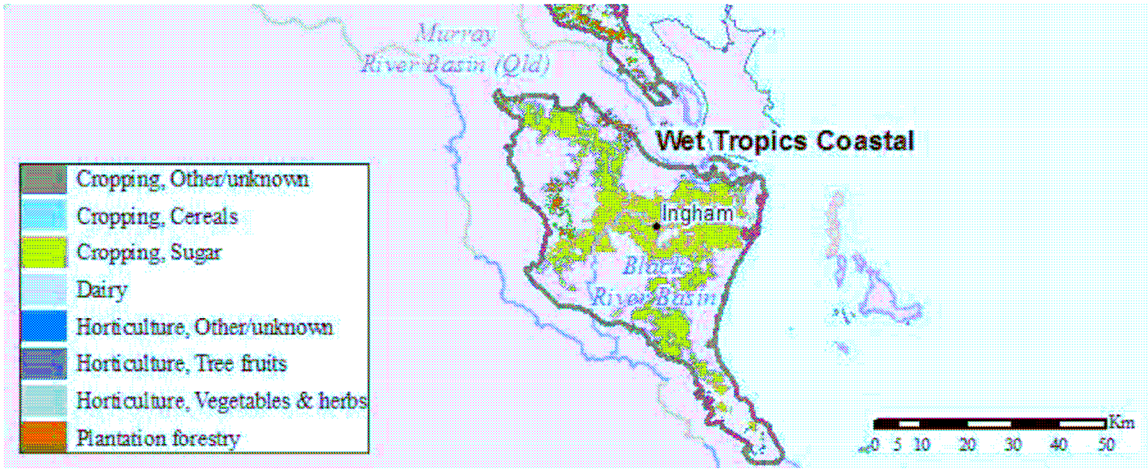
It is the intention of the Black Ross WQIP to adopt the most appropriate measures from both the Burdekin and Mackay Whitsunday WQIPs (and potentially the Tully WQIP) for application in the Crystal Creek Sub Basin. The most appropriate way to do this would be in conjunction with the sugar cane industry in the Herbert sugar cane district (Ingham). The Herbert Basin does not have a WQIP in place at present however measures included in the Tully WQIP may be applicable to the Herbert Basin and Crystal Creek Sub Basin.

As an initial action discussions will be held with NQ Dry Tropics, Reef Catchments (Mackay Whitsunday), and Terrain (Tully) WQIP managers to determine the possibility of including the small area of sugar cane land in the Black Ross WQIP area in their Reef Rescue programs.

Direct funding for such actions is not available to Creek to Coral and a partnership arrangement is the most likely option to enable water quality improvement actions to be extended to the areas of intensive agriculture in the Black Ross WQIP area.

The northern section of the Black Basin is also included in the Wet Tropics Coastal Nutrient Management Zone (see Figure 4.2), one of three priority areas identified for special effort to improve nutrient management in a Technical Report issued by the Queensland Department of Primary Industries and Fisheries in 2007 (Brodie 2007).

Figure 4.2 Wet Tropics Coastal Nutrient Management Zone (South)



4.2.3 Horticulture

Horticulture is a relatively minor land use in the Black Ross WQIP area and it is intended that the management interventions identified in the Mackay Whitsunday WQIP be adopted for the Black Ross WQIP. A brief explanation of the Mackay Whitsunday approach is provided in the text box below.

ABCD management practice framework

Mackay Whitsunday NRM (now Reef Catchments) has developed an ABCD management practice framework designed to categorise and communicate the different standards of management practice associated with a particular land use i.e. grazing, horticulture, sugar cane production and urban. The ABCD framework for horticulture has separate components for Soil, Nutrient and Pesticide management.

The framework assumes, based on available science and stakeholder consultation that adoption of a 'higher' standard of management practices will eventually result in a corresponding improvement in resource condition and water quality. The framework places 'old' and unsustainable practices in the D category and 'cutting edge' sustainable practices in the A category.

Industry consultation has shown that the majority of land managers are operating in the C category and that a significant improvement in water quality can be achieved if category B management practices are adopted. The ultimate goal is have all land managers using category B and A management practice.

Depending on the location of horticultural areas in the Black Ross WQIP area the Mackay Whitsunday management practice framework for horticulture may be appropriately included in the proposed peri-urban catchment management guidelines. As an initial action discussions with Reef Catchments and NQ Dry Tropics will be necessary to determine possible implementation options associated with their Reef Rescue arrangements and funding.

5. Enabling Management Options, Costs and Benefits

5.1 Introduction

Enabling actions are not necessarily confined to a particular land use or catchment area and may be more socially based than the physically orientated options associated with point sources and developing areas. Enabling actions, in many cases, will assist with the implementation and/or adoption of the physical management options for specific land uses and geographic management areas.

5.2 Enabling Actions and Programs

A range of enabling activities were identified that will assist with the delivery of the Black Ross WQIP, as well as providing a significant contribution to program design and redesign as an integral component of the adaptive management framework. These actions span issues and geographic areas and are predominantly associated with information gathering and analysis, mapping, prioritisation of efforts, policy input, development of education and training programs and dissemination of information. The main enabling action options are discussed below.

5.3 Legislation and Governance

A review of governance arrangements and current legislation relevant to water quality was undertaken by Aurecon (2009) (formerly Connell Wagner) to suggest amendments that may lead to improved water quality outcomes. Potential application of Queensland legislation is listed in Table 5.1.

Table 5.1 Potential Application of State Legislation

Legislation	Application
Integrated Planning Act 1997	• Preparation of a Regional Plan for Townsville, which includes waterway and wetland priority conservation areas, biodiversity corridors and catchment management principles with associated measures for water quality protection. • Greater integration of State Planning Policies in the new Planning Scheme.
Environmental Protection Act 1994	• Development of an effective Urban Stormwater Quality Management Plan, and associated plans. • Greater surveillance of ERAs and monitoring of licence conditions. • Stricter enforcement of breaches of Duty of Care in regard to water quality, particularly in relation to development sites.
Coastal Protection and Management Act 1995	• Active involvement in the development of the Dry Tropical Coast Regional Coastal Management Plan (no longer applicable under revised legislation). • Incorporation of water quality protection measures in the new Planning Scheme for the Coastal Management District (no longer applicable under revised legislation).
Water Act 2000	• Maintenance of water extraction at sustainable levels for all surface water entitlements in terms of environmental flows. • Investigate potential advantages of declaring the upper Ross River as a catchment area.
Vegetation Management Act 1999	• Declaration of areas that are vulnerable to land degradation where there is a significant impact on water quality.
Local Government Act 1994	• Prepare Local Laws to reinforce the strength of measures that are ambiguous in the Planning Schemes, and to enable protection of critical areas outside the development framework e.g. vegetation management in urban areas.

A single planning scheme and policy set will be developed for the new Townsville City Council local government area as part of the post amalgamation requirements for local government in Queensland. Recommendations relevant to the former Townsville and Thuringowa City Planning Schemes and Policies are provided in Table 5.2. It is considered that these recommendations, if incorporated into the preparation of the new planning scheme and policies will contribute to improved water quality outcomes for Townsville City. Any amendments that can be implemented in the interim will also contribute to water quality outcomes.

Table 5.2 Local Planning Instruments Application

Planning Instruments and recommendations	LG
Planning Schemes - Development Assessment	Both
• More stringent requirements for development on steep gradients and especially high erosion risk areas (see Steep or Unstable Land Code). • Incorporate various improvements to Overlays, Codes and Policies.	
Waterways and Wetlands Overlay and Code	TCC
• Update mapping and overlay to identify environmentally sensitive and risk areas. • Develop a system to determine appropriate buffer zone widths for waterways and wetlands to protect water quality as part of the development assessment process. • Include water quality environmental values and water quality objectives (WQO) in the development assessment approval process. • Define acceptable stormwater quality parameters for all new development and link the achievement of WQOs to implementation of Water Sensitive Urban Design (WSUD) measures. • Consider flooding as a component of waterways and wetlands. • Guidelines and training for development assessment staff. • Consistent application and enforcement.	
Steep or Unstable Land Code	Both
• Develop an overlay showing areas of high, medium and low sensitivity/risk for soil erosion. • Development of more specific outcomes and benchmarks. • Develop performance criteria to specifically address water quality issues. • Consistent application and enforcement. • Guidelines and training for development assessment staff.	
Biodiversity Overlay and Code	TCC
• Review and integration with other Codes. • Development of more specific outcomes and benchmarks. • Consistent application and enforcement. • Guidelines and training for development assessment staff.	
Water Resources Catchment Overlay and Code	TCC
• Review current development assessment conditions and management guidelines. • Consider catchment area declaration under the Water Act.	
Acid Sulphate Soils Overlay and Code	Both
• Provide acid sulphate soils tests before development approval. • Guidelines and training for development assessment staff and development industry.	
Community and Government Precincts	TCC
• Management guidelines in priority areas for water quality protection i.e. riparian zones (proximity to waterways), wetlands, steep slopes and unstable soils.	
Rural	Both
• Guidelines for livestock grazing and intensive agriculture in rural areas in priority areas for water quality protection i.e. riparian zones (proximity to waterways), wetlands, steep slopes and unstable soils. • Development applications categorised as Assessable.	
Soil Erosion and Sediment Control Policy	TCC
• Review soil erosion and sediment control requirements for all development. • Greater level of monitoring and enforcement including maintenance of soil erosion prevention measures and sediment movement control devices. • Update Erosion and Sediment Control training course. • Guidelines and training for development assessment staff. • Create a separate section or new policy for stormwater quality management.	
Environmental Impact Assessment and Management Policy	TCC
• Review requirements for Environmental Impact Assessment. • Create risk assessment categories.	

• Research categories for construction phases including pre-construction, construction and post construction	
Ross River Dam and Haughton River Catchment	CoT
• Measures may be translatable to other planning scheme and development assessment areas.	
Filling and Excavation	CoT
• Develop Performance Criteria and Acceptable Solutions for water quality	
Landscaping	CoT
• Develop Performance Criteria and Acceptable Solutions for water quality	
Transport	CoT
• Develop Performance Criteria and Acceptable Solutions for water quality	
Compliance Monitoring	Both
• General increase in compliance monitoring.	
Infrastructure Contributions	Both
• Apply a component of stormwater contributions to water quality improvement e.g. for compliance monitoring.	

Note: TCC is the former Townsville City Council and CoT is the former Thuringowa City Council (City of Thuringowa)

5.4 New and Draft Legislation

Following the review of legislation by Aurecon (2009) some of the existing water quality related legislation was revised and a draft State Planning Policy (SPP) was released for comment. New legislation has also been passed which will either directly or indirectly influence water quality improvement measures and their incorporation across Council activities. The main pieces of new and draft legislation are discussed briefly below.

5.4.1 Revised Environmental Protection Water Policy 2009

The revised 2009 Water EPP replaces the 1997 Water EPP and is closely aligned with the draft Healthy Waters SPP (see section 5.4.2). Underlying the Water EPP is the identification of environmental values (EVs), water quality guidelines (WQGs) and water quality objectives (WQOs). This was also one of the tasks involved in the preparation of the Black Ross WQIP (see Gunn, Manning and McHarg 2009).

The purpose of the Water EPP remains the same i.e. "*to achieve the object of the Act in relation to Queensland waters*" (Water EPP, p.3), however the ways in which the policy is achieved have changed subtly (see Appendix D for a comparison). One change made in the revised policy is the addition of the identification of management goals to accompany the identification of EVs, WGQs and WQOs.

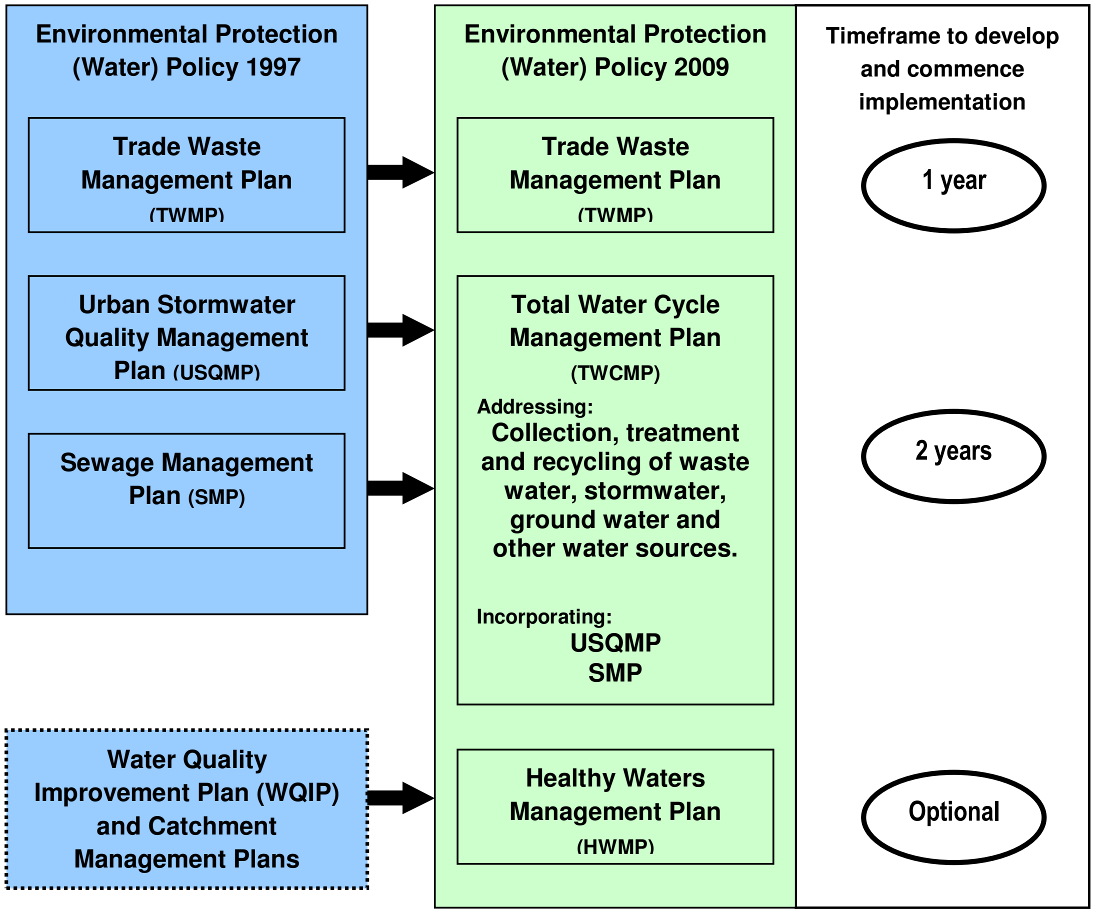
Also the basic concept of EV categories has changed and there are now four categories rather than the previous three i.e. slightly to moderately disturbed (SMD) has been separated into slightly disturbed and moderately disturbed. This has implications for translation of the Black Ross WQIP results across to maps, plans and planning instruments, as the 'old' classification system was used when developing the Black Ross WQIP.

The relationship between EVs, WQOs, and WQGs are defined in the Water EPP and the process for determining EVs and WQOs is referred to. In the revised Water EPP, WQOs do not apply to "*water in a stormwater treatment system*" (p.8), amongst other exempt water types. Other subjects the Water EPP addresses include:

- The management hierarchy for surface or ground water relative to release of contaminants and waste water to waters; and
- The management intent for waters subject to an activity that releases contaminants or wastewater to the waters.

The section (Part 6) on Environmental Plans has been amended with new timeframes and priorities for plan development (see Figure 5.1).

Figure 5.1 Water EPP Environmental Plan Changes



Note: HWMPs are similar to voluntary WQIPs and catchment management plans that have used EVs and WQOs in their structure.

A comparison of the environmental management plan elements of the revised and previous Water EPP is provided in Table 5.3. These changes have been taken into consideration in the Black Ross WQIP as part of the adaptive management process and the draft WQIP was amended appropriately. For a comparison of the main changes between the 1997 and 2009 Water EPPs see Appendix D.

Figure 5.2 Lake Ross

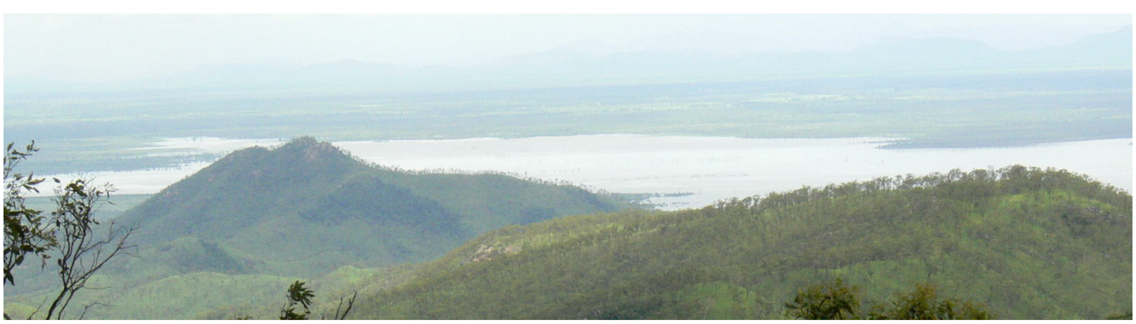


Table 5.3 Old and New Water EPP Plans

Subject	Water EPP 1997	Water EPP 2009
Environmental plans	**Part 7 Environmental Plans** **Section 34-39** Local Government to determine the priority for plans to be developed and the timetable for development and implementation. Must develop and start implementing at least 1 environmental plan for each matter within 5 years of the commencement of the policy. Section 37 'Regular' review of environmental plans. Section 39 Reporting – 3 years after the policy commences and at twelve month periods if a plan is being implemented.	**Part 6 Environmental Plans** **Section 15-18** **Section 16** Local Government or sewerage service provider must ***develop and start implementing the plan***— (a) for an environmental plan about trade waste management—within 1 year after the commencement of this policy; or (b) for another environmental plan—***within 2 years after the commencement of this policy***. Section 17 Reporting and Review Report 4 years after policy start and review within 5 years of plan publishing. **Section 23** Certification of Plans
Sewage management plan	**Section 40 Sewage management** (1) A local government that is a sewerage service provider must develop and implement an environmental plan about sewage management that minimises unnecessary flows entering the sewerage service.	**Section 20** A local government's total water cycle management plan must include provisions [about the following] for each waste water treatment plant in its local government area
Trade waste management plan	**Section 41 Trade waste management** (1) A local government that is a sewerage service provider must develop and implement an environmental plan about trade waste management that controls trade wastes entering the sewerage service.	**Section 22** (1) A local government or other entity that is a sewerage service provider must develop and implement an environmental plan about trade waste management to control trade waste entering its sewerage services.
Urban stormwater quality management plan	**Section 42 Urban stormwater quality management** (1) A local government that has an urban stormwater system must develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system.	**Section 21** A local government's total water cycle management plan must include provisions about its stormwater quality management to improve the quality and flow of stormwater in ways that protect the environmental values of waters affected by the local government's urban stormwater system.
Total water cycle management plan		**Section 19** Local government with a population of at least 10,000 people must develop and implement an environmental plan about water cycle management for its local government area i.e. a total water cycle management plan.
Healthy waters management plan	[*No requirements for this scale of planning which has similarities to Catchment Management Plans and Water Quality Improvement Plans*]	**Section 24** (2) Also, a recognised entity, in cooperation with the chief executive, may develop and implement a healthy waters management plan.

5.4.2 Draft State Planning Policy – Healthy Waters 2009

The draft Healthy Waters SPP links closely with the (revised) *Environmental Protection Water Policy 2009* (Water EPP 2009), which is subordinate legislation under the existing *Environmental Protection Act 1994*.

The aim of the draft Healthy Waters SPP is to guide water quality outcomes in urban areas in relation to development activities. It is proposed that local planning schemes and regional plans, under the *Integrated Planning Act 1997*, will incorporate the Healthy Waters SPP in their content and processes (land use planning and development assessment) to ensure development "*avoids adverse impacts on Queensland waters or, where this is not feasible, adverse impacts are minimised and any residual adverse impacts offset*" and "*development is undertaken in accordance with best practice environmental management*" (DERM 2009a, p.2).

Relationships between the draft Healthy Waters SPP in the context of existing (and revised) legislation is illustrated in Figure 5.3.

The draft Healthy Waters SPP is supported by the draft State Planning Policy Guideline: Healthy Waters (draft SPP Guideline), which in turn refers to the key tools to assist with the implementation of the Healthy Waters SPP. The SPP Guideline is considered to be extrinsic material under the Statutory Instruments Act 1992 (section 15). The key tools associated with the draft Healthy Waters SPP are:

- Urban Stormwater - Queensland Best Practice Environmental Management (BPEM) Guidelines (DERM 2009k);
- Regionally based design objectives for urban stormwater quality management;
- Urban stormwater quality management plans (USQMP) (as per Water EPP 2009); and
- Waste water management plans (WWMP) (as per Water EPP 2009);

The relationship between the various components of the draft Healthy Waters SPP is shown in Figure 5.5.

For stormwater quality management purposes, if/when the draft Healthy Waters SPP is adopted, it will apply to urban development that involves land areas greater than 2,500 square metres, or where six or more dwellings will be created. In terms of wastewater management the Healthy Waters SPP will apply to industrial and commercial development involving wastewater discharge.

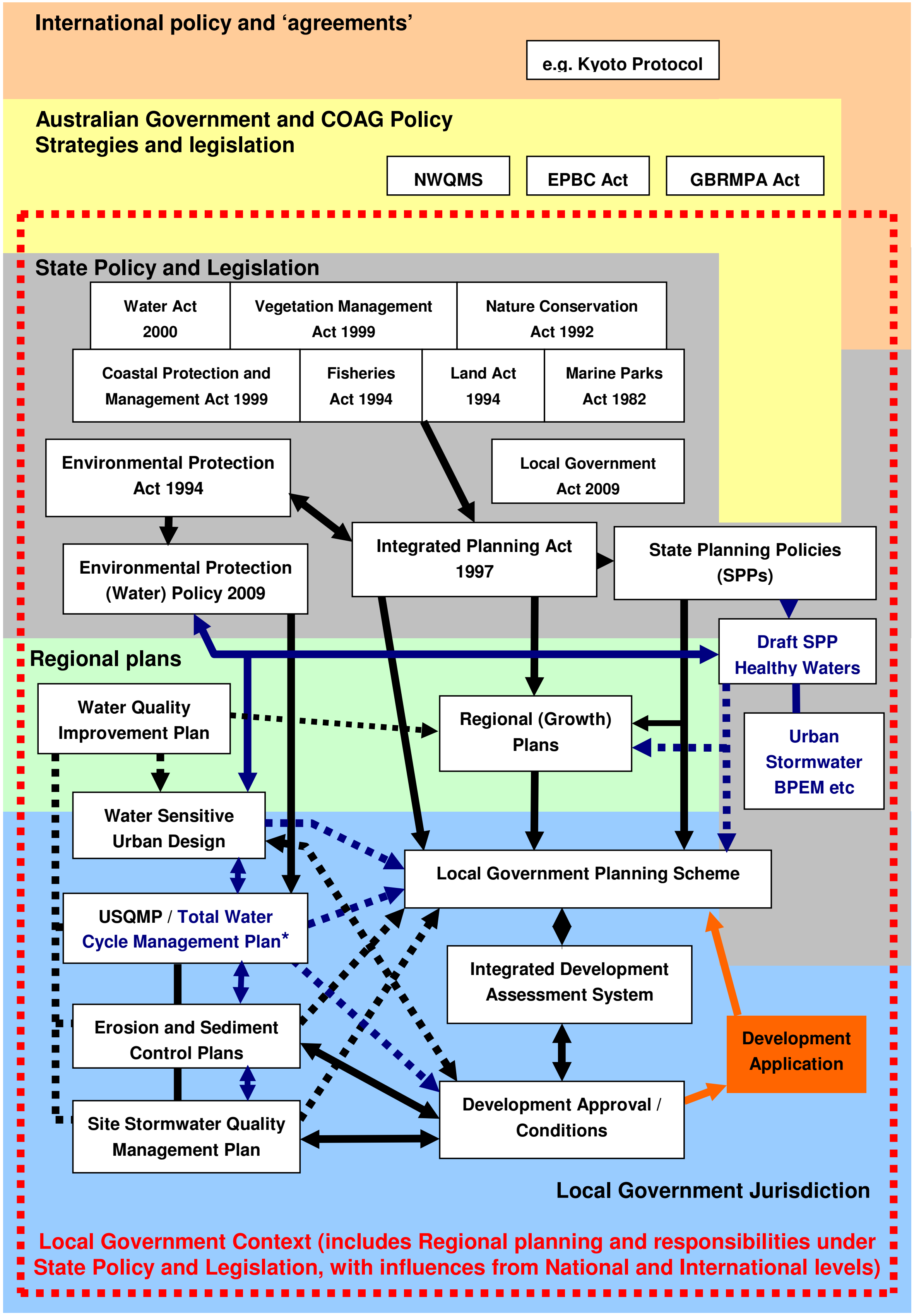
The Healthy Waters SPP also applies to proposals for the designation of community infrastructure along the same lines as mentioned for stormwater quality and wastewater management for urban and industrial and commercial developments.

There are a number of exclusions from the scope of the draft Healthy Waters SPP including material change of use (MCU) for Environmentally Relevant Activities (ERAs) under the EP Act and certain development made assessable under Schedule 8 of the IP Act.

The aims of the draft Healthy Waters SPP are achieved through development assessment (and designating community infrastructure) when:

(A) Receiving water EVs are protected from impacts associated with stormwater quality and altered stormwater flow resulting from development and construction activities (relative to stormwater management design objectives to achieve WQOs;
(B) Receiving water EVs are protected from impacts associated with waste water impacts (other than stormwater) relative to WQOs;
(C) Receiving water EVs are protected from impacts associated with the creation or expansion of non-tidal artificial waterways e.g. urban lakes.

Figure 5.3 Draft SPP Healthy Waters in Context



Notes: * Incorporating Urban Stormwater Management Plan (USQMP) from the 1997 Water EPP. Black arrows and connections are the pathways in place for water quality related input to planning schemes and development assessment processes prior to the introduction of the draft SPP Healthy Waters, including the broken lines that are optional/potential pathways i.e. may have been used. The blue lines are the connections between the draft SPP and other existing water quality related components, and broken lines show new pathways that could come into play if the draft SPP Healthy Waters is adopted.

In order to improve consideration of water quality management and to foster more consistent development assessment decisions Annex 1 of the draft Healthy Waters SPP lists generic codes for each of the three waterway health issues above, that outline specific outcomes to be met and providing probable solutions to satisfy some of the specific outcomes (see Appendix D). Equivalent provisions should be developed for use in the relevant planning instruments. The draft Policy code will need to be applied to development assessment unless the relevant planning instrument adequately reflects the draft Policy.

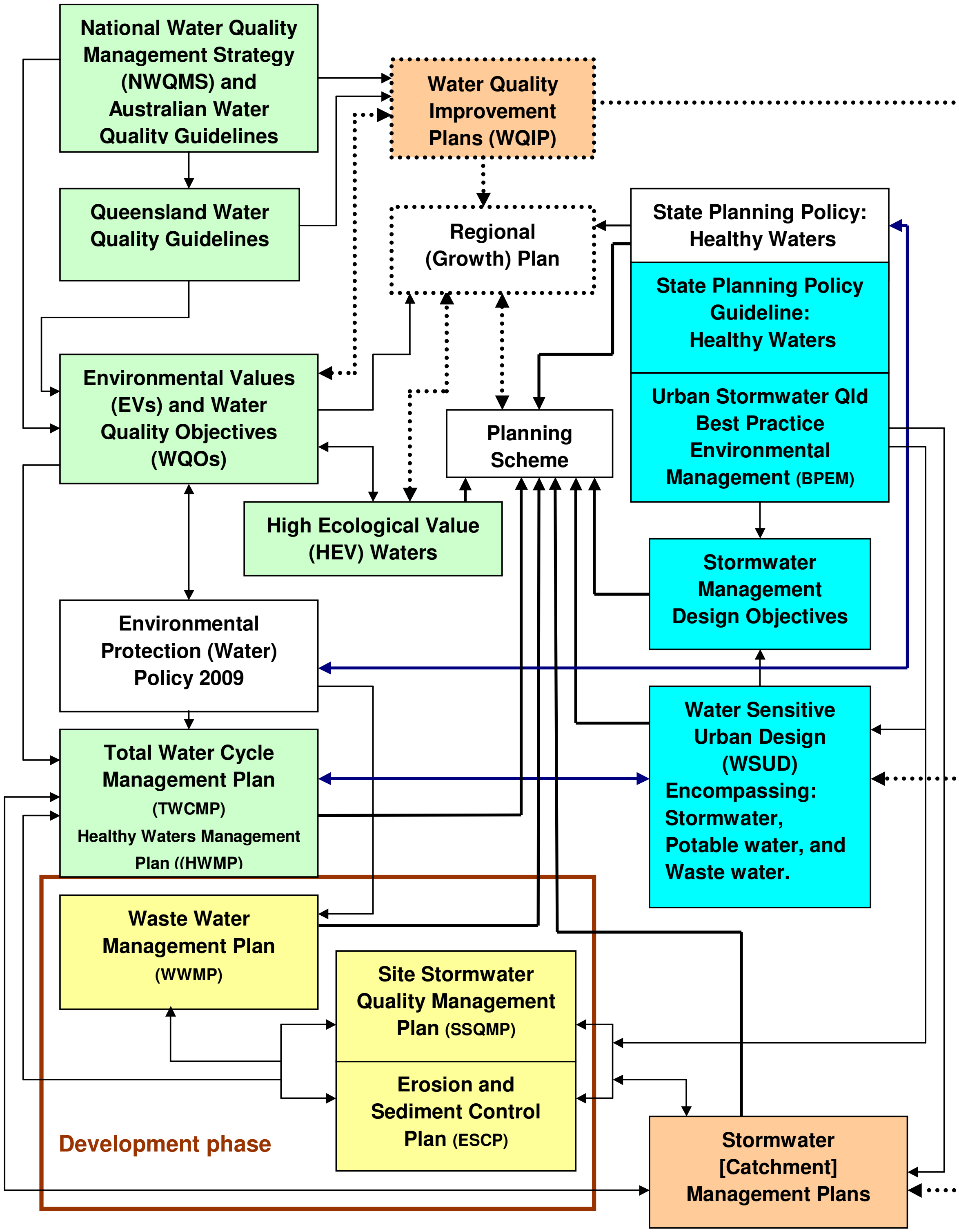
For urban stormwater management in particular, the design objectives provided in Chapter 2 of the Urban Stormwater BPEM Guidelines are referred to as being suitable to meet WQOs and therefore protect the EVs of receiving waters. If measures are put in place to achieve the design objectives listed in the BPEM Guidelines then the specific outcomes are deemed to have been met. The design objectives are considered to be the minimum necessary for planning new development. More stringent design objectives can be applied locally when supported by local water quality monitoring and modelling. The BPEM Guidelines also provide information on ways and means to meet the design objectives through the implementation of strategies and actions at the development design stage, during construction and post development (see Appendix D).

For the Healthy Waters SPP to have full effect it will need to be reflected in Regional Plans and local planning schemes when they are prepared or amended. The Townsville-Thuringowa Strategy Plan (TTSP) is not a statutory Regional Plan, for the purposes of the Healthy Waters SPP. The intent of the Healthy Waters SPP will therefore need to be reflected in the new Townsville City Planning Scheme covering the amalgamated former Townsville City and Thuringowa City local government areas, also the previous extent of the TTSP.

The most relevant recent 'regional' planning process, which could inform the preparation of the new Townsville City Planning Scheme with respect to the draft Healthy Waters SPP, is the Black Ross WQIP. Section 3.3 of the draft Healthy Waters SPP lists the way that the aims of the Healthy Waters SPP can be met through a planning scheme. These components are compared to the outputs of the Black Ross WQIP and discussed briefly in Table 2.18 in relation to the management options and potential implementation actions of the Black Ross WQIP.

Figure 5.4 Mt Louisa

Figure 5.5 Draft SPP Main Components and Connections



Note: Solid dark lines are potential input paths for planning schemes. Thinner black lines indicate connections and pathways between various SPP components and associated processes and plans/strategies etc. The blue lines indicate the connection between the main components of the SPP and EPP Water. Broken lines indicate potential planning process and connections that are applicable to local government areas and planning scheme development.

5.5 Other Legislative Changes

While the draft Healthy Waters SPP and Water EPP 2009 provide the foundation for stormwater management reforms in Queensland there are a number of other related legislative changes that need to be taken into account both in terms of total water cycle management and development assessment processes. The main legislative changes that need to be considered are mentioned below.

5.5.1 Coastal Act

The Coastal Protection and Management Act 1995 (Coastal Act) provides the legislative framework for achieving integrated coastal zone management in Queensland. The Draft Queensland Coastal Plan 2009 was released under the Coastal Act in August 2009.

The Draft Queensland Coastal Plan 2009 includes:

- The Draft State Planning Policy (SPP) Coastal Protection; and
- The Draft State Policy Coastal Management.

"The draft coastal plan has been considerably simplified from the [previous] *State Coastal Management Plan by removing polices that are now addressed by separate contemporary or proposed policy mechanisms (e.g. heritage, water quality, mining and fishing"* (http://www.derm.qld.gov.au/coastalplan/index.html).

The Draft State Planning Policy Coastal Protection (draft SPP) ensures the objects of the Coastal Protection and Management Act 1995 are considered during development assessment and land-use planning within the coastal zone under IPA." (Draft Queensland Coastal Plan 2009 — Explanatory Notes, p.5)

"The coastal zone encompasses all Queensland coastal waters and islands, and the area landward to 5 km from the coast or to where the land is below 10 m Australian height datum (AHD), whichever is further from the coast. The draft SPP applies beyond the coast to the broader coastal zone due to the flow-on effect to the coast of activities occurring within the coastal zone. The coastal zone is delineated on maps 1-8 contained in Annexe 1 of the draft SPP."

As the draft coastal plan, incorporating the draft SPP, has not been finalised an in depth analysis of its potential impact on water quality matters has not been undertaken. It is anticipated that the majority of the implications for Council will be in relation to development assessment matters, which will require mapping layers and other input from the environmental management section of Council. This is considered in the mapping and assessment options in section 5.6. It is anticipated that the options proposed will be able to incorporate any requirements introduced as a result of the draft Queensland Coastal Plan becoming a State Planning Policy.

5.5.2 Sustainable Planning Act 2009

The Minister for Infrastructure and Planning, Stirling Hinchliffe tabled the Sustainable Planning Bill 2009 in Parliament on 19 June 2009. It was passed on 16 September 2009 and assented to on 22 September 2009. It replaces the Integrated Panning Act 1997 (IPA), and came into effect on 18 December 2009.

According to the Department of Infrastructure and Planning (DIP), "*this new legislation:*

- *Shifts the focus from planning process to delivering sustainable outcomes;*
- *Reduces complexity through standardization;*
- *Adopts a risk management approach to development assessment;*
- *Introduces a broader range of opportunities for people to reach agreement and resolve disputes;*
- *Provides improved opportunities for the community to understand and participate in the planning system.*

These changes will assist in delivering a contemporary planning, development and building system that can provide sustainable development outcomes for all Queenslanders."
(Source: http://www.dip.qld.gov.au/planning-reform/index.php)

Standard planning scheme provisions have been introduced as an addition to Regional Plans and State Planning Policies to advance the purpose of the Act. They provide a consistent structure for planning schemes and standard provisions for implementing integrated planning at the local level. A local government must ensure each of its local planning instruments is consistent with the standard planning scheme provisions.

Part of the sustainable development approach involves protection of water quality and biodiversity. It is assumed that the majority of the uptake of these sustainability initiatives will be through the preparation of the new planning scheme for Townsville City. As with the Coastal Act the options associated with inclusion of water quality improvement in the new planning scheme are considered in section 5.6

5.5.3 Local Government Act 2009

The Bill was tabled by Desley Boyle on 22 April 2009 and was assented to on 12 June 2009. The Local Government Act 2009 replaces the previous Local Government Act (1993) and came into effect on 1 July 2010. It is not considered that this will have any direct effect on the matters dealt with in the Black Ross WQIP although there are new requirements for Council to:

- Adopt a 10-year Community Plan;
- Develop a 10-year financial strategy;
- Develop a 10-year, detailed asset management strategy;
- Adopt a Community Engagement Policy;
- Implement and report annually on six key sustainability performance ratio measures in addition to the usual set of financial statements.

These requirements could result in some additional actions as part of WQIP implementation activities and need to be considered when preparing action plans especially when community consultation is involved. Total water cycle management and water quality may also be involved in the development of the key sustainability performance ratio measures mentioned above, which would then require consideration in the total water cycle management planning process. It is assumed that environmental infrastructure associated with water quality and biodiversity protection will also need to be included in the asset management strategy.

5.5.4 Water Supply (Safety and Reliability) Act 2008

Introduced in 2008 the purpose of the Act is to provide for the safety and reliability of water supply.

"The purpose is achieved primarily by—
(a) providing for—
(i) a regulatory framework for providing water and sewerage services in the State, including functions and powers of service providers; and
(ii) a regulatory framework for providing recycled water and drinking water quality, primarily for protecting public health; and
(iii) the regulation of referable dams; and
(iv) flood mitigation responsibilities; and
(b) protecting the interests of customers of service providers." (section 3, p.20)

Amongst other things, "Each service provider must have an approved strategic asset management plan for ensuring continuity of supply of each of the service provider's registered services". (section 70, p.52)

Other plans to be prepared by service providers include:

- "an approved system leakage management plan directed at minimising water losses from leakage from the water service provider's distribution system". (section 79, p.56)
- "a drinking water quality management plan for the provider's drinking water service and apply to the regulator for approval of the plan". (section 95, pp. 63-4)
- "a drought management Plan" (section 123, p.82)

- an "outdoor water use conservation plan", for reducing outdoor water use and promoting efficient outdoor water use by customers of the service provider (section 133, p.87)
- a recycled water management plan for any recycling schemes (section 201, p.114)

The drinking water quality management plan—
(a) must be prepared in accordance with the guidelines, if any, made by the regulator about preparing the plan; and

(i) state the registered services to which the plan applies; and
(ii) include details of the infrastructure for providing the services; and
(iii) identify the hazards and hazardous events the drinking water service provider considers may affect the quality of water to which the services relate; and
(iv) include an assessment of the risks posed by the hazards and hazardous events; and
(v) demonstrate how the drinking water service provider intends to manage the risks posed by the hazards and hazardous events; and
(vi) include details of the operational and verification monitoring programs under the plan, including the parameters to be used for indicating compliance with the plan to the extent the plan requires the provider to maintain water quality in accordance with the water quality criteria for drinking water.

The drinking water quality management plan could include a risk management assessment of the raw drinking water supply catchments to determine and hazards and risks to the supply service associated with the catchments. Associated risks could then be addressed through a catchment management plan for the supply catchments. Previous studies and plans could be utilised and included in the drinking water quality plan with appropriate development controls translated across to the planning scheme and development assessment process. It is considered that any requirements associated with the Act will be encompassed through the management options included in the peri-urban section (section 3) and through the development of a Total Water Cycle Management Plan for Townsville (section 2.8.3).

5.5.5 Vegetation Management (Regrowth Clearing Moratorium) Act 2009

The purpose of the Vegetation Management (Regrowth Clearing Moratorium) Act 2009 was to protect regrowth vegetation. The moratorium expired on 7 October 2009 with new arrangements put in place from 8 October 2009 to protect high-value regrowth (native) vegetation. The new arrangements consist of regrowth vegetation maps and a regrowth vegetation code.

High-value regrowth vegetation is mature native vegetation that hasn't been cleared since 31 December 1989. High-value regrowth vegetation and regrowth watercourses are now regulated under the vegetation management framework. All native vegetation within 50 metres of a regrowth watercourse is regulated in the priority Great Barrier Reef catchments of Burdekin, Mackay Whitsunday and Wet Tropics.

"*Vegetation along creeks, streams and rivers plays an important role in bank stability, maintaining water quality, providing wildlife habitat and maintaining biodiversity and ecological processes. The code protects these areas of regrowth vegetation by establishing stream protection zones where clearing of regulated regrowth vegetation is restricted in terms of both location and extent, and the purpose of the clearing*" (DERM 2009, p.19). New rules also apply to the clearing of regrowth:

- in the vicinity of wetlands with a general application of a 100 metre buffer, and
- on steep slopes i.e. 12% gradient.

Restrictions on clearing already apply to remnant native vegetation under the *Vegetation Management Act 1999*, although the application of the Act is limited in urban areas. The planning scheme could reflect the intent of the changes to the Vegetation Management Act 1999 through preferential development areas by excluding certain development from riparian and wetland buffer zones. These matters are considered in section 5.6.

5.5.6 Great Barrier Reef Protection Amendment Act 2009

The Great Barrier Reef Protection Amendment Act 2009 amends the Environmental Protection Act 1994 and Integrated Planning Act 1997, with the intent of reducing the impact of agricultural activities on the quality of water entering the reef.

The Act is also aimed at achieving the targets about water quality improvement for the reef under agreements between the State and the Commonwealth, such as the Reef Water Quality Protection Plan and the Reef Rescue component of the Australian Government's Caring for Our Country program.

The aim of the Act is achieved by prescribing agricultural Environmentally Relevant Activities (ERAs), and the requirements for carrying out an agricultural ERA. While not relevant to Townsville's urban areas, the Act will have some impact on rural areas and activities, especially in the cane growing areas of the Crystal Creek Sub Basin and larger grazing properties, which are included in the Burdekin dry tropics catchment as defined by the Act (p.12). The Burdekin dry tropics catchment is equivalent to the Burdekin Dry Tropics NRM region, which includes the Black Ross WQIP area. This has implications for delivery of the Reef Rescue program in sugar cane growing areas as discussed in section 4.2.2 and also in grazing areas (see section 4.2.1).

5.5.7 Reef Plan

In addition to the legislative changes the updated Reef Water Quality Protection Plan was released in 2009 (for the Great Barrier Reef World Heritage Area and adjacent catchments). "*Reef Plan outlines actions to minimise non-point source pollution from broadscale land use and reduce the entry of those pollutants to the Reef. It specifically targets nutrients, pesticides and sediment that wash into wetlands and waterways, leach into groundwater or flow overland across floodplains and ultimately enter the Reef lagoon because of agricultural activities in Reef catchments*."

While not directly applicable to urban areas Reef Plan will have implications for stormwater management in Townsville's peri-urban and rural areas, as part of the broader stormwater management activities outlined in the Black Ross WQIP.

5.6 Planning Studies and Instruments

There are a number of planning studies that will need to be completed to inform the preparation of the Planning Scheme for the new Townsville City local government area. There is a considerable amount of potential overlap between the condition assessments and studies required to successfully implement the Black Ross WQIP and the studies required to inform the preparation of the Townsville City Council Planning Scheme.

Additionally there are a number of areas associated with the planning instruments of the former Thuringowa and Townsville Cities that could be amended to support water quality improvement. Similarly the inclusion of 'new' components in the yet to be prepared Planning Scheme for the new Townsville City local government area could help achieve outcomes of the Black Ross WQIP.

Potential amendments to planning instruments are identified in section 5.3. Potential planning studies that are related to WQIP outcomes are discussed briefly in Table 5.4.

Table 5.4 Planning Studies Relevant to the Black Ross WQIP

Study	Commentary
Housing Density	The density review is intended to shape the form and character of future land use and development in the Townville urban area. The outcomes of the review seek to encourage development where residents are located close to a mix of facilities and services including, but not limited to, higher order commercial/retail centres, educational facilities, open space areas, employment nodes and public transport.
Growth Spatial	Population/demographics, patterns of settlement and land uptake, requirements for park land/sports fields, landfills/transfer stations, community facilities, road networks etc. The

Studies	residential component could be covered by the Housing Density project.
Catchment studies for Waterways & Wetlands Overlay	Based on the Bohle River Environmental Values study. The catchment based environmental values studies are fairly comprehensive and cover more then the current code and overlay. They identify primary, secondary and possibly even tertiary water bodies with associated riparian vegetation in the context of the whole catchment and include water quality issues and potential links to the WSUD guidelines. There is a need to identify criteria that triggers assessment of water bodies not identified by developers i.e. not identified on 1:100,000 topographic maps. This will help maintain existing smaller watercourses that are locally significant in the urban context rather than having them turned into concrete drains.
Biodiversity Overlay	To provide additional information to inform the new Biodiversity Code and prioritise areas of significance for a variety of reasons e.g. movement corridors, bank stability, water quality filter buffers, ecosystem maintenance, connectivity, essential habitat, refuge areas, rare and threatened species and communities.
Bushfire Overlay	Would make sense to combine this with the Biodiversity study as it is based on vegetation type and condition.
Acid Sulphate Overlay	Need research to determine if the overlay could be included in a code, in-house based on current default settings. Additional mapping would be useful and this could be discussed with DERM. At this stage there are no DERM programs to undertake this mapping, however DERM staff would be available to assist in project development.
Agricultural Overlay	Needs to be scoped to determine if the overlay requires updating. Old Thuringowa has more good quality land and we need to discuss further with staff, in-house.
Steep and Unstable Lands Overlay	This may require additional geotechnical and soil studies to ground truth current overlay mapping as there are known discrepancies. Additionally the links need to be made between geology, soils, slope, erosion potential, vegetation type and cover/condition to water quality and WSUD measures.
Cultural Heritage Overlay	It may be possible to include this overlay in the Cultural Precinct project, although this will not take into account Cultural and Spiritual Environmental Values associated with waterways and waterbodies (see section 5.6.2).

5.6.1 Landscape planning

The concept of a Strategic Landscape Master Plan is a significant project akin to regional growth planning or regional coastal management planning. It most closely resembles the development of a blueprint for maintaining ecosystem function in the context of human population expansion through identification of landscape elements that are essential for maintaining ecosystem services that support the biological environment, which coincidently includes human beings.

It can be seen as a large-scale constraints mapping and risk management exercise to determine the (theoretical) limits of development that can be achieved without degrading the environmental capital necessary for our survival, and the maintenance of biological processes. To ensure we don't approach the limits of survival we would need to build in a buffer (level of tolerance and resilience) to allow for unforeseen perturbances such as the impacts of climate change i.e. sustainable landscape planning.

In terms of water quality outcomes the broad scale master planning and constraints mapping can be used to identify areas of significance for water quality outcomes as part of a long term growth management strategy for Townsville City which secures public open space for water quality improvement measures e.g. wetlands and waterways as part of the treatment train process, at the regional and catchment scale.

This type of planning would be most cost effective if it could be implemented as part of the preparatory work for the new Planning Scheme for Townsville City Council, and also feed into the broader regional growth strategy, and other regional planning processes. This would necessarily require a significant coordination effort and the cooperative involvement of relevant state and Australian government agencies.

While probably best to be done as a landscape scale project it could also be accomplished by the coordinated agglomeration of smaller parts including the combination of condition assessment components (pressure and state) of catchment management plans, or other condition assessment and planning studies.

To implement the findings of the landscape planning studies would require strategic priority areas to be set aside at the landscape level through both a regional planning instrument and the new Townsville City Planning Scheme to enable catchment scale water quality impact mitigation measure areas to be preserved in the face of population growth and urban expansion. Priority Infrastructure Planning may be another local mechanism for identifying and obtaining land required for regional/catchment scale WSUD measures.

5.6.2 Condition assessment and prioritisation

Gaps have been found in information related to water quality and ecosystem health, which need to be filled to:

- Determine baseline and benchmark conditions for target setting including for;
    - Riparian condition,
    - Channel and bank condition, and
    - Aquatic ecosystem health,
    - Wetlands.
- Inform the location for priority works;
- Inform the development of total water cycle and urban nature management systems;
- Establish local water quality guidelines.

There are various linkages associated with condition assessment studies and other parts of the WQIP as well as with various programs and projects within Council, and with initiatives of external partners. While not being planning scheme studies the results from the condition assessment studies and mapping could be used to inform the proposed planning scheme studies and value-add to the process. The combined objectives of Council's programs and projects need to be taken into account to ensure the most efficient use of resources and achievement of integrated outputs.

The main condition assessment program areas are listed in Table 5.5.

Table 5.5 Condition Assessment and Management Systems

1 Catchment condition assessment
• Compile catchment condition information as per the draft report card format (Connell Wagner 2009) and task 4 (below) including; o Land use and management practice, o Erosion status including channel and bank. (Informs TWCMP and USQMP (see section 2.8.3) and also part of any State of the Waterways study and Waterway Management Plans)
2 Aquatic ecosystem health assessment
(Part of a State of the Waterways study and Waterway Management Plans) • Literature review and scoping study to collate current information and determine gaps and requirements to report on aquatic ecosystem health in terms of the main indicator groupings (see draft report card format (Connell Wagner 2009) and task 4 (below): o Water quality (physico-chemical) (additional analysis required using the database collated during development of the Black Ross WQIP), o Freshwater fish, o Aquatic invertebrates, o Aquatic vegetation.
3 Riparian condition assessment
(Part of a State of the Waterways study and contributes to Waterway Management Plans) Build on the preliminary study prepared during the WQIP development (see also draft report card format (Connell Wagner

2009) and task 4 below) including:

- Preliminary prioritisation of areas for detailed on-ground condition assessment based on;
  - Proximity to high risk pollutant contribution areas/land use,
  - Current threats e.g. urban expansion,
  - Current level of protection,
  - Environmental values of waterways,
  - Potential for water quality improvement through establishment of buffers/filter zones (expert advice).
- Detailed on ground condition assessment of priority areas and reconnaissance of adjacent reaches.

4 Report card format validation

A draft report card format has been developed for the Black Ross WQIP area (Connell Wagner 2009). The format needs to be tested to ensure the rating system is appropriate for local conditions. The main tasks are:

- Collate available water quality, aquatic ecosystem health and catchment condition information/data (linked to condition assessment tasks 1-3 above);
- Input available information into the report card format for catchments in the Black Ross WQIP area;
- Compare the results (expert advice) to determine the validity of results based on current information i.e. can we determine appropriateness of the format with just current data or do we need to fill the knowledge gaps before we have enough information to determine if the format needs to be amended.

5 Natural area management for water quality and biodiversity outcomes

- Interpret Riparian Condition Assessment results (task 3 above) to determine the most effective areas for protection and rehabilitation to achieve water quality improvement;
- Develop Rehabilitation/Revegetation and Maintenance Plans for high and medium priority sites (links to Waterway Management Plans).

6 Wetland condition

- The application of spatially explicit models to conservation planning and prioritisation of wetlands in the Burdekin basin. The ultimate objective is to provide a mechanism to assess the functional significance of individual wetlands in a regional context that can be applied, through a decision support tool, to inform prioritisation processes for wetland conservation and rehabilitation programs. [EPA/ACTFR led initiative – Sheaves and Connolly]

7 Green space management system

Waterways, wetlands and riparian zones in the urban context are often part of the green space network managed, in part, by Townsville City Council. An integrated green space management system (urban context) would assist Council, state government agencies and community groups to understand roles and responsibilities with regard to ‘public’ green space and the potential for contributing to management outcomes for water quality, biodiversity and recreational opportunities. The management system would provide guidelines and specific management plans for various natural green space areas and types. The main tasks include:

- Collation of information on all former TCC and CoT ‘green space’ i.e. parkland, waterways, drains and natural areas including current management plans and programs in place or in preparation;
- Compilation of a single green space database (with reference to any associated reports and plans);
- Production of GIS layer/s locating all green space;
- Gap analysis to determine areas requiring site assessment prior to categorisation and inclusion in the green space management system;
- Site assessments and mapping as required;
- Green space management system development including:
  - Legislation review,
  - Determination of management precincts,
  - Risk assessment,
  - Management type categorisation,
  - Determination of management options,
  - Integration with existing plans,
  - Prepare site management plans,
  - Prepare asset improvement plans,

○ Develop other system components e.g. monitoring and evaluation, communication and coordination strategy, information management system etc.
8 Acid sulphate soils mapping
Potential joint venture between TCC, Department of Environment and Resource Management (DERM) and NQ Dry Tropics.
9 Indigenous Cultural and Spiritual Environmental Values of Waterways and Waterbodies
Initial consultation has been undertaken with the Burdekin Traditional Owners Management Group to identify cultural and spiritual environmental values of waterways and waterbodies in the Black Ross WQIP area. Workshops and meetings need to be arranged with interested Traditional Owners to develop an understanding of these values and potential management actions to protect them. These values can then be incorporated in the new planning scheme for Townsville City.

5.7 Climate Change

A study of climate change in relation to water quality was undertaken for the Townsville region as part of the preparation of the Black Ross WQIP (see SEAO2 2008). It was concluded that there is unlikely to be any significant direct or indirect impacts on water quality as a result of climate change in the short term i.e. to 2030, with the possible exception of seasonal variability in storm activity and intensity. These impacts can be addressed through erosion prevention measures associated with developing areas and in particular through increased compliance measures for development.

In the longer term there is greater likelihood of climate change impacting water quality as the variations in climatic factors increases. While we can make the linkages between climatic variability and potential water quality impacts we cannot state precisely that a certain increase or decrease in a climatic variable will lead to a corresponding quantifiable impact on water quality.

The most relevant action from a water quality perspective with respect to climate change may be to further investigate the potential linkages between climate change and impacts on water quality. This could be done through a comprehensive literature review to determine the current state of knowledge including the use of ecological monitoring and models to estimate the trigger points for significant alterations to vegetation communities and erosion and sediment transport rates.

Meaningful short-term climate change associated actions could be introduced through the development assessment process and the preparation of the new planning scheme. The first potential action relates to erosion and sediment control and stormwater management measures.

If storm intensity and frequency increases as anticipated then there will be a need to improve risk management and control measures to ensure erosion and sediment transport rates do not increase correspondingly. As groundcover is the principal factor associated with erosion rates and, to a lesser degree, sediment transport, appropriate measures may relate to ensuring staged clearing to minimise ground disturbance on development sites rather than the current common practice of broadscale pre-development clearing. In situations where land is cleared prior to development and construction activities appropriate erosion prevention measures need to be put in place to ensure environmental harm is not caused. Where environmental harm results as a consequence of inadequate action then legal action should be taken including through the issue of Environmental Protection Orders and other remediation notices under the EP Act.

The second action is to build safeguards into the new planning scheme so that the worst-case climate change scenario is taken into account. This is a generic measure and is not confined to water quality impacts. This action will ensure that future planning decisions are based on the precautionary principle and the highest level of risk management. In this way Council can protect its constituents from any potential land use associated impacts of climate change and ensure that it meets its duty of care responsibilities in terms of approving developments. Impacts on environmental infrastructure should also be taken into account and buffers included to protect significant areas from sea level rise.

5.8 Behaviour change and social learning

The Black Ross WQIP will not achieve long-term sustainable outcomes without a significant behavioural shift amongst the land managers of the GBR catchments. The Creek to Coral initiative does not have the capacity to manage all the environmental elements of the urban, peri-urban and rural water catchments of the Black Ross WQIP area. However, with a strategic and coordinated effort there is great potential for Creek to Coral to influence the behaviour of land managers at all levels to achieve improved water quality, aquatic ecosystem health, biodiversity maintenance and general sustainability outcomes.

The Community Based Education and Involvement (CBEI) program (see section 5.8.1) is based on experiential learning, also a foundation stone of the Landcare and Catchment Management philosophy. Experiential learning is in itself a powerful tool for improving the capacity of individuals and organisations to monitor and manage natural assets e.g. Creekwatch.

5.8.1 Community based education and involvement

Creek to Coral has a strong community based education and involvement (CBEI) program designed around catchment management principles and integration of all components of sustainable living. This involves working with organisations such as Conservation Volunteers Australia (CVA) and conducting catchment tours for schools. The main CBEI activities are listed in Table 5.6.

Table 5.6 CBEI Activities

Creekwatch
Creekwatch is a community involvement and education program. Objectives of the project include: awareness raising, waterway management, community involvement, community stewardship and data collection. Activities undertaken include physical and chemical water quality monitoring; fish and macro invertebrate assessment; limited revegetation activities. Creekwatch is a TCC supported Conservation Volunteers Australia implementation program. Creekwatch is active in: Mundy Creek, Sachs Creek, Bluewater Creek, Stuart Creek, Loiusa Creek, Town Common, and the Ross River Network.
Total Water Cycle Tours
Provides community education and participation in waterway, Creekwatch, catchment tours and total water cycle management. Tours focus on going to key places in the catchment to provide understanding of the integrated nature of the catchment and creek system in Townsville, and why revegetation, waste and water management are important to total water cycle management. Tour includes catchment water quality management aspects for the Townsville region. Four messages are presented, those being: Water - connectivity; Energy - climate change mitigation; Biodiversity - links to both catchment and climate change outcomes; and Water: water quality, management and energy use components.
Dry Tropics Watersmart
Dry tropics water smart program - is a residential urban water efficiency program targeting all levels of the community. Part of the focus is to look at recycling wastewater rather than releasing it to receiving waters.
Rowes Bay Sustainability Education Centre, Learnscapes and Transect
The ‘old’ waste management depot at Rowes Bay has been the ‘home’ of the Natural Area Team and it is now being transformed it into an environment and sustainability education hub to include Integrated Sustainability Services (Townsville City Council) and eventually Reef Guardian Schools, Reef Guardian Councils, NGOs e.g. Landcare and NRM organisations and community learning spaces. Work is well advanced to transform the old caretakers residence into a sustainable office and learnscape.
CitiSolar
Promoting the use of photovoltaic energy production systems as a partner in a consortium led by Ergon Energy, and co-funded by the Australian Government’s Solar Cities program.

5.8.2 Reef Guardian Councils

Council and the Great Barrier Reef Marine Park Authority (GBRMPA) are working together to identify and/or develop actions to protect the water quality of the Great Barrier Reef Marine Park. Many of the actions are already included in the key concepts promoted by Creek to Coral. Some synergies and potential actions are listed below.

- TCC and GBRMPA to work together to produce media with key Great Barrier Reef messages for events such as Ecofiesta and River Festival;
- Developing best management practice approaches and guidelines for Council staff and management actions;
- Wastewater reuse (as part of Dry Tropics Watersmart) aims to reduce pressure on water resources, improve the Council's greenhouse footprint and manage nutrient outfall, and provide a renewable resource from this waste. The project may also provide a leadership platform for water reform for the community.

5.8.3 Market based instruments

There is a range of policy instruments available in the natural resource management field with four broad categories being:

- **Suasive approaches** are policy tools that encourage changes in behaviour through the provision of information, such as via general education programs, guidelines and codes of practice, training programs, extension services, and research and development;
- **Regulatory approaches** require changes in behaviour by introducing penalties for parties who don't comply with the regulatory provisions. Types of regulatory instruments include standards (including planning instruments), licensing, mandatory management plans and covenants;
- **Market-based instruments**; and
- **Public provision of services** is often used where the management solution has the characteristics of a public good which make it difficult or uneconomic for the service to be provided by the private sector. A national park is an example of a public good that is provided by government (Collins and Scoccimarro 2008).

Market Based Instruments (MBIs) are tools that use market-like approaches to positively influence the behaviour of people through the use of market signals rather than through explicit directives or regulations. They are also known as market mechanisms or market incentives for achieving environmental outcomes. MBIs need to be supported by appropriate regulatory and institutional frameworks. MBIs would have previously been included in the broader 'incentive' category of measures to improve NRM outcomes e.g. *Incentive measures for conserving freshwater ecosystems: Review and recommendations for Australian policy makers* (Whitten et al 2002).

Figure 5.6 Types of Market Based Instruments

Market Based Instruments

Price based	Quantity based	Market friction
• Auctions • Conservation agreements • Tax incentives • Beneficial rating	• Cap and trade • Offsets	• Leveraging private investment • Risk management • Product differentiation • Revolving funds

MBIs are being tested and implemented across Australia to improve the efficiency and effectiveness of expenditure on natural resource management by governments, industries, landholders and the wider community (DAFF 2007 and Collins and Scoccimarro 2008). Some of the main types of MBIs are shown in Figure 5.6.

MBIs are another tool that could be used to support improved water quality outcomes. Use of appropriate MBIs will be further investigated for urban and peri-urban areas and incorporated into the behaviour change studies proposed for the Black Ross WQIP area as an implementation action (see section 5.8).

5.8.4 New behaviour change strategies

There is an even greater need to engage the remainder (majority) of the community in natural asset management and sustainability initiatives whether or not they are aware of the issues or are committed to the concept. We need to make the leap from ‘preaching to the converted’ to facilitating behaviour change in the broader community, and in specific communities of interest.

Integrated Sustainability Services (Townsville City Council) with the Creek to Coral initiative has been exploring new ways of promoting environmental outcomes using simple yet powerful processes based on adult learning and cognitive and behavioural psychology theory. Instead of starting from a base of thinking we know what our audience of interest needs to know and then developing a corresponding education and involvement program we start with the premise that we will not be able to develop an effective program until we have an understanding of why the audience behaves in the way they do.

The three principal processes to be used in this altered paradigm of people based environmental management through behaviour change are:

- Thematic Interpretation/Communication – based on the work of Professor (Dr) Sam Ham and the uncovering of motivational beliefs prior to the development of theme based communications to promote behaviour change.
- Community Based Social Marketing – based on the work of Dr Doug McKenzie-Mohr and the identification of barriers and benefits associated with specific behaviours prior to developing a program of enabling actions and communications to promote a desired behaviour.
- Collective Social Learning and Transformation – based on the work of Professor Valerie Brown and enunciated in the publication *Leonardo’s Vision: A guide to collective thinking and action* (Brown 2008).

Each process has its own area of application and all are interrelated to some extent. Determining which process, or processes, to use is based on each individual situation and the issues to be addressed. The processes may be used in tandem or parallel as appropriate.

The behaviour change processes are a key element of the adaptive management strategy as their power lies in both identifying and assisting in designing the most appropriate direction and actions for influencing water quality improvement outcomes. Monitoring behaviour change through management practice uptake will be a key component of the social learning component of the Black Ross WQIP with a monitoring and evaluation process to be designed into each study, project and program instigated.

For moreon information on behaviour changes see *Social Approaches to Water Quality Improvement in the Black Ross WQIP Area* (Gunn 2010).

6. Rehabilitation Options, Costs and Benefits

6.1 Introduction

The costs of rehabilitation are often prohibitively expensive and it is important to prioritise areas to identify where the maximum benefits can be obtained in a cost effective manner. This is not an easy task as it is difficult to measure the water quality benefits of small actions on a catchment scale. In reality the benefits can probably only be measured in a semi-quantitative way as there are many qualitative ecosystem services and social benefits that have not been translated into monetary terms. At the least we can estimate relative potential benefits and then apply available resources to the highest relative benefit areas as the priority.

6.2 Riparian Restoration

The Mackay Whitsunday WQIP team (Drewry et al 2008a) used SedNet modelling to investigate the potential water quality benefits associated with increasing the cover of riparian vegetation. The riparian vegetation scenario modelled involved increasing vegetation cover to 75% where stream links had less than 75% initial (i.e. estimate of current situation) riparian vegetation by stream length. The scenario was aimed at evaluating the effect of increasing riparian vegetation on total suspended sediment (SS) loads and event mean concentrations (EMC).

The SedNet modelling predicted that improvements in water quality (SS loads and EMCs) would generally be low if riparian vegetation is increased to 75% of all stream length. However, due to the assumptions inherent in the SedNet model the results should be viewed with caution, as potential water quality benefits are likely to be underestimated. SedNet models the riparian vegetation as affecting stream bank erosion only. It uses a linear relationship between the total amount of riparian vegetation and the amount of sediment that can be eroded from the stream bank. Groundcover is not adequately taken into account by SedNet for assessing the reduction in hillslope and gully erosion in riparian areas. One of the most important functions of riparian vegetation i.e. overland flow filtering, is therefore not taken into account by SedNet.

"*In summary, there are a wide range of issues associated with riparian zone trapping of sediments, delivery and transformations of nutrients to streams and attempts to model potential reductions to streams. However, a balance between complexity and simplicity is important, when considering errors as discussed elsewhere in this report. Currently models such as SedNet do not take such issues into account so caution should be applied when assuming the importance of outputs in the riparian modelling scenario*" (Drewry et al 2008a, p. 33).

6.2.1 Riparian vegetation condition

Creek to Coral commissioned C and R Consulting to assess the condition of riparian vegetation in the Black Ross WQIP area (see C and R Consulting 2007 and 2008). The study, in two parts, was based on a review of existing aerial photography, satellite imagery, vegetation maps (Regional Ecosystem data from the Queensland Herbarium), soils maps and pre-existing knowledge of the study area. Limited ground-truthing was carried out where necessary to clarify desktop findings. A summary of findings is included in Appendix H.

To quantify the area of riparian zones that may benefit from restoration work further finer scale GIS analysis was applied to the waterways. The GIS analysis was based on the assumption that the most cost effective pollutant filtering and bank stabilisation benefits would be derived from having a 20 metre wide strip of riparian vegetation along the entire length of a stream i.e. closer to natural conditions (Gunn 2001). The GIS analysis used a 25 metre wide strip either side of waterways for order 1 and 2 streams and 35 metres beside order 3 and 4 streams. This allowed for an average waterway width of 10 metres for order 1 and 2 streams and 30 metres for order 3 and 4 streams, in addition to the 20-metre riparian vegetation zone adjacent to the high banks. The length and area of riparian areas with non-remnant vegetation have been calculated and are shown in Appendix G.

To prioritise areas for restoration the GIS results need to be cross-referenced with the C and R riparian assessment and the prioritised areas ground truthed to ensure accuracy of the assumptions associated with the condition assessment and GIS analysis.

6.2.2 Riparian revegetation costs

The cost of establishing riparian vegetation varies considerably based on the features of the site, current condition of the vegetation and the measures applied. Costs range from $1,000 per hectare for assisted natural regeneration to $8,500 per hectare for re-establishment of a wet tropics rainforest ecosystem (calculations were based on a 10 hectare site) (Binney 2007).

In a series of waterway rehabilitation case studies from Western Australia (Water and Rivers Commission 1999) costs were shown to vary widely depending on the situation and type of works undertaken. Rural based revegetation carried out by the landowner as part of their property management plan ($1200/hectare) were considerably lower than more intensive rehabilitation works in highly disturbed and degraded urban areas ($24,000 - $150,000 hectare).

The lesson from the case studies, and a water quality perspective, is that revegetation works for biodiversity purposes alone are less expensive than rehabilitation works for erosion prevention, bank stabilisation and pollutant filtering. Designing and implementing a works program for water quality improvement through riparian zone and waterway rehabilitation is an expensive exercise. It is the last resort from a treatment train perspective and may have minimal benefits if the fundamental principles of water sensitive urban design are not implemented in conjunction with waterway restoration.

Riparian revegetation costs for the Black Ross WQIP area are based on a one-hectare site for ease of calculation. This area can be translated to a stream length on the assumption that a 20 metre wide strip on both sides of a waterway is being revegetated i.e. 40 metre width per lineal metre of stream x 250 metres of stream length = one hectare (10,000m^2). An upper end cost for riparian revegetation of $8,000 hectare equates to approximately $32 per lineal metre of stream revegetated or $32,000 per kilometre.

The assumptions for the one hectare revegetation scenario are:

- Costs are for revegetation works only. This includes planning, site preparation, planting and one post planting follow up site visit for maintenance (does not include ongoing maintenance);
- The banks of the waterway are not actively eroding so an additional width factor is not required to compensate for incremental erosion while the vegetation becomes established (see Abernethy and Rutherford 1999);
- The 20 metre riparian vegetation width will reduce sediment input to waterways from overland flow and hillslope erosion and improve bank stability thereby reducing bank and gully erosion. 20 metres is the minimum width required for removal of nutrients. Depending on landscape position, topography and biophysical elements this width may not be effective in all situations. Site specific investigations and modelling is required to determine potential effectiveness for fine sediment, nutrient and pesticide removal;
- Riverine protection works are not included in the cost, which may involve engineering design, earthworks and erosion prevention measures.

Ongoing maintenance costs are again a function of the site and the degree of rehabilitation required. In general terms maintenance at revegetation sites is about weed control. Weed control should reduce over time as a site becomes more established and the native vegetation dominates the site. The amount of weed control required is therefore usually a function of time i.e. the older the site the less weed control required. Weed control is essential and most intensive for the first two years after site planting.

6.2.3 Black Ross WQIP area cost

Indicative riparian zone revegetation costs have been calculated (see Table 6.1) using the results of the GIS analysis displayed in Appendix G. The costs are based on a mid range revegation cost of $5,000 per hectare which equates to $20,000 per kilometre of stream length (includes both sides). The indicative cost for the revegetation of riparian zones mapped as non-remnant is between $4.2m and $6.4m.

Table 6.1 Indicative Cost of Riparian Revegetation

Catchment	Non remnant area/cost		Non remnant length/cost		Non remnant %
	Hectares	Total cost	Metres	Total cost	
Alice River	20.7	$103,316.99	16,565	$165,647.67	8.2
Alligator Creek	65.8	$329,159.09	51,116	$511,159.07	22.5
Antill Plains Creek	40.7	$203,455.53	29,664	$296,640.80	22.3
Arcadia	1.0	$5,077.62	804	$8,041.71	39.3
Black River	41.8	$209,115.88	32,262	$322,619.98	11.2
Bluewater Creek	11.7	$58,586.77	7,167	$71,669.04	4.0
Bohle River	47.5	$237,540.49	38,103	$381,033.96	18.2
Bohle River 2	100.8	$504,061.90	75,987	$759,867.32	31.9
Cape Cleveland	0				0
Cassowary Creek	0.8	$4,135.70	640	$6,397.38	2.8
Cocoa Creek	0				0
Crocodile Creek	3.9	$19,593.88	3,036	$30,363.33	2.2
Crystal Creek	15.8	$78,999.87	10,804	$108,038.27	5.6
Deep Creek	26.4	$132,068.85	21,070	$210,696.84	15.1
Hencamp Creek	17.2	$86,060.17	13,812	$138,118.60	24.0
Horseshoe Bay	1.5	$7,371.19	1,166	$11,661.65	8.0
Leichhardt Creek	9.7	$48,737.18	7,562	$75,619.86	8.1
Lorna Creek	7.0	$34,876.24	5,503	$55,033.36	40.0
Mt Stuart	11.6	$57,909.55	7,366	$73,657.42	15.4
Mundy Creek	16.9	$84,610.21	13,573	$135,725.41	1,357.8
Nelly Bay	2.3	$11,542.31	1,832	$18,315.16	49.2
Offshore	0.2	$1,101.45	192	$1,922.12	8.9
Ollera Creek	12.2	$60,907.58	8,859	$88,585.59	8.2
Pallarenda	0.2	$1,150.21	171	$1,712.16	2.8
Picnic Bay	1.8	$8,859.49	1,399	$13,988.49	74.7
Rollingstone Creek	13.7	$68,503.90	9,916	$99,159.37	7.5
Ross Creek	40.2	$200,946.80	32,315	$323,150.50	100.0
Ross River (atd)	36.3	$181,375.01	25,719	$257,188.38	4.8
Ross River (btd)	70.5	$352,495.20	55,505	$555,048.18	48.4
Sachs Creek	26.6	$133,097.11	19,765	$197,654.46	42.4
Saltwater Creek	3.6	$17,805.60	2,698	$26,981.82	2.8
Sandfly Creek	30.4	$152,052.04	23,953	$239,525.90	42.7
Scrubby Creek	11.9	$59,406.88	9,594	$95,940.15	37.3
Shelly Beach	0				
Six Mile Creek	17.2	$86,129.15	12,704	$127,043.38	15.8
Sleeper Log Creek	14.0	$69,809.49	10,973	$109,726.94	8.9
Station Creek	0.6	$3,078.35	489	$4,890.35	2.2
Stuart Creek	19.0	$95,187.99	11,845	$118,450.30	13.3
Surveyors Creek	17.5	$87,363.42	13,876	$138,756.34	39.5
Toonpan Lagoon	71.9	$359,491.02	55,396	$553,958.49	21.8
Two Mile Creek	2.3	$11,440.03	1,766	$17,662.69	7.8
Unamed	0.1	$326.74	50	$504.04	1.7
West Coast	1.5	$7,367.48	1,154	$11,542.45	4.6
Wild Boar Creek	0.3	$1,617.54	250	$2,496.14	2.5
Totals	835	$4,175,731.91	636,620	$6,366,195.07	(Average) 16

Notes: Non remnant % is based on the ratio of the length non remnant to remnant vegetation in a 20m wide riparian zone for the main streams in each catchment. (atd) is above the dam and (btd) is below the dam.

The ratio of non-remnant vegetation in the riparian zone provides an indication of the catchments that require the most work to increase the overall extent of native vegetation fringing the waterways. These catchments should not automatically be assumed to be the ones where the most benefit will be derived for water quality outcomes from revegetation. Ground cover consisting of non-remnant vegetation is also useful in terms of erosion and sediment control, bank stability and sediment filtering, which are the desired water quality outcomes.

Reinstating remnant vegetation will therefore not be necessary in all non-remnant riparian areas for water quality purposes and areas will need to be assessed on a case-by-case basis to determine the benefits. The distinction also needs to be made between urban and non-urban areas and the purpose and type of revegetation required. Rural areas may also require stock management options to be included in revegetation measures to ensure the successful establishment of plantings or natural regeneration. Biodiversity outcomes should be incorporated in revegetation design wherever possible in all areas to maximise the benefits achieved from works.

6.3 Wetland Management

Constructed wetlands are now more prevalent in the landscape and are accompanied by a range of management requirements associated with biological function and community expectations. In the Townsville region weed control is the main component of wetland management and needs to be taken into account when designing constructed wetlands to avoid unnecessary expense.

In terms of water quality some weeds can be beneficial even though they may not be desirable in terms of biodiversity or aesthetics. All the biophysical and social issues need to be taken into account when dealing with wetland management, especially in the urban and peri-urban context. Areas for wetland rehabilitation have not been prioritised for the Black Ross WQIP as yet. Any future wetland rehabilitation works will need to be prioritised and costed on a site-specific basis. As an interim measure costing for weed control can be applied to wetland management assuming that this will be one of the priority management actions.

Figure 6.1 Constructed Wetlands – Asset or Liability?

7. Monitoring and Communications

7.1 Introduction

Monitoring the results of implementation actions and adapting the WQIP to reflect the findings of evaluation, review and new science is fundamental to the success of the plan. The planning process identifies the best bet strategies and actions and it is only after these have been tested can we be confident about the choice. If a choice is shown to be lacking in some respect then the mechanism for adaptation needs to be triggered to ensure we take a different path to achieve better results. Information on the adaptive management approach is provided in Appendix J.

Good communication as a component of the adaptive planning and management system is also important to achieve the outcomes of the WQIP. Ideally a communication strategy is prepared as an initial step associated with the implementation of the overall plan or failing this each implementation action should have the lines of communication and reporting defined as a minimum with consultation strategies prepared where there is a significant stakeholder engagement component. Good communications are also a prerequisite for the integration of the various connected programs within Council, and between Council and external stakeholders. Some of the key programs that should be included in communication strategies are noted in Appendix K.

Two of the key elements of the monitoring, evaluation and adaptation framework are interlinked and require additional investigation and calibration to enable them to be usefully incorporated into the framework. These options are discussed below.

7.2 Bayesian Belief Network

Catchment modelling relies on the input of various data including pollutant run-off coefficients related to different land uses. The coefficients are usually derived from event water quality monitoring results and are dependent on relative uniformity across a land use. For the Black Ross WQIP the land use pollutant run-off coefficients were derived where possible from the event water quality monitoring undertaken by the Australian Centre for Tropical Freshwater Research (ACTFR) during the 2006/07 and 2007/08 'wet seasons'.

To enable changes in management practices that lead to reduced erosion and pollutant run-off to be accounted for preliminary work was carried out to develop a Bayesian Belief Network model for the Black Ross WQIP area. The management practice changes are linked to various land uses and the land use pollutant run-off coefficients. Bayesian Belief Networks (BBN) and their application to the Black Ross WQIP are explained in more detail in a draft report prepared by the BBN project team leader, Tim Lynam (Lynam et al 2008).

The idea is to use a BBN as a probability based decision support system to explore the relationships between management practice, land use and water quality (pollutant loads). The BBN is designed to assist with setting, or verifying, direction for potential management interventions and subsequently redirecting management interventions as part of the adaptive management approach to catchment management and water quality improvement in the Black Ross WQIP area.

When fully developed the BBN will be used in conjunction with catchment modelling to establish proportional benefits in relation to costs and provide a level of confidence in proposed management actions. Additional information on the BBN is provided in Appendix L.

7.3 ABCD framework

A tool to assist with the promotion and measurement of management practice uptake is the ABCD management practice framework. The framework was initially developed for grazing and intensive agricultural land uses (sugar cane and horticulture) by the Mackay Whitsunday WQIP team with preliminary development of the ABCD management practice framework for urban areas carried out in conjunction with the Black Ross WQIP management team, and Councils in the Mackay Whitsunday WQIP area.

The ABCD framework concept has been adopted for the Black Ross WQIP area and the urban component further developed. Work has also commenced on a peri-urban ABCD framework for the Townsville region.

The ABCD management practice framework is being developed for urban and peri-urban areas, in part; to provide some form of delineation of the pollutant generation variables associated with different management practices for various land uses, and thereby determine the range of potential water quality improvement likely by moving from a 'lower' to a 'higher' management practice category.

The end game is to use the ABCD management practice framework in concert with the BBN to determine the most effective management interventions for each land use based on potential water quality improvement associated with the suggested management practices. Further development of the ABCD management practice framework and a significant amount of testing and calibration of the BBN is required to attain greater levels of certainty associated with modelled results i.e. the better the input the better the output.

The current ABCD framework for urban and peri-urban areas is included in Appendix M. The general concepts associated with the ABCD framework are presented in Table 7.1.

Table 7.1 ABCD Framework Concepts

Class	Description of practice	Relevant Plan	Community and industry standard	Effect on resource condition	Cost/Benefit
A	Cutting-edge practices that require further validation of environmental, social and economic costs/benefits	Yes, develops and tests innovative technology	When validated is an acceptable practice for the long term (may not be universally endorsed as feasible by industry and community)	When validated, practice likely to achieve long term resource condition goals if widely adopted	When validated, improves profitability in the medium to long term (may reduce profitability during the transition)
B	Currently promoted practices often referred to as "Best Management Practices"	Yes, and utilises common technology	Acceptable practice for the medium term	Practice likely to achieve medium term resource condition goals if widely adopted	Improves profitability in the short to medium term
C	Common practices. Often referred to as 'Code of Practice'	Basic	Acceptable practice today but may not be acceptable in medium term	Practice unlikely to achieve acceptable resource condition goals if widely adopted	Decline of profitability in the medium to long term
D	Practices that are superseded or unacceptable by industry and community standards	None	Superseded or unacceptable practice today	Practice likely to degrade resource condition if widely adopted	Decline of profitability in the short to medium term

Source: Adapted from Table 21 Management classes and description for ABCD framework for management practices (Drewry et al 2008a, p.61)

7.4 Cost of Improved Water Quality and Ecosystem Health

An initial costing of management actions was prepared as part of the proposal submitted to the Australian Government to deliver relevant components of the Caring for Our Country Business Plan 2009/10. The funding proposal was unsuccessful and costings were subsequently revised to reflect the estimated cost of delivery regardless of secured funding. These costs are shown in Table 7.2. A cost summary by action area for the first five-year term of the Black Ross WQIP is provided in Table 7.3.

Table 7.2 Short Term Costs

No.	Action areas and tasks	2009/10	2010/11	2011/12	2012/13	2013/14	Total Cost
1	***Erosion and Sediment Control for development***						
	Review the effectiveness of current measures	2,000	9,000				11,000
	Link with the WSUD implementation process		2,000	2,000	1,000		5,000
	Investigate risk management for climate change		6,000	27,000	18,000		51,000
	Develop generic guidelines for developers / construction industry		14,000				14,000
	Monitoring and enforcement			90,000	90,000	50,000	230,000
	Sub totals	2,000	31,000	119,000	109,000	50,000	311,000
2	***Site based Stormwater Management Plans for development***						
	Review the effectiveness of current measures	2,000	5,000				7,000
	Link with the WSUD implementation process		2,000	3,000			5,000
	Investigate risk management for climate change		3,000	13,000			16,000
	Develop generic guidelines for developers/construction industry		11,000				11,000
	Monitoring and enforcement			90,000	90,000	50,000	230,000
	Sub totals	2,000	21,000	106,000	90,000	50,000	269,000
3	***Water Sensitive Urban Design (WSUD) guideline adoption and adaptation***						
	Finalise strategic framework for introducing WSUD	2,000	2,000				4,000
	Additional WSUD product development/adaptation: • Socio-economic case, • Concept Design Guidelines, • Construction and Establishment Guideline, • Asset Management Guideline, • Deemed to Comply and Standard Drawings, • MUSIC Auditing Tool (to assist with the development assessment process).	5,000	30,000	25,000	5,000	5,000	70,000

	Prepare a WSUD Communication Strategy	1,000	5,000				6,000
	Investigate Market Based Incentive options for WSUD		13,000				13,000
	Develop a WSUD information and training package, and support (development in the first year and support thereafter)		18,000	8,000	8,000	8,000	42,000
	Training days (@ $1500/training day includes part cost recovery)		12,000	12,000	12,000	12,000	48,000
	WSUD integration with TWCMP and new TCC Planning Scheme			25,000	25,000	10,000	60,000
	Model Subdivision Project		30,000	30,000	30,000	30,000	120,000
	Revise WSUD guidelines and materials (adaptive management)		15,000	5,000	3,000		23,000
	Advisory and compliance services				90,000	90,000	180,000
	Sub totals	8,000	125,000	105,000	173,000	155,000	566,000
4	***Develop Coastal Dry Tropics Guide for Urban Water Management***						
5	***Urban Stormwater Quality Management (USQM) and TWCMP***						
	Update the *Stormwater Quality Management Framework for Townsville* (2006)		2,000				2,000
	Link with the WSUD implementation process		2,000				2,000
	Total Water Cycle Management Plan scoping and preparation	1,000	10,000	15,000	15,000	10,000	51,000
	Prepare Urban Stormwater Quality Management Plan for TCC LGA		40,000	70,000	80,000	40,000	230,000
	Waterway management plan / Catchment strategy preparation		50,000	80,000	50,000	50,000	230,000
	Sub totals	1,000	104,000	165,000	145,000	100,000	515,000
6	***Urban stormwater treatment trains***						
	WSUD Stormwater quality improvement working demonstration sites	270,000	240,000	300,000	300,000	300,000	1,410,000
	Soil health for water quality trials		75,000	75,000	20,000	10,000	180,000
	Investigate 'household' options using modelling e.g. MUSIC		28,000				28,000
	Sub totals	270,000	343,000	375,000	320,000	310,000	1,618,000
7	***WSUD retrofit for water quality improvement***						
	Expand the WQIP SQID Report to include all TCC LGA (part USQMP)		20,000				20,000
	Prioritise areas for cost effective WSUD retrofit (MUSIC modelling)		30,000				30,000
	WSUD retrofit demonstration sites		150,000	150,000	150,000		450,000
	Sub totals		200,000	150,000	150,000		500,000
8	***Develop peri-urban catchment management guidelines and implementation activities***						
	Prepare GIS mapping of peri-urban extent		4,000				4,000

	Develop *Dry Tropics Peri-urban Catchment Health Guidelines*		85,000	10,000			95,000
	Refine ABCD peri-urban management practice framework		4,000				4,000
	Develop a peri-urban catchment health education and incentive program			32,000			32,000
	Implement the peri-urban catchment health education and incentive program			120,000	120,000	80,000	320,000
	Sub totals		93,000	162,000	120,000	80,000	455,000
9	***Water Resource Catchment Management (Ross River Dam)***						
	Integration with WQIP activities with emphasise on water quality monitoring, peri-urban management and planning scheme studies		5,000	10,000	10,000	10,000	35,000
10	***Promote "Managing for WQ within grazing lands of the Burdekin Catchment" (BDT NRM)***						
	Investigate the need for 'wet catchment' amendments BDT guide		7,000				7,000
	Modify rangeland grazing management practices as required		3,000				3,000
	Work with NQ Dry Tropics to develop and roll out BMP adoption programs for rural areas		10,000	10,000	10,000	10,000	40,000
	Sub totals		20,000	10,000	10,000	10,000	50,000
11	***Promote management practice ABCD framework for sugar cane and horticulture (Mackay Whitsunday NRM)***						
	Liaise with regional NRM group/s for ABCD framework and DPIF Nutrient Management Zones (NMZ)		6,000				6,000
	Monitor roll out in association with partners		2,000	2,000	2,000	2,000	8,000
	Sub totals		8,000	2,000	2,000	2,000	14,000
12	***Legislation and Governance***						
	Various coordination and integration components based on tasks 1, 4, 5, 9, an d 13 to 26 and the new TCC planning scheme	3,000	12,000	12,000	12,000	12,000	51,000
13	***Policy investigations and development***		10,000	10,000	10,000	10,000	40,000
14	***Planning Scheme studies and instruments review***						
	Provide input to Planning Scheme (PS) studies scoping	8,000	80,000				88,000
	Integrate WQIP condition assessment studies with PS studies		40,000	30,000	30,000		100,000
	Sub totals	8,000	120,000	30,000	30,000		188,000
15	***Strategic landscape mapping and habitat prioritisation***						

	Landscape health data collation and studies coordination		193,000				193,000
	GIS and Report on Priority Landscapes		198,000				198,000
	Integrate Priority Landscapes with TCC Planning Scheme			10,000	17,000		27,000
	Sub totals		391,000	10,000	17,000		418,000
16	***Population Growth and Climate Change considerations***						
	Update and refine population growth and urban expansion projections for modelling		6,000				6,000
	Adapt management actions to suit growth projections		4,000				4,000
	Climate change and water quality literature review		12,000				12,000
	Model impacts on water quality from climate change			42,000			42,000
	Develop objectives and actions for climate change adaptation			11,000			11,000
	Incorporate climate change components into planning scheme				20,000		20,000
	Sub totals		22,000	53,000	20,000		95,000
17	***Condition assessment and prioritisation***						
	Scope condition assessment requirements including liaison		7,000				7,000
	Condition assessments and prioritisation process		120,000	130,000	80,000	20,000	350,000
	Green space management system scoping and preparation	2,000	70,000	70,000	70,000	15,000	227,000
	Indigenous cultural and spiritual values of waterways study		27,000	27,000			54,000
	Sub totals	2,000	224,000	227,000	150,000	35,000	638,000
18	***Community Based Education and Involvement (CBEI)***	403,000	453,000	453,000	453,000	460,000	2,222,000
19	***Reef Guardian Councils implementation***	10,000	20,000	20,000	20,000	20,000	90,000
20	***Social learning and behaviour change studies***						
	Peri-urban behaviour change studies		24,000				24,000
	Urban water and biodiversity behaviour change studies		75,000	80,000	40,000	40,000	235,000
	Behaviour change studies for stormwater management and WSUD adoption		37,000				37,000
	Sub totals		136,000	80,000	40,000	40,000	296,000
21	***Market Based Instruments investigation***		13,000				13,000
22	***Riparian zone rehabilitation***						
	Identification and prioritisation of areas		30,000				30,000
	Develop action plans		40,000				40,000
	Implement actions and protection measures		100,000	400,000	400,000	400,000	1,300,000

	Sub totals		170,000	400,000	400,000	400,000	1,370,000
23	***Wetland restoration and construction***						
	Identification and prioritisation of areas		20,000				20,000
	Develop action plans		20,000				20,000
	Sub totals		40,000				40,000
24	***Aquatic ecosystem health improvement***						
	Waterway improvement plans and implementation	250,000	250,000	250,000	250,000	250,000	1,250,000
25	***Water quality monitoring and modelling***						
	Water quality monitoring and modelling detailed design	1,000	25,000				26,000
	Event water quality monitoring		53,000	153,000	153,000	173,000	632,000
	Ambient water quality monitoring (including local water quality guidelines)		80,000	80,000	80,000	80,000	320,000
	Formalise and expand data sharing protocols and systems		8,000				8,000
	Update and add to existing Townsville WQ database		25,000	15,000	15,000	15,000	70,000
	Analyse stormwater data for action determination		12,000	6,000			18,000
	Refining catchment scale models with new monitoring data		30,000	6,000	36,000	15,000	87,000
	Linking catchment models and receiving waters models		10,000	10,000	10,000	10,000	40,000
	Social resilience (MTSRF) Project 4.9.7 involvement		6,000	6,000			12,000
	Sub totals		349,000	276,000	294,000	293,000	1,213,000
26	***Integration, Communication, Monitoring, Evaluation and Adaptive Management***						
	Black Ross WQIP monitoring and evaluation (MERI) (Management practice uptake, BBN and social learning, modelling, WQIP)		160,000	160,000	160,000	160,000	640,000
	Develop Black Ross WQIP Communication Strategy		6,000				6,000
	Creek to Coral website update	5,000	20,000	3,000	3,000		31,000
	Further develop and test the Bayesian Belief Network model		25,000	25,000	15,000	15,000	80,000
	Refine and extend the Urban ABCD Management Practice Framework		5,000	4,000			9,000
	Project management (1 FTE)	60,000	90,000	90,000	90,000	90,000	420,000
	Sub totals	65,000	306,000	282,000	268,000	265,000	1,186,000
	Totals	1,024,000	3,466,000	3,307,000	3,093,000	2,552,000	13,443,000

Notes: All figures are exclusive of GST. Some portion of the actions in the preliminary costing may be delivered in-kind through TCC staff time, through sourcing external funding or from internal allocation of existing budget items.

Table 7.3 Cost Summary

No.	Action Areas	Cost $
1	Erosion and sediment control for development [2009-2014]	311,000
2	Site-based stormwater management plans for development [2009-2014]	269,000
3	Water sensitive urban design (WSUD) guideline adoption and additional products [2009-2014]	566,000
4	Total Water Cycle Management Plan and Urban Stormwater Quality Management Plan integration [2009-2014]	515,000
5	Urban stormwater treatment trains [2009-2014]	1,618,000
6	WSUD retrofit [2010-2014]	500,000
7	Develop peri-urban catchment management guidelines and implementation activities [2010-2014]	455,000
8	Water resource catchment management (Ross River Dam) [2010-2014]	35,000
9	Promote *Managing for WQ within grazing lands of the Burdekin Catchment* developed by NQ Dry Tropics [2010-2014]	50,000
10	Promote management practice ABCD framework for sugar cane and horticulture developed by Mackay Whitsunday NRM [2010-2014]	14,000
11	Legislation and governance [2009-2014]	51,000
12	Policy investigations and development [2010-2014]	40,000
13	Planning scheme studies and instruments review [2009-2014]	188,000
14	Strategic landscape mapping and habitat prioritisation [2010-2013]	418,000
15	Population growth and climate change considerations [2010-2013]	95,000
16	Condition assessment and prioritisation [2009-2014]	638,000
17	Community Based Education and Involvement (CBEI) (awareness and capacity building) [2009-2014]	2,222,000
18	Reef Guardian Councils implementation [2009-2014]	90,000
19	Social learning and behaviour change studies (for determining effective management interventions) – urban and peri-urban [2010-2014]	296,000
20	Market based instruments investigation [2010-2011]	13,000
21	Riparian zone rehabilitation [2010-2014]	1,370,000
22	Wetland restoration and construction prioritisation [2010-2011]	40,000
23	Aquatic ecosystem health improvement [2009-2014]	1,250,000
24	Integrated water quality monitoring and modelling [2010-2014]	1,213,000
25	Integration, communication (includes Reporting), monitoring (including behaviour change), evaluation and adaptive management [2009-2014]	1,186,000
	Total	$13,443,000

Note: Costs (exc. GST) are for all actions within action areas for the 2009/10 to 2013/14 financial years. Average annual expenditure is $2,688,600 with approximately 30% ($800,000 per annum) of this provided internally by TCC from current programs and projects ($1.9m/annum funding shortfall).

The costs are an initial estimate and will be refined, as implementation actions are trialled and adapted to maximise benefits derived in terms of water quality improvement. Wherever possible water quality outcomes will be integrated with other sustainability outcomes to increase the benefits derived for the investment cost.

Appendix A

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Appendix B

Catchment Modelling Summary Results

Catchment Water Quality Modelling Summary Results

The 'raw' results from the catchment modelling carried out by BMT WBM have been arranged in a variety of ways to provide a picture of the options associated with different management scenarios applied to the Black Ross WQIP area. The following tables include compilations of the scenario results and the changes in land use associated with the results. A list of the tables is provided as a precursor.

Load increases/change over time with business as usual:

Table AA Load estimates based on the 2005 land use business as usual (BAU) scenario (base case) with cross reference between modelled sub catchments and WQIP catchments, sub basins and basins

Table AB Load estimates based on the interpolated 2021 land use business as usual (BAU) scenario (base case) with cross reference between modelled sub catchments and WQIP catchments, sub basins and basins

Table AC Load estimates based on the 2045 land use business as usual (BAU) scenario (base case) with cross reference between modelled sub catchments and WQIP catchments, sub basins and basins

Table AD 2021 interpolated BAU diffuse source loads

Table AE 2045 modelled BAU diffuse source loads

Table AF TSS diffuse source BAU load changes from 2005 to 2021 and 2045

Table AG TN diffuse source BAU load changes from 2005 to 2021 and 2045

Table AH TP diffuse source BAU load changes from 2005 to 2021 and 2045

Table AI All diffuse source pollutants loads and flow summary for BAU and changes from 1850 to 2005, 2021 and 2045, and 2005 to 2021 and 2045

Land use:

Table LA Land use area and percentage change by sub basin for modelling load change from 2005 to 2045

Table LB Land use area change by sub basin and percentage change relative to WQIP area for modelling load change from 2005 to 2045

Table LC Land use change by WQIP area for modelling load change from 2005 to 2045

Scenario load reductions:

Table BA Potential TSS load reductions at 2045 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Table BB Potential TSS load reductions at 2021 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Table BC Potential TN load reductions at 2045 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Table BD Potential TN load reductions at 2021 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Table BE Potential TP load reductions at 2045 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Table BF Potential TP load reductions at 2021 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Table BG Potential load change at 2045 from BAU by implementing GF WSUD and percentage change by sub basin and WQIP area for all pollutants

Table BH Potential load change at 2045 from BAU by implementing GF WSUD and percentage change by sub basin and WQIP area for all pollutants

Table BI Potential load change at 2045 from BAU by implementing All urban WSUD and percentage change by sub basin and WQIP area for all pollutants

Table BJ Potential load change at 2021 from BAU by implementing All urban WSUD and percentage change by sub basin and WQIP area for all pollutants

Table BK Potential load change at 2045 from BAU by implementing Rural BMP and percentage change by sub basin and WQIP area for all pollutants

Table BL Potential load change at 2021 from BAU by implementing Rural BMP and percentage change by sub basin and WQIP area for all pollutants

Table BM Potential load increases 2005 to 2021 and potential load reduction and percentage changes at 2021 from BAU by 100% adoption of WSUD practices by Basin and WQIP area for all pollutants

Table BN Potential load increases 2005 to 2045 and potential load reduction and percentage changes at 2045 from BAU by 100% adoption of WSUD practices by Basin and WQIP area for all pollutants

Load reduction targets:
Table CA 2021 TSS load reduction potential, reduction targets and total load reduction

Table CB 2021 TN load reduction potential, reduction targets and total load reduction

Table CC 2021 TP load reduction potential, reduction targets and total load reduction

Table CD 2045 TSS load reduction potential, reduction targets and total load reduction

Table CE 2045 TN load reduction potential, reduction targets and total load reduction

Table CF 2045 TP load reduction potential, reduction targets and total load reduction

Table CG TSS 2021 load reduction targets summary

Table CH TN 2021 load reduction targets summary

Table CI TP 2021 load reduction targets summary

Table CJ 2045 TSS load reduction targets summary

Table CK 2045 TN load reduction targets summary

Table CL 2045 TP load reduction targets summary

Load calculations from event monitoring results:

Prior to the modelling results becoming available estimates of loads for selected catchments were calculated using the results of the ACTFR event monitoring.

Table DA Sediment Load Main Catchments 2006-2008

Table DB Nitrogen Load Main Catchments 2006-2008

Table DC Phosphorus Load Main Catchments 2006-2008

Load increases/change over time with business as usual

Table AA Load estimates based on the 2005 land use business as usual (BAU) scenario (base case) with cross reference between modelled sub catchments and WQIP catchments, sub basins and basins

Model SC No.	WQIP No.	Catchment	TSS	TN	TP
			kg/year	kg/year	kg/year
40	1-1	Crystal Creek	3,071,753	47,117	5,150
39	1-2	Lorna Creek	59,171	2,319	92
14	1-2	Lorna Ck /Ollera Ck	613,620	8,072	822
38	1-3	Ollera Creek	174,590	3,357	273
41	1-3	Ollera Creek	405,428	12,345	1,030
37	1-4	Scrubby Creek	220,976	5,625	391
36	1-5	Hencamp Creek	967,913	11,286	1,625
		Crystal Creek SB	5,513,449	90,122	9,383
21	2-1	Rollingstone Creek	785,288	16,217	1,724
53	2-2	Unnamed	113,593	1,567	260
54	2-3	Surveyors Creek	123,820	3,550	308
35	2-4	Wild Boar Creek	11,286	537	54
34	2-5	Station Creek	45,656	1,337	144
51	2-6	Saltwater Creek	300,601	8,255	920
51	2-7	Cassowary Creek	Included above	Included above	Included above
50	2-8	Leichhardt Creek	222,803	8,985	610
		Rollingstone Creek SB	1,603,046	40,448	4,021
33	3-1	Sleeper Log Creek	620,925	21,623	1,026
42	3-2	Two Mile Creek	129,664	5,296	206
52	3-3	Bluewater Creek	891,210	30,718	1,410
43	3-3	Bluewater Creek	193,583	4,748	369
44	3-4	Deep Creek	971,565	30,316	1,629
		Bluewater Creek SB	2,806,946	92,700	4,641
48	4-1	Black River (upper and Alice)	5,844,000	52,596	7,597
45	4-1	Black River (lower)	1,351,425	16,582	2,425
		Black River SB	7,195,425	69,178	10,022
10	5-1	Bohle River	8,620	202	21
32	5-1	Bohle River	155,597	3,653	387
16	5-1	Bohle River	271,746	3,174	552
6	5-1	Bohle River	456,563	3,010	917
27	5-1	Bohle River	588,053	3,762	1,114

20	5-1	Bohle River	529,613	3,433	1,019
1	5-1	Bohle River	4,529	39	6
28	5-1	Bohle River	1,157,843	9,533	1,629
31	5-1	Bohle River	1,997,918	16,400	2,864
2	5-2	Bohle River 2	1,300,290	11,359	1,658
26	5-2	Bohle River 2	2,713,808	22,755	3,835
11	5-2	Bohle River 2	111,036	1,008	144
4	5-3	Shelly Beach	Included below	Included below	Included below
		Bohle River SB	9,295,613	78,328	14,146
4	6-1	Pallarenda	186,643	3,053	373
23	6-2	Mundy Creek	242,161	2,013	427
5	6-3	Esplanade	134,047	723	196
17	6-3	Esplanade	42,004	237	70
19	6-4	Ross Creek	715,890	4,529	1,319
24	6-4	Ross Creek	211,845	1,297	365
9	6-5	Ross River (btdam)	412,733	4,602	654
29	6-5	Ross River (btdam)	1,581,533	11,798	2,330
30	6-5	Ross River (btdam)	268,094	1,991	522
18	6-5	Ross River (btdam)	318,498	1,918	592
12	6-5	Ross River (btdam)	92,408	961	133
		Lower Ross River SB	4,205,854	33,120	6,981
49	7-1	Ross River (atd)			
49	7-2	Six Mile Creek			
49	7-3	Toonpan Lagoon			
49	7-4	Antill Plains Creek			
49	7-5	Sachs Creek			
49	7-6	Mt Stuart			
		Upper Ross River SB	8,108,550	100,444	12,784
7	8-1	Stuart Creek			
7	8-2	Sandfly Creek			
		Stuart Creek SB	1,650,930	18,956	2,959
47	9-1	Alligator Creek	774,330	14,245	1,676
13	9-1	Alligator Creek	591,705	11,250	1,304
8	9-2	Crocodile Creek	467,520	11,396	1,187
25	9-3	Cocoa Creek	98,252	2,429	250
46	9-4	Cape Cleveland	58,805	1,147	133

60	9-4	Cape Cleveland	114,323	2,250	260
		Alligator Creek SB	2,104,936	42,716	4,811
59	10-1	West Coast	37,621	1,563	166
3	10-2	Picnic Bay	39,082	303	81
15	10-3	Nelly Bay	121,628	1,275	272
22	10-4	Arcadia	40,908	420	92
58	10-5	Radical Bay	8,072	369	38
57	10-6	Horseshoe Bay	81,451	1,717	231
56	10-7	Five Beach Bay	9,825	468	47
55	10-8	Rollingstone Bay	3,631	172	17
		Magnetic Island SB	342,217	6,286	944
		Black Basin	17,118,866	292,448	28,067
		Ross Basin	25,365,882	273,565	41,680
		Black Ross WQIP area	42,826,965	572,299	70,690

Notes: SC is sub catchment (used for modelling). U is upper and L is lower. SB is sub basin. MI is Magnetic Island. Upper Ross River (SC#49) modelling relates to loads considered to be trapped by Ross River Dam. Pollutant loads delivered to the dam will be calculated and a proportion of the pollutant load will be added to the end of catchment loads for the Ross River.

Table AB Load estimates based on the interpolated 2021 land use business as usual (BAU) scenario (base case) with cross reference between modelled sub catchments and WQIP catchments, sub basins and basins

Model SC No.	WQIP No.	Catchment	TSS	TN	TP
			kg/year	kg/year	kg/year
40	1-1	Crystal Creek	3,011,852	46,533	5,092
39	1-2	Lorna Creek	65,599	2,331	100
14	1-2	Lorna Ck /Ollera Ck	641,379	8,379	850
38	1-3	Ollera Creek	203,517	3,796	299
41	1-3	Ollera Creek	500,393	14,040	1,107
37	1-4	Scrubby Creek	242,599	6,063	410
36	1-5	Hencamp Creek	1,850,357	16,823	2,495
		Crystal Creek SB	6,515,695	97,966	10,352
21	2-1	Rollingstone Creek	1,160,765	19,650	2,094
53	2-2	Unnamed	149,095	1,918	289
54	2-3	Surveyors Creek	188,834	4,161	362
35	2-4	Wild Boar Creek	11,286	537	54
34	2-5	Station Creek	42,442	1,305	144
51	2-6	Saltwater Creek	384,900	8,795	1,015
51	2-7	Cassowary Creek			
50	2-8	Leichhardt Creek	231,422	9,277	614
		Rollingstone Creek SB	2,168,745	45,643	4,572
33	3-1	Sleeper Log Creek	615,081	21,857	1,009
42	3-2	Two Mile Creek	129,664	5,296	206
52	3-3	Bluewater Creek	949,650	32,661	1,438
43	3-3	Bluewater Creek	186,424	4,807	342
44	3-4	Deep Creek	926,274	30,593	1,521
		Bluewater Creek SB	2,807,092	95,213	4,515
48	4-1	Black River (upper and Alice)	5,990,100	53,180	7,773
45	4-1	Black River (lower)	1,418,631	17,488	2,473
		Black River SB	7,408,731	70,669	10,246
10	5-1	Bohle River	8,620	202	21
32	5-1	Bohle River	204,832	3,842	435
16	5-1	Bohle River	369,049	3,512	644
6	5-1	Bohle River	456,563	3,007	917
27	5-1	Bohle River	599,741	3,908	1,111

20	5-1	Bohle River	539,840	3,460	1,040
1	5-1	Bohle River	4,456	38	6
28	5-1	Bohle River	1,159,304	9,168	1,604
31	5-1	Bohle River	2,085,578	16,195	2,847
2	5-2	Bohle River 2	1,282,758	11,330	1,648
26	5-2	Bohle River 2	2,671,439	22,653	3,806
11	5-2	Bohle River 2	112,643	1,011	146
4	5-3	Shelly Beach			
		Bohle River SB	9,494,820	78,326	14,225
4	6-1	Pallarenda	209,142	2,979	389
23	6-2	Mundy Creek	266,413	2,128	451
5	6-3	Esplanade	148,072	719	204
17	6-3	Esplanade	47,117	245	75
19	6-4	Ross Creek	737,805	4,631	1,351
24	6-4	Ross Creek	213,744	1,300	369
9	6-5	Ross River (btdam)	678,635	6,385	949
29	6-5	Ross River (btdam)	2,053,436	13,186	2,736
30	6-5	Ross River (btdam)	304,765	2,042	556
18	6-5	Ross River (btdam)	294,538	1,920	516
12	6-5	Ross River (btdam)	127,764	1,184	170
		Lower Ross River SB	5,081,431	36,718	7,766
49	7-1	Ross River (atd)			
49	7-2	Six Mile Creek			
49	7-3	Toonpan Lagoon			
49	7-4	Antill Plains Creek			
49	7-5	Sachs Creek			
49	7-6	Mt Stuart			
		Upper Ross River SB	10,153,950	110,232	14,741
7	8-1	Stuart Creek			
7	8-2	Sandfly Creek			
		Stuart Creek SB	2,429,643	23,559	3,777
47	9-1	Alligator Creek	1,399,638	18,102	2,325
13	9-1	Alligator Creek	1,475,610	17,079	2,258
8	9-2	Crocodile Creek	645,762	12,243	1,359
25	9-3	Cocoa Creek	98,252	2,429	250
46	9-4	Cape Cleveland	58,513	1,145	133

60	9-4	Cape Cleveland	114,323	2,250	260
		Alligator Creek SB	3,792,099	53,248	6,586
59	10-1	West Coast	39,666	1,573	170
3	10-2	Picnic Bay	39,082	303	81
15	10-3	Nelly Bay	132,878	1,288	275
22	10-4	Arcadia	37,270	404	85
58	10-5	Radical Bay	10,366	376	42
57	10-6	Horseshoe Bay	126,742	1,798	283
56	10-7	Five Beach Bay	9,825	468	47
55	10-8	Rollingstone Bay	3,631	172	17
		Magnetic Island SB	399,459	6,383	1,000
		Black Basin	18,900,263	309,491	29,686
		Ross Basin	30,951,942	302,083	47,094
		Black Ross WQIP area	50,251,665	617,957	77,780

Table AC Load estimates based on the 2045 land use business as usual (BAU) scenario (base case) with cross reference between modelled sub catchments and WQIP catchments, sub basins and basins

Model SC No.	WQIP No.	Catchment	TSS	TN	TP
			kg/year	kg/year	kg/year
40	1-1	Crystal Creek	2,922,000	45,656	5,004
39	1-2	Lorna Creek	75,242	2,349	112
14	1-2	Lorna Ck /Ollera Ck	683,018	8,839	891
38	1-3	Ollera Creek	246,909	4,456	339
41	1-3	Ollera Creek	642,840	16,582	1,224
37	1-4	Scrubby Creek	275,033	6,721	438
36	1-5	Hencamp Creek	3,174,023	25,129	3,799
		Crystal Creek SB	8,019,064	109,732	11,806
21	2-1	Rollingstone Creek	1,723,980	24,800	2,648
53	2-2	Unnamed	202,349	2,444	333
54	2-3	Surveyors Creek	286,356	5,077	442
35	2-4	Wild Boar Creek	11,286	537	54
34	2-5	Station Creek	37,621	1,256	145
51	2-6	Saltwater Creek	511,350	9,606	1,158
51	2-7	Cassowary Creek			
50	2-8	Leichhardt Creek	244,352	9,716	621
		Rollingstone Creek SB	3,017,294	53,436	5,400
33	3-1	Sleeper Log Creek	606,315	22,207	983
42	3-2	Two Mile Creek	129,664	5,296	206
52	3-3	Bluewater Creek	1,037,310	35,575	1,479
43	3-3	Bluewater Creek	175,685	4,894	301
44	3-4	Deep Creek	858,338	31,010	1,359
		Bluewater Creek SB	2,807,312	98,983	4,327
48	4-1	Black River (upper and Alice)	6,209,250	54,057	8,036
45	4-1	Black River (lower)	1,519,440	18,847	2,546
		Black River SB	7,728,690	72,904	10,581
10	5-1	Bohle River	8,620	202	21
32	5-1	Bohle River	278,686	4,127	508
16	5-1	Bohle River	515,003	4,018	782
6	5-1	Bohle River	456,563	3,002	917
27	5-1	Bohle River	617,273	4,127	1,107
20	5-1	Bohle River	555,180	3,499	1,070
1	5-1	Bohle River	4,346	37	6

28	5-1	Bohle River	1,161,495	8,620	1,567
31	5-1	Bohle River	2,217,068	15,888	2,823
2	5-2	Bohle River 2	1,256,460	11,286	1,633
26	5-2	Bohle River 2	2,607,885	22,499	3,762
11	5-2	Bohle River 2	115,054	1,015	148
4	5-3	Shelly Beach			
		Bohle River SB	9,793,631	78,322	14,343
4	6-1	Pallarenda	242,891	2,867	413
23	6-2	Mundy Creek	302,792	2,301	486
5	6-3	Esplanade	169,111	712	217
17	6-3	Esplanade	54,788	256	81
19	6-4	Ross Creek	770,678	4,785	1,399
24	6-4	Ross Creek	216,593	1,304	376
9	6-5	Ross River (btdam)	1,077,488	9,058	1,392
29	6-5	Ross River (btdam)	2,761,290	15,267	3,346
30	6-5	Ross River (btdam)	359,771	2,118	606
18	6-5	Ross River (btdam)	258,597	1,925	402
12	6-5	Ross River (btdam)	180,799	1,519	226
		Lower Ross River SB	6,394,797	42,114	8,943
49	7-1	Ross River (atd)			
49	7-2	Six Mile Creek			
49	7-3	Toonpan Lagoon			
49	7-4	Antill Plains Creek			
49	7-5	Sachs Creek			
49	7-6	Mt Stuart			
		Upper Ross River SB	13,222,050	124,916	17,678
7	8-1	Stuart Creek			
7	8-2	Sandfly Creek			
		Stuart Creek SB	3,597,713	30,462	5,004
47	9-1	Alligator Creek	2,337,600	23,887	3,298
13	9-1	Alligator Creek	2,801,468	25,823	3,689
8	9-2	Crocodile Creek	913,125	13,514	1,618
25	9-3	Cocoa Creek	98,252	2,429	250
46	9-4	Cape Cleveland	58,075	1,143	133
60	9-4	Cape Cleveland	114,323	2,250	260
		Alligator Creek SB	6,322,843	69,047	9,248

59	10-1	West Coast	42,734	1,589	176
3	10-2	Picnic Bay	39,082	303	81
15	10-3	Nelly Bay	149,753	1,308	279
22	10-4	Arcadia	31,813	380	75
58	10-5	Radical Bay	13,806	387	48
57	10-6	Horseshoe Bay	194,678	1,921	361
56	10-7	Five Beach Bay	9,825	468	47
55	10-8	Rollingstone Bay	3,631	172	17
		Magnetic Island SB	485,322	6,527	1,084
		Black Basin	21,572,359	335,055	32,115
		Ross Basin	39,331,033	344,860	55,216
		Black Ross WQIP area	61,388,714	686,442	88,416

Source: CCI\WQ monitoring and modelling\Modelling BMT\loads etc\previous working\results tables 20090529 and 0601 0604 05.Updated using: CCI\WQ monitoring and modelling\Modelling BMT\loads etc\all diffuse no stps final results 0610 and 12

Table AD 2021 interpolated BAU diffuse source loads

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	t/year	t/year	t/year
Crystal Creek	1	24,074	239,283	6,516	97.9	10.4
Rollingstone Creek	2	21,986	144,635	2,169	45.6	4.6
Bluewater Creek	3	28,973	145,245	2,807	95.2	4.5
Black River (no STP)	4	30,258	114,411	7,409	70.7	10.2
Black Basin		105,291	643,574	18,900	309.5	29.7
Bohle River (no STPs)	5	33,155	132,384	9,495	78.3	14.2
Lower Ross River	6	13,478	54,146	5,081	36.7	7.8
Upper Ross River	7		196,578	10,154	110.2	14.7
Stuart Creek (no STP)	8	11,158	47,483	2,430	23.6	3.8
Alligator Creek	9	27,365	104,410	3,792	53.2	6.6
Ross Basin		85,155	535,001	30,952	302	47.1
Magnetic Island	10	4,923	27,430	399	6.4	1
Black Ross Total		195,369	1,206,004	50,252	618	77.8

Table AE 2045 modelled BAU diffuse source loads

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	t/year	t/year	t/year
Crystal Creek	1	24,074	239,042	8,019	110	11.8
Rollingstone Creek	2	21,986	14,5008	3,017	53.4	5.4
Bluewater Creek	3	28,973	144,566	2,807	98.9	4.3
Black River (no STP)	4	30,258	114,433	7,729	72.9	10.6
Black Basin		105,291	643,048	21,572	335	32.1
Bohle River (no STPs)	5	33,155	133,397	9,794	78.3	14.3
Lower Ross River	6	13,478	54,795	6,395	42.1	8.9
Upper Ross River	7		196,139	13,222	124.9	17.7
Stuart Creek (no STP)	8	11,158	47,483	3,598	30.5	5
Alligator Creek	9	27,365	103,775	6,323	69	9.2
Ross Basin		85,155	535,589	39,331	344.9	55.2
Magnetic Island	10	4,923	27,489	485	6.5	1.1
Black Ross Total		195,369	1,206,126	61,389	686.4	88.4

Table AF TSS diffuse source BAU load changes from 2005 to 2021 and 2045

Catchment	Base case (2005)	2021	Change (from Base)		2045	Change (from Base)	
			t/year	%		t/year	%
Crystal Creek SB	5,513.4	6,515.7	1,002.2	18	8,019	2,505.6	45
Rollingstone Creek SB	1,603	2,168.7	565.7	35	3,017.3	1,414.2	88
Bluewater Creek SB	2,806.9	2,807.1	146	0	2,807.3	365	0
Black River SB	7,195.4	7,408.7	213.3	3	7,728.7	533.3	7
Black Basin	17,118.9	18,900.3	1,781.4	10	21,572.4	4,453.5	26
Bohle River SB	9,295.6	9,494.8	199.2	2	9,793.6	498	5
Lower Ross River SB	4,205.9	5,081.4	875.6	21	6,394.8	2,188.9	52
Upper Ross River SB	8,108.6	10,154	2,045.4	25	13,222.1	5,113.5	63
Stuart Creek SB	1,650.9	2,429.6	778.7	47	3,597.7	1,946.8	118
Alligator Creek SB	2,104.9	3,792.1	1,687.2	80	6,322.8	4,217.9	200
Ross Basin	25,365.9	30,951.9	5,586	22	39,331	13,965.1	55
Magnetic Island SB	342.2	399.5	57.2	17	485	143.1	42
Black Ross WQIP area	42,827	50,251.7	7,424.7	17	61,388.7	18,561.7	43

Table AG TN diffuse source BAU load changes from 2005 to 2021 and 2045

Catchment	Base case (2005)	2021	Change (from Base)		2045	Change (from Base)	
			t/year	%		t/year	%
Crystal Creek SB	90.1	98	7.8	8.7	109.7	19.6	21.8
Rollingstone Creek SB	40.4	45.6	5.2	12.8	53.4	13	32.1
Bluewater Creek SB	92.7	95.2	2.5	2.7	99	6.3	6.8
Black River SB	69.2	70.7	1.5	2.2	72.9	3.7	5.4
Black Basin	292.4	309.5	17	5.8	335.1	42.6	14.6
Bohle River SB	78.3	78.3	-2	0.0	78.3	-6	0.0
Lower Ross River SB	33.1	36.7	3.6	10.9	42.1	9	27.2
Upper Ross River SB	100.4	110.2	9.8	9.7	124.9	24.5	24.4
Stuart Creek SB	19	23.6	4.6	24.3	30.5	11.5	60.7
Alligator Creek SB	42.7	53.2	10.5	24.7	69	26.3	61.6
Ross Basin	273.5	302	28.5	10.4	344.9	71.3	26.1
Magnetic Island SB	6.3	6.4	96	1.5	6.5	241	3.8
Black Ross WQIP area	572.3	618	45.7	8.0	686	114.1	19.9

Table AH TP diffuse source BAU load changes from 2005 to 2021 and 2045

Catchment	Base case (2005)	2021	Change (from Base)		2045	Change (from Base)	
			t/year	%		t/year	%
Crystal Creek SB	9.4	10.4	1	10.3	11.8	2.4	25.8
Rollingstone Creek SB	4	4.6	0.6	13.7	5.4	1,.4	34.3
Bluewater Creek SB	4.6	4.5	-0.1	-2.7	4.3	-0.3	-6.7
Black River SB	10	10.2	0.2	2.2	10.6	0.6	5.6
Black Basin	28.1	29.7	1.6	5.8	32.1	4	14.4
Bohle River SB	14.1	14.2	0.1	0.6	14.3	0.2	1.4
Lower Ross River SB	7	7.8	0.8	11.2	9	2	28.1
Upper Ross River SB	12.8	14.7	2	15.3	17.7	4.9	38.3
Stuart Creek SB	3	3.8	0.8	27.7	5	2	69.1
Alligator Creek SB	4.8	6.6	1.8	36.9	9.2	4.4	92.2
Ross Basin	41.7	47.1	5.4	13.0	55.2	13.5	32.5
Magnetic Island SB	944	1	0.1	6.0	1.1	0.1	14.9
Black Ross WQIP area	70.7	77.8	7.1	10.0	88.4	17.7	25.1

Table AI All diffuse source pollutants loads and flow summary for BAU and changes from 1850 to 2005, 2021 and 2045, and 2005 to 2021 and 2045

Sub Basin	Area	2005 Flow	2005 TSS	2005 TN	2005 TP	2021 TSS	2021 TN	2021 TP	2045 Flow	2045 TSS	2045 TN	2045 TP
	Hectare	ML/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	ML/year	kg/year	kg/year	kg/year
Crystal Creek	22,629	239,443	5,513,449	90,122	9,383	6,515,695	97,966	10,352	239,042	8,019,064	109,732	11,806
Rollingstone Creek	21,822	144,387	1,603,046	40,448	4,021	2,168,745	45,643	4,572	14,5008	3,017,294	53,436	5,400
Bluewater Creek	28,872	145,698	2,806,946	92,700	4,641	2,807,092	95,213	4,515	144,566	2,807,312	98,983	4,327
Black River	29,539	114,396	7,195,425	69,178	10,022	7,408,731	70,669	10,246	114,433	7,728,690	72,904	10,581
Black Basin total	105,291	643,925	17,118,866	292,448	28,067	18,900,263	309,491	29,686	643,048	21,572,359	335,055	32,115
Bohle River	33,194	131,708	9,295,613	78,328	14,146	9,494,820	78,326	14,225	133,397	9,793,631	78,322	14,343
Lower Ross River	13,244	53,714	4,205,854	33,120	6,981	5,081,431	36,718	7,766	54,795	6,394,797	42,114	8,943
Upper Ross River	74,929	196,870	8,108,550	100,444	12,784	10,153,950	110,232	14,741	196,139	13,222,050	124,916	17,678
Stuart Creek	11,024	47,483	1,650,930	18,956	2,959	2,429,643	23,559	3,777	47,483	3,597,713	30,462	5,004
Alligator Creek	27,490	104,834	2,104,936	42,716	4,811	3,792,099	53,248	6,586	103,775	6,322,843	69,047	9,248
Ross Basin total	159,882	534,608	25,365,882	273,565	41,680	30,951,942	302,083	47,094	535,589	39,331,033	344,860	55,216
Magnetic Island	4,815	27,390	342,217	6,286	944	399,459	6,383	1,000	27,489	485,322	6,527	1,084
Black Ross Total	267,559	1,205,923	42,826,965	572,299	70,690	50,251,665	617,957	77,780	1,206,126	61,388,714	686,442	88,416
Change from 2005						7,424,700	45,657	7,090	202	18,561,749	114,143	17,726
% change from 2005						17	8	10	0	43	20	25
Change from 1850		21,485	30,718,792	227,354	34,388	38,143,492	273,011	41,478	21,688	49,280,542	341,497	52,114
% increase from 1850		1.8	254	66	95	315	79	114	1.8	407	99	144

Note: Figures represent average annual outputs. 1850 is considered to be the pre-settlement scenario with 'natural' background outputs from a forested catchment. 2005 is the base case for current loads using the most recent land use data. 2021 is the medium term scenario where differences could be seen at the 'paddock' scale from the introduction of management practice scenarios and 2045 is the long term scenario where wide spread adoption of water quality improvement measures may be measured at the end of catchment through water quality monitoring. Figures have been rounded to the nearest whole number (Updated using 9/6/09, 10/6/09 and 12/6/09 data)

Land use

Table LA Land use area and percentage change by sub basin for modelling load change from 2005 to 2045

Landuse	Urban 2				Rural Residential				Green Space				Rural			
Sub basin	Area (hectares)		Change		Area (hectares)		Change		Area (hectares)		Change		Area (hectares)		Change	
	2006	2045	Ha	%	2006	2045	Ha	%	2006	2045	Ha	%	2006	2045	Ha	%
Crystal	3.2	81	77.9	2,453	15	15			15,777	15,777	0	0.0	6,833	6,755	-78	-1.1
Rollingstone	22	200	178	824	83	106	23	27	16,336	16,336	0	0.0	5,381	5,181	-201	-3.7
Bluewater	26	69	42.5	163	429	622	193	45	2,759	2,759	0	0.0	25,658	25,422	-235	-0.9
Black	70	320	250	358	531	669	137	26	1,963	1,963	0	0.0	26,974	26,587	-387	-1.4
Bohle	2146	4937	2791	130	1,376	1,732	356	26	5,650	5,650	0	0.0	24,022	20,876	-3,146	-13.1
Lower Ross	3112	4776	1660	53	5	6	1	13	3,698	3,629	-68	-1.8	6,430	4,837	-1,592	-24.8
Upper Ross	1	14	13	1,899	106	203	97	91	7,053	7,053	0	0.0	67,769	67,659	-110	-0.2
Stuart	27	44	17	64	19	32	13	66	1,623	1,623	0	0.0	9,355	9,325	-30	-0.3
Alligator	1	2	1	47	306	608	302	99	16,537	16,537	0	0.0	10,645	10,343	-302	-2.8
Magnetic Is.	75	339	264	350	25	37	12	50	4,486	4,423	-63	-1.4	230	17	-213	-92.6
Black Basin	121	669	548	454	1,058	1,412	353	33	36,836	36,836	0	0.0	64,846	63,945	-901	-1.4
Ross Basin	5,287	9,768	4,481	85	1,813	2,581	768	42	34,562	34,494	-68	-0.2	118,221	113,040	-5,181	-4.4
Black Ross	5,483	10,776	5,293	97	2,896	4,029	1,133	39	75,883	75,752	-131	-0.2	183,297	177,002	-6,295	-3.4

Note: Figures have been rounded to the nearest whole number except for percentages in greenspace and rural land uses. Urban 2 is the sum of urban (residential) and Commercial and industrial land use categories

Table LB Land use area change by sub basin and percentage change relative to WQIP area for modelling load change from 2005 to 2045

Sub basin	C and I		Urban		Urban 2		Rural Res		Green Space		Agriculture		Grazing		Rural	
	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR	Ha	% BR
Crystal	1.5	0.6	76	1.5	77.9	1.5	0	0.0	0	0.0	-74	-2.6	-4	-0.1	-78	-1.2
Rollingstone	1.1	0.5	177	3.5	178	3.4	23	2.0	0	0.0	-37	-1.3	-164	-4.8	-201	-3.2
Bluewater	1.0	0.4	41	0.8	42.5	0.8	193	17.0	0	0.0	-3	-0.1	-232	-6.8	-235	-3.7
Black	1.8	0.7	248	4.9	250	4.7	137	12.1	0	0.0	-49	-1.7	-339	-9.9	-387	-6.2
Bohle	130.6	53.6	2,660	52.7	2791	52.7	356	31.4	0	0.0	-916	-31.8	-2,230	-65.4	-3,146	-50.0
Lower Ross	101.4	41.6	1,559	30.9	1660	31.4	1	0.1	-68	-52.1	-1,493	-51.7	-99	-2.9	-1,592	-25.3
Upper Ross	0.0	0.0	13	0.3	13	0.2	97	8.6	0	0.0	-6	-0.2	-104	-3.0	-110	-1.7
Stuart	3.9	1.6	13	0.3	17	0.3	13	1.1	0	0.0	-13	-0.5	-17	-0.5	-30	-0.5
Alligator	0.6	0.2	0	0.0	1	0.0	302	26.6	0	0.0	-293	-10.2	-9	-0.3	-302	-4.8
Magnetic Is.	1.8	0.7	262	5.2	264	5.0	12	1.1	-63	-48.1	0	0.0	-213	-6.2	-213	-3.4
Black Basin	5.5	2.2	543	10.7	548	10.4	353	31.2	0	0.0	-163	-5.7	-738	-21.6	-901	-14.3
Ross Basin	236.5	97.0	4,245	84.1	4,481	84.7	768	67.8	-68	-52.1	-2,722	-94.3	-2,458	-72.1	-5,181	-82.3
Black Ross	243.7	100.0	5,049	100.0	5,293	100.0	1,133	100	-131	-100	-2,886	-100.0	-3,409	-100.0	-6,295	-100

Table LC Land use change by WQIP area for modelling load change from 2005 to 2045

Land use	C and I	Urban	Urban 2	Rural Res	Greenspace	Agriculture	Grazing	Rural
2005 hectares	335	5,148	5,483	2,896	75,883	30,744	152,553	183,297
2005 %	0	2	2.05	1	28	11	57	69
2045 hectares	578	10,197	10,776	4,029	75,752	27,858	149,144	177,002
2045 %	0	4	4.03	2	28	10	56	66
Change (ha)	243	5,049	5,293	1133	-131	-2886	-3409	-6295
% change	0.09	1.89	1.98	0.42	-0.05	-1.08	-1.27	-2.35

Scenario load reduction potential

Table BA Potential TSS load reductions at 2045 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Sub Basin	BAU	GF WSUD	Change	% SB	% BR	All WSUD	Change	% SB	% BR	Rural BMP	Change	% SB	% BR
	t/year	t/year	t/year			t/year	t/year			t/year	t/year	t/year	
Crystal Creek	8,019	7,847	172	2.1	11.8	7,847	172	2.1	2.8	3,349	4,670	58.2	17.8
Rollingstone Creek	3,017	2,841	176	5.8	12.2	2,736	281	9.3	4.5	1,656	1,361	45.1	5.2
Bluewater Creek	2,807	2,803	4	0.1	0.3	2,778	29	1.0	0.5	1,735	1,072	38.2	4.1
Black River	7,729	7,729	0	0	0	7,433	296	3.8	4.7	4,489	3,240	41.9	12.4
Bohle River	9,794	8,972	822	8.4	56.7	7,268	2526	25.8	40.5	6,931	2,863	29.2	10.9
Lower Ross River	6,395	6,221	174	2.7	12.0	3,760	2635	41.2	42.2	4,716	1,679	26.2	6.4
Upper Ross River	13,222	13,222	0	0	0	13,222	0	0	0	6,940	6,282	47.5	24.0
Stuart Creek	3,598	3,598	0	0	0	3,568	30	0.8	0.5	1,855	1,743	48.4	6.6
Alligator Creek	6,323	6,323	0	0	0	6,323	0	0	0	3,009	3,314	52.4	12.6
Magnetic Island	485	384	101	20.8	7.0	214	271	55.9	4.3	485	0	0	0
Black Basin	21,572	21,220	352	1.6	24.3	20,795	777	3.6	12.5	11,229	10,343	47.9	39.4
Ross Basin	39,331	38,335	996	2.5	68.7	34,141	5190	13.2	83.2	23,452	15,879	40.4	60.6
Black Ross Total	61,389	59,939	1,450	2.4	100.0	55,150	6239	10.2	100.0	35,166	26,223	42.7	100.0

Note: BAU is business as usual i.e. no water quality improvement actions applied. SB is sub basin. BR is Black Ross WQIP area GF WSUD is

Table BB Potential TSS load reductions at 2021 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Sub Basin	BAU	GF WSUD	Change	% SB	% BR	All WSUD	Change	% SB	% BR	Rural BMP	Change	% SB	% BR
	t/year	t/year	t/year			t/year	t/year			t/year	t/year	t/year	
Crystal Creek	6,516	6,447	-69	1.1	11.8	6,447	-69	1.1	2.8	4,648	-1,868	28.7	17.8
Rollingstone Creek	2,169	2,098	-71	3.3	12.2	2,056	-112	5.2	4.5	1,624	-545	25.1	5.2
Bluewater Creek	2,807	2,805	-2	0.1	0.3	2,796	-12	0.4	0.5	2,378	-429	15.3	4.1
Black River	7,409	7,409	0	0	0	7,290	-118	1.6	4.7	6,113	-1,296	17.5	12.4
Bohle River	9,495	9,166	-329	3.5	56.7	8,484	-1,010	10.6	40.5	8,350	-1,145	12.1	10.9
Lower Ross River	5,081	5,012	-70	1.4	12.0	4,028	-1,054	20.7	42.2	4,410	-671	13.2	6.4
Upper Ross River	10,154	10,154	0	0	0	10,154	0	0	0	7,641	-2,513	24.7	24.0
Stuart Creek	2,430	2,430	0	0	0	2,418	-12	0.5	0.5	1,733	-697	28.7	6.6
Alligator Creek	3,792	3,792	0	0	0	3,792	0	0	0	2,467	-1,325	35.0	12.6
Magnetic Island	399	359	-40	10.1	7.0	291	-109	27.2	4.4	399	0	0	0
Black Basin	18,900	18,759	-141	0.7	24.3	18,589	-311	1.6	12.5	14,763	-4,137	21.9	39.4
Ross Basin	30,952	30,554	-398	1.3	68.7	28,876	-2,076	6.7	83.2	24,600	-6,352	20.5	60.6
Black Ross Total	50,252	49,672	-580	1.2	100.0	47,756	-2,495	5.0	100.0	39,763	-10,489	20.9	100.0

Table BC Potential TN load reductions at 2045 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Sub Basin	BAU	GF WSUD	Change	% SB	% BR	All WSUD	Change	% SB	% BR	Rural BMP	Change	% SB	% BR
	t/year	t/year	t/year			t/year	t/year			t/year	t/year	t/year	
Crystal Creek	109.7	109.5	0.2	0.1	12.5	109.5	0.2	0.1	1.3	97.7	12.0	10.9	19.4
Rollingstone Creek	53.4	53.2	0.2	0.3	12.5	53.0	0.4	0.8	3.6	49.1	4.3	8.1	7.0
Bluewater Creek	99.0	98.9	0.1	0.1	4.5	98.9	0.1	0.1	0.8	87.6	11.4	11.5	18.5
Black River	72.9	72.9	0	0	-0.3	72.1	0.8	1.0	6.6	66.5	6.4	8.8	10.4
Bohle River	78.3	77.4	0.9	1.1	74.6	73.1	5.2	6.7	44.9	73.4	4.9	6.3	8.0
Lower Ross River	42.1	41.9	0.2	0.4	15.2	37.4	4.7	11.2	40.8	39.0	3.1	7.3	5.0
Upper Ross River	125.0	124.9	0.1	0.1	7.0	124.9	0.1	0.1	0.7	114.3	10.7	8.5	17.3
Stuart Creek	30.5	30.5	0	0.1	3.2	30.4	0.1	0.4	1.0	27.3	3.2	10.4	5.2
Alligator Creek	69.0	69.0	0	-0.1	-3.9	69.0	0.0	-0.1	-0.4	62.9	6.1	8.8	9.9
Magnetic Island	6.5	6.4	0.1	1.5	8.4	6.0	0.5	8.2	4.6	6.5	0	-0.4	0.0
Black Basin	335.1	334.6	0.5	0.1	37.6	333.6	1.5	0.5	13.1	300.9	34.2	10.2	55.4
Ross Basin	344.9	343.7	1.2	0.3	96.1	334.8	10.1	2.9	87.0	316.9	28.0	8.1	45.4
Black Ross Total	686.0	684.8	1.2	0.2	100	674.4	11.6	1.7	100	624.4	61.6	9.0	100

Table BD Potential TN load reductions at 2021 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Sub Basin	BAU	GF WSUD	Change	% SB	% BR	All WSUD	Change	% SB	% BR	Rural BMP	Change	% SB	% BR
	t/year	t/year	t/year			t/year	t/year			t/year	t/year	t/year	
Crystal Creek	98	98	-0.07	0.1	11.1	98	-0.1	0.1	1.5	93	-4.8	4.9	19
Rollingstone Creek	46	46	-0.07	0.2	11.3	45	-0.2	0.4	3.7	44	-1.7	3.8	7
Bluewater Creek	95	95	-0.01	0	2.2	95	0	0	0.6	91	-4.5	4.8	18
Black River	71	71	0.00	0	0	70	-0.3	0.4	6.3	68	-2.6	3.6	10
Bohle River	78	78	-0.37	0.5	55.7	76	-2.1	2.7	43.3	76	-2.0	2.5	8
Lower Ross River	37	37	-0.08	0.2	11.9	35	-1.9	5.2	39.3	35	-1.2	3.4	5
Upper Ross River	110	110	0	0	0	110	0	0	0	106	-4.2	3.8	17
Stuart Creek	24	24	0	0	0	24	0	0.1	0.6	22	-1.3	5.3	5
Alligator Creek	53	53	0	0	0	53	0	0	0	51	-2.5	4.6	10
Magnetic Island	6	6	-0.05	0.8	7.8	6	-0.2	3.5	4.7	6	0	0	0
Black Basin	309	309	-0.16	0.1	24.6	309	-0.6	0.2	12.2	296	-13.6	4.4	55
Ross Basin	302	302	-0.45	0.1	67.6	298	-4.0	1.3	83.2	291	-11.2	3.7	45
Black Ross Total	618	617	-0.66	0.1	100	613	-4.8	0.8	100	593	-24.8	4.0	100

Table BE Potential TP load reductions at 2045 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Sub Basin	BAU	GF WSUD	Change	% SB	% BR	All WSUD	Change	% SB	% BR	Rural BMP	Change	% SB	% BR
	t/year	t/year	t/year			t/year	t/year			t/year	t/year	t/year	
Crystal Creek	11.8	11.7	0.1	0.9	11.3	11.7	0.1	0.9	1.5	11.0	0.8	6.8	12.5
Rollingstone Creek	5.4	5.3	0.1	2.2	13.0	5.1	0.3	4.9	3.9	5.1	0.3	4.8	4.0
Bluewater Creek	4.3	4.3	0	-0.6	-2.7	4.3	0	0.2	0.1	3.9	0.4	8.9	6.0
Black River	10.6	10.6	0	0.2	2.1	10.2	0.4	3.9	6.2	9.6	1.0	9.6	15.8
Bohle River	14.3	13.8	0.5	3.3	51.7	11.4	2.9	20.0	42.3	13.5	0.8	5.6	12.4
Lower Ross River	8.9	8.8	0.1	0.7	7.0	6.3	2.6	29.6	38.9	8.7	0.2	2.5	3.4
Upper Ross River	17.7	17.7	0	0.1	2.4	17.7	0	0.1	0.3	15.7	2.0	11.1	30.5
Stuart Creek	5.0	5.0	0	-0.1	-0.4	4.9	0.1	1.4	1.0	4.6	0.4	7.2	5.6
Alligator Creek	9.2	9.2	0	-0.5	-5.3	9.2	0	-0.5	-0.7	8.7	0.5	5.5	7.9
Magnetic Island	1.1	1.0	0.1	8.0	9.6	0.8	0.3	30.0	4.9	1.1	0.0	1.5	0.2
Black Basin	32.1	31.9	0.2	0.7	23.6	31.3	0.8	2.5	11.7	29.6	2.5	7.7	38.4
Ross Basin	55.2	54.6	0.6	1.1	66.4	49.6	5.6	10.2	83.4	51.3	3.9	7.1	61.4
Black Ross Total	88.4	87.5	0.9	1.0	100	81.6	6.8	7.7	100	82.0	6.4	7.3	100

Table BF Potential TP load reductions at 2021 for all management practice scenarios and percentage change from BAU for sub basins and WQIP area

Sub Basin	BAU	GF WSUD	Change	% SB	% BR	All WSUD	Change	% SB	% BR	Rural BMP	Change	% SB	% BR
	t/year	t/year	t/year			t/year	t/year			t/year	t/year	t/year	
Crystal Creek	10.4	10.3	-0.04	0.4	11.8	10.3	-0.04	0.4	1.6	10.0	-0.32	3.1	12.6
Rollingstone Creek	4.6	4.5	-0.05	1.0	12.8	4.5	-0.11	2.3	3.9	4.5	-0.10	2.3	4.0
Bluewater Creek	4.5	4.5	0	0	0.3	4.5	-0.01	0.3	0.5	4.4	-0.16	3.6	6.4
Black River	10.2	10.2	0	0	0	10.1	-0.16	1.6	5.9	9.8	-0.40	3.9	15.5
Bohle River	14.2	14.0	-0.21	1.4	55.5	13.1	-1.16	8.2	42.9	13.9	-0.34	2.4	13.1
Lower Ross River	7.8	7.7	-0.04	0.5	11.5	6.7	-1.07	13.8	39.5	7.7	-0.10	1.4	4.1
Upper Ross River	14.7	14.7	0	0	0	14.7	0	0	0	14.0	-0.77	5.3	30.1
Stuart Creek	3.8	3.8	0	0	0	3.7	-0.03	0.8	1.1	3.6	-0.15	3.9	5.7
Alligator Creek	6.6	6.6	0	0	0	6.6	0	0	0	6.4	-0.22	3.3	8.6
Magnetic Island	1.0	1.0	-0.03	2.9	7.8	0.9	-0.13	12.6	4.6	1.0	0	0	0
Black Basin	29.7	29.6	-0.09	0.3	24.9	29.4	-0.32	1.1	11.9	28.7	-0.99	3.3	38.5
Ross Basin	47.1	46.8	-0.25	0.5	67.0	44.8	-2.26	4.8	83.6	45.5	-1.58	3.4	61.5
Black Ross Total	77.8	77.4	-0.37	0.5	100	75.1	-2.71	3.5	100	75.2	-2.57	3.3	100

Table BG Potential load change at 2045 from BAU by implementing GF WSUD and percentage change by sub basin and WQIP area for all pollutants

Sub Basin	TSS BAU t/year	TSS WSUD t/year	TSS Change t/year	TSS % SB	TSS % BR	TN BAU t/year	TN WSUD t/year	TN Change t/year	TN % SB	TN % BR	TP BAU t/year	TP WSUD t/year	TP Change t/year	TP % SB	TP % BR
Crystal Creek	8,019	7,847	-172	2.1	11.8	109.7	109.5	-0.2	0.1	12.5	11.8	11.7	-0.1	0.9	11.3
Rollingstone Creek	3,017	2,841	-176	5.8	12.2	53.4	53.2	-0.2	0.3	12.5	5.4	5.3	-0.1	2.2	13.0
Bluewater Creek	2,807	2,803	-4	0.1	0.3	99.0	98.9	-0.1	0.1	4.5	4.3	4.3	0.0	-0.6	-2.7
Black River	7,729	7,729	0	0.0	0.0	72.9	72.9	0.0	0.0	-0.3	10.6	10.6	0.0	0.2	2.1
Bohle River	9,794	8,972	-822	8.4	56.7	78.3	77.4	-0.9	1.1	74.6	14.3	13.8	-0.5	3.3	51.7
Lower Ross River	6,395	6,221	-174	2.7	12.0	42.1	41.9	-0.2	0.4	15.2	8.9	8.8	-0.1	0.7	7.0
Upper Ross River	13,222	13,222	0	0.0	0.0	125.0	124.9	-0.1	0.1	7.0	17.7	17.7	0.0	0.1	2.4
Stuart Creek	3,598	3,598	0	0.0	0.0	30.5	30.5	0.0	0.1	3.2	5.0	5.0	0.0	-0.1	-0.4
Alligator Creek	6,323	6,323	0	0.0	0.0	69.0	69.0	0.0	-0.1	-3.9	9.2	9.2	0.0	-0.5	-5.3
Magnetic Island	485	384	-101	20.8	7.0	6.5	6.4	-0.1	1.5	8.4	1.1	1.0	-0.1	8.0	9.6
Black Basin	21,572	21,220	-352	1.6	24.3	335.1	334.6	-0.5	0.1	37.6	32.1	31.9	-0.2	0.7	23.6
Ross Basin	39,331	38,335	-996	2.5	68.7	344.9	343.7	-1.2	0.3	96.1	55.2	54.6	-0.6	1.1	66.4
Black Ross Total	61,389	59,939	-1,450	2.4	100.0	686.0	684.8	-1.2	0.2	100	88.4	87.5	0.9	1.0	100

Table BH Potential load change at 2045 from BAU by implementing GF WSUD and percentage change by sub basin and WQIP area for all pollutants

	TSS	TSS	TSS	TSS	TSS	TN	TN	TN	TN	TN	TP	TP	TP	TP	TP
Sub Basin	**BAU**	**WSUD**	**Change**			**BAU**	**WSUD**	**Change**			**BAU**	**WSUD**	**Change**		
	t/year	**t/year**	**t/year**	**% SB**	**% BR**	**t/year**	**t/year**	**t/year**	**% SB**	**% BR**	**t/year**	**t/year**	**t/year**	**% SB**	**% BR**
Crystal Creek	6,516	6,447	-69	1.1	11.8	98	98	-0.07	0.1	11.1	10.4	10.3	-0.04	0.4	11.8
Rollingstone Creek	2,169	2,098	-71	3.3	12.2	46	46	-0.07	0.2	11.3	4.6	4.5	-0.05	1.0	12.8
Bluewater Creek	2,807	2,805	-2	0.1	0.3	95	95	-0.01	0	2.2	4.5	4.5	0	0	0.3
Black River	7,409	7,409	0	0	0	71	71	0.00	0	0	10.2	10.2	0	0	0
Bohle River	9,495	9,166	-329	3.5	56.7	78	78	-0.37	0.5	55.7	14.2	14.0	-0.21	1.4	55.5
Lower Ross River	5,081	5,012	-70	1.4	12.0	37	37	-0.08	0.2	11.9	7.8	7.7	-0.04	0.5	11.5
Upper Ross River	10,154	10,154	0	0	0	110	110	0	0	0	14.7	14.7	0	0	0
Stuart Creek	2,430	2,430	0	0	0	24	24	0	0	0	3.8	3.8	0	0	0
Alligator Creek	3,792	3,792	0	0	0	53	53	0	0	0	6.6	6.6	0	0	0
Magnetic Island	399	359	-40	10.1	7.0	6	6	-0.05	0.8	7.8	1.0	1.0	-0.03	2.9	7.8
Black Basin	18,900	18,759	-141	0.7	24.3	309	309	-0.16	0.1	24.6	29.7	29.6	-0.09	0.3	24.9
Ross Basin	30,952	30,554	-398	1.3	68.7	302	302	-0.45	0.1	67.6	47.1	46.8	-0.25	0.5	67.0
Black Ross Total	50,252	49,672	-580	1.2	100.0	618	617	-0.66	0.1	100	77.8	77.4	-0.37	0.5	100

Table BI Potential load change at 2045 from BAU by implementing All urban WSUD and percentage change by sub basin and WQIP area for all pollutants

Sub Basin	TSS BAU t/year	TSS WSUD t/year	TSS Change t/year	TSS % SB	TSS % BR	TN BAU t/year	TN WSUD t/year	TN Change t/year	TN % SB	TN % BR	TP BAU t/year	TP WSUD t/year	TP Change t/year	TP % SB	TP % BR
Crystal Creek	8,019	7,847	172	2.1	2.8	109.7	109.5	0.2	0.1	1.3	11.8	11.0	0.8	6.8	12.5
Rollingstone Creek	3,017	2,736	281	9.3	4.5	53.4	53.0	0.4	0.8	3.6	5.4	5.1	0.3	4.8	4.0
Bluewater Creek	2,807	2,778	29	1.0	0.5	99.0	98.9	0.1	0.1	0.8	4.3	3.9	0.4	8.9	6.0
Black River	7,729	7,433	296	3.8	4.7	72.9	72.1	0.8	1.0	6.6	10.6	9.6	1.0	9.6	15.8
Bohle River	9,794	7,268	2526	25.8	40.5	78.3	73.1	5.2	6.7	44.9	14.3	13.5	0.8	5.6	12.4
Lower Ross River	6,395	3,760	2635	41.2	42.2	42.1	37.4	4.7	11.2	40.8	8.9	8.7	0.2	2.5	3.4
Upper Ross River	13,222	13,222	0	0.0	0.0	125.0	124.9	0.1	0.1	0.7	17.7	15.7	2.0	11.1	30.5
Stuart Creek	3,598	3,568	30	0.8	0.5	30.5	30.4	0.1	0.4	1.0	5.0	4.6	0.4	7.2	5.6
Alligator Creek	6,323	6,323	0	0.0	0.0	69.0	69.0	0.0	-0.1	-0.4	9.2	8.7	0.5	5.5	7.9
Magnetic Island	485	214	271	55.9	4.3	6.5	6.0	0.5	8.2	4.6	1.1	1.1	0.0	1.5	0.2
Black Basin	21,572	20,795	777	3.6	12.5	335.1	333.6	1.5	0.5	13.1	32.1	29.6	2.5	7.7	38.4
Ross Basin	39,331	34,141	5190	13.2	83.2	344.9	334.8	10.1	2.9	87.0	55.2	51.3	3.9	7.1	61.4
Black Ross Total	61,389	55,150	6239	10.2	100.0	686.0	674.4	11.6	1.7	100	88.4	82.0	6.4	7.3	100

Table BJ Potential load change at 2021 from BAU by implementing All urban WSUD and percentage change by sub basin and WQIP area for all pollutants

Sub Basin	TSS BAU t/year	TSS WSUD t/year	TSS Change t/year	TSS % SB	TSS % BR	TN BAU t/year	TN WSUD t/year	TN Change t/year	TN % SB	TN % BR	TP BAU t/year	TP WSUD t/year	TP Change t/year	TP % SB	TP % BR
Crystal Creek	6,516	6,447	-69	1.1	2.8	98	98	-0.1	0.1	1.5	10.4	10.3	-0.04	0.4	1.6
Rollingstone Creek	2,169	2,056	-112	5.2	4.5	46	45	-0.2	0.4	3.7	4.6	4.5	-0.11	2.3	3.9
Bluewater Creek	2,807	2,796	-12	0.4	0.5	95	95	0	0	0.6	4.5	4.5	-0.01	0.3	0.5
Black River	7,409	7,290	-118	1.6	4.7	71	70	-0.3	0.4	6.3	10.2	10.1	-0.16	1.6	5.9
Bohle River	9,495	8,484	-1,010	10.6	40.5	78	76	-2.1	2.7	43.3	14.2	13.1	-1.16	8.2	42.9
Lower Ross River	5,081	4,028	-1,054	20.7	42.2	37	35	-1.9	5.2	39.3	7.8	6.7	-1.07	13.8	39.5
Upper Ross River	10,154	10,154	0	0	0	110	110	0	0	0	14.7	14.7	0	0	0
Stuart Creek	2,430	2,418	-12	0.5	0.5	24	24	0	0.1	0.6	3.8	3.7	-0.03	0.8	1.1
Alligator Creek	3,792	3,792	0	0	0	53	53	0	0	0	6.6	6.6	0	0	0
Magnetic Island	399	291	-109	27.2	4.4	6	6	-0.2	3.5	4.7	1.0	0.9	-0.13	12.6	4.6
Black Basin	18,900	18,589	-311	1.6	12.5	309	309	-0.6	0.2	12.2	29.7	29.4	-0.32	1.1	11.9
Ross Basin	30,952	28,876	-2,076	6.7	83.2	302	298	-4.0	1.3	83.2	47.1	44.8	-2.26	4.8	83.6
Black Ross Total	50,252	47,756	-2,495	5.0	100.0	618	613	-4.8	0.8	100	77.8	75.1	-2.71	3.5	100

Table BK Potential load change at 2045 from BAU by implementing Rural BMP and percentage change by sub basin and WQIP area for all pollutants

Sub Basin	TSS BAU t/year	TSS BMP t/year	TSS Change t/year	TSS % SB	TSS % BR	TN BMP t/year	TN WSUD t/year	TN Change t/year	TN % SB	TN % BR	TP BAU t/year	TP BMP t/year	TP Change t/year	TP % SB	TP % BR
Crystal Creek	8,019	3349	4,670	58.2	17.8	109.7	97.7	12.0	10.9	19.4	11.8	11.0	0.8	6.8	12.5
Rollingstone Creek	3,017	1656	1,361	45.1	5.2	53.4	49.1	4.3	8.1	7.0	5.4	5.1	0.3	4.8	4.0
Bluewater Creek	2,807	1735	1,072	38.2	4.1	99.0	87.6	11.4	11.5	18.5	4.3	3.9	0.4	8.9	6.0
Black River	7,729	4489	3,240	41.9	12.4	72.9	66.5	6.4	8.8	10.4	10.6	9.6	1.0	9.6	15.8
Bohle River	9,794	6931	2,863	29.2	10.9	78.3	73.4	4.9	6.3	8.0	14.3	13.5	0.8	5.6	12.4
Lower Ross River	6,395	4716	1,679	26.2	6.4	42.1	39.0	3.1	7.3	5.0	8.9	8.7	0.2	2.5	3.4
Upper Ross River	13,222	6940	6,282	47.5	24.0	125.0	114.3	10.7	8.5	17.3	17.7	15.7	2.0	11.1	30.5
Stuart Creek	3,598	1855	1,743	48.4	6.6	30.5	27.3	3.2	10.4	5.2	5.0	4.6	0.4	7.2	5.6
Alligator Creek	6,323	3009	3,314	52.4	12.6	69.0	62.9	6.1	8.8	9.9	9.2	8.7	0.5	5.5	7.9
Magnetic Island	485	485	0	0.0	0.0	6.5	6.5	0.0	-0.4	0.0	1.1	1.1	0.0	1.5	0.2
Black Basin	21,572	11229	10,343	47.9	39.4	335.1	300.9	34.2	10.2	55.4	32.1	29.6	2.5	7.7	38.4
Ross Basin	39,331	23452	15,879	40.4	60.6	344.9	316.9	28.0	8.1	45.4	55.2	51.3	3.9	7.1	61.4
Black Ross Total	61,389	35166	26,223	42.7	100.0	686.0	624.4	61.6	9.0	100	88.4	82.0	6.4	7.3	100

Table BL Potential load change at 2021 from BAU by implementing Rural BMP and percentage change by sub basin and WQIP area for all pollutants

	TSS	TSS	TSS	TSS	TSS	TN	TN	TN	TN	TN	TP	TP	TP	TP	TP
Sub Basin	BAU	BMP	Change			BMP	WSUD	Change			BAU	BMP	Change		
	t/year	t/year	t/year	% SB	% BR	t/year	t/year	t/year	% SB	% BR	t/year	t/year	t/year	% SB	% BR
Crystal Creek	6,516	4,648	-1,868	28.7	17.8	98	93	-4.8	4.9	19	10.4	10.0	-0.32	3.1	12.6
Rollingstone Creek	2,169	1,624	-545	25.1	5.2	46	44	-1.7	3.8	7	4.6	4.5	-0.10	2.3	4.0
Bluewater Creek	2,807	2,378	-429	15.3	4.1	95	91	-4.5	4.8	18	4.5	4.4	-0.16	3.6	6.4
Black River	7,409	6,113	-1,296	17.5	12.4	71	68	-2.6	3.6	10	10.2	9.8	-0.40	3.9	15.5
Bohle River	9,495	8,350	-1,145	12.1	10.9	78	76	-2.0	2.5	8	14.2	13.9	-0.34	2.4	13.1
Lower Ross River	5,081	4,410	-671	13.2	6.4	37	35	-1.2	3.4	5	7.8	7.7	-0.10	1.4	4.1
Upper Ross River	10,154	7,641	-2,513	24.7	24.0	110	106	-4.2	3.8	17	14.7	14.0	-0.77	5.3	30.1
Stuart Creek	2,430	1,733	-697	28.7	6.6	24	22	-1.3	5.3	5	3.8	3.6	-0.15	3.9	5.7
Alligator Creek	3,792	2,467	-1,325	35.0	12.6	53	51	-2.5	4.6	10	6.6	6.4	-0.22	3.3	8.6
Magnetic Island	399	399	0	0	0	6	6	0	0	0	1.0	1.0	0	0	0
Black Basin	18,900	14,763	-4,137	21.9	39.4	309	296	-13.6	4.4	55	29.7	28.7	-0.99	3.3	38.5
Ross Basin	30,952	24,600	-6,352	20.5	60.6	302	291	-11.2	3.7	45	47.1	45.5	-1.58	3.4	61.5
Black Ross Total	50,252	39,763	-10,489	20.9	100.0	618	593	-24.8	4.0	100	77.8	75.2	-2.57	3.3	100

Table BM Potential load increases 2005 to 2021 and potential load reduction and percentage changes at 2021 from BAU by 100% adoption of WSUD practices by Basin and WQIP area for all pollutants

Basin	2005	2005 to 2021 Increase		2021	Greenfield WSUD			Existing Urban WSUD			All Urban WSUD		
	BAU			BAU	Treated	Change		Treated	Change		Treated	Change	
	t/year	t/year	%	t/year	t/year	t/year	%	t/year	t/year	%	t/year	t/year	%
Total suspended solids (TSS)													
Black Basin	17,119	1,781	10	18,900	18,759	141	0.7	18,730	170	0.9	18,589	311	1.6
Ross Basin	25,366	5,586	22	30,952	30,554	398	1.3	29,274	1,678	5.4	28,876	2,076	6.7
Black Ross Total	42,827	7,425	17	50,252	49,672	580	1.2	48,336	1,915	3.8	47,756	2,495	5.0
Total nitrogen (TN)													
Black Basin	292	17	6	310	309	0.16	0.1	309	0.4	0.1	309	0.6	0.2
Ross Basin	274	29	10	302	302	0.45	0.1	299	3.6	1.2	298	4.0	1.3
Black Ross Total	572	46	8	618	617	0.66	0.1	614	4.2	0.7	613	4.8	0.8
Total phosphorus (TP)													
Black Basin	28	2	6	30	30	0.09	0.3	29.5	0.2	0.8	29.4	0.32	1.1
Ross Basin	42	5	13	47	47	0.25	0.5	45.1	2.0	4.3	44.8	2.26	4.8
Black Ross Total	71	7	10	78	77	0.37	0.5	75.4	2.3	3.0	75.1	2.71	3.5

Note: BAU is business as usual (2045). WSUD is water sensitive urban design. All Urban WSUD is the total of Existing Urban WSUD and Greenfield WSUD. Greenfield WSUD is new urban development outside already existing urban areas (Updated using 9/6/09, 10/6/09 and 12/6/09 data)

Table BN Potential load increases 2005 to 2045 and potential load reduction and percentage changes at 2045 from BAU by 100% adoption of WSUD practices by Basin and WQIP area for all pollutants

Basin	2005	2005 to 2045 Increase		2045	Greenfield WSUD			Existing Urban WSUD			All Urban WSUD		
	BAU			BAU	Treated	Change		Treated	Change		Treated	Change	
	t/year	t/year	%	t/year	t/year	t/year	%	t/year	t/year	%	t/year	t/year	%
Total suspended solids (TSS)													
Black Basin	17,119	4,453	26.0	21,572	21,220	352	1.6	21,148	424	2.0	20,795	777	3.6
Ross Basin	25,366	13,965	55.1	39,331	38,335	996	2.5	35,137	4,194	10.7	34,141	5,190	13.2
Black Ross Total	42,827	18,562	43.3	61,389	59,939	1,450	2.4	56,600	4,789	7.8	55,150	6,239	10.2
Total nitrogen (TN)													
Black Basin	292	43	14.8	335.1	334.6	0.5	0.1	334.0	1.1	-0.3	333.6	1.5	0.5
Ross Basin	274	71	25.9	344.9	343.7	1.2	0.3	336.0	8.9	-2.6	334.8	10.1	2.9
Black Ross Total	572	114	19.9	686.0	684.8	1.2	0.2	675.6	10.4	-1.5	674.4	11.6	1.7
Total phosphorus (TP)													
Black Basin	28	4	14.6	32.1	31.9	0.2	0.7	31.5	0.6	1.8	31.3	0.8	2.5
Ross Basin	42	13	31.4	55.2	54.6	0.6	1.1	50.2	5.0	9.1	49.6	5.6	10.2
Black Ross Total	71	17	24.5	88.4	87.5	0.9	1.0	82.5	5.9	6.6	81.6	6.8	7.7

Note: BAU is business as usual (2045). WSUD is water sensitive urban design. All Urban WSUD is the total of Existing Urban WSUD and Greenfield WSUD. Greenfield WSUD is new urban development outside already existing urban areas (Updated using 9/6/09, 10/6/09 and 12/6/09 data)

Load reduction targets

Table CA 2021 TSS load reduction potential, reduction targets and total load reduction

Sub Basin	2021 BAU load (t/yr)	Load with 100% GF WSUD (t/yr)	Potential GF WSUD load reduction (t/yr)	GF WSUD load reduction Target (t/yr)	Load with 100% Existing Urban WSUD (t/yr)	Potential Existing Urban WSUD load reduction (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Load with 100% Rural BMP (t/yr)	Potential Rural BMP load reduction (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2021 BAU load
Crystal	6,516	6,447	69	69	6,516	0	0	4,648	1,868	560	629	9.7
Rollingstone	2,169	2,098	71	71	2,127	42	8	1,624	545	163	242	11.2
Bluewater	2,807	2,805	2	2	2,797	10	2	2,378	429	129	132	4.7
Black	7,409	7,409	0	0	7,290	118	24	6,113	1,296	389	412	5.6
Bohle	9,495	9,166	329	329	8,813	682	136	8,350	1,145	344	809	8.5
Lower Ross	5,081	5,012	70	70	4,097	984	197	4,410	671	201	468	9.2
Upper Ross	10,154	10,154	0	0	10,154	0	0	7,641	2,513	754	754	7.4
Stuart	2,430	2,430	0	0	2,418	12	2	1,733	697	209	211	8.7
Alligator	3,792	3,792	0	0	3,792	0	0	2,467	1,325	398	398	10.5
Magnetic Is.	399	359	40	40	331	68	14	399	0	0	54	13.5
Black Basin	18,900	18,759	141	141	18,730	170	34	14,763	4,137	1,241	1,416	7.5
Ross Basin	30,952	30,554	398	398	29,274	1,678	336	24,600	6,352	1,906	2,639	8.5
Black Ross	50,252	49,672	580	580	48,336	1,915	383	39,763	10,489	3,147	4,110	8.2

Notes: Initial load reduction targets GF WSUD 100% adoption, Existing Urban WSUD 20% adoption and Rural BMP 30% adoption

Table CB 2021 TN load reduction potential, reduction targets and total load reduction

Sub Basin	2021 BAU load (t/yr)	Load with 100% GF WSUD (t/yr)	Potential GF WSUD load reduction (t/yr)	GF WSUD load reduction Target (t/yr)	Load with 100% Existing Urban WSUD (t/yr)	Potential Existing Urban WSUD load reduction (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Load with 100% Rural BMP (t/yr)	Potential Rural BMP load reduction (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2021 BAU load
Crystal	98	98	0.07	0.07	98	0.0	0.00	93	4.8	1.4	1.5	1.5
Rollingstone	46	46	0.07	0.07	46	0.1	0.02	44	1.7	0.5	0.6	1.4
Bluewater	95	95	0.01	0.01	95	0.0	0.00	91	4.5	1.4	1.4	1.5
Black	71	71	0.00	0.00	70	0.3	0.06	68	2.6	0.8	0.8	1.2
Bohle	78	78	0.37	0.37	77	1.7	0.35	76	2.0	0.6	1.3	1.7
Lower Ross	37	37	0.08	0.08	35	1.8	0.36	35	1.2	0.4	0.8	2.2
Upper Ross	110	110	0.00	0.00	110	0.0	0.00	106	4.2	1.3	1.3	1.2
Stuart	24	24	0.00	0.00	24	0.0	0.01	22	1.3	0.4	0.4	1.6
Alligator	53	53	0.00	0.00	53	0.0	0.00	51	2.5	0.7	0.7	1.4
Magnetic Is.	6	6	0.05	0.05	6	0.2	0.03	6	0.0	0.0	0.1	1.4
Black Basin	309	309	0.16	0.16	309	0.4	0.09	296	13.6	4.1	4.3	1.4
Ross Basin	302	302	0.45	0.45	299	3.6	0.72	291	11.2	3.3	4.5	1.5
Black Ross	618	617	0.66	0.66	614	4.2	0.84	593	24.8	7.4	8.9	1.4

Notes: Initial load reduction targets GF WSUD 100% adoption, Existing Urban WSUD 20% adoption and Rural BMP 30% adoption

Table CC 2021 TP load reduction potential, reduction targets and total load reduction

Sub Basin	2021 BAU load (t/yr)	Load with 100% GF WSUD (t/yr)	Potential GF WSUD load reduction (t/yr)	GF WSUD load reduction Target (t/yr)	Load with 100% Existing Urban WSUD (t/yr)	Potential Existing Urban WSUD load reduction (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Load with 100% Rural BMP (t/yr)	Potential Rural BMP load reduction (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2021 BAU load
Crystal	10.4	10.3	0.04	0.04	10.4	0.0	0.00	10.0	0.3	0.1	0.14	1.4
Rollingstone	4.6	4.5	0.05	0.05	4.5	0.1	0.01	4.5	0.1	0.0	0.09	2.0
Bluewater	4.5	4.5	0.00	0.00	4.5	0.0	0.00	4.4	0.2	0.0	0.05	1.2
Black	10.2	10.2	0.00	0.00	10.1	0.2	0.03	9.8	0.4	0.1	0.15	1.5
Bohle	14.2	14.0	0.21	0.21	13.3	1.0	0.19	13.9	0.3	0.1	0.50	3.5
Lower Ross	7.8	7.7	0.04	0.04	6.7	1.0	0.21	7.7	0.1	0.0	0.28	3.6
Upper Ross	14.7	14.7	0.00	0.00	14.7	0.0	0.00	14.0	0.8	0.2	0.23	1.6
Stuart	3.8	3.8	0.00	0.00	3.7	0.0	0.01	3.6	0.1	0.0	0.05	1.3
Alligator	6.6	6.6	0.00	0.00	6.6	0.0	0.00	6.4	0.2	0.1	0.07	1.0
Magnetic Is.	1.0	1.0	0.03	0.03	0.9	0.1	0.02	1.0	0.0	0.0	0.05	4.8
Black Basin	29.7	29.6	0.09	0.09	29.5	0.2	0.05	28.7	1.0	0.3	0.44	1.5
Ross Basin	47.1	46.8	0.25	0.25	45.1	2.0	0.40	45.5	1.6	0.5	1.13	2.4
Black Ross	77.8	77.4	0.37	0.37	75.4	2.3	0.47	75.2	2.6	0.8	1.61	2.1

Notes: Initial load reduction targets GF WSUD 100% adoption, Existing Urban WSUD 20% adoption and Rural BMP 30% adoption

Table CD 2045 TSS load reduction potential, reduction targets and total load reduction

Sub Basin	2045 BAU load (t/yr)	Load with 100% GF WSUD (t/yr)	Potential GF WSUD load reduction (t/yr)	GF WSUD load reduction Target (t/yr)	Load with 100% Existing Urban WSUD (t/yr)	Potential Existing Urban WSUD load reduction (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Load with 100% Rural BMP (t/yr)	Potential Rural BMP load reduction (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2045 BAU load
Crystal	8,019	7,847	172	172	8,019	0	0	3,349	4,670	3,736	3,907	48.7
Rollingstone	3,017	2,841	176	176	2,913	104	52	1,656	1,361	1,089	1,318	43.7
Bluewater	2,807	2,803	4	4	2,783	24	12	1,735	1,072	857	874	31.1
Black	7,729	7,729	0	0	7,433	296	148	4,489	3,240	2,592	2,740	35.5
Bohle	9,794	8,972	822	822	8,090	1,704	852	6,931	2,863	2,290	3,965	40.5
Lower Ross	6,395	6,221	174	174	3,935	2,460	1,230	4,716	1,679	1,343	2,747	43.0
Upper Ross	13,222	13,222	0	0	13,222	0	0	6,940	6,282	5,026	5,026	38.0
Stuart	3,598	3,598	0	0	3,569	29	15	1,855	1,743	1,394	1,409	39.2
Alligator	6,323	6,323	0	0	6,323	0	0	3,009	3,314	2,651	2,651	41.9
Magnetic Is.	485	384	101	101	315	170	85	485	0	0	186	38.4
Black Basin	21,572	21,220	352	352	21,148	424	212	11,229	10,343	8,274	8,839	41.0
Ross Basin	39,331	38,335	996	996	35,137	4,194	2,097	23,452	15,879	12,703	15,796	40.2
Black Ross	61,389	59,939	1,450	1,450	56,600	4,789	2,394	35,166	26,223	20,978	24,823	40.4

Notes: Initial load reduction targets GF WSUD 100% adoption, Existing Urban WSUD 50% adoption and Rural BMP 80% adoption

Table CE 2045 TN load reduction potential, reduction targets and total load reduction

Sub Basin	2045 BAU load (t/yr)	Load with 100% GF WSUD (t/yr)	Potential GF WSUD load reduction (t/yr)	GF WSUD load reduction Target (t/yr)	Load with 100% Existing Urban WSUD (t/yr)	Potential Existing Urban WSUD load reduction (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Load with 100% Rural BMP (t/yr)	Potential Rural BMP load reduction (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2045 BAU load
Crystal	109.7	109.5	0.2	0.2	109.7	0.0	0.0	97.7	12.0	9.6	9.7	8.9
Rollingstone	53.4	53.2	0.2	0.2	53.1	0.3	0.1	49.1	4.3	3.4	3.7	7.0
Bluewater	99.0	98.9	0.1	0.1	99.0	0.0	0.0	87.6	11.4	9.1	9.2	9.3
Black	72.9	72.9	0.0	0.0	72.1	0.8	0.4	66.5	6.4	5.1	5.5	7.5
Bohle	78.3	77.4	0.9	0.9	74.0	4.3	2.2	73.4	4.9	3.9	7.0	8.9
Lower Ross	42.1	41.9	0.2	0.2	37.5	4.6	2.3	39.0	3.1	2.5	4.9	11.7
Upper Ross	125.0	124.9	0.1	0.1	125.0	0.0	0.0	114.3	10.7	8.5	8.6	6.9
Stuart	30.5	30.5	0.0	0.0	30.4	0.1	0.0	27.3	3.2	2.5	2.6	8.6
Alligator	69.0	69.0	0.0	0.0	69.0	0.0	0.0	62.9	6.1	4.9	4.8	7.0
Magnetic Is.	6.5	6.4	0.1	0.1	6.1	0.4	0.2	6.5	0.0	0.0	0.3	4.6
Black Basin	335.1	334.6	0.5	0.5	334.0	1.1	0.5	300.9	34.2	27.3	28.3	8.4
Ross Basin	344.9	343.7	1.2	1.2	336.0	8.9	4.5	316.9	28.0	22.4	28.0	8.1
Black Ross	686.0	684.8	1.2	1.2	675.6	10.4	5.2	624.4	61.6	49.3	55.7	8.1

Notes: Initial load reduction targets GF WSUD 100% adoption, Existing Urban WSUD 50% adoption and Rural BMP 80% adoption

Table CF 2045 TP load reduction potential, reduction targets and total load reduction

Sub Basin	2045 BAU load (t/yr)	Load with 100% GF WSUD (t/yr)	Potential GF WSUD load reduction (t/yr)	GF WSUD load reduction Target (t/yr)	Load with 100% Existing Urban WSUD (t/yr)	Potential Existing Urban WSUD load reduction (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Load with 100% Rural BMP (t/yr)	Potential Rural BMP load reduction (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2045 BAU load
Crystal	11.80	11.70	0.10	0.10	11.80	0.00	0.00	11.00	0.80	0.64	0.7	6.3
Rollingstone	5.40	5.28	0.12	0.12	5.25	0.15	0.07	5.14	0.26	0.21	0.4	7.4
Bluewater	4.30	4.32	-0.02	-0.02	4.27	0.03	0.02	3.92	0.38	0.31	0.3	6.9
Black	10.60	10.58	0.02	0.02	10.20	0.40	0.20	9.58	1.02	0.81	1.0	9.7
Bohle	14.30	13.83	0.47	0.47	11.90	2.40	1.20	13.50	0.80	0.64	2.3	16.1
Lower Ross	8.90	8.84	0.06	0.06	6.33	2.57	1.29	8.68	0.22	0.18	1.5	17.1
Upper Ross	17.70	17.68	0.02	0.02	17.70	0.00	0.00	15.74	1.96	1.57	1.6	9.0
Stuart	5.00	5.00	0.00	0.00	4.93	0.07	0.04	4.64	0.36	0.29	0.3	6.4
Alligator	9.20	9.25	-0.05	-0.05	9.20	0.00	0.00	8.70	0.50	0.40	0.4	3.9
Magnetic Is.	1.10	1.01	0.09	0.09	0.86	0.24	0.12	1.08	0.02	0.01	0.2	20.1
Black Basin	32.10	31.88	0.22	0.22	31.5	0.58	0.29	29.64	2.46	1.97	2.5	7.7
Ross Basin	55.20	54.60	0.60	0.60	50.2	5.04	2.52	51.26	3.94	3.15	6.3	11.4
Black Ross	88.40	87.49	0.91	0.91	82.5	5.86	2.93	81.99	6.41	5.13	9.0	10.1

Notes: Initial load reduction targets GF WSUD 100% adoption, Existing Urban WSUD 50% adoption and Rural BMP 80% adoption

Table CG TSS 2021 load reduction targets summary

Sub Basin	2021 BAU load (t/yr)	GF WSUD load reduction Target (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2021 BAU load	Total load reduction as % of 2021 BAU - 1850 load
Crystal	6,516	69	0	560	629	9.7	11.3
Rollingstone	2,169	71	8	163	242	11.2	15.3
Bluewater	2,807	2	2	129	132	4.7	5.9
Black	7,409	0	24	389	412	5.6	7.0
Bohle	9,495	329	136	344	809	8.5	10.7
Lower Ross	5,081	70	197	201	468	9.2	10.8
Upper Ross	10,154	0	0	754	754	7.4	10.7
Stuart	2,430	0	2	209	211	8.7	11.6
Alligator	3,792	0	0	398	398	10.5	21.0
Magnetic Is.	399	40	14	0	54	13.5	18.5
Black Basin	18,900	141	34	1,241	1,416	7.5	9.3
Ross Basin	30,952	398	336	1,906	2,639	8.5	11.7
Black Ross	50,252	580	383	3,147	4,110	8.2	10.8

Table CH TN 2021 load reduction targets summary

Sub Basin	2021 BAU load (t/yr)	GF WSUD load reduction Target (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2021 BAU load	Total load reduction as % of 2021 BAU - 1850 load
Crystal	98	0.07	0.00	1.4	1.5	1.5	2.9
Rollingstone	46	0.07	0.02	0.5	0.6	1.4	3.4
Bluewater	95	0.01	0.00	1.4	1.4	1.5	2.0
Black	71	0.00	0.06	0.8	0.8	1.2	2.6
Bohle	78	0.37	0.35	0.6	1.3	1.7	4.1
Lower Ross	37	0.08	0.36	0.4	0.8	2.2	4.4
Upper Ross	110	0.00	0.00	1.3	1.3	1.2	3.9
Stuart	24	0.00	0.01	0.4	0.4	1.6	4.4
Alligator	53	0.00	0.00	0.7	0.7	1.4	7.0
Magnetic Is.	6	0.05	0.03	0.0	0.1	1.4	6.7
Black Basin	309	0.16	0.09	4.1	4.3	1.4	2.6
Ross Basin	302	0.45	0.72	3.3	4.5	1.5	4.4
Black Ross	618	0.66	0.84	7.4	8.9	1.4	3.3

Table CI TP 2021 load reduction targets summary

Sub Basin	2021 BAU load (t/yr)	GF WSUD load reduction Target (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2021 BAU load	Total load reduction as % of 2021 BAU - 1850 load
Crystal	10.4	0.04	0.00	0.1	0.14	1.4	2.5
Rollingstone	4.6	0.05	0.01	0.0	0.09	2.0	5.5
Bluewater	4.5	0.00	0.00	0.0	0.05	1.2	3.8
Black	10.2	0.00	0.03	0.1	0.15	1.5	2.5
Bohle	14.2	0.21	0.19	0.1	0.50	3.5	5.3
Lower Ross	7.8	0.04	0.21	0.0	0.28	3.6	4.8
Upper Ross	14.7	0.00	0.00	0.2	0.23	1.6	3.4
Stuart	3.8	0.00	0.01	0.0	0.05	1.3	2.2
Alligator	6.6	0.00	0.00	0.1	0.07	1.0	3.4
Magnetic Is.	1.0	0.03	0.02	0.0	0.05	4.8	10.0
Black Basin	29.7	0.09	0.05	0.3	0.44	1.5	2.9
Ross Basin	47.1	0.25	0.40	0.5	1.13	2.4	4.3
Black Ross	77.8	0.37	0.47	0.8	1.61	2.1	3.9

Table CJ 2045 TSS load reduction targets summary

Sub Basin	2045 BAU load (t/yr)	GF WSUD load reduction Target (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2045 BAU load	Total load reduction as % of 2045 BAU - 1850 load
Crystal	8,019	172	0	3,736	3,907	48.7	55.4
Rollingstone	3,017	176	52	1,089	1,318	43.7	54.1
Bluewater	2,807	4	12	857	874	31.1	39.3
Black	7,729	0	148	2,592	2,740	35.5	44.2
Bohle	9,794	822	852	2,290	3,965	40.5	50.6
Lower Ross	6,395	174	1,230	1,343	2,747	43.0	48.8
Upper Ross	13,222	0	0	5,026	5,026	38.0	49.7
Stuart	3,598	0	15	1,394	1,409	39.2	47.2
Alligator	6,323	0	0	2,651	2,651	41.9	60.0
Magnetic Is.	485	101	85	0	186	38.4	49.2
Black Basin	21,572	352	212	8,274	8,839	41.0	49.3
Ross Basin	39,331	996	2,097	12,703	15,796	40.2	51.0
Black Ross	61,389	1,450	2,394	20,978	24,823	40.4	50.4

Table CK 2045 TN load reduction targets summary

Sub Basin	2045 BAU load (t/yr)	GF WSUD load reduction Target (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2045 BAU load	Total load reduction as % of 2045 BAU - 1850 load
Crystal	109.7	0.2	0.0	9.6	9.7	8.9	15.3
Rollingstone	53.4	0.2	0.1	3.4	3.7	7.0	14.5
Bluewater	99.0	0.1	0.0	9.1	9.2	9.3	12.9
Black	72.9	0.0	0.4	5.1	5.5	7.5	16.1
Bohle	78.3	0.9	2.2	3.9	7.0	8.9	22.0
Lower Ross	42.1	0.2	2.3	2.5	4.9	11.7	20.6
Upper Ross	125.0	0.1	0.0	8.5	8.6	6.9	18.2
Stuart	30.5	0.0	0.0	2.5	2.6	8.6	16.7
Alligator	69.0	0.0	0.0	4.9	4.8	7.0	18.4
Magnetic Is.	6.5	0.1	0.2	0.0	0.3	4.6	20.8
Black Basin	335.1	0.5	0.5	27.3	28.3	8.4	14.5
Ross Basin	344.9	1.2	4.5	22.4	28.0	8.1	19.3
Black Ross	686.0	1.2	5.2	49.3	55.7	8.1	16.3

Table CL 2045 TP load reduction targets summary

Sub Basin	2045 BAU load (t/yr)	GF WSUD load reduction Target (t/yr)	Existing Urban WSUD load reduction Target (t/yr)	Rural BMP load reduction Target (t/yr)	Total load reduction (t/yr)	Total load reduction as % of 2045 BAU load	Total load reduction as % of 2045 BAU - 1850 load
Crystal	11.80	0.10	0.00	0.64	0.7	6.3	10.5
Rollingstone	5.40	0.12	0.07	0.21	0.4	7.4	16.2
Bluewater	4.30	-0.02	0.02	0.31	0.3	6.9	24.4
Black	10.60	0.02	0.20	0.81	1.0	9.7	15.9
Bohle	14.30	0.47	1.20	0.64	2.3	16.1	24.4
Lower Ross	8.90	0.06	1.29	0.18	1.5	17.1	21.7
Upper Ross	17.70	0.02	0.00	1.57	1.6	9.0	16.3
Stuart	5.00	0.00	0.04	0.29	0.3	6.4	9.3
Alligator	9.20	-0.05	0.00	0.40	0.4	3.9	7.7
Magnetic Is.	1.10	0.09	0.12	0.01	0.2	20.1	39.1
Black Basin	32.10	0.22	0.29	1.97	2.5	7.7	14.3
Ross Basin	55.20	0.60	2.52	3.15	6.3	11.4	18.3
Black Ross	88.40	0.91	2.93	5.13	9.0	10.1	17.2

Calculation of loads for Basins using main catchment event monitoring results

As load calculations were not available for all catchments from the event water quality monitoring carried out by ACTFR over the 2006/07 and 2007/08 wet seasons, it was not possible to directly calculate loads for the Black Basin, Ross Basin and Black Ross WQIP area. Inferred basin loads were calculated by first determining the percentage discharges from each catchment (sub basin) in each basin using the results of the 2005 (baseline) modelling run (BMT WBM 2009) as per Table 1.5. The discharge percentages for each parameter for each catchment (sub basin) were then related to the loads measured for the main catchments during the event monitoring and used to infer the total for the whole of the Black and Ross Basins.

Example: If the percentage of sediment discharge for the Black Basin from the Black River is 41.8% and from Bluewater Creek is 16.3% (from modelled results for all catchments in the Black Basin) and the 'known' discharge from the Black Basin calculated from the 2006/07 event monitoring data is 35,700 tonnes then the inferred sediment discharge total for the Black Basin is 35,700/58.2 x 100 = 61,340 tonnes

Table DA Sediment Load Main Catchments 2006-2008

Wet Season	2006/07	2006/07	2007/08	2007/08
Basins and Catchments	**Sediment load (tonnes)**	**Total flow volume ML**	**Sediment load (tonnes)**	**Total flow volume ML**
Black Basin				
Black River	33,000	135,000	41,000	180,400
Bluewater Creek	2,700	63,500	nd	nd
Totals	35,700	198,500	41,000	180,400
Inferred Basin Totals	61,340	491,337	98,086	1,013,483
Ross Basin				
Bohle River	22,000	147,000	35,100	154,200
Ross River	26,500	261,000	14,500	290,000
Alligator Creek	600	41,500	nd	nd
Totals	49,100	449,500	49,600	444,200
Inferred Basin Totals	52,796	493,956	58,353	616,944
Black Ross Totals	114,136	985,293	156,439	1,630,428

Source: Lewis et al (2008, p.17)Table 3.

Table DB Nitrogen Load Main Catchments 2006-2008

Wet Season	2006/07	2006/07	2007/08	2007/08
Basins and Catchments	**TN load (kilograms)**	**Total flow volume ML**	**TN load (kilograms)**	**Total flow volume ML**
Black River	59,700	135,000	91,500	180,400
Bluewater Creek	17,630	63,500	nd	nd
Totals	77,330	198,500	91,500	180,400
Inferred Basin Totals	139,585	491,337	386,076	1,013,483
Bohle River	71,200	147,000	83,400	154,200
Ross River	173,000	261,000	149,700	290,000
Alligator Creek	9,440	41,500	nd	nd
Totals	253,640	449,500	233,100	444,200
Inferred Basin Totals	272,731	493,956	302,727	616,944
Black Ross Totals	412,316	985,293	688,803	1,630,428

Source: Lewis et al (2008) Tables 5, 9, 13, 15 and 16.

Table DC Phosphorus Load Main Catchments 2006-2008

Wet Season	2006/07	2006/07	2007/08	2007/08
Basins and Catchments	**TP load (kilograms)**	**Total flow volume ML**	**TP load (kilograms)**	**Total flow volume ML**
Black River	15,200	135,000	17,900	180,400
Bluewater Creek	1,240	63,500	nd	nd
Totals	16,440	198,500	17,900	180,400
Inferred Basin Totals	31,494	491,337	50,140	1,013,483
Bohle River	23,000	147,000	24,300	154,200
Ross River	20,800	261,000	22,300	290,000
Alligator Creek	1,540	41,500	nd	nd
Totals	45,340	449,500	46,600	444,200
Inferred Basin Totals	48,753	493,956	57,531	616,944
Black Ross Totals	80,247	985,293	107,671	1,630,428

Source: Lewis et al (2008) Tables 6, 10 and 18

Appendix C

Point Source Costs

Source: Maunsell 2008, *Wastewater Upgrade Program Planning Report*, Townsville City Council, Townsville.

Executive Summary

The Townsville region is undergoing significant population growth and this is placing pressure on the region's wastewater infrastructure. Table A shows the projected population growth till 2025 and the corresponding capacities at each of the region's wastewater purification plants (WPP) [wastewater treatment plants].

Table A – Population projections 2008 – 2025 and available plant capacity

WWP Catchments	Projected population (EP) for various end of calendar years					Available plant capacity (EP)
	2008	2009	2010	2015	2025	
Cleveland Bay WPP Catchment						
Eastern /Western/Southern	102,000	103,050	104,100	109,358	120,799	
Sub-Total Cleveland Bay	102,000	103,050	104,100	109,358	120,799	126,000
Mt St John WPP Catchment						
Mt Louisa	5,200	5,460	5,730	7,310	11,920	
Mather St PS Balance Area	18,400	18,400	18,400	18,400	18,400	
Kirwan	27,200	27,600	28,000	30,000	32,100	
Sub-Total Mt St John	50,800	51,460	52,130	55,710	62,420	45,000
Condon WPP Catchment						
Condon/Kelso/Rasmussen	17,000	17,600	18,200	20,600	24,200	
Bohle Plains	1,500	2,000	2,600	8,100	14,700	
Sub-Total Condon	18,500	19,600	20,800	28,700	38,900	23,000
Mt Low WPP Catchment						
Mt Low/ Bushland Beach	4,000	4,900	5,800	9,250	13,790	
Sub-Total Mt Low	4,000	4,900	5,800	9,250	29,340	3,000
Deeragun WPP Catchment						
Deeragun/ Burdell	3,550	4,520	5,870	9,120	15,550	
Sub-Total Deeragun	3,550	4,420	5,870	9,120	15,550	4,300
Overall Total All Catchments	178,850	183,430	188,700	212,138	267,009	201,300

The figures highlight that there is only a small amount of capacity remaining in existing wastewater treatment infrastructure. A number of existing treatment plants have reached or will soon reach their maximum treatment capacity and hence there is an imperative that the new Townsville City Council (TCC) ensures the timely delivery of additional treatment infrastructure to meet the ongoing growth needs of the Townsville community.

Submissions for Pre-Amalgamation Projects

Prior to the amalgamation of Townsville City Council and the City of Thuringowa (COT) Council in March 2008 to form the New Townsville City Council, each entity was responsible for their own catchments and infrastructure. The MCU applications were made by the new Townsville City Council for the previous City of Thuringowa projects for the following works:

- Interim plant upgrades to Mt Low and Deeragun WPP's to provide sufficient capacity and treatment capability to meet the load requirements till 2010.

- Upgrades to Mt Low WPP and Condon WPP's. Deeragun WPP was to be decommissioned.

In addition to the MCU applications, the new TCC had also submitted applications for subsidy for the upgrades required to the three plants (both the interim and major upgrades at Mt Low were applied for). TCC had recently upgraded their Cleveland Bay WPP, and were considering a quality upgrade to their Mt St John WPP to meet EPA discharge limits.

Environmental Constraints
Subsequent to the MCU applications for Mt Low and Condon, the EPA had revised their discharge limits for discharges from Condon (which discharges into the upper freshwater reaches of the Bohle River) and for Mount Low (which discharges into the mouth of the Black River). These revised limits were much more stringent and were based on the receiving waters for both these discharges being not suitable to receive the proposed nutrient loads.

For Condon, the EPA has indicated previously that they would prefer that no additional flows should be discharged to the Bohle River as it is an Ephemeral Stream at the discharge location of Condon WPP.

Also for the Mt Low discharge to the Black River, EPA's position was that the assimilation capacities of the Black River were not well understood.

To comply with these new limits required significantly more capital infrastructure. That is capital estimates went from $152.9M to $267.7M, an increase of $114.8M.

Post Amalgamation - A Regional Strategy
The amalgamation of the two councils provided a previously unrealisable opportunity to review the strategies in a more regional context. At the same time the New Townsville City Council was reviewing their potable water regional strategy with a view to looking at potable water replacement opportunities as a means of deferring a potable water upgrade to their Toonpan WTP. The new TCC asked the project design team to develop and review a number of regional strategies for wastewater treatment against the existing approach to ensure the best long-term approach is adopted.

After investigating a wide range of potential scenarios, the project team settled on two broad strategies to conduct an in depth comparison, a decentralised and a centralised option. The pre-amalgamation approach detailed above was considered a decentralised approach with upgrades to three of the WPPs (ie. Mt St John, Condon, and Mt Low). This was compared to a single large upgrade at the Mt St John WPP and the diversion of the major growth areas to this plant, referred to as the centralised approach.

A combination of cost (capital, operating and lifecycle (NPV)) and non-financial criteria were used to assess the two options including:

1) Capital Cost
2) Operating & Maintenance (O&M) Cost implications.
3) Environmental Considerations including GHG considerations and immediate and long term impacts on receiving waters.
4) Opportunity of the option for generating future reuse opportunities.
5) Social Considerations including potential odour, noise and visual impacts.
6) That the infrastructure provides a sound long term base for the future.
7) Project Timing

Table B shows the cost summary for the two options (from the report titled, Regional Strategy Review & Preliminary Business Case, June 2008):

Table B – Capital Cost Comparison

	Decentralised	Centralised
Overall Capital Cost	$264m	$189m*
Operations & Maintenance at 2025	$5m	$4m
Life Cycle Cost (Total Present Value over at 7% over 15 years to 2025)	$306m	$236m

Note: * includes costs only estimated for items in the Business Case Report.

On the basis of the of the approximate $75M capital cost saving, net present value, and the non financial analysis, the business case for the centralised option was compelling and was endorsed by council on 22 July, 2008.

Integrated Water Management

TCC recognise the importance of considering the WPP upgrades in light of any future integrated water management strategy developed for the region. Potable water replacement initiatives for recycling effluent have real and tangible benefits in deferring water infrastructure requirements for the Townsville region and this was considered in the regional strategy developed.

TCC have commenced an investigation into the feasibility of deferring capital for the upgrade to Toonpan WTP through the introduction of both two tiered water pricing and potable water replacement strategies. However, this is only the first phase of this study. Council is likely to require some time (more than 2-3 years) to develop a market for reuse. This is because there is a need to align the current price of potable water to represent the margin cost of providing future potable capacity. A full understanding of the future costs of both potable and recycled water in Townsville needs to be attained before a plan for future recycling in the region can be developed and assessed. As a result effluent re-use and potable water replacement does not form part of this planning report.

A Three Stage Approach

The new Townsville City Council has undertaken a thorough re-evaluation of wastewater upgrade options from a regional perspective. Given the population growth pressures and time constraints a staged approach is required to ensure infrastructure can meet short and long terms needs of the community. Three stages are proposed:

1. Stage One will involve interim upgrades at the existing Deeragun and Mt Low sites to allow these plants to meet EPA requirements until new infrastructure can be provided around 2010 to meet the region's longer term needs. Both these sites will be decommissioned once Stage Two works are fully operational.

2. Stage Two is focused on providing the necessary wastewater treatment infrastructure to meet the requirements to 2025 and is the main focus of this planning report.

3. Stage Three is focused on providing the additional infrastructure required to further reduce nutrient discharge from all discharge locations. The focus will be on developing a regional water management plan. The aim of this plan is to consider water supply in Townsville in an integrated way. It is likely from this plan that effluent reuse can be used to offset the need or defer the next potable replacement upgrade. This will also reduce the nutrient discharges to the environment resulting in a "win win" outcome.

TCC intend to seek additional Federal funding to assist with the implementation of Stage Three infrastructure and will be the subject of a separate planning report.

Stage 1 – Interim Upgrades
The objective of the interim upgrades to Mount Low and Deeragun WPP's is to provide sufficient short term capacity to enable the design, construction and commissioning of the major upgrade to Mt St John WPP to be completed without failure of the plant's licence conditions.

Improvements to the plant capacity are to be achieved through minor plant changes such as:

- Bypassing of wet weather flows in excess of 3 x ADWF;
- Upgrades to disinfection systems;
- Additional aeration capacity to the oxidation ditches;
- Aerobic digestion of the sludge.

The interim upgrade works will be issued for tender in September, with works expected to commence late November 2008. The estimated capital requirement for these works (both plants) is $3.2M.

Stage 2 – Centralised Strategy
A summary of the capital works includes the following:

- Construction of a 106,500EP BNR upgrade to Mt St John WPP;
- Diversion of sewer flows from Bushland Beach/Deeragun to Mt St John WPP;
- Diversion of sewer flows from Kirwan/Bohle Plains to Mt St John WPP;
- Transfer of Bohle Industrial WPP effluent to Mount St John WPP;
- Decommissioning of Mt Low / Deeragun WPPs.

The existing plant at Condon would remain and provide treatment to the Upper Ross catchment only (Condon/Kelso/Rasmussen) avoiding the need for a capacity upgrade to Condon until 2025.

Conclusion & Recommendation
TCC has developed a systematic and logical three stage strategic approach to address the population growth on Townsville's wastewater treatment infrastructure. The three stage approach prioritises action given the timing imperative to deliver the overall wastewater upgrade program.

The adopted strategy is the correct investment decision for the following reasons [part only]:

- It reduces the loads and environmental impact to the sensitive receiving waterways of the upper freshwater reaches of the Bohle.
- It eliminates discharge to the sensitive receiving waterways of the Black River.
- It upgrades the existing Mt St John WPP leading to significant load reduction to the estuary of the Bohle River (70% nitrogen, 62% phosphorus and >98% ammonia). These levels can be further improved by increased effluent reuse.

It is therefore recommended that the three stage strategy implemented by TCC be endorsed and funding be assessed on the full capital works value of $206.9 M.

Appendix D

Draft and New Legislation

Environmental Protection Water Policy 2009
The revised Water EPP 2009 replaces the Water EPP 1997 and has been closely aligned with the draft Healthy Waters SPP. Underlying the Water EPP is the identification of environmental values (EVs), water quality guidelines (WQGs) and water quality objectives (WQOs).

Other subjects the Water EPP addresses, which are also relevant to the Healthy Waters SPP, include:

- The management hierarchy for surface or ground water relative to release of contaminants and waste water to waters; and
- The management intent for waters subject to an activity that releases contaminants or wastewater to the waters.

Possibly the most significant change in the Water EPP appears in the section on Environmental Plans. This includes a more comprehensive planning process and new timeframes and priorities for plan development. The main changes to the Water EPP are shown in the table below.

Comparison of previous and revised EPP Water

EPP Water 1997	EPP Water 2009
Part 2 Application and purpose of policy **s 6 How purpose of policy is to be achieved** The purpose of this policy is to be achieved by providing a framework for— (a) identifying environmental values for Queensland waters; and (b) deciding and stating water quality guidelines and objectives to enhance or protect the environmental values; and (c) making consistent and equitable decisions about Queensland waters that promote efficient use of resources and best practice environmental management; and (d) involving the community through consultation and education, and promoting community responsibility.	**Part 2 Application and purpose of policy** **s 5 How purpose of policy is achieved** The purpose of this policy is achieved by— (a) identifying environmental values and management goals for Queensland waters; and (b) stating water quality guidelines and water quality objectives to enhance or protect the environmental values; and (p.3) (c) providing a framework for making consistent, equitable and informed decisions about Queensland waters; and (d) monitoring and reporting on the condition of Queensland waters.
Part 3 Basic concepts **s 7 Environmental values to be enhanced or protected** (1) The environmental values of waters to be enhanced or protected under this policy are— (a) for a water in schedule 1, column 1—the environmental values stated in the document opposite the water in schedule 1, column 2; or (b) for another water—the qualities in subsection (2). (2) For subsection (1)(b), the qualities are— (a) for high ecological value waters—the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued; and	**Part 3 Basic concepts** **s 6 Environmental values to be enhanced or protected** (1) The environmental values of waters to be enhanced or protected under this policy are— (a) for water mentioned in schedule 1, column 1—the environmental values stated in the document opposite the water in schedule 1, column 2; or (b) for other water—the environmental values stated in subsection (2). (2) For subsection (1)(b), the environmental values are as follows— (a) for high ecological value waters—the biological

(b) for slightly to moderately disturbed waters—the biological integrity of an aquatic ecosystem that is affected adversely to a relatively small but measurable degree by human activity; and (c) for highly disturbed waters—the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned in paragraph (a) or (b)	integrity of an aquatic ecosystem that is effectively unmodified or highly valued; (b) for slightly disturbed waters—the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators; (c) for moderately disturbed waters—the biological integrity of an aquatic ecosystem that is adversely affected by human activity to a relatively small but measurable degree; (d) for highly disturbed waters—the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned in paragraphs (a) to (c)
s 9 Water quality guidelines for indicators for environmental values (1) Water quality guidelines are quantitative measures or statements for indicators that protect a stated environmental value.	**s 7 Indicators and water quality guidelines for environmental values** (2) ***Water quality guidelines*** are quantitative measures or statements for indicators, including contaminant concentration or sustainable load measures of water, that protect a stated environmental value. [***sustainable load measure***, of water, means the maximum concentration of contaminants the water can accommodate while achieving the water quality objectives for the water.]
Part 4 Management goals for waters **s 11 Water quality objectives** (3) However, water quality objectives do not apply to- (a) water in swimming pools; and (b) drinking water in a domestic water supply system, including, for example, water in a local government or privately owned water supply system; and (c) waste water in a storage including, for example, a sewage lagoon, mine tailings dam, irrigation tailwater dam and piggery or dairy waste water pond; and (d) water in a pond used for aquaculture; and (e) water within an initial mixing zone or attenuation zone.	**Part 4 Management goals and water quality objectives for waters** **s 10 Water quality objectives** (3) However, water quality objectives do not apply to- (a) water in swimming pools; and (b) drinking water in a domestic water supply system, including, for example, water in a local government or privately owned water supply system; and (c) waste water in a storage including, for example, a sewage lagoon, mine tailings dam, irrigation tailwater dam and piggery or dairy waste water pond; and (d) water in a pond used for aquaculture; and (e) water in a stormwater treatment system.

Part 5 Management of activities **s 15 Management hierarchy for water** (1) This section states the management hierarchy for an activity that may affect a water. 16 Management intent for waters (1) This section states the management intent for waters that are subject to an activity that involves the release of waste water or contaminants to the waters.	**Part 5 Management of activities** **s 13 Management hierarchy for surface or ground water** (1) This section states the management hierarchy for an activity that may affect water. 14 Management intent for waters (1) This section states the management intent for waters subject to an activity that involves the release of waste water or contaminants to the waters.
Part 6 On-site sewerage facilities	
Part 7 Environmental plans **Division 1 Preliminary** **s 34 Priorities and timetable for environmental plans** (1) If a local government is required to develop more than 1 environmental plan about a matter under this part, it must— (a) prioritise the plans to be developed and implemented about the matter; and (b) determine a timetable for developing and implementing the plans. **s 35 Purpose of policy to be considered** In developing and implementing the environmental plans, the local government or chief executive (water resources) must consider the purpose of this policy and how the purpose is to be achieved. **s 36 Time for development and implementation of environmental plans** Within 5 years after the commencement of this policy, the local government or chief executive (water resources) must develop and start implementing at least 1 environmental plan for each matter. **s 37 Review of environmental plans** The local government or chief executive (water resources) must regularly review— (a) the priorities and timetable for the development and implementation of environmental plans; and (b) after a plan has been developed and implemented—the performance of the plan, including its economic and social impacts.	**Part 6 Environmental plans** **Division 1 Preliminary** **s 15 Purpose of policy to be considered** In developing and implementing an environmental plan under this part, a local government or sewerage service provider must consider the purpose of this policy and how the purpose is to be achieved. [essentially the same as s 35 from 1997] **s 16 Development and implementation of environmental plans** If, under this part, a local government or sewerage service provider must develop and implement an environmental plan for a matter, it must develop and start implementing the plan— (a) for an environmental plan about trade waste management—within 1 year after the commencement of this policy; or (b) for another environmental plan—within 2 years after the commencement of this policy. [Encompasses s 34 and s 36 from 1997] **s 17 Reporting and review of environmental plans** (1) The local government or sewerage service provider must— (a) after an environmental plan has been developed and certified under section 23—publish the plan on its website; and (b) within 4 years after the commencement of this policy—give the chief executive a report on the plan's implementation; and (c) within 5 years after the plan is published under paragraph (a)—review and update the plan. (2) The chief executive may at any time require a

s 38 Compliance with part A local government may achieve compliance with this part by implementing a plan prepared by it that substantially complies with this policy, even though the plan was not originally prepared for this policy. **s 39 Reporting** (1) A local government that is required to develop and implement environmental plans must give the chief executive— (a) a report on the development and implementation of plans within 3 years after the commencement of this policy; and (b) after the local government has started implementing an environmental plan—a report on the plan's implementation within 2 months after the end of each financial year.	local government or sewerage service provider to review and amend its environmental plans. [Encompasses s 37 and s 39 from 1997] **s 18 Compliance with part** A local government may comply with a requirement under this part to develop and implement an environmental plan by using and implementing a plan prepared by it that complies with this policy, even though the plan was not originally prepared for this policy. [essentially the same as s 38 from 1997]
Division 2 Local government environmental plans **s 40 Sewage management** (1) A local government that is a sewerage service provider must develop and implement an environmental plan about sewage management that minimises unnecessary flows entering the sewerage service. **s 41 Trade waste management** (1) A local government that is a sewerage service provider must develop and implement an environmental plan about trade waste management that controls trade wastes entering the sewerage service. **s 42 Urban stormwater quality management** (1) A local government that has an urban stormwater system must develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system. [Reference document prepared by the EPA to assist local government to develop USQMPs was: Environmental Protection Agency 2001, *Model urban stormwater quality management plans and guideline* Prepared to assist local governments meet their obligations under the Environmental Protection (Water) Policy 1997]	**Division 2 Environmental plans—local governments and sewerage service providers** **s 19 Total water cycle management—general** (1) A following local government must develop and implement an environmental plan about water cycle management for its local government area (*a total water cycle management plan*)— (a) a local government if its local government area has a population of at least 10000; (b) another local government if the chief executive requires it to develop and implement a total water cycle management plan, having regard to the water management requirements for the local government's area, including any results of ambient monitoring carried out under section 26. (2) A local government's total water cycle management plan must include provisions about— (a) the collection, treatment and recycling of waste water, stormwater, ground water and other water sources; and (b) the integration of water use in its area. **s 20 Total water cycle management—sewage management** **s 21 Total water cycle management—urban stormwater quality management** (1) A local government's total water cycle management plan must include provisions about its stormwater quality management to improve the quality and flow of stormwater in ways that protect the environmental values of waters affected by the

	local government's urban stormwater system. [Relates to and expands upon s42 from 1997] **22 Trade waste management** (1) A local government or other entity that is a sewerage service provider must develop and implement an environmental plan about trade waste management to control trade waste entering its sewerage services. [Relates to s 41 from 1997 and is substantially the same] **23 Certification of plans** (1) This section applies to the following— (a) a plan to which section 18 applies; (b) a total water cycle management plan; (c) a management plan about trade waste management. (2) Each plan must be independently certified by a registered professional engineer under the *Professional Engineers Act 2002* as complying with this policy.
Division 3 Other environmental plans **s 44 Environmental water provisions** (1) The chief executive (water resources) must develop and implement environmental plans about environmental water provisions for Queensland waters. **s 45 Protection of ground waters** (1) The chief executive (water resources) must develop and implement environmental plans about protecting ground waters.	**Division 3 Other environmental plans** **s 24 Healthy waters management plans** (1) The chief executive may, in cooperation with the chief executive (fisheries), develop and implement an environmental plan about water (*a healthy waters management plan*) to decide ways to improve the quality of the water. (2) Also, a recognised entity, in cooperation with the chief executive, may develop and implement a healthy waters management plan.
Part 8 Miscellaneous **Division 1 Functions of chief executive** **s 46 Education and information** (1) The chief executive, in cooperation with the chief executive (water resources) and other relevant entities, must promote a coordinated strategy to educate and inform the community about water quality management issues. (2) The chief executive's role in developing the strategy is to— (a) identify water quality management issues not being adequately addressed and liaise with relevant entities to address the issues; and (b) identify any overlap of functions and activities and minimise duplication of resources.	**Part 7 Functions of chief executive** **s 25 Community awareness and involvement** (1) This section applies if the chief executive decides to develop and implement a plan to— (a) raise community awareness of issues about water quality; and (b) involve the community in water quality management. (2) The chief executive must consider including in the plan— (a) a description of the issues about water quality; and (b) ways to raise community awareness and understanding about water quality policy, planning and management; and

(3) The strategy must include— (a) identifying and prioritising water quality management issues; and (b) identifying persons and organisations requiring education and information about the issues; and (c) developing and implementing education programs about water quality management issues for persons and organisations identified in paragraph (b). (4) An administering authority must promote community education and information about water quality management issues for which it is responsible. **s 47 Ambient monitoring** (1) If the chief executive carries out ambient monitoring of waters to assess the state of Queensland waters the chief executive must— (a) prepare a report about the results of the monitoring; or (b) include the results in an appropriate state of the environment report. (2) If practicable, the report must include a comparison of ambient monitoring results with the water quality objectives for, and freshwater flows to, the waters during the time of the monitoring. (3) For a report prepared under this section, if the measure of an indicator does not comply with a water quality guideline because of a natural property of the water, the measure of the indicator is taken to comply with the water quality guideline.	(c) ways to improve levels of community consultation in relation to water quality management, including consultation carried out under this policy; and (d) ways to better inform the community of issues about water quality management. **26 Ambient monitoring** (1) If the chief executive carries out a program of ambient monitoring of waters to assess the state of Queensland waters, the chief executive must— (a) carry out the monitoring under— (i) the document called 'Monitoring and Sampling Manual 2009' published by the department; and (ii) the AWQ guidelines; and (b) publish the results of the monitoring on the department's website; and (c) prepare a report about the results of the monitoring. [Essentially the same as s 47 (1 (b)) from 1997] (2) To the extent of any inconsistency between the documents mentioned in subsection (1)(a), the document mentioned in subsection (1)(a)(i) prevails. (3) If practicable, a comparison of ambient monitoring results with the water quality objectives for, and freshwater flows to, the water during the time of the monitoring must be included in the report. [Essentially the same as s 47 (2) from 1997] (4) For a report prepared under this section, if the measure of an indicator does not comply with a water quality guideline because of a natural property of the water, the measure of the indicator is taken to comply with the water quality guideline. [Essentially the same as s 47 (3) from 1997] (5) If the results of monitoring show the water quality objectives for the water have not been met, the chief executive may investigate the reasons why the water fails to meet the water quality objectives.
Division 2 Miscellaneous **s 48A Operation of sch 1** (1) The boundaries of a water listed in schedule 1, column 1 are the boundaries identified in the document stated in column 2 of the schedule opposite the water.	**Part 8 Miscellaneous** **s 27 Operation of sch 1** The boundaries of water mentioned in schedule 1, column 1 are the boundaries identified in the document stated opposite the water in schedule 1, column 2.
	Part 9 Repeal and transitional provisions **30 Effect of particular environmental plans** (1) This section applies if— (a) a local government must, under this policy, develop and implement a total water cycle

	management plan; and (b) on the commencement, the local government has any of the following plans developed under the repealed policy— (i) an environmental plan about sewage management; (ii) an environmental plan about stormwater quality management; and (c) the plans mentioned in paragraph (b) comply with the requirements under this policy for a part of a total water cycle management plan. (2) The local government's plan developed under the repealed policy is taken to be a plan to which section 18 applies. **31 Effect of trade waste management plan** [As for s 30 above] (2) The local government's plan about trade waste management developed under the repealed policy is taken to be a plan about trade waste management under section 22.
Schedule 1 Environmental values and water quality objectives for waters	**Schedule 1 Environmental values and water quality objectives for waters**
Schedule 2 Dictionary	**Schedule 2 Dictionary** [Variations and new definitions apply. Needs to be reviewed in the context of the changes in the body of the Policy]

Note: Yellow highlights indicate difference between 1997 and 2009 versions of the Water EPP. Where headings only are highlighted indicates substantial changes to the whole section/subject.

Draft State Planning Policy Healthy Waters

The key reference document associated with the draft Healthy Waters SPP is; Urban Stormwater - Queensland Best Practice Environmental Management (USBPEM) Guidelines (DERM 2009).

To assist with the achievement of the aim of the Healthy Waters SPP urban stormwater management design objectives are listed in Chapter 2 of the USBPEM Guidelines.

The USBPEM Guidelines also provide information on ways and means to meet the design objectives through the implementation of strategies and actions at the development design stage, during construction and post development. This includes:

- Stormwater Management Plan preparation i.e. Urban Stormwater Quality Management Plans (USQMPs), including provisions for inclusion in Planning Schemes;
- Structures for Planning Controls including Urban Capability Mapping;
- Water Sensitive Urban Design (WSUD);
- Source Controls including Erosion and Sediment Control;
- Structural Treatment Measures for WSUD.

Section 3.3 of the draft Healthy Waters SPP (see text box below) lists the way that the aims of the Healthy Waters SPP can be met through a planning scheme.

s3.3 When making or amending a local planning instrument, the draft Policy outcome is achieved when:
a. land allocated or zoned for urban or future urban purposes is compatible with natural drainage, erosion potential, watertable levels and landscape features;
b. the local planning instrument clearly identifies the measures required by development to protect water environmental values;
c. areas that drain directly into waters mapped as being of high ecological value are not allocated or zoned for urban or future urban purposes unless relevant water quality objectives can be achieved;
d. the local planning instrument is in accordance with any urban stormwater quality management plan relevant to the area;
e. the local planning instrument is in accordance with any waste management plan relevant to the area;
f. the local planning instrument ensures waste-disposal facilities are not located in areas with highly permeable soils or a high groundwater table;
g. the local planning instrument ensures development to which this draft Policy applies is assessable or self-assessable;
h. the code set out at Annex 1 of this draft Policy is incorporated in the local planning instrument in a way that provides for the same or better water quality management outcomes as that code;
i. the local planning instrument states that the information that may be requested for assessing development to which the draft Policy applies will include matters in accordance with the *Urban Stormwater - Queensland Best Practice Environmental Management Guidelines* and best practice waste water management and best practice environmental management of non-tidal artificial waterways; and
j. the local planning instrument identifies nutrient hazardous areas and ensures development in these areas is located, designed, constructed and operated to void the mobilisation and release of nutrients of concern for coastal algal blooms.

Potential Implications - Healthy Waters SPP and Water EPP

The most obvious implication of the Healthy Waters SPP is the requirement to consider the State's interests, as outlined in the SPP, during the development assessment process and when preparing local and regional planning instruments.

Initial guidance is provided in terms of generic codes for development assessment that can be used prior to incorporation of the SPP in local planning instruments i.e. planning policies and the planning scheme. Guidance is also provided in terms of best practice environmental management for stormwater, which outlines the most appropriate activities to maintain the health of Queensland waters at all stages of development. Potential implications associated with the SPP via the USBPEM Guideline are discussed briefly below.

Chapter 2 Stormwater Management Design Objectives

The design objectives listed in Chapter 2 were initially derived from the preparation of the WSUD products developed for Creek to Coral as part of the Coastal Catchments Initiative (CCI) project, which also saw the preparation of the draft Black Ross WQIP. As such Townsville already has 'local' stormwater management design objectives, consistent with the SPP.

Chapter 3 Stormwater Management Planning

This chapter refers to the Environmental Protection (Water) Policy 2009 and requirements for the development of environmental plans for a local government area dealing with Total Water Cycle Management, including plans about Urban Stormwater Quality Management (USQMP). This is potentially the most significant component of the SPP with the remaining components able to be encompassed by a Total Water Cycle Management Plan (TWCMP). Scoping the preparation of a TWCMP is a significant task and, if properly executed, has the potential to ensure the majority of the requirements of the Healthy Waters SPP and Water EPP will be met through the development and implementation of a TWCMP.

Chapter 4 Planning Controls

This chapter identifies some mechanisms for ensuring inclusion of stormwater management outcomes through planning controls. This is about the interface between the various components of theTWCMP (including USQMP) and local planning instruments.

Land use, natural asset (including high ecological value areas), biophysical constraints and urban capability mapping is a key component of the risk management process incorporated in the preparation of a TWCMP. The mapping and risk assessment results can then be translated across to local planning instruments (policy and planning scheme), through the desired environmental outcomes/strategic outcomes, tables of assessment, planning scheme zones and overlays, local plans and accompanying development assessment criteria, including codes.

To ensure the required input to local planning instruments involves a significant 'project' to:

- Define the requirements (part of the TWCMP scoping process) including for the draft Coastal Plan,
- Collate existing GIS data,
- Add the missing links,
- Identify environmental values and high ecological value areas,
- Undertake the stormwater management risk assessment, and
- Develop the interface components for the local planning instruments.

The upside is that some of this work has already been done at the 'regional' scale through the development of the draft Black Ross WQIP e.g. identification of regional scale environmental values.

Chapter 5 Water Sensitive Urban Design (WSUD)
"*Water sensitive urban design (WSUD) is a holistic approach to the planning and design of urban development that aims to minimise impacts on the natural water cycle and protect the health of aquatic ecosystems and environmental values. WSUD requires inter-disciplinary cooperation among the fields of water supply, sewerage, groundwater and stormwater management*" (DERM 2009k, p.97).

Implications of this chapter are limited as the former Townsville and Thuringowa City Councils, through Creek to Coral, have been proactive in developing locally relevant WSUD technical design guidelines (stormwater) for our region. These draft guidelines have been developed to reflect our unique climatic, soils and vegetation characteristics and are now ready for public consultation.

Development of WSUD technical design guidelines for the Coastal Dry Tropics has several benefits and also meets several objectives for project partners including helping to:

- Reduce the overall costs of waterway management by reducing the remediation and maintenance costs currently being borne by Council;
- Enhance the environmental and aesthetic aspect of our waterways for our community (thus help to reduce resident complaints);
- Ensure compliance with the emerging Queensland Government policy positions for water quality management and WSUD implementation across the state;
- Provide our development industry with a consistent and equitable approach to WSUD in our region, which is reflective of our unique climate and soils, while also nesting within the emerging State SPP framework.

The Draft Water Sensitive Urban Design (stormwater) technical design guideline:

- Identifies and recommends locally relevant and scientifically defensible water quality discharge objectives for adoption by Council through its planning instruments and development assessment processes (as per the Healthy Waters SPP); and
- Provides technical design guidelines and other tools to guide the conceptualisation, assessment and implementation of design solutions across new and infill development to achieve the adopted discharge water quality objectives.

Additional tools include:

- Draft Water Sensitive Urban Design (stormwater) factsheets;
- A draft Water Sensitive Urban Design (stormwater) strategy roadmap (a web based portal with information and process guidance for developers, consultants, planners and other stakeholders when they are designing, developing and implementing WSUD in our region.

The final WSUD technical design guidelines for the Coastal Dry Tropics will be presented to Council in early 2010 for consideration in adopting them.

A number of associated products and tools need to be developed to accompany the WSUD technical design guidelines, and are included in the Black Ross WQIP implementation process, albeit with limited funding for completion.

Chapter 6 Source Controls

Dealing with stormwater pollution at the source is the most effective way of protecting stormwater quality. This applies to all stages of development and a variety of activities. Along with Council's requirements to ensure new developments incorporate WSUD and land development and construction activities have the appropriate measures in place to manage stormwater e.g. site management and erosion and sediment control plans, Council is also obliged to manage its own activities in a similar way.

Through their operations in areas such as road and pipeline construction and maintenance, street cleaning, sewerage reticulation and pump stations, and waste collection, local and regional Councils directly influence the quality of stormwater within a catchment. By applying stormwater best practices in its operational activities, local and regional councils can significantly improve the quality of urban stormwater run-off, and lead by example.

The implications of this chapter are dependent on the current arrangements in place, and the amount of integration of management systems between the former Thuringowa and Townsville City Councils. The potential first stage would be an audit of Council activities and environmental management systems to assess the requirements in terms of the integration, adaptation and development of management systems and processes to address the Healthy Waters SPP, Water EPP and Coastal Plan.

A known area of deficiency at present is green space management, where urban and 'natural' environments interface. An environmental management system is required to address deficiencies in this area and could be used as the framework for incorporating the stormwater management component as required by the Healthy Waters SPP.

Chapter 7 Structural Treatment Measures

Stormwater structural treatment measures in this chapter deal with the post construction, operational phase of development. Amongst other things, structural treatment measures are incorporated into the WSUD conceptual planning stage and are 'tested' during the development assessment process using models such as MUSIC.

Structural treatment measures can also be retrofitted to areas that were constructed prior to WSUD principles being introduced. This is another component of USQMP investigations and has implications for that process. In some situations, structural treatment measures may not be physically or economically feasible to implement and the preferred (most effective) option may be education and awareness programs to change behaviours and address the issues at the source (see previous chapter).

To adequately address the structural treatment methods component of the Healthy Waters SPP requires the consolidation of all the available information on what works (and doesn't work) in the Townsville region, and the subsequent preparation of guidelines specific to the Townsville region.

Creek to Coral has commenced the process through the CCI project with the development of the various WSUD guideline components and compilation of a draft report on some of the stormwater treatment measures installed in the former Townsville City local government area.

Appendix E

WSUD Business Case

Based on material extracted from (Draft) *Water Sensitive Urban Design to Meet the Proposed Stormwater Management Objectives in Queensland: A Business Case* (Water by Design 2009).

[Extract from the Executive Summary]

"The draft *State Planning Policy for Healthy Waterways* (the draft policy) mandates stormwater management for new urban development across Queensland by setting design objectives for the management of stormwater quality, waterway stability and frequent flows. These stormwater management objectives can be achieved through the adoption of water sensitive urban design (WSUD), however, the costs associated with delivering WSUD are often perceived as a barrier to wide spread adoption (Colmar Brunton, 2005)."

"A Business Case was prepared to assess the practicality and determine if there is likely net benefit of implementing WSUD at the development scale to meet the new stormwater management objectives defined in the draft policy."

"The assessment illustrates the stormwater management objectives established by the draft *State Planning Policy for Healthy Waters* and its supporting codes and guidelines can be practically achieved for urban developments captured by Queensland's Integrated Development Assessment System by adopting WSUD solutions. WSUD provides an effective way to manage stormwater runoff entering waterways from urban development and there is a net benefit associated with WSUD." (Water by Design 2009)

[Extracts from Section 3]

"The case study assessment was undertaken for six typical developments which represent examples of 'greenfield' and 'infill' development that would be captured by the *Integrated Development Assessment System,* the draft *State Planning Policy for Healthy Waters* and the *South East Queensland Regional Plan 2009 to 2026: Implementation Guideline No. 7*."

The case studies are summarised below:

- **"Case study 1:** Residential greenfield development on a sloping site (5% or greater). The case study site covers an area of 76ha within an overall subdivision of approximately 1,000 ha. There are 951 detached houses, with a typical lot size of between 400 - 700m².
- **Case study 2:** Residential Greenfield development on flat topography. The case study site covers an area of 6.3ha within an overall subdivision of approximately 100 ha. There are 84 detached houses within the site, with typical lot sizes between 400 - 500m².
- **Case study 3:** Residential townhouse development. The case study site comprises 25 two-storey townhouses plus the site has landscaped areas, an internal road network, visitor parking spaces and a loading bay.
- **Case study 4:** Urban renewal development (high density development). The case study is a large-scale urban renewal project involving conversion of an industrial area into a high-density residential development. The development includes 7ha of high-rise residential towers and 5ha with 5-storey residential apartment buildings. There are 25 separate buildings within the site.
- **Case study 5:** Commercial development. The case study is a small-scale commercial development comprising a neighbourhood shopping centre on a 0.42 ha site. Two buildings are separated by a central arcade and 15–20 ground-level shops.

- **Case study 6:** Industrial development. The case study is a medium-scale industrial development comprising a factory and warehouse on a 1.0 ha site. The single building is surrounded by an internal driveway and car park with approximately 100 car parking spaces."

"Each case study is a real development that has either been designed or built somewhere in Queensland, with or without WSUD elements. Choosing case studies based on real developments ensures the developments' characteristics are consistent with current town planning scheme provisions and reflect current stakeholder and market expectations in Queensland." (Water by Design 2009, p.3-6)

"The case study assessment was undertaken for four geographic locations: Brisbane, Mackay, Townsville and Cairns. The four locations were chosen as they allowed the assessment of WSUD under different climatic conditions. These locations represent areas where significant pressure on waterway health is expected as a result of increases in population growth and urban expansion."

"One of the aims of the Business Case is to determine what *additional* costs, if any, are generally added to developments as a result of meeting the proposed stormwater management objectives. To do this, the WSUD developments (those that meet the new stormwater management objectives) have been compared to a 'Base Case' development. The Base Case reflects the development which complies with current mandatory State Government policy."

The Base Case development assumes:

- "Conventional stormwater drainage management.
- Flood management (flood detention storage).
- Compliance with the Queensland Development Code by using rainwater tanks." (Water by Design 2009, p.3-7)

"The WSUD Case for each development scenario identifies the additional WSUD infrastructure required, above and beyond the Base Case, to meet the new stormwater management objectives defined by the draft *State Planning Policy for Healthy Waters*."

The WSUD Case development assumes:

- "As per Base Case.
- WSUD elements (e.g. bioretention systems, etc.) to meet the stormwater management objectives."

"The performance of each scenario was calculated using desk top and modelling analysis."

"For the WSUD Case, all costs of WSUD elements were calculated and presented to identify the <u>additional</u> costs associated with achieving the stormwater management objectives (i.e. costs in addition to those in the Base Case)."

"Where possible (within the scope of this project) in terms of costing, the costs have taken into account the Base Case scenario. For example, the bioretention systems in each of the case studies typically occupy areas that would otherwise be landscaped as turf or garden beds. Therefore, the net cost (acquisition and maintenance) of bioretention systems calculated for the Business Case is the cost of the bioretention system less the cost of typical landscaping." (Water by Design 2009, p.3-8)

[Extracts from Section 5]

"From the case studies, the following general observations can be made:

- **Treatment size**: The bioretention system size required to meet the new stormwater management objectives varies from 0.8% to 1.6% of the development footprint. This represents the actual flat surface area of the bioretention systems with additional area required for batters.
- **Geographic location**: Geographic location influences the size of the treatment systems required. Further north in Queensland, where annual rainfall is higher, treatment systems generally need to be slightly larger to achieve the stormwater quality objectives.
- **Influence of rainwater tanks**: Note that if rainwater tanks are not adopted to meet the requirements of the Queensland Development Code, then the stormwater treatment size (i.e. bioretention system) generally needs to increase in order for the development to meet the water quality management objectives. The lower the rainfall area, the larger the increase required. Using Case Study 4 as an example, when there are no tanks in Cairns the bioretention size stays the same, in Townsville it increases by 0.1% and in Brisbane it increases by 0.5% (this influence is less pronounced for the other case studies). The reason for these geographic differences is that in the relatively lower rainfall areas like Brisbane, the rainwater tanks are treating (reusing) a relatively larger portion of annual runoff volume from the site, hence the bioretention system to treat the remainder of the site runoff can be smaller. In Cairns, the proportion of rainfall that is reused from the tank is much smaller compared to total annual runoff from the site.
- **WSUD and urban design**: In each of the case studies the stormwater management objectives can be achieved without any material change to the urban design and loss of developable land. This is a significant finding. Bioretention basins were integrated into landscaped areas and simple adjustments to the stormwater drainage layout made to support WSUD. It is, however, important to note that the earlier WSUD elements are included in the urban design, the better and more cost effective the outcome will be. Currently in many development situations across Queensland, WSUD is not being considered early in the design process resulting in the cost of WSUD being higher than it should be.
- **Practicality**: Based on the case study assessment the new stormwater management objectives can be practically achieved through the implementation of WSUD. In all cases WSUD solutions can be effectively built into the developments, readily integrated into the development layout and landscape design with no loss of development yield."

(Water by Design 2009, p.5-17)

Development scale

The most readily identifiable costs associated with WSUD are the direct financial costs. The acquisition (capital) costs and the annual maintenance costs of achieving the new stormwater objectives in Townsville are presented in the table below (see Case Studies for more detail). The total lifecycle costs for Townsville are presented in a separate table (below). The costs represent the incremental cost of going from the Base Case to the WSUD Case. The costs have been calculated on a $ per lot and $ per hectare basis.

In addition the costs for Case Studies 1-3 have been recalculated without rainwater tanks. These figures also appear in the tables below.

"Note that a lifecycle cost period of 25 years has been used for this assessment, as this is the typical period used for public benefit cost analysis. Due to the discounting used, impacts after 25 years rarely have a material impact on benefits or costs. A discount rate of 5.5% has been used in the lifecycle cost calculations, which is supported by Queensland Treasury who usually suggest a real discount rate of between 5 and 6%."

(Water by Design 2009, p.5-18)

Case Study Acquisition and Maintenance Costs (2009 $Au) for Townsville: Incremental Cost of going from Base Case to WSUD Case (i.e. the additional cost of achieving the new stormwater objectives)

	Case Study Description	Capital Costs $ / lot*	Annual Maintenance $ / lot*	Capital Costs $ / ha	Annual Maintenance $ / ha
1	Residential greenfield (large scale) on sloping topography	2,745	34	34,450	425
1[1]	Residential greenfield (large scale) on sloping topography	2,955	37	37,100	455
2	Residential greenfield on flat topography	3,235	32	42,890	420
2[1]	Residential greenfield on flat topography	3,486	35	46,189	455
3	Residential townhouse development	1,055	10	39,590	390
3[1]	Residential townhouse development	1,143	12	42,889	423
4A	Urban renewal development	345	3	49,500	490
4B	Urban renewal development (no rainwater tanks) [1]	370	4	52,800	520
5	Commercial development**	11,498	100	54,750	490
6	Industrial development**	49,500	490	49,500	490

Notes: Information was sourced primarily from Table 5-1 (Water by Design 2009, p.5-19)

* Lot refers to household or dwelling.

** Per lot estimates for industrial and commercial cases are dependent on lot numbers and sizes which vary considerably.

[1] recalculated WSUD Case for Townsville without rainwater tanks and with enlarged bioretention systems to compensate for the water quality benefits associated with rainwater tanks.

[1] The water conservation requirements of the QDC do not currently apply to high density residential, therefore two WSUD solution were trialled, with and without rainwater tanks

Case Study Life Cycle Costs (2009 $Au) for Townsville: Incremental Cost of going from Base Case to WSUD Case (i.e. the additional cost of achieving the new stormwater objectives)

Case Study Description		$ / lot*	$ / ha	Annualised cost $/lot/yr	Annualised cost $/ha/yr
1	Residential greenfield (large scale) on sloping topography	3,840	48,220	154	1,929
1[1]	Residential greenfield (large scale) on sloping topography	4,136	51,927	166	2,077
2	Residential greenfield on flat topography	4,395	58,260	176	2,330
2[1]	Residential greenfield on flat topography	4,735	62,739	190	2,510
3	Residential townhouse development	1,435	53,775	58	2,151
3[1]	Residential townhouse development	1,552	58,258	62	2,330
4A	Urban renewal development	470	67,235	19	2,689
4B	Urban renewal development (no rainwater tanks)	500	71,720	20	2,869
5	Commercial development**	15,430	73,485	617	2,939
6	Industrial development**	67,235	67,235	2,689	2,689

Notes: Information was sourced primarily from Table 5-2 (Water by Design 2009, p.5-20)

* Lot refers to household or dwelling.

** Per lot estimates for industrial and commercial cases are dependent on lot numbers and sizes which vary considerably.

[1] recalculated WSUD Case for Townsville without rainwater tanks and with enlarged bioretention systems to compensate for the water quality benefits associated with rainwater tanks.

"To put the costs in the above tables into context, they can be compared to the Base Case cost:

- Case Studies 1 and 2 - the Base Case acquisition cost (rainwater tanks) is $3,000/dwelling with an annual maintenance cost of $90/dwelling.
- Case Study 3 – the Base Case acquisition cost is $2,500/dwelling and the annual maintenance cost is $90/dwelling.

The cost of complying with the new stormwater management objectives (WSUD Case) is less than complying with the current Queensland Development Code (Base Case – rainwater tanks)."

Cost analysis

"Key points regarding capital costs are:

- Implementing the stormwater management components of WSUD is typically less than 1% of the total cost of establishing a new dwelling;
- The capital costs of implementing WSUD solutions range from approximately $400 per dwelling for units in large complexes to around $4,000 for more complex WSUD solutions for detached houses in case study 2 in Cairns;
- As housing density increases, the acquisition cost decreases. In a detached dwelling development, capital costs of the WSUD solution are approximately $1600 - $4000 per household. In a townhouse development this reduces to $800 - $1,200 per dwelling, and for units it reduces to about $400 per dwelling. The same can be said for total life cycle costs. In a detached dwelling development, total life cycle costs of the WSUD solution are approximately $4000 - $5000 per household. In a townhouse development this reduces to $1000 - $1500 per dwelling, and for units it reduces to about $500 per dwelling.

Key points regarding ongoing costs are:

- Ongoing operating and maintenance costs per annum for stormwater WSUD elements range from less than $5 a year per dwelling for units to around $50 a year per dwelling for detached houses (Cairns);
- The ongoing costs for WSUD in public areas would be initially be met by local governments and then passed onto households via rates or other means. For detached dwellings this would translate to rates being marginally higher in new developments where WSUD was established. While the gross increase in rates could be as high as 2–3% of an average rates bill of $1,200 per annum, Councils would save in other areas (e.g. lower costs of waterway rehabilitation), bringing the potential net increase in rates down considerably and potentially offsetting the cost altogether2.

In summary, the ongoing operations and maintenance costs of WSUD to meet the stormwater management objectives of the draft policy are typically less than $40 per annum per dwelling, which is less than 2–3% of the cost of annual property rates charged by local government authorities.

This is a relatively minor financial impost considering the effectiveness of WSUD in achieving enhanced environmental and social outcomes for the community. Councils would save in other areas (e.g. lower costs of waterway rehabilitation), bringing the potential net increase in rates down considerably or even offsetting the cost altogether." (Water by Design 2009, p.5-21)

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[2] For example, assume a low density residential development (per Case Study 1) with 1,000 lots has an annual WSUD maintenance cost of $20,000 to $40,000 ($20-40/lot). Assume 500 m of downstream waterway is protected from degradation as a result of the WSUD. The local Council saves $12,500 per annual in waterway maintenance rehabilitation costs (i.e. $25/m/year which excludes rectification capital costs). In this case, annual maintenance costs are partly covered by savings. Where significant maintenance works in downstream ecosystems are required (i.e. large scale algae blooms and weed infestation) then these maintenance costs could significantly outweigh WSUD maintenance costs.

Benefits

Pollutant Loads

"For each case study the annual reduction in pollutant loads of total nitrogen (TN) as a result of the WSUD element has been calculated3. The TN loads removed were then converted into a dollar value using an estimated treatment cost from the literature4. This annual benefit value has then been compared to an annualised life cycle cost for the WSUD treatment."

From the numbers provided in the table below it is apparent that the benefits of the pollutant load reduction provided by the WSUD treatment are likely to outweigh the costs when compared to the point-source treatment option. (Water by Design 2009, p.5-22)

Pollutant load reductions: associated costs and benefits for Townsville

Case Study Description		TN removed (kg/ha/yr)	Equivalent annual TN removal treatment costs[5] ($/kg/year)	Annualised life cycle cost of WSUD[6,7] ($/ha/yr)
1	Residential greenfield (large scale) sloping topography	5 [6.2]	2,575 [3,193]	1,929 [2,077]
2	Residential greenfield on flat topography	5.4 [6.6]	2,781 [3,399]	2,330 [2,510]
3	Residential townhouse development	5.3 [7.3]	2,730 [3,760]	2,151 [2,330]
4A	Urban renewal development	7.6	3,914	2,770
4B	Urban renewal development (no rainwater tanks)	7.9	4,069	2,869
5	Commercial development	12.8 [13.8]	6,592 [7,107]	2,940 [3,175*]
6	Industrial development	8.6 [9.2]	4,429 [4,738]	2,689 [2,904*]

Notes: Information was sourced primarily from Table 5-3 (Water by Design 2009, p.5-23)
"TN removed" column – TN removed with increased bioretention system size is included in [square brackets].
"Equivalent annual TN removal treatment costs" column – recalculated cost including the TN removed with increased bioretention system size shown in [square brackets]
"Annualised lifecycle cost of WSUD" column - Annualised lifecycle cost of WSUD recalculated for Townsville without rainwater tanks, and with larger bioretention systems, is included in [square brackets].
WSUD TN removal cost as a percentage of equivalent TN point source removal cost is; $335 - 13% for Case Study (CS) 1, $381 - 14% for CS2, $320 - 12% for CS3, $364 - 13% for CS4B, $230 - 3% for CS5 and $316 - 7% for CS6. Annual TN removal costs attributed to WSUD measures in $/kg/year above are based on bioretention systems only for Case Study 1, 2, 3 and 4B, and a combination of rainwater tanks and bioretention systems for Case Study 5 and 6 (*the annualised lifecycle cost was adjusted upwards by 8% to compensate for not calculating the increased cost of bioretention systems which would result in the increased TN removal figures used to calculate the $/kg/yr cost of TN removal).

[3] This calculation did not include the pollutant loads removed in the base case scenario (loads associated with rainwater reuse)
[4] Melbourne Water: *Stormwater Quality Offsets, A guide for developers.*
[5] A levelised annual treatment cost of $ 515,000 per tonne (the average of the $ 180,000 to $ 850,000 range as presented above) of nitrogen removed has been used in this calculation. The estimates were originally calculated to provide estimates for efficient pricing of wastewater services and it is recognised that there are inherent limitations with adopting this data for this calculation, however this data represents the best estimate available.
[6] The incremental costs of WSUD compared to the base case
[7] The life cycle of the WSUD elements has been modelled as 25 years

Avoided Cost of Waterway Rectification / Maintenance

"The introduction of a WSUD solution results in lower loads of pollutants discharged to downstream waterways, fewer weeds being transported to downstream waterways and less erosion of downstream waterways. If a WSUD approach is not adopted, experience indicates that local authorities would need to undertake maintenance of downstream waterways and, in many cases, periodically rehabilitate the waterway. There are many examples in Queensland where significant local government effort and funding has been required to rectify and maintain waterways and water bodies as a result of poor catchment management in development catchments. This is a cost that would be avoided (or partially avoided) if WSUD were adopted.

This avoided cost has been estimated for the purpose of the Business Case by defining typical waterway rehabilitation and maintenance requirements that would be incurred if WSUD is not adopted. The cost estimates have been developed in the following manner:

- Obtain representative unit rates per linear metre of stream for major rehabilitation works and annual maintenance works. Capital cost rates ranged from $200-$800/m for a number of Gold Coast City Council projects to $2500-$3000/m for Brisbane City Council projects. Maintenance cost rates were provided as $25/m of stream.
- Convert these unit rates per linear metre of stream to unit rates per square metre of development, using case study 1 as an example of a typical Greenfield development as this case study contained a waterway. The stream length is 1,000m for the 75.75ha development."

Case Study 1 (residential greenfield – sloping) - Avoided cost of Waterway Rectification / Maintenance

Life Cycle cost of waterway rehabilitation works[8]		WSUD Life Cycle Cost ($/ha)			
($/lot)	($/ha of catchment)	Brisbane	Mackay	Townsville	Cairns
638-4,780 (2,709)[1]	8,000 - 60,000 (average = 34,000)	29,675	44,510	48,220 51,927[2]	55,635

Notes: Information was sourced primarily from Table 5-4 (Water by Design 2009, p.5-24)
Averages in (brackets).
[1] $/lot lifecycle cost range is for Townsville Case Study 1 using Total Lifecycle cost of waterway rehabilitation works per kilometre of stream length ranging between $606,000 and $4,545,000 (Average $2,575,890).
[2] recalculated based on no rainwater tanks and larger bioretention systems to compensate.

"Using Case Study 1 as an example, it can be seen that although the lifecycle costs of the WSUD treatment are likely to be higher than costs of the waterway rehabilitation works, however, the value of the benefit is still significant." (Water by Design 2009, p.5-24). Capital and maintenance cost ranges of waterway rehabilitation works have been calculated for Case Study 1 for Townsville and are presented comparatively as a cost per lot and a cost per hectare of the development site.

Case Study 1 Comparative Avoided cost of Waterway Rectification / Maintenance

Capital cost $ per lot	Capital cost $/ha of site	Maintenance costs $/yr per lot	Maintenance costs $/ha/yr of site
210-3,155 (1,682)	2,640-39,604 (21,122)	27	330

Notes: Averages in (brackets). Capital cost range used $200,000 to $3,000,000.

[8] Note that in reality, local authorities will not always complete waterway rectification when WSUD is not adopted, so the true avoided costs are likely to be at the lower end of this range on average.

Property Values

"There are two key ways in which WSUD can add value to property prices:

1. WSUD elements
    a. improve the amenity within the development
    b. provide a 'sustainable development' marketing angle
    c. can add passive recreation value to the development (additional landscape, walking, increased ecology etc)
2. Maintained or enhanced water quality and stream health in receiving waterways
    a. Local streams and creeks (freshwater)
    b. Regional waterways (estuarine and marine)

The following data has been obtained from the literature on house price premiums associated with WSUD: (Water by Design 2009, p.5-24)

- Interviews with developers identified the value associated with the recreational and amenity value of waterways in Queensland is typically worth 2-5 % of the total value of property9.
- Research undertaken by CSIRO and Maroochy Shire Council found that the Maroochy River is underpins property value in the region to the value of $951m. This represents 8-10% of the total value of property within the region of the river.
- Research in Western Australia (Tapsuwan et al, 2007) indicates property values increase by 7% when located adjacent to natural wetlands which are preserved (or newly created stormwater treatment wetlands).
- A study in Washington found the premium associated with improvements in water quality on nearby properties typically ranges from 1% to 20%.

A benefit value of 1% represents the lowest end of the range of reported values in literature. It is not straightforward to take this number and adopt it for the case study assessment, so a more conservative estimate has been adopted. It is also recognised that the benefit value for a detached dwelling is likely to be higher than for a unit or a townhouse.

For the purpose of the case study assessment, the following premiums have been adopted:

- A benefit value in the range of 0.25% to 1% has been adopted for the detached dwelling developments (Case Studies 1 and 2)
- A benefit value in the range of 0.25% to 0.5% has been adopted for the townhouse and unit developments (Case Studies 3 and 4)"

Property Premiums Associated with WSUD - Townsville example with and without rainwater tankers

Case Study		Property premiums associated with WSUD ($/ha)	Capital Costs of WSUD Measures ($/ha)	
			Townsville	**Townsville[1]**
1	Residential greenfield (sloping)[10]	11,000 – 44,000 (27,500)	34,450	37,100
2	Residential greenfield on flat topography[11]	11,000 – 44,000 (27,500)	42,890	46,189

[9] This represents an average value across Queensland. The closer to waterways the higher the property value (or premium) and the further away from waterways the lower the property value.
[10] Using an average house price of $400,000 and 11 dwellings per hectare
[11] Using an average house price of $400,000 and 11 dwellings per hectare

3	Residential townhouse development[12]	35,000 – 70,000 (52,500)	39,590	42,889
4	Urban renewal development (no tanks)[13]	175,000 – 350,000 (262,500)	49,500	49,500

Notes: Information was sourced primarily from Table 5-5 (Water by Design 2009, p.5-25)

¹ recalculated capital costs based on no rainwater tanks and correspondingly larger bioretention systems to compensate. It was not considered possible to quantify this benefit for commercial development within the scope of the assessment (Case Study 5). It is not clear how this benefit would impact on industrial sites and this was therefore not calculated (Case Study 6).

"This premium takes into account the impact on amenity in the development due to the WSUD elements themselves, local water quality protection and regional water quality protection. Attributing a benefit value of improvement in regional water quality is contentious. The health of regional waterways, however, are an important aspect of property in Queensland as the value of land / property is underpinned by the recreational and amenity values provided by its waterways and open space. For this reason also the benefit value is lumped and a conservative benefit value has been used.

While this benefit will impact on residential developments, and commercial developments in high amenity areas, it is not clear how this benefit would impact on industrial sites so this benefit may not apply to case study 6. Whilst a benefit would apply to a commercial development (an enhanced streetscape likely to deliver premium on rents received by landlords related to increased patronage for retail and service businesses) it is not considered possible to quantify this benefit within the scope of this assessment."
(Water by Design 2009, p.5-25)

"The results indicate that the premium on property values associated with WSUD will either outweigh the capital cost of implementing WSUD within residential developments, or return the majority of the capital cost."

Avoided Development Costs

"In many situations, the application of WSUD to a new urban development can reduce or avoid the cost associated with other elements of the development. At a local scale, infrastructure costs such as conventional pits/pipes and earthworks costs can be substantially reduced through alternative stormwater conveyance and management approaches and the need to adopt alternative urban design approaches rather than conventional."

"Boubli (2003) undertook a study of two typical urban developments in Sydney and illustrated that WSUD could be applied to these sites without increasing the overall development costs. This is supported by practical experience at development projects across Queensland where significant cost savings have resulted through the incorporation of WSUD and its influence on engineering and urban design (i.e. Bellvista at Caloundra, North Shore at Townsville, Victoria Park in Sydney).

In particular, the adoption of conventional urban design and pit/pipe drain on flat sites can result in significant development costs as a result of the large diameter pipes and earthworks required to drain these sites. The WSUD approach adopts an at-surface approach to conveying and treating stormwater on flat sites which reduces/avoids this cost."

[12] Using an average townhouse price of $350,000 and 40 dwellings per hectare
[13] Using an average unit price of $350,000 and 200 dwellings per hectare

The potential reduction in drainage and earthworks costs (avoided) associated with adopting WSUD for case studies 2, 4 and 6 (flat sites) "are based on the following assumptions:

- The capital cost of conventional pit and pipe drainage (Base Case) is $55,000 per hectare (Bligh Tanner and DesignFlow, 2009). When the site is designed to ensure at-surface drainage on pavements, within kerb/channel and swales, the pit and pipe drainage is assumed to reduce by at least 20% (i.e. $11,000 per hectare). Additionally, some of the pit and pipe costs form part of the WSUD Case costs (i.e. the overflow pit and pit within the bioretention basins are incorporated into the unit cost).
- In order to drain flat sites via conventional pit/pipes to the receiving waterway or drainage system, filling is required due to large pipe diameters. The capital cost of earthworks required to raise the development to allow for drainage is $10 per m3 (even higher if importing fill). For the case studies it was assumed the whole site would require a minimum 0.25m of additional fill under the conventional design case (Base Case) than the WSUD Case.
- Considering the above assumptions, the avoided capital cost on flat sites is likely to be $36,000 per hectare or greater (or life cycle costs of $34,123)."

Potential avoided development costs associated with WSUD on flat sites - Townsville example

Case Study Description		Avoided capital cost ($/ha)	Avoided annualised lifecycle cost ($/ha)	Acquisition (capital) costs of WSUD ($/ha)	Annualised life cycle cost of WSUD[14],[15] ($/ha/yr)
2	Residential greenfield on flat topography	36,000	1,365	42,890	2,330
4A	Urban renewal development	36,000	1,365	49,500	2,689
4B	Urban renewal development (no rainwater tanks)	36,000	1,365	52,800	2,869
6	Industrial development	36,000	1,365	49,500	2,690

Notes: Information was sourced primarily from Table 5-6 (Water by Design 2009, p.5-26)

"It can be seen that although the lifecycle costs of the WSUD treatment are likely to be higher than the avoided development costs the value of the benefit is still significant. Additionally, this avoided cost represents the likely minimum avoided costs on flat sites."

The actual avoided cost will vary considerably depending on site conditions. Experience indicates the avoided costs are often considerably higher than the WSUD costs e.g. North Shore in Townsville.

Case Study Cost Benefit Framework

"After estimating those costs and benefits which can be quantified, the cost benefit framework has been applied to the case studies."

"For Case Studies 1 and 2, the cost and benefit framework results are similar which allowed lumping of the case studies to provide a generalised result. This was similar for Case Studies 3 and 4 and Case Studies 5 and 6 (commercial and industrial developments)." (Water by Design 2009, p.5-27)

[14] Range provided for all geographic locations (climatic zones)
[15] The life cycle of the WSUD elements has been modelled as 25 years

Quantifiable costs and benefits - Case Studies 1 and 2 (low density residential case studies) for Townsville (without rainwater tanks)

Major quantifiable costs

1. **Capital (Acquisition) costs** *(note: included in life cycle cost)*

- ($ / lot) = $2,955 and $3,486 (average = $3,220) (Qld average = $2,800)
- ($ / hectare) = $37,100 and $ 46,189 (average = $41,645) (Qld average = $30,425)

2. **Annual maintenance costs:** *(note: included in life cycle cost)*

- ($ / lot) = $37 and $35 (average = $36) (Qld average = $30)
- ($ / hectare) = $458 and $453 (average = $456) (Qld average = $390)
- 2 to 3 % of the developments' annual property rates (average = 2.5%)*

3. **Life Cycle Costs (capital + maintenance + renewal + decommission)**

- ($ / lot) = $4,136 and $4,735 (average = $4,436). (Qld average = $3,890)
- ($ / hectare) = $51,927 and $62,739 / hectare (average = $57,333) (Qld average = $50,680 / ha)

4. ***Annualised Life Cycle Costs* (capital + maintenance + renewal + decommission)**

- ($ / lot) = $166 and $190 (average = $178) (Qld average = $155).
- ($ / hectare) = $2,077 and $2,510 (average = $2,294) (Qld average = $3,330)

Note: Townsville figures include the additional costs associated with larger bioretention systems to compensate for the omission of rainwater tanks.

** Assumes average rates of $1,200/yr across Queensland. Using an average rate for Townsville of $1,500/yr equates to an annual maintenance cost of 2.4% of property rates.*

Minor costs

- Additional development assessment, compliance checking and enforcement costs associated with WSUD assets. Relatively minor and reducing over time as WSUD becomes mainstream practice.
- Potential increase in maintenance tasks for residents at WSUD streetscape area.

Major quantifiable benefits

1. **Value of the reduction in N loads in stormwater**

The equivalent wastewater treatment cost to remove annual N loads

- ($/kg/yr) = $2,575 and $2,781 (average = $ 2,678) (Qld average = $ 3,630)
- % of the annualised life cycle cost of the WSUD 'treatment train' = 124% and 119% (average = 122%) (Qld 95% to 180% - average = 110%)

2. **Avoided costs associated with waterway rehabilitation / maintenance**

- $ / ha of development = $8,000 to $60,000 (Qld average = $ 34,000)
- % of the life cycle cost of the WSUD 'treatment train' = 65% and 54% (average = 60%) (Qld 25% to 85% - average = 67%)

3. **Increased property values (premium)**

- $ / ha = $11,000 to $44,000 (Qld average = $27,500)
- % of the capital cost of the WSUD 'treatment train' = 74% and 60% (average 67%) (Qld 52% to 110% - average = 90%)

4. **Avoided development costs (applicable only on flat sites)**

- $ / ha = $36,000
- % of the capital cost (average) of the WSUD treatment train' = 78% (Townsville) and 120% (Qld)

Notes: Information was sourced primarily from Table 5-7 (Water by Design 2009, p.5-28)

Quantifiable costs and benefits - Case Studies 3 and 4B (mid and high density residential development case studies) for Townsville (without rainwater tanks)

Major quantifiable costs

1. **Capital (Acquisition) costs** *(note: included in life cycle cost)*

- ($ / lot) = $1,143 and $370 (average = $757) (Qld average = $775)
- ($ / hectare) = $42,889 and $ 52,800 (average = $47,845) (Qld average = $37,930)

2. **Annual maintenance costs:** *(note: included in life cycle cost)*

- ($ / lot) = $12 and $4 (average = $8) (Qld average = $22)
- ($ / hectare) = $423 and $520 (average = $472) (Qld average = $390)

3. **Life Cycle Costs (capital + maintenance + renewal + decommission)**

- ($ / lot) = $1,552 and $500 (average = $1,026). (Qld average = $1,100)
- ($ / hectare) = $58,258 and $71,720 / hectare (average = $64,989) (Qld average = $55,930 / ha)

4. **Annualised Life Cycle Costs (capital + maintenance + renewal + decommission)/year**

- ($ / lot) = $62 and $20 (average = $41) (Qld average = $45).
- ($ / hectare) = $2,330 and $2,869 (average = $2,600) (Qld average = $2,240)

Note: Townsville figures include the additional costs associated with larger bioretention systems to compensate for the omission of rainwater tanks.

Minor costs

- Additional development assessment, compliance checking and enforcement costs associated with WSUD assets. Relatively minor and reducing over time as WSUD becomes mainstream practice.
- Potential increase in maintenance tasks for residents at WSUD streetscape area.

Major quantifiable benefits

1. **Value of the reduction in N loads in stormwater**

The equivalent wastewater treatment cost to remove annual N loads

- ($/kg/yr) = $2,730 and $4,069 (average = 3,400) (Qld average = $ 4,195)
- % of the annualised life cycle cost of the WSUD 'treatment train' = 117% and 142% (average = 130%) (Qld 150% to 205% - average = 185%)

2. **Avoided costs associated with waterway rehabilitation / maintenance**

- $ / ha of development = $8,000 to $60,000 (Qld average = $ 34,000)
- % of the life cycle cost of the WSUD 'treatment train' = 58% and 47% (average = 53%) (Qld 20% to 85% - average = 60%)

3. **Increased property values (premium)**

- $ / ha = $35,000 to $70,000 (Qld average = $52,500) medium density
- % of the capital cost of the WSUD 'treatment train' = 122% (Qld 120% to 150% - average = 135%)
- $ / ha = $175,000 to $350,000 (Qld average = $262,500) high density
- % of the capital cost of the WSUD 'treatment train' = 500% (Qld 480% to 700% - average = 520%)

4. **Avoided development costs (applicable only on flat sites)**

- $ / ha = $36,000
- % of the capital cost (average) of the WSUD treatment train' = 84% and 68% (average 76%) (Townsville) and 95% (Qld)

Notes: Information was sourced primarily from Table 5-8 (Water by Design 2009, p.5-29)

Quantifiable costs and benefits - Case Studies 5 and 6 (commercial and industrial developments)) for Townsville (with rainwater tanks)

Major quantifiable costs

1. **Capital (Acquisition) costs** *(note: included in life cycle cost)*

- ($ / hectare) = $54,750 and $ 49,500 (average = $52,125) (Qld average = $48,825)

2. **Annual maintenance costs:** *(note: included in life cycle cost)*

- ($ / hectare) = $490 and $490 (average = $490) (Qld average = $440)

3. **Life Cycle Costs (capital + maintenance + renewal + decommission)**

- ($ / hectare) = $73,485 and $67,235 / hectare (average = $64,989) (Qld average = $65,880 / ha)

4. **Annualised Life Cycle Costs (capital + maintenance + renewal + decommission)/year**

- ($ / hectare) = $2,939 and $2,689 (average = $2,814) (Qld average = $2,635)

Minor costs

- Additional development assessment, compliance checking and enforcement costs associated with WSUD assets. Relatively minor and reducing over time as WSUD becomes mainstream practice.

Major quantifiable benefits

1. **Value of the reduction in N loads in stormwater**

The equivalent wastewater treatment cost to remove annual N loads

- ($/kg/yr) = $ 6,592 and $4,429 (average = $5,511) (Qld average = $ 7,855)
- % of the annualised life cycle cost of the WSUD 'treatment train' = 224% and 165% (average = 195%) (Qld 190% to 380% - average = 300%)

2. **Avoided costs associated with waterway rehabilitation / maintenance**

- $ / ha of development = $8,000 to $60,000 (Qld average = $ 34,000)
- % of the life cycle cost of the WSUD 'treatment train' = 46% and 51% (average = 49 %) (Qld 15% to 80% - average = 52%)

3. **Increased property values (premium)**

This value has not been quantified for commercial and industrial developments for this case study.

4. **Avoided development costs (applicable only on flat sites)**

- $ / ha = $36,000
- % of the capital cost (average) of the WSUD treatment train' = 66% and 73 % (average 70%) (Townsville) and 75% (Qld)

Notes: Information was sourced primarily from Table 5-9 (Water by Design 2009, p.5-30)

Quantifiable costs and benefits summary conclusion

Low Density Residential Development Case Studies (1 and 2) Conclusions – Townsville example

The capital costs of applying WSUD within low-density residential developments equate to an average cost of $3,220 (Qld $2,800) per dwelling. This value is equivalent to 0.8% (Qld 0.7%) of a typical house worth $400,000. The annual maintenance costs are an average of $36 / year (Qld $30 / year), which is less than 3% of the cost of annual property rates (based on average annual rates of $1,500). Considering the quantifiable benefits, on average the value of the nitrogen reduction is worth more than the cost of WSUD. The avoided waterway rehabilitation costs are worth around 60% (Qld 67%) of the cost of WSUD and the potential property premiums are worth around 67% (Qld 90%) of the cost of WSUD. Avoided development costs (flat sites) can equate to more than 78% (Qld 120%) of the WSUD treatment train capital cost. Considering the quantifiable benefits in a lumped group, the potential quantifiable benefits outweigh the costs.

Notes: Information was sourced primarily from Table 5-7 (Water by Design 2009, p.5-28)

Medium to High Density Development Case Studies (3 and 4B) Conclusions – Townsville example

The capital costs of applying WSUD within medium to high density residential developments equate to an average cost of $757 (Qld $775) per dwelling. This value is equivalent to 0.2% of a typical unit or townhouse worth $350,000. The annual maintenance costs are an average of $8 ($22 / year), which is less than 2% of the cost of annual property rates (based on average annual rates of $1,200). Considering the quantifiable benefits, on average the value of the nitrogen reduction is worth more than the cost of WSUD. The avoided waterway rehabilitation costs are worth around 53% (Qld 60%) of the cost of WSUD and the potential property premiums are worth around 122% (Qld 135%) of the cost of WSUD. Avoided development costs (flat sites) can equate to more than 76% (Qld 95%) of the WSUD treatment train capital cost. Considering the quantifiable benefits in a lumped group, the potential quantifiable benefits outweigh the costs.

Notes: Information was sourced primarily from Table 5-8 (Water by Design 2009, p.5-29)

Commercial and Industrial Development Case Studies (5 and 6) Conclusions – Townsville example

The capital costs of applying WSUD within commercial and industrial developments equate to an average cost of $52,125 (Qld $48,825 per hectare). Construction costs for commercial and industrial developments can range from about $10M - $40M per hectare. The cost of WSUD is therefore about 0.13% to 0.5% (Qld 0.12% to 0.5%) of construction costs. Considering the quantifiable benefits, on average the value of the nitrogen reduction is worth more than the cost of WSUD. The avoided waterway rehabilitation costs are worth around 49% (Qld 52%) of the cost of WSUD. Potential property premiums have not been calculated. Avoided development costs (flat sites) can equate to more than 70% (Qld 75%) of the WSUD treatment train capital cost. Considering the quantifiable benefits in a lumped group, the potential quantifiable benefits outweigh the costs.

Notes: Information was sourced primarily from Table 5-9 (Water by Design 2009, p.5-30)

Unquantifiable benefits

"There are also many unquantifiable benefits that are hugely important. The combined markets of recreational and commercial fishing, tourism and the seafood Industry are worth billions of dollars each year to the Queensland economy. A reduction in water quality and the health of Queensland's waterways will directly affect each of these industries. Achieving the stormwater management objectives with WSUD provides an opportunity to assist to maintain or enhance the water quality in Queensland's water bodies in or near urban areas. The unquantifiable benefits are potentially worth millions of dollars each year.

Additionally, there are benefits, which are unable to be quantified, and these include ecological benefits such as option, existence and bequest values. These benefits refer to the impact on the ecological health of affected local and/or regional ecosystems, the impact of the value of having healthy aquatic and riparian ecosystems for potential use in the future, and the impact of the value of providing healthy aquatic and riparian ecosystems for future generations. Arguably these are ecological functions that are vital to protect. Employing WSUD in urban areas to maintain or enhance these values provides a clear benefit."

The unquantified benefits identified by Water by Design (2009) for the various case studies are listed in the table below.

Unquantified Benfits of WSUD

Unquantified Benefit Description	**CS1 and 2**	**CS3 and 4B**	**CS5 and 6**
Protection of the numerous values associated with healthy downstream waterways:			
• Ecosystem services (which may include some of the benefits below)	√	√	√
• Recreational and commercial fishing	√	√	√
• Tourism	√	√	√
• Seafood Industry	√	√	√
• Option, Existence and Bequest values	√	√	√
• Community amenity at local and regional scale (i.e. connection to water cycle)	√		
Minor benefits:			
• Increased rate of sales in developments with landscaped WSUD features	√	√	
• Increased local streetscape and parkland amenity	√	√	√
• Shading and urban cooling (potentially reducing energy consumption)	√	√	√
• Some direct and indirect aspects of implementing WSUD will result in changes to the configuration of development that will enhance open space	√	√	
• Education and research	√		
• Enhanced streetscape likely to deliver premium on rents received by landlords (related to increased patronage for retail and service businesses			√
•			

Notes: Information was sourced from Table 5-7 (Water by Design 2009, p.5-28), Table 5-8 (Water by Design 2009, p.5-29), and Table 5-9 (Water by Design 2009, p.5-30). CS is case study. A **√** indicates that the unquantified benefit was identified as being applicable to the case studies.

"Therefore, considering all the costs and all the potential benefits of applying WSUD to achieve the new storm water management objectives, **it is clear that the benefits are likely to outweigh the costs**" (Water by Design 2009, p.5-28) for all of the case studies examined.

Section 6 Summary and Conclusions

"This Business Case was undertaken to confirm the costs of applying WSUD to typical urban development to meet the proposed stormwater management objectives and to illustrate that the benefits of applying WSUD are likely to outweigh the costs. In order to achieve this literature reviews, technical case studies and a comparison of likely costs and benefits was undertaken.

There are many benefits and costs associated with using WSUD to meet the stormwater objectives set by the draft policy. Some are quantifiable financial values, while other values are not readily represented in financial terms (for example, the value of an enhanced aquatic environment). Costs are relatively easy to quantify, however, many of the benefits are difficult to quantify. Therefore, in order to determine if the benefits of applying WSUD to achieve the stormwater management objectives are likely to outweigh the costs, a cost-benefit framework has been prepared.

The frameworks (provided in Section 5) bring together both quantitative and qualitative values of benefits and costs to assist in approximating the net benefit of WSUD. The frameworks present stakeholders with the costs and benefits associated with meeting the stormwater management objectives on typical developments through WSUD. **The cost benefit frameworks demonstrate that the benefits of using WSUD to achieve the new stormwater management objectives on typical residential, commercial and industrial developments in QLD are likely to exceed the costs.**

In addition to presenting the likely 'net benefit' of WSUD, this Business Case also found the following:

- When implemented well, WSUD (bioretention systems) can be accommodated within developments without loss of developable land.
- WSUD has sufficient flexibility to comply with current town planning provisions of local governments while meeting the broader objectives of the draft policy.
- Geographic location influences the size of the treatment systems required. Further north in Queensland, where rainfall is higher, treatment systems generally need to be slightly larger to achieve the stormwater quality objectives.
- The cost of applying WSUD should not impact on the profitability of residential, commercial and industrial development. For example, for residential developments the capital costs of establishing WSUD to meet the stormwater management objectives are typically less than 1% of the cost of a new dwelling. Note that as dwelling density increases, the total life cycle costs of WSUD elements per dwelling decreases.
- Ultimately all WSUD-related costs will be borne by householders, whilst benefits are distributed over a wide range of geographic, societal and temporal scales."

(Water by Design 2009, p.6-31)

Detention storage preliminary findings for Townsville

Information from the WSUD Business Case has been compiled for the urban residential case studies and are shown below.

Case Study 1 Residential greenfield (large) on sloping topography

Option Characteristics

Element	Option A	Option B
Impervious surface	47% of the site	47% of the site
Rainwater tank	5kL per residence	None
Rainwater tank storage capacity	4.8ML	0
Annual flow	473ML	509ML
Annual flow reduction rainwater tanks	36ML (7%)	0
Detention basins for flood storage	20,000–25,000 m^3	19,000–23,750 m^3
Total bioretention area (0.6m)*	9,848m^2 (1.3% of site area)	10,605m^2 (1.4% of site area)
Detention volume required	14,792 m^3 (195 m^3 per ha)	14,792 m^3 (195 m^3 per ha)
Detention volume – above bioretention	5,909 m^3	6,363 m^3 (7.7% increase)
Detention volume – in bioretention	384m^3	413m^3 (7.6% increase)
Detention volume – in detention basins	8,499 m^3	8,016 m^3 (5.7% reduction)

Note: * indicates average depth of detention area

Costs and Benefits

Element	Lifecycle	Acquisition	Maintenance*
Rainwater tanks[1]	$4,214,208	$2,853,000	$85,590
Bioretention cost – Option A	$3,652,509	$2,609,588	$32,004
Bioretention cost – Option B	$3,933,471	$2,810,326	$34,466
Bioretention cost increase – Option B[2]	$280,962	$200,738	$2,462
Cost saving without rainwater tanks	$3,933,246	$2,652,262	$83,128
Detention storage cost – Option A	$364,085	$212,475	$8,499
Detention storage cost – Option B[3]	$345,881	$201,851	$8,074
Detention storage cost reduction	$18,204	$10,624	$425
Total cost reduction with Option B	$3,951,450	$2,622,886	$83,553

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 8.2% increase in detention capacity. The cost increase due to bioretention systems is 7% (6.7%) of the cost of rainwater tanks i.e. 93% cost saving, without any significant impact on detention costs

[3]based on a 5% size reduction.

Case Study 2 Residential greenfield (small/medium) on flat topography

Option Characteristics

Element	Option A	Option B
Impervious surface	56% of the site	56% of the site
Rainwater tank	5kL per residence	None
Rainwater tank storage capacity	0.42ML	0
Annual flow	40ML	43ML
Annual flow reduction rainwater tanks	3ML (7%)	0
Detention tanks	450 m^3	430 m^3
Total bioretention area (0.3m)*	824 m^2 (1.3% of site area)	887 m^2 (1.4% of site area)
Detention volume required	1,278 m^3 (202 m^3 per ha)	1,278 m^3 (202 m^3 per ha)
Detention volume – above bioretention	247 m^3	266 m^3 (7.7% increase)
Detention volume – in bioretention	34m^3	37 m^3 (8.8% increase)
Detention volume – in/above u/g tanks	997 m^3	975 m^3 (2.2% reduction)

Note: * indicates average depth of detention area

Costs and Benefits

Element	Lifecycle	Acquisition	Maintenance*
Rainwater tanks[1]	$372,233	$252,000	$7,560
Bioretention cost – Option A	$369,356	$271,920	$2,678
Bioretention cost – Option B	$397,768	$292,837	$2,884
Bioretention cost increase – Option B[2]	$28,412	$20,917	$206
Cost saving without rainwater tanks	$343,821	$231,083	$7,354
Detention storage cost – Option A	$177,966	$148,675	$997
Detention storage cost – Option B[3]	$174,051	$145,404	$975
Detention storage cost reduction	$3,915	$3,271	$22
Total cost reduction with Option B	$347,736	$234,354	$7,376

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 7.8% increase in detention capacity. The cost increase due to bioretention systems is 8% (7.6%) of the cost of rainwater tanks i.e. 92% cost saving, without any significant impact on detention costs

[3] based on a 2.2% size reduction.

Case Study 3 Residential townhouse development

Option Characteristics

Element	Option A	Option B
Impervious surface	61% of the site	61% of the site
Rainwater tank	3kL per residence	None
Rainwater tank storage capacity	75kL	0
Annual flow	4.57 ML	5.16 ML
Annual flow reduction rainwater tanks	0.59 ML (11%)	0
Detention tanks	79.9 m³	77.16 m³
Total bioretention area (0.4m)*	79.9 m² (1.2% of site area)	86.6 m² (1.3% of site area)
Detention volume required	137.1 m³ (206 m³ per ha)	137.1 m³ (206 m³ per ha)
Detention volume – above bioretention	32 m³	34.6 m³ (7.6% increase)
Detention volume – in bioretention	3 m³	3.24 m³ (8% increase)
Detention volume – u/g tanks	79.9 m³	77.16 m³ (3.4% reduction)
Surface ponding	22.2 m³	22.2 m³

Note: * indicates average depth of detention area

Costs and Benefits

Element	Lifecycle	Acquisition	Maintenance*
Rainwater tanks[1]	$96,998	$62,500	$2,250
Bioretention cost – Option A	$35,815	$26,367	$260
Bioretention cost – Option B	$38,800	$28,564	$282
Bioretention cost increase – Option B[2]	$2,985	$2,197	$12
Cost saving without rainwater tanks	$94,013	$60,303	$2,238
Detention storage cost – Option A	$28,389	$24,526	$102
Detention storage cost – Option B[3]	$27,424	$23,692	$99
Detention storage cost reduction	$965	$834	$3
Total cost reduction with Option B	$94,978	$61,137	$2,241

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 8.1% increase in detention capacity. The cost increase due to bioretention systems is 3% of the cost of rainwater tanks i.e. 97% cost saving. Detention cost reduction is 3.4% (based on lifecycle cost).

[3] based on a 3.4% size reduction.

Case Study 4 Urban Renewal

Option Characteristics

Element	**Option A**	**Option B**
Impervious surface	81% of the site	81% of the site
Rainwater tank	1kL - 800 dwellings	None
Rainwater tank storage capacity	0.8ML	0
Annual flow	117ML	130ML
Annual flow reduction rainwater tanks	13ML (10%)	0
Detention tanks	948 m^3	802 m^3
Total bioretention area (1m)*	2,100m^2 (1.5% of site area)	2,240m^2 (1.6% of site area)
Detention volume required	3,140 m^3 (224 m^3 per ha)	3,140 m^3 (224 m^3 per ha)
Detention volume – above bioretention	2,100 m^3	2,240 m^3 (6.7% increase)
Detention volume – in bioretention	93 m^3	99 m^3 (6.7% increase)
Detention volume – in detention tanks	943 m^3	802 m^3 (14% reduction)

Note: * indicates average depth of detention area

Costs and Benefits

Element	**Lifecycle**	**Acquisition**	**Maintenance***
Rainwater tanks[1]	$645,062	$500,000	$7,500
Bioretention cost – Option A	$941,320	$693,000	$6,825
Bioretention cost – Option B	$1,004,075	$739,200	$7,280
Bioretention cost increase – Option B[2]	$62,755	$46,200	$455
Cost saving without rainwater tanks	$582,307	$453,800	$7,045
Detention storage cost – Option A	$325,549	$284,400	$948
Detention storage cost – Option B[3]	$275,412	$240,600	$802
Detention storage cost reduction	$50,430	$43,800	$146
Total cost reduction with Option B	$632,737	$497,600	$7,191

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 4.6% increase in detention capacity. The cost increase due to bioretention systems is 10% of the cost of rainwater tanks i.e. 90% cost saving. Detention cost reduction is 15.4% (based on lifecycle cost).

[3] based on a 15% size reduction.

Appendix A Technical Report (The Case Studies)

The case study development scenarios are summarised in the table below.

Case Study summary

No.	Development type	Key elements
1	Residential greenfield (large scale) on sloping topography	• 76 ha of detached residential • 951 detached houses (400–700 m^2/lot) • 5.5 ha of active and passive parkland • 8.75 ha drainage and restored waterway (vegetated) • 47% impervious surfaces on site.
2	Residential greenfield on flat topography	• 6.4 ha of detached residential • 84 detached houses (400–500m2 p/lot) • 56% impervious surfaces on site.
3	Residential townhouse development	• 0.67 ha of attached residential • 25 townhouse dwellings • 61% impervious surfaces on site • 15% pervious landscaped areas on site.
4	Urban renewal development	• Conversion of 14 ha of light industrial area to high-density residential • 7 ha high rise residential towers • 5 ha five-storey residential apartment buildings • 2000 + dwellings (units and apartments) • 40 m-wide road reserve and substantial promenades • 81% impervious surfaces on site.
5	Commercial development	• 0.42 ha neighbourhood shopping centre • 15-20 ground-level shops • 95-98% impervious surfaces on site.
6	Industrial development	• 1.0 ha factory and warehouse • 86% impervious surfaces on site.

Note: Information from Table 1 (Water by Design 2009, p.ii)

"For modelling purposes, historical rainfall data and evapotranspiration data was used. Each model used ten years of rainfall data, at a six-minute time interval. The ten years' data series used for this assessment were selected as they provide a similar average annual rainfall to the long-term average climatic conditions in each region."

The climatic data used for the Townsville case studies was:

Region	Period of modelling	Rainfall station	Long-term mean annual rainfall (mm)*	Mean annual rainfall for modelling period (mm)	Annual evapotranspiration (mm)
Dry Tropics	14 years (1970–1983)	32040 Townsville	1,130	1,165	1,856

Note: Information from Table 2 (Water by Design 2009, p.iii). *www.bom.gov.au /climate/averages.

Stormwater quality objectives used for Townsville (as per the Townsville WSUD Design Objectives) were:

Pollutant	TSS	TP	TN	GP
Load reduction	80%	65%	40%	90%

Note: Information from Table 3 (Water by Design 2009, p.iv)

"To meet the draft stormwater management objectives and the alternative water source requirement, the WSUD solution for the case studies include a combination of elements:

- **Rainwater tanks —** The primary role of the rainwater tanks is to satisfy the alternative water source requirement of the Queensland Development Code Mandatory Parts 4.2 and 4.3. Tanks can also help achieve the WSUD objectives. **Tanks are not necessarily required to meet the stormwater management objectives** (i.e. the stormwater management objectives could be achieved with bioretention systems and detention storage alone).
- **Bioretention systems** — Bioretention systems ensure compliance with the stormwater quality and frequent flow objectives.
- **Detention storage —** Detention storage detains or retards the 1-year ARI flow for the waterway stability objective. As highlighted in Section 2.4, the waterway stability objective will not apply in many development situations and detention storage will not be required. Where the waterway stability objective does apply, it is likely flood storage will also be required and the waterway stability detention storage will be integrated into the flood storage at minimal cost. Therefore the cost of the detention storage does not form part of the WSUD Case costs, but it still presented in the case study results for illustration purposes." (Water by Design 2009, p.vi)

Rainwater tanks
The rainwater tank sizes adopted for each case study are the minimum required by the *Queensland Development Code Mandatory Parts 4.2 and 4.3* to meet the alternative water source requirement. [Townsville has an exemption and is not required to install rainwater tanks as part of new development. The case studies do however include the rainwater tank requirement for Townsville as with the other Queensland regions.]

"For the residential development case studies, water use (demand) from the tanks was assumed (as adopted by the Queensland Water Commission based on recent research on the Gold Coast[16]) as:

- indoor demand (toilets and laundry cold) = 43.4 litres / person / day
- outdoor demand (garden irrigation and pool top-up) = 60 litres / household per day (for purposes of this assessment conservatively low outdoor demands were adopted to account for water restrictions and to avoid undersizing of stormwater treatment systems)

This demand was also based on occupancy assumptions for residential case studies:

- Case study 1 (detached houses): 2.5 people per household
- Case study 2 (detached houses): 2.5 people per household
- Case study 3 (townhouses): 2.0 people per household
- Case study 4 (units): 1.8 people per household." (Water by Design 2009, p.vii)

"The outdoor demand for case study 4 was estimated at 5000kL/yr, based on an irrigated area of 1ha and an application rate of 500 mm/yr. For case study 5 and case study 6 rainwater tank demands were case-specific. For all case studies, it was assumed that the overflow from the rainwater tanks is directed to a bioretention system." (Water by Design 2009, p.viii)

[16] Willis, R. Stewart, R.A. Chen, L. and Rutherford, L. (2009) Water end use consumption analysis into Gold Coast dual reticulated households: Pilot. *Australia's National Water Conference and Exhibition: OzWater'09, Melbourne Convention & Exhibition Centre, Melbourne, March 16-18, 2009.* Melbourne

Bioretention systems
"Bioretention systems treat stormwater by filtering runoff through densely planted vegetation and percolating the runoff through a filter media, such as sandy loam. As stormwater percolates through the soil, pollutants are captured by fine filtration, adsorption and biological uptake."

"For the case studies, bioretention systems were assumed to have the following configuration:

- Extended detention depth 0.2 m;
- Filter media depth 0.6 m;
- Saturated hydraulic conductivity 200 mm/hr;
- Batters to surrounds 1 in 4 preferably (1 in 2 max vegetated).

This size of the bioretention system required to meet the stormwater quality objectives varies between climatic regions."

Detention storage
"If the waterway stability objective is applicable, storage is required to detain and retard the 1-year ARI flow. The key elements of detention are a storage volume and a choked outlet designed to restrict the outflow rate.

Detention storage options considered for the case studies include:" (Water by Design 2009, p.viii)

- "Within and above the bioretention systems — storage over the bioretention system above the overflow pit crest (allowing for 10% of the extended detention);
- Above ground open detention basin — typically a shallow, vegetated area surrounded by earth bunds;
- Informal surface ponding — where relatively small storage volumes are required, it may be appropriate to allow temporary ponding over landscaped or car park areas;
- Above ground tanks — rainwater tanks which do not retain water for reuse but drain down fully after each storm event;
- Underground storages — tanks located underground as either reinforced tanks, sealed stormwater pipes or voids filled with rocks or gravel." (Water by Design 2009, p.ix)

Modelled Performance
"The Model for Urban Stormwater Improvement Conceptualisation (MUSIC version 3.01) was used to assess stormwater quality treatment performance for each case study. MUSIC is the preferred assessment tool for stormwater quality objectives in Australia. It was developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH) to model the industry's current best understanding of:

- the transformation of rainfall to runoff (surface and baseflow) in urban environments
- the generation of key stormwater pollutants (stressors) in surface flows and base flows from various land surfaces
- the removal of key pollutants (stressors) from urban stormwater runoff by contemporary best practice stormwater treatment technologies.

A number of assumptions underpin the MUSIC modelling undertaken for the case studies:

- 10 years of 6 minute rainfall for the rainfall stations described in Section 2.2, Table 2.
- Table 7 shows the rainfall–runoff parameters used in the case study modelling. These parameters are based on the MUSIC default parameters for Brisbane as provided in the MUSIC Manual

- The storm pollutant generation parameters are presented in Tables 8–10. These parameters are from *Gold Coast City Council's Stormwater Quality Management Guidelines*, (GCCC 2006), which is the best available information for Queensland. The baseflow pollution generation parameters are based on *Guidelines for Pollutant Export Modelling in Brisbane Version 8*, April 2006 (BCC 2006).
- The rainwater tank volumes are defined by the requirements of the *Queensland Development Code* and the demands as summarised in Section 2.5.1.
- The bioretention system design assumptions provided in Section 2.5.2 were adopted. The MUSIC default stormwater quality treatment performance parameters for bioretention were used. These were derived from performance monitoring data collected from across Australia and internationally by the CRCCH (refer to MUSIC Version 3.01 User Manual, Appendix F). Insufficient local stormwater treatment performance data was available for bioretention systems to allow for local performance data sets to be used for each climatic region." (Water by Design 2009, p.x)

Costing and Assumptions

"Cost estimates were prepared for the WSUD solutions developed for each case study. The following cost components were calculated:

- Acquisition costs (including design and capital costs for construction and establishment);
- Typical annual maintenance costs;
- Renewal costs (i.e. corrective maintenance costs);
- Decommissioning costs.

These costs were used to determine a total lifecycle cost for the WSUD solution for each case study, as well the lifecycle cost of the individual components of the solution (e.g. rainwater tanks, bioretention systems, detention storages). Details of the cost estimates are presented in the case study summaries.

The cost assessment evaluates a net cost difference between a development that incorporates a WSUD solution and a 'traditional', or 'business-as-usual' development."

Component costs

"Unit rates were prepared to estimate the acquisition costs and the typical annual maintenance costs for each WSUD element. Given the limited information about renewal and decommissioning costs for WSUD infrastructure, these costs were estimated as a fraction of the acquisition costs. The following assumptions were applied to the renewal and the decommissioning costs:

- Renewal cost (bioretention systems): 40% of acquisition cost;
- Renewal cost (other WSUD infrastructure): 30% of acquisition cost;
- Decommissioning cost (bioretention systems): 40% of acquisition cost;
- Decommissioning cost (other WSUD infrastructure): 20% of acquisition cost.

Rainwater tanks

The unit rates adopted for rainwater tanks are based on a review of recent reference material and advice from rainwater tank suppliers. The operation and maintenance costs include an annualised cost to cover pump replacement. This is typically a large component of the annual maintenance cost and is heavily influenced by the assumed pump life. A pump life of 10 years has been assumed for this assessment." (Water by Design 2009, p.xvi)

Bioretention systems

"The unit rates adopted for bioretention systems are based on actual costs incurred in recent projects and on data from related research projects. Due to the significant effort required to ensure the bioretention plants establish, which usually takes up to two years, the maintenance costs in the first two years were estimated as three times the long-term annual maintenance costs.

Bioretention systems typically occupy areas that would otherwise be landscaped as turf or garden beds. Therefore, the net cost (acquisition and maintenance) of bioretention systems was calculated as the cost of the bioretention system less the cost of typical landscaping. It was assumed that half the area occupied by a bioretention system would otherwise be covered with turf and the other half would be covered with garden beds.

The unit cost of bioretention systems ($\$/m^2$) decreases as size increases. This is because the costs for infrastructure such as overflow pits and site establishment is spread across a larger area as the bioretention size increases." (Water by Design 2009, pp.xvii-xviii)

Detention storages

"The detention storages used in the case studies are either 'above ground' or 'below ground'. Unit rates, have been assigned to each broad category and based on actual costs from recent projects. Due to the significant maintenance input required to ensure plants in above-ground detention storages establish successfully, the maintenance costs in the first two years were estimated as twice the ongoing annual maintenance cost.

Above-ground detention storages typically occupy areas that would otherwise be landscaped with turf or garden beds. As such, the net cost (acquisition and maintenance) of detention storages has been calculated as the cost of the detention storage less the cost associated with typical landscaping (i.e. acquisition and maintenance cost representative cost above normal landscape)." (Water by Design 2009, p.xix)

Lifecycle costs

"For each case study the lifecycle cost for the overall WSUD solution, as well as the individual components of the solution, have been calculated. A lifecycle cost period of 25 years has been used as this is the typical period used for public benefit cost analysis. A discount rate of 5.5% has been used in the lifecycle cost calculations, which is supported by Queensland Treasury who suggest a real discount rate of between 5 and 6%. Due to the discounting, impacts after 25 years rarely have a material impact on benefits or costs." (Water by Design 2009, p.xix)

Case study 1: Residential greenfield (sloping topography) - Townsville

(Source: Water by Design 2009, pp.xx-xxvii)

Case study 1 is a residential greenfield development that consists of numerous stages, or land releases, within a large-scale (approximately 1,000 hectares), mixed-use subdivision. The case study site has an area of approximately 76 hectares.

There are 951 detached houses, with a typical lot size of between 400–700 m². The remainder of the site comprises an internal road network to service the lots, and 5.5 ha of creditable open space parklands.

The site is focused around a creek corridor, with residential areas covering the ridges that flank the creek. The ridge crests are approximately 10m higher than the creek, resulting in moderate slopes (5–10%) throughout the residential areas. The drainage reserve containing the creek is not included in the case study site area.

Breakdown of the site areas (from Table 15)

Site area breakdown	Area (ha)	% Impervious
Roof	19.2	100%
Road/driveway	21.5	60%
Other areas (landscape, pavement)	35.1	11%
Total site area	**75.8**	**47%**

Site conditions and constraints

The moderate slopes generally limit the design of stormwater drainage to conventional drainage and the associated WSUD solutions to precinct scale or end-of-line.

Case study 1 follows this standard approach, with a pit and pipe stormwater drainage system collecting stormwater runoff from the residential lots, roads and open space areas. Stormwater is conveyed to end-of-line stormwater management systems located within the creek corridor.

The topography of the site and the earthworks' design dictate approximately twelve separate locations for stormwater to be discharged from the piped drainage network. This provides some flexibility regarding the overall number and configuration of the stormwater management systems.

The site design for case study 1 incorporates substantial flood detention storage. Two dry detention basins are located within the creek corridor. This flood detention storage totals approximately 20,000–25,000 m³ to meet the local council's stormwater design requirements.

WSUD solution

The Base Case included rainwater tanks as required by the Queensland Development Code and flood detention.

To meet the stormwater management objectives, the WSUD Case included the following:

- Rainwater tanks as required by the Queensland Development Code;
- End-of-line bioretention systems to deliver the stormwater quality and frequent flow objectives;

- Above-ground detention storage to manage the 1-year ARI flow to deliver the waterway stability objective (assumed to form part of flood storage in Base Case).

Rainwater tanks

As required by the *Queensland Development Code*, each detached house will have a 5kL rainwater tank to supply toilet flushing, laundry cold and outdoor demands. The overflow from the rainwater tanks will discharge to the drainage system, which is directed towards a bioretention system.

Bioretention systems

Twelve precinct-scale bioretention systems will treat water quality for the remainder of the site, including half of the roof area plus overflows from the rainwater tanks. The bioretention systems will be located along the edge of the drainage corridor with discharge directed into the creek corridor. The total bioretention area required to deliver best practice stormwater quality for the site for Townsville is 9,848m², which is 1.3% of the site area (from Table 16).

If the frequent flow objective applies, the extended detention zone of the bioretention system provides sufficient storage to meet the frequent flow requirements.

Detention storage

The waterway stability objective applies to this case study. The detention volume required for the site for Townsville is 14,792 m^3 and would be incorporated in the flood storage element of the Base Case. This represents a storage rate of 195 m^3 per hectare (from Table 17).

The detention storage is provided within the site in three ways:

- In bioretention systems: 10% of the bioretention systems with an extended detention depth and pore space volume in the filter media.
- Above the bioretention systems: storage volume above the bioretention systems in the zone between the level of the low-flow outlet and the level of the high-flow outlet. This volume is estimated as the equivalent of 0.6 m depth across the bioretention surface area.
- Above-ground storage: the site design incorporates substantial flood detention storage with two dry detention basins. The additional storage required to meet the waterway stability objective can be provided by these detention storages, without compromising the flood detention function. Therefore, no additional detention basins are required.

A breakdown of the storages required for Townsville is shown in the table below.

Detention storage allocation for the waterway stability objective for Townsville (from Table 18)

Portion of bioretention system extended detention and pore space	Above bioretention systems	Above-ground storage within flood storage	Total
384 m³	5,909 m³	8,499 m³	14,792 m³

Performance

The MUSIC results for the WSUD solution demonstrate that the proposed stormwater treatment train meets the stormwater quality objectives for Townsville.

Townsville MUSIC results (from Table 19)

Scenario	Unmitigated	Base Case		WSUD Case		Stormwater quality objective
Stormwater management parameter	Average annual loads	Average annual loads	% reduction in loads	Average annual loads	% reduction in loads	as % load reduction from unmitigated
Flow (ML/yr)	509	473	7%	474	7%	-
Total Suspended Solids (kg/yr)	104,000	102,400	2%	19,300	81%	80%
Total Phosphorus (kg/yr)	200	193	3%	65	68%	65%
Total Nitrogen (kg/yr)	1,070	988	8%	603	44%	40%

Costs

The table below shows the costs of the Base Case and the WSUD Case for Townsville. The table also identifies the incremental cost of the WSUD Case when compared to the Base Case (i.e. identifies the cost of the bioretention systems). The results shows that the costs of meeting the Queensland Development Code (rainwater tanks) requirements is the dominant cost, although this is not relevant to Townsville at this time. The incremental cost of meeting the stormwater management objectives is the bioretention cost, with the lifecycle cost being $3,840 per lot.

WSUD Costs (from Table 20)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	4,214,208	2,853,000	85,590	855,900	570,600
Bioretention systems (incremental cost)	3,652,509	2,609,588	32,004	1,043,835	1,043,835
- per hectare	48,218	34,450	423		
- per lot	3,841	2,744	34		
Detention storages*	364,085*	212,475	8,499	63,743	42,495
Overall (WSUD Case)[1]	7,866,717	5,462,588			
- per hectare	103,851	72,113			
- per lot	8,272	5,744			

Note: Calculations are based on 951 lots over 75.75 hectares. * This item is associated with detention storage to meet the waterway stability objective. In this case study, the storage is incorporated into the flood detention storage for the site, therefore the costs for this item have not been included in the overall costs. The costs are presented for illustration purposes. [1] The Overall (WSUD Case) is the sum of the Base Case and Bioretention systems.

No Rainwater Tanks - Townsville

Given that the Base Case i.e. rainwater tanks, is not a requirement of WSUD for Townsville, due to an exemption under the Queensland Development Code, the Overall (WSUD Case) costs need to be recalculated based on total lifecycle costs of the bioretention systems only.

To achieve the stormwater quality and frequent flow objectives will require a slight increase in bioretention system size (7.7%) to compensate for the load and flow reductions from rainwater tanks. This will therefore increase the overall costs of the bioretention systems. The total bioretention area required to deliver best practice stormwater quality on the site in Townsville, without rainwater tanks, is 10,605 m². This is 1.4% of the site (formerly 9,848 m² or 1.3% of the site).

The detention storage allocation for the waterway stability objective for Townsville, along with the costs of the detention storage, will also need to be recalculated for the Base Case. This will not affect the WSUD Case, as the detention storage costs are not included in the WSUD Case costs.

An estimate is provided in the table below based on the requirement to increase the bioretention system area by 0.1% of the development site area i.e. from 1.3% to 1.4% as per the draft WSUD business case report (Water by Design 2009).

WSUD Costs (recalculated originally from Table 20)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	0	0	0	0	0
Bioretention systems (incremental cost) and Overall (WSUD Case)	3,933,471	2,810,326	34,466	1,124,130	1,124,130
- per hectare	51,927	37,100	455		
- per lot	4,136	2,955	37		
Detention storages*	364,085*	212,475	8,499	63,743	42,495

Note: Calculations are based on 951 lots over 75.75 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.

The additional costs associated with the increase in bioretention size are:

- Total lifecycle - $ 280,962 added cost;
- Acquisition - $200,738 added cost;
- Annual maintenance $2,462 added cost;
- Renewal $80,295 added cost;
- Decommission $80,295 added cost.

The total lifecycle cost for the WSUD Case without rainwater tanks ($3,933,471) is substantially lower than the Overall (WSUD Case) lifecycle cost with rainwater tanks ($7,866,717). This represents a 50% saving across the site.

Case study 2: residential greenfield (flat topography)-Townsville

(Source: Water by Design 2009, pp. xxviii-xxv)

Case study 2 consists of several residential stages, or land releases, within a large-scale residential subdivision (approximately 100 hectares). The case study site covers an area of approximately 6.3ha.

There are 84 detached houses within the site, with typical lot sizes between 400–500 m². There is an internal road network to service the houses, but no significant park areas or communal buildings within the site.

The site is located on flat, low-lying ground close to the coast. Small waterways flow along two sides of the site and are the ultimate discharge locations for stormwater.

Breakdown of the site areas (from Table 21)

Site area breakdown	Area (ha)	% Impervious
Roof	1.94	100%
Road/driveway	2.47	50%
Other areas (landscape, pavement)	1.93	20%
Total site area	**6.34**	**56%**

Site conditions and constraints

The site has slopes of less than 1%. Civil designs for flat sites typically incorporate substantial re-profiling to create a gently undulating site with sufficient grade for surface drainage.

Flat sites present significant challenges for stormwater drainage design and associated WSUD solutions. Underground stormwater pipes must be laid at flat grades and need to be relatively large to convey the required flow. Conventional design approaches to flat sites can result in very large drainage and earthworks costs.

The development layout for Case Study 2 has been designed to avoid these drainage and earthworks issues. Much of the site incorporates stormwater management systems into the road reserves with stormwater runoff from the remainder of the site directed to stormwater management systems via short lengths of small pipes.

WSUD solution

The Base Case included rainwater tanks as required by the Queensland Development Code. To meet the stormwater management objectives, the WSUD Case includes the following:

- Rainwater tanks as required by the Queensland Development Code
- Bioretention systems to deliver the stormwater quality and frequent flow objectives
- Detention storage to manage the 1-year ARI flow in accordance with the waterway stability objective.

Rainwater tanks

Each lot will have a 5 kL rainwater tank as required by the *Queensland Development Code* connected to half the roof, which will service the toilet, laundry, and outdoor uses. The overflow from the tank will be directed to the stormwater drainage network and, ultimately, to one of the bioretention systems.

Bioretention systems

Nine bioretention pods will be integrated into road reserves to treat stormwater runoff from half of the site and six bioretention systems incorporated into open space areas at end-of-line locations to treat stormwater runoff from the other half of the site.

The total bioretention area required to deliver best practice stormwater quality on the site in Townsville is 824 m^2, which is 1.3% of the development site area (from Table 22).

If the frequent flow objective applies, the extended detention zone of the bioretention system provides sufficient storage to meet the frequent flow requirements.

Detention storage (if applicable)

The case study assumed the waterway stability detention storage is not required or would be incorporated into flood storage (Base Case). If the waterway stability objective were to apply and there was no flood storage requirement, the detention volume required for Townsville would be 1,278 m^3. This represents a storage rate of 202 m^3 per hectare (from Table 23).

The detention storage would be provided within the site four ways:

- In bioretention systems: 10 %of the bioretention systems' extended detention depth and pore space volume is in the filter media.
- Above the bioretention systems: storage volume above the bioretention systems in the zone between the level of the low-flow outlet and the level of the high-flow outlet. This volume is estimated as the equivalent of 0.3 m depth across the bioretention surface area.
- Underground storage: an underground detention tank will be provided within the road reserve at each of the six end-of-line locations. These underground detention tanks are sealed stormwater pipes and provide 450 m^3 of the additional storage requirement.
- The remaining storage volume will be achieved by expanding the footprint of five of the six end-of-line bioretention systems so that they provide additional storage volume between the level of the low-flow outlet and the high-flow outlet.

A breakdown of the storages required for Townsville is shown in the table below.

Detention storage allocation for the waterway stability objective for Townsville (from Table 24)

Portion of bioretention system extended detention and pore space	Above bioretention systems	Underground detention tank	Above end of line systems – additional storage	Total
34 m^3	247 m^3	450 m^3	547 m^3	1,278 m^3

Performance

The MUSIC results for the WSUD solution demonstrate that the proposed stormwater treatment train meets the stormwater quality objectives for Townsville.

Townsville MUSIC results (from Table 25)

Scenario	Unmitigated	Base Case		WSUD Case		Stormwater quality objective
Stormwater management parameter	Average annual loads	Average annual loads	% reduction in loads	Average annual loads	% reduction in loads	(as % load reduction from unmitigated)
Flow (ML/yr)	47	44	7%	44	7%	-
Total Suspended Solids (kg/yr)	9,490	9,341	2%	1,870	80%	80%
Total Phosphorus (kg/yr)	18	18	3%	6	67%	65%
Total Nitrogen (kg/yr)	99	91	8%	57	43%	40%

Costs

The table below shows the costs of the Base Case and the WSUD Case for Townsville. The table also identifies the incremental cost of the WSUD Case when compared to the Base Case (i.e. identifies the cost of the bioretention systems). The results shows that the costs of meeting the Queensland Development Code (rainwater tanks) requirements is marginally the dominant cost (50.2%), although this is not relevant to Townsville at this time. The incremental cost of meeting the stormwater management objectives is the bioretention cost with the lifecycle cost being $4,397 per lot for Townsville.

WSUD Costs (from Table 26)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	372,233	252,000	7,560	75,600	50,400
Bioretention systems (incremental cost)	369,356	271,920	2,678	108,768	108,768
- per hectare	58,258	42,890	422		
- per lot	4,397	3,237	32		
Detention tanks*	154,533*	135,000	450	40,500	27,000
Detention storages*	23,433*	13,675	547	4,103	2,735
Overall (WSUD Case)[1]	741,587	523,920			
- per hectare	116,970	82,637			
- per lot	8,828	6,237			

Note: Calculations are based on 84 lots over 6.34 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.[1] The Overall (WSUD Case) is the sum of the Base Case and Bioretention systems.

No Rainwater Tanks - Townsville

Given that the Base Case i.e. rainwater tanks, is not a requirement of WSUD for Townsville, due to an exemption under the Queensland Development Code, the Overall (WSUD Case) costs need to be recalculated based on total lifecycle costs of the bioretention systems only.

To achieve the stormwater quality and frequent flow objectives will require a slight increase in bioretention system size (7.7%) to compensate for the load and flow reductions from rainwater tanks. This will therefore increase the overall costs of the bioretention systems. The total bioretention area required to deliver best practice stormwater quality on the site in Townsville without rainwater tanks is 887 m², which is 1.4% of the site (formerly 824 m² or 1.3% of the site).

The detention storage allocation for the waterway stability objective for Townsville, along with the costs of the detention storage, will also need to be recalculated for the Base Case. This will not affect the WSUD Case, as the detention storage costs are not included in the WSUD Case costs.

An estimate is provided in the table below based on the requirement to increase the bioretention system area by 0.1% of the development site area i.e. from 1.3% to 1.4% as per the draft WSUD business case report (Water by Design 2009).

WSUD Costs (recalculated originally from Table 26)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	0	0	0	0	0
Bioretention systems (incremental cost) and Overall (WSUD Case)	397,768	292,837	2,884	117,135	117,135
- per hectare	62,739	46,189	455		
- per lot	4,735	3,486	35		
Detention tanks*	154,533*	135,000	450	40,500	27,000
Detention storages*	23,433*	13,675	547	4,103	2,735

Note: Calculations are based on 84 lots over 6.34 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.

The additional costs associated with the increase in bioretention size are:

- Total lifecycle - $ 28,412 added cost;
- Acquisition - $ 20,917added cost;
- Annual maintenance $206 added cost;
- Renewal $8,367 added cost;
- Decommission $8,367 added cost.

The total lifecycle cost for the WSUD Case without rainwater tanks ($397,768) is substantially lower than the Overall (WSUD Case) lifecycle cost with rainwater tanks ($741,587). This represents a 46% saving across the site.

Case study 3: townhouses - Townsville

(Source: Water by Design 2009, pp. xxvi-xliii)

Case study 3 is a townhouse development located within a large master-planned residential community. The total site area is 6,660 m².

The case study site comprises 25 two-storey townhouses. As well as the townhouse dwellings, the site has landscaped areas, an internal road network, visitor parking spaces and a loading bay.

Breakdown of the site areas (from Table 27)

Site area breakdown	Area (ha)	% Impervious
Roof	0.22	100%
Road/driveway	0.183	100%
Other areas (landscape, pavement)	0.263	0%
Total site area	**0.666**	**61%**

Site conditions and constraints

The site is flat with an average slope of less than 1%. The ultimate discharge locations for stormwater are existing stormwater drainage networks. There is a level difference of 1.5–2 m from the surface of the site to the invert of the external drainage. This limits flexibility for the location and level of stormwater management systems.

The central landscaped area provides a suitable location for vegetated stormwater treatment systems, such as bioretention systems. However, to enable piped roof water drainage to discharge onto the surface of a bioretention system, surcharge pits are required in some instances. The compact nature of the site allows a stormwater management strategy that maximises the proportion of the site drained via surface flow paths and minimises the use of stormwater pits and pipes.

The areas to be treated are split into components. Twelve townhouses have roof areas of 92 m² and thirteen have roof areas of 84 m². It is assumed that half the area of each roof will drain to a rainwater tank to meet the minimum requirements of the Queensland Development Code. Runoff from the other half of the roof, combined with overflow from the tanks, will enter the shallow drainage system and flow to the stormwater management systems.

WSUD solution

The Base Case included rainwater tanks as required by the Queensland Development Code and flood detention.

To meet the stormwater management objectives, the WSUD Case included the following:

- Rainwater tanks as required by the Queensland Development Code;
- Bioretention systems to deliver the stormwater quality and frequent flow objectives;
- Detention storage to manage the 1-year ARI flow to deliver the waterway stability objective if it applies.

Rainwater tanks

As required by the Queensland Development Code, each townhouse will have a 3 kL rainwater tank for toilet flushing, laundry and outdoor demands. The overflows from the rainwater tanks will discharge to the drainage system, which is directed towards a bioretention system.

Bioretention systems

Bioretention systems will accept surface runoff from the road and ground level areas, together with piped flows from the roof areas and tank overflows.

It has been assumed that the majority of the bioretention systems could be incorporated into existing landscaped areas on common ground. The total bioretention area required to deliver best practice stormwater quality on the site in Townsville is 79.9 m^2, which is 1.2% of the site area (from Table 28).

If the frequent flow objective applies, the extended detention zone of the bioretention system provides sufficient storage to meet the frequent flow requirements.

Detention storage (if applicable)

The case study assumed the waterway stability detention storage is not required or would be incorporated into flood storage (Base Case). If the waterway stability objective were to apply and there was no flood storage requirement, the detention volume required is 137.1 $m^{3.}$ This represents a storage volume of 206 m^3 per hectare (from Table 29).

The detention storage could be provided within the site in four ways:

- In bioretention systems: 10% of the bioretention systems' extended detention depth and pore space volume in the filter media.
- Above the bioretention systems: storage volume above the bioretention systems in the zone between the level of the low-flow outlet and the level of the high-flow outlet. This volume is estimated as the equivalent of 0.4 m depth across the bioretention surface area.
- Underground storage: provided as underground storage beneath the landscape area with the invert level of the storage above the level of the discharge point from the site (i.e. flat 1350 mm or 1500 mm pipe).
- Surface storage: temporary ponding within a portion of the landscape areas adjacent to the bioretention systems.

Stormwater will preferentially fill the underground storage, so surface ponding will be restricted to relatively infrequent, high-intensity storm events. Stormwater that temporarily ponds in the landscaped areas will ultimately drain into the underground tanks. Therefore, the outflow from the underground tanks will be choked to ensure the target flow rate is achieved.

A breakdown of the storages required for Townsville is shown in the table below.

Detention storage allocation for the waterway stability objective for Townsville (from Table 30)

Portion of bioretention system extended detention and pore space	Above bioretention systems	Underground storage	Surface storage	Total
3 m^3	32 m^3	79.9 m^3	22.2 m^3	137.1 m^3

Performance

The MUSIC results for the WSUD solution demonstrate that the proposed stormwater treatment train meets the stormwater quality objectives for Townsville.

Townsville MUSIC results (from Table 31)

Scenario	Unmitigated	Base Case		WSUD Case		Stormwater quality objective
Stormwater management parameter	Average annual loads	Average annual loads	% reduction in loads	Average annual loads	% reduction in loads	as % load reduction from unmitigated
Flow (ML/yr)	5.16	4.57	11%	4.57	11%	-
Total Suspended Solids (kg/yr)	1,060	1,036	2%	206	81%	80%
Total Phosphorus (kg/yr)	2.03	1.92	5%	0.67	67%	65%
Total Nitrogen (kg/yr)	10.8	9.49	12%	5.97	45%	40%

Costs

The table below shows the costs of the Base Case and the WSUD Case for Townsville. The table also identifies the incremental cost of the WSUD Case when compared to the Base Case (i.e. identifies the cost of the bioretention systems). The results show that the costs of meeting the Queensland Development Code (rainwater tanks) requirements is the dominant cost (73% of the Overall WSUD Case), although this is not relevant to Townsville at this time. The incremental cost of meeting the stormwater management objectives is the bioretention cost with the lifecycle cost being $1,433 per lot.

WSUD Costs (from Table 32)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	96,998	62,500	2,250	18,750	12,500
Bioretention systems (incremental cost)	35,815	26,367	260	10,547	10,547
- per hectare	53,776	39,590	390		
- per lot	1,433	1,055	11		
Detention tanks*	27,438	23,970	80	7,191	4,794
Detention storages*	951*	555	22	167	111
Overall (WSUD Case)[1]	132,809	88,867			
- per hectare	199,414	133,434			
- per lot	5,312	3,555			

Note: Calculations are based on 25 lots over 0.666 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.[1] The Overall (WSUD Case) is the sum of the Base Case and Bioretention systems.

No Rainwater Tanks - Townsville

Given that the Base Case i.e. rainwater tanks, is not a requirement of WSUD for Townsville, due to an exemption under the Queensland Development Code, the Overall (WSUD Case) costs need to be recalculated based on total lifecycle costs of the bioretention systems only.

To achieve the stormwater quality and frequent flow objectives will require a slight increase in bioretention system size (8.3%) to compensate for the load and flow reductions from rainwater tanks. This will therefore increase the overall costs of the bioretention systems. The total bioretention area required to deliver best practice stormwater quality on the site in Townsville without rainwater tanks is 86.6 m², which is 1.3% of the site (formerly 79.9 m² or 1.2% of the site).

The detention storage allocation for the waterway stability objective for Townsville, along with the costs of the detention storage, will also need to be recalculated for the Base Case. This will not affect the WSUD Case, as the detention storage costs are not included in the WSUD Case costs.

An estimate is provided in the table below based on the requirement to increase the bioretention system area by 0.1% of the development site area i.e. from 1.2% to 1.3% as per the draft WSUD business case report (Water by Design 2009).

WSUD Costs (recalculated originally from Table 32)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	0	0	0	0	0
Bioretention systems (incremental cost) and Overall (WSUD Case)	38,800	28,564	282	11,426	11,426
- per hectare	58,258	42,889	423		
- per lot	1,552	1,143	12		
Detention tanks*	27,438	23,970	80	7,191	4,794
Detention storages*	951*	555	22	167	111

Note: Calculations are based on 25 lots over 0.666 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.

The additional costs associated with the increase in bioretention size are:

- Total lifecycle - $ 2,985 added cost;
- Acquisition - $2,197 added cost;
- Annual maintenance $22 added cost;
- Renewal $879 added cost;
- Decommission $879 added cost.

The total lifecycle cost for the WSUD Case without rainwater tanks ($38,800) is substantially lower than the Overall (WSUD Case) lifecycle cost with rainwater tanks ($132,809). This represents a 71% saving.

Case study 4: urban renewal - Townsville

(Source: Water by Design 2009, pp. xliv-lvii)

Case study 4 is a large-scale urban renewal project involving conversion of an industrial area into a high-density residential development. The case study site comprises 14 ha located within a larger redevelopment site (approximately 100 ha).

The development includes 7 ha of high-rise residential towers and 5 ha with 5-storey residential apartment buildings. There are 25 separate buildings within the site. An internal road network services the buildings and the central road is characterised by a 40m wide road reserve. The site also contains substantial promenade areas and has river frontage along one boundary.

Breakdown of the site areas (from Table 33)

Site area breakdown	Area (ha)	% Impervious
Roof	7.29	100%
Road/driveway	3.79	54%
Other areas (landscape, pavement)	2.92	66%
Total site area	**14**	**81%**

Site conditions and constraints

The site is located on flat ground, with slopes of less than 1%. Flat sites present challenges for stormwater drainage design and the associated WSUD solutions. The case study site incorporates stormwater management systems on the lots and within the road reserves, rather than at end-of-line locations. The generous road reserves are capable of accommodating relatively large stormwater treatment systems. Stormwater runoff from the site discharges at a single location into an adjacent stage of the larger redevelopment site.

At the time this case study was developed, the alternative water source requirements of the Queensland Development Code did not apply to multi-storey residential buildings. Given that the inclusion of rainwater tanks has a significant influence on the overall cost estimate, two potential WSUD solutions have been developed for the site: Option A and Option B.

The key difference between the two proposals is that Option A incorporates rainwater tanks to collect roof runoff and assumes reuse of this water for internal and external purposes. Additional roofwater detention tanks are used to provide a portion of the storage volume required for the waterway stability objective.

Option B does not include rainwater tanks or roofwater detention tanks. All stormwater treatment is provided in bioretention systems and underground detention tanks are used to provide a portion of the storage volume required for the waterway stability objective.

WSUD solution — Option A

The Base Case included rainwater tanks.

To meet the stormwater management objectives, the WSUD Case included the following:

- Rainwater tanks
- Bioretention systems to deliver the stormwater quality and frequent flow objectives
- Roof water detention tanks to manage the 1-year ARI flow to deliver the waterway stability objective (if it applies).

Rainwater tanks

Centralised rainwater tanks are provided for each building. Runoff from 75 % of the roof area will be diverted to the rainwater tanks, while runoff from the remaining 25 % will be diverted to the bioretention systems.

Collected rainwater will be reused for toilet and laundry uses in the dwellings located on the bottom five storeys. The total rainwater tank volume is based on a unit rate of 1 kL per dwelling, with a total of 800 dwellings. Overflows from the rainwater tanks are directed to bioretention systems via shallow drainage pipes.

Bioretention systems

Linear bioretention systems are incorporated into the road reserves. The 40 m wide road reserve for the central boulevard provides substantial space (15–20 m) on one side of the road pavement for a linear park that incorporates stormwater treatment infrastructure. The road reserves for the side streets are sufficiently wide to incorporate a bioretention system either within the centre median or on one side of the road pavement.

Stormwater runoff from the internal road pavements drains via sheet flow onto the surface of the bioretention systems. Roofwater is conveyed via a shallow underground pipe network to the bioretention systems. The total bioretention area required to deliver best practice stormwater quality on the site in Townsville is 2,100 m^2, which is 1.5% of the site area (from Table 34).

If the frequent flow objective applies, the extended detention zone of the bioretention system provides sufficient storage to meet the frequent flow requirements.

Detention storage (if applicable)

The case study assumed the waterway stability detention storage is not required or would be incorporated into flood storage (Base Case). If the waterway stability objective were to apply and there was no flood storage requirement, the detention volume required for Townsville is 3,140 m$^{3.}$ This represents a storage volume of 224 m^3 per hectare (from Table 35).

The detention storage could be provided within the site in three ways:

- In bioretention systems: 10 % of the bioretention systems' extended detention depth and pore space volume in the filter media.
- Above the bioretention systems: storage volume above the bioretention systems in the zone between the level of the low-flow outlet and the level of the high-flow outlet. This volume is estimated as the equivalent of 1.0 m depth across the bioretention surface area.
- Roofwater detention tanks: The additional required storage will be provided by roofwater detention tanks. Each building will have a detention tank, sized based on the roof area and runoff from the entire roof that will be directed to the tank.

A breakdown of the storages required for Townsville is shown in the table below.

Detention storage allocation for the waterway stability objective for Townsville (from Table 36)

Portion of bioretention system extended detention and pore space	Above bioretention systems	Roof water detention tank	Total
92 m^3	2,100 m^3	948 m^3	3,140 m^3

Performance — Option A

The MUSIC results for the WSUD solution demonstrate that the proposed stormwater treatment train meets the stormwater quality objectives for Townsville for case study 4A.

Townsville MUSIC results (from Table 37)

Scenario	Unmitigated	Base Case		WSUD Case		Stormwater quality objective
Stormwater management parameter	Average annual loads	Average annual loads	% reduction in loads	Average annual loads	% reduction in loads	as % load reduction from unmitigated
Flow (ML/yr)	130	117	10%	117	10%	-
Total Suspended Solids (kg/yr)	18,600	18,060	3%	3,520	81%	80%
Total Phosphorus (kg/yr)	41.3	38.8	6%	13.8	67%	65%
Total Nitrogen (kg/yr)	273	245	10%	151	45%	40%

Costs — Option A

The table below shows the costs of the Base Case and the WSUD Case for Townsville. The table also identifies the incremental cost of the WSUD Case when compared to the Base Case (i.e. identifies the cost of the bioretention systems). The results shows that the costs of meeting the Queensland Development Code (rainwater tanks) requirements is a substantial portion of the overall cost (41% for Townsville), although this is not relevant to Townsville at this time. The incremental cost of meeting the stormwater management objectives is the bioretention cost with the lifecycle cost being $471 per dwelling.

This is substantially lower than the cost per dwelling compared to a low or medium density residential development i.e. compared to case studies 1, 2 and 3. The higher the density of development the lower the cost of the WSUD solution per dwelling.

WSUD Costs (from Table 38)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	645,062	500,000	7,500	150,000	100,000
Bioretention systems (incremental cost)	941,320	693,000	6,825	277,200	277,200
- per hectare	67,237	49,500	488		
- per dwelling	471	347	3.40		
Detention storages*	325,549	284,400	948	85,320	56,880
Overall (WSUD Case)[1]	1,586,382	1,193,000			
- per hectare	113,313	85,214			
- per dwelling	793	597			

Note: Calculations are based on 2,000 dwellings over 14 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.[1] The Overall (WSUD Case) is the sum of the Base Case and Bioretention systems.

WSUD solution — Option B

The Base Case did not include WSUD measures.

To meet the stormwater management objectives, the WSUD Case included the following:

- Bioretention systems to deliver the stormwater quality and frequent flow objectives
- Underground detention tanks to manage the 1-year ARI flow in accordance with the waterway stability objective (if it applies).

Bioretention systems

As with Option A, linear bioretention systems were incorporated into the road reserves. However, because Option B does not include rainwater tanks, all of the stormwater treatment will be provided by the bioretention systems.

The total bioretention area required to deliver best practice stormwater quality on the site in Townsville is 2,240 m^2, which is 1.6% of the site area (from Table 39).

If the frequent flow objective applies, the extended detention zone of the bioretention system provides sufficient storage to meet the frequent flow requirements.

Detention storage (if applicable)

The case study assumed the waterway stability detention storage is not required or would be incorporated into flood storage (Base Case). If the waterway stability objective were to apply and there was no flood storage requirement, the detention volume required for Townsville is 3,140 m^3. This represents a storage volume of 224 m^3 per hectare (from Table 35).

For Option B, the detention storage could be provided within the site in three ways:

- In bioretention systems: 10 % of the bioretention systems' extended detention depth and pore space volume in the filter media.
- Above the bioretention systems: storage volume above the bioretention systems in the zone between the level of the low-flow outlet and the level of the high-flow outlet. This volume is estimated as the equivalent of 1.0 m depth across the bioretention surface area.
- Underground detention tanks: additional storage required will be provided by underground detention tanks. The detention tanks are located within the road reserve, underneath the verge.

A breakdown of the storages required for Townsville is shown in the table below.

Detention storage allocation for the waterway stability objective for Townsville (from Table 40)

Portion of bioretention system extended detention and pore space	Above bioretention systems	Underground detention tank	Total
99 m^3	2,240 m^3	802 m^3	3,140 m^3

Performance — Option B

The MUSIC results for the WSUD solution demonstrate that the proposed stormwater treatment train meets the stormwater quality objectives for Townsville for case study 4B.

Townsville MUSIC results (from Table 41)

Scenario	Unmitigated	Base Case		WSUD Case		Stormwater quality objective
Stormwater management parameter	Average annual loads	Average annual loads	% reduction in loads	Average annual loads	% reduction in loads	as % load reduction from unmitigated
Flow (ML/yr)	130	130	0%	130	0%	-
Total Suspended Solids (kg/yr)	18,600	18,600	0%	3,480	81%	80%
Total Phosphorus (kg/yr)	41.2	41.2	0%	14.1	66%	65%
Total Nitrogen (kg/yr)	274	274	0%	163	41%	40%

Costs — Option B

The table below shows the costs of the WSUD solution for Townsville for Option B. Option B is 37% more cost-effective than Option A, due to the absence of rainwater tanks. This solution, however, does not benefit from being able to use the water that the tanks provide, which means annual water charges could be higher for this development.

WSUD Costs (from Table 42)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	0	0	0	0	0
Bioretention systems (incremental cost) and Overall (WSUD Case)	1,004,075	739,200	7,280	295,680	295,680
- per hectare	71,720	52,800			
- per dwelling	502	370			
Detention storages*	275,412	240,600	802	72,180	48,120

Note: Calculations are based on 2,000 dwellings over 14 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.

Case study 5: commercial -Townsville

(Source: Water by Design 2009, pp. lviii-lxv)

Case study 5 is a small-scale commercial development comprising a neighbourhood shopping centre on a 0.42 ha site. Two buildings are separated by a central arcade and 15–20 ground-level shops. The remainder of the site contains an internal driveway and car park with approximately 60 car parking spaces.

Breakdown of the site areas (from Table 43)

Site area breakdown	Area (ha)	% Impervious
Roof	0.17	100%
Road/driveway	0.2	100%
Other areas (landscape, pavement)	0.05	80%
Total site area	**0.42**	**98%**

Site conditions and constraints

The site is very flat with an average slope of less than 1%. The site design includes small landscaped areas dispersed throughout the car park. These areas are the only practical location for vegetated stormwater treatment systems such as bioretention systems. To enable piped roof water drainage to discharge onto the surface of the bioretention system, surcharge pits were adopted in some cases. Retail shops have a relatively low demand for water; therefore the opportunities for on-site reuse of stormwater are limited.

The ultimate discharge location for stormwater is the existing stormwater drainage networks. This limits the flexibility for the location of the stormwater management systems.

WSUD solution

The Base Case included rainwater tanks as required by the Queensland Development Code.

To meet the stormwater management objectives, the WSUD Case included the following:

- Rainwater tanks as required by the Queensland Development Code
- Bioretention systems to deliver the stormwater quality and frequent flow objectives
- Detention storage to manage the 1-year ARI flow to deliver the waterway stability objective if it applies.

Rainwater tanks

As required by the *Queensland Development Code*, a 9kL rainwater tank will collect roof runoff from one of the buildings. This water will be reused for toilet and outdoor uses. It is assumed six toilets will be provided within the building with a combined demand of 1.3kL/day. It is assumed there is no guaranteed outdoor demand for collected rainwater due to the relatively small area of landscaping. The overflow from the rainwater tank will be diverted to one of the bioretention systems via a stormwater pipe.

Bioretention systems

Bioretention systems will provide water quality treatment for the remainder of the site, including the roof areas that are not directed to the tank, and overflow from the tank. Six bioretention systems will be dispersed throughout the car park and incorporated into the more substantial landscaped areas. Stormwater runoff from the driveway and car park will drain onto the surface of the bioretention systems. Roof water will be conveyed via a shallow underground pipe network to the bioretention systems.

The total bioretention area required to deliver best practice stormwater quality on the site in Townsville is 63 m^2, which is 1.5% of the site area (from Table 44).

It may be necessary to use 'hard' edges and vertical walls in the design of the bioretention systems due to the limited available space.

Detention storage (if applicable)

The case study assumed the waterway stability detention storage is not required or would be incorporated into flood storage (Base Case). If the waterway stability objective were to apply and there was no flood storage requirement, the detention volume required is 100.2 m^3. This represents a storage volume of 239 m^3 per hectare (from Table 45).

The detention storage could be provided within the site in three ways:

- In bioretention systems: 10 % of the bioretention systems' extended detention depth and pore space volume in the filter media.
- Above the bioretention systems: storage volume above the bioretention systems in the zone between the level of the low-flow outlet and the level of the high-flow outlet. This volume is estimated as the equivalent of 0.4 m depth across the bioretention surface area.
- Above ground storage: Additional storage is proposed in landscaped and car park areas adjacent to the bioretention systems.

Stormwater will preferentially fill the storage volume available in the landscaped areas, so surface ponding within the car park will be restricted to relatively infrequent, high intensity storm events.

A breakdown of the storages required for Townsville is shown in the table below.

Detention storage allocation for the waterway stability objective for Townsville (from Table 46)

Portion of bioretention system extended detention and pore space volume	Above bioretention systems	Landscaped areas and car park storage	Total
2.4 m^3	25.2 m^3	72.6 m^3	100.2 m^3

If the frequent flow objective applies, the extended detention zone of the bioretention system provides sufficient storage to meet the frequent flow requirements.

Performance

The MUSIC results for the WSUD solution demonstrate that the proposed stormwater treatment train meets the stormwater quality objectives for Townsville.

Townsville MUSIC results (from Table 47)

Scenario	Unmitigated	Base Case		WSUD Case		Stormwater quality objective
Stormwater management parameter	Average annual loads	Average annual loads	% reduction in loads	Average annual loads	% reduction in loads	as % load reduction from unmitigated
Flow (ML/yr)	4.47	4.34	3%	4.34	3%	-
Total Suspended Solids (kg/yr)	1,010	1,005	0%	198	80%	80%
Total Phosphorus (kg/yr)	2.02	1.99	1%	0.66	67%	65%
Total Nitrogen (kg/yr)	14.0	13.6	3%	8.2	42%	40%

Costs

The table below shows the costs of the Base Case and the WSUD Case for Townsville. The table also identifies the incremental cost of the WSUD Case when compared to the Base Case (i.e. identifies the cost of the bioretention systems). The results shows that the costs of meeting the Queensland Development Code (rainwater tanks) requirements is the dominant cost, although this is not relevant to Townsville at this time. The incremental cost of meeting the stormwater management objectives is the bioretention cost with the lifecycle cost being $15,432 per lot.

WSUD Costs (from Table 48)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	12,110	9,000	175	2,700	1,800
Bioretention systems (incremental cost)	30,863	22,995	205	9,198	9,198
- per hectare	73,484	54,750			
- per lot	15,432	11,498			
Detention storages*	3,110	1,815	73	545	363
Overall (WSUD Case)[1]	42,973	31,995			
- per hectare	102,317	76,179			
- per lot	21,486	15,998			

Note: Calculations are based on 2 lots over 0.42 hectares. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.[1] The Overall (WSUD Case) is the sum of the Base Case and Bioretention systems.

The bioretention systems account for 72% of the Overall WSUD Case. Given the style of development the WSUD Case without rainwater tanks has not been calculated.

Case study 6: industrial

(Source: Water by Design 2009, pp.lxvi-lxxiii)

Case study 6 is a medium-scale industrial development comprising a factory and warehouse on a 1 ha site. The single building is surrounded by an internal driveway and car park with approximately 100 car parking spaces. Offices and general amenities are incorporated into the building. There are significant landscaped areas, both active and passive, distributed throughout the site.

Breakdown of the site areas (from Table 49)

Site area breakdown	Area (ha)	% Impervious
Roof	0.397	100%
Road/driveway	0.389	100%
Other areas (landscape, pavement)	0.214	34%
Total site area	**1.0**	**86%**

Site conditions and constraints

The site is very flat with an average slope of less than 1%. The site design includes significant passive landscaped areas, most of which are suitable locations for stormwater management infrastructure. Industrial warehouses have a relatively low demand for water; therefore the opportunities for on-site reuse of stormwater are limited.

The ultimate discharge location for stormwater is the existing stormwater drainage network. This limits the flexibility for the location of stormwater management systems.

WSUD solution

The Base Case included rainwater tanks as required by the Queensland Development Code.

To meet the stormwater management objectives, the WSUD Case included the following:

- Rainwater tanks as required by the Queensland Development Code
- Bioretention systems to deliver the stormwater quality and frequent flow objectives
- Above-ground detention storage to manage the 1-year ARI flow to deliver the waterway stability objective if it applies.

Rainwater tanks

As required by the *Queensland Development Code*, a 21kL rainwater tank will collect roof runoff from the building. Collected water will be reused for toilet and outdoor uses. It has been assumed that fourteen toilets will be provided within the building with a combined demand of 1.5kL/day. It has been assumed that a typical landscape design for an industrial site uses native species that require minimal irrigation. Therefore, there is no guaranteed outdoor demand for collected rainwater. The overflow from the rainwater tank will be diverted to one of the bioretention systems via a stormwater pipe.

Bioretention systems
Bioretention systems will provide water quality treatment for the remainder of the site, including the roof areas that are not directed to the tank and for overflow from the tank. Two bioretention systems will be incorporated into landscaped areas at strategic locations. Stormwater runoff from the roof, driveway and car park will be collected in a shallow pit and pipe drainage network and conveyed to one of the two bioretention systems.

Where possible, runoff will be conveyed in surface drainage systems such as swales and dish drains.

The total bioretention area required to deliver best practice stormwater quality on the site in Townsville is 150 m², which is 1.5% of the site area (from Table 50).

If the frequent flow objective applies, the extended detention zone of the bioretention system provides sufficient storage to meet the frequent flow requirements.

Detention storage (if applicable)
The case study assumed the waterway stability detention storage is not required or would be incorporated into flood storage (Base Case). If the waterway stability objective were to apply and there was no flood storage requirement, the detention volume required is 227.9 m3. This represents a storage volume of 228 m3 per hectare (from Table 51).

The detention storage could be provided within the site in three ways:

- In bioretention systems: 10% of the bioretention systems' extended detention depth and pore space volume in the filter media.
- Above the bioretention systems: storage volume above the bioretention systems in the zone between the level of the low-flow outlet and the level of the high-flow outlet. This volume is estimated as the equivalent of 0.45m depth across the bioretention surface area.
- Above ground storage: it is proposed to provide the additional storage required in landscaped and car park areas adjacent to the bioretention systems.

Stormwater will preferentially fill the storage volume available in the landscaped areas, so surface ponding within the car park will be restricted to relatively infrequent, high intensity storm events.

A breakdown of the storages required for Townsville is shown in the table below.

Detention storage allocation for the waterway stability objective for Townsville (from Table 52)

Portion of bioretention system extended detention and pore space volume	Above bioretention systems	Landscaped areas and car park storage	Total
5.7 m³	67.5 m³	154.7 m³	227.9 m³

Performance

The MUSIC results for the WSUD solution demonstrate that the proposed stormwater treatment train meets the stormwater quality objectives for Townsville.

Townsville MUSIC results (from Table 53)

Scenario	Unmitigated	Base Case		WSUD Case		Stormwater quality objective
Stormwater management parameter	Average annual loads	Average annual loads	% reduction in loads	Average annual loads	% reduction in loads	as % load reduction from unmitigated
Flow (ML/yr)	9.73	9.47	3%	9.47	3%	-
Total Suspended Solids (kg/yr)	2,340	2,327	1%	441	81%	80%
Total Phosphorus (kg/yr)	4.41	4.35	1%	1.45	67%	65%
Total Nitrogen (kg/yr)	22.6	22.0	3%	13.4	41%	40%

Costs

The table below shows the costs of the Base Case and the WSUD Case for Townsville. The table also identifies the incremental cost of the WSUD Case when compared to the Base Case (i.e. identifies the cost of the bioretention systems). The results show that the cost of meeting the Queensland Development Code (rainwater tanks) requirements is a minor portion of the overall cost, accounting for 12% of the overall cost. The incremental cost of meeting the stormwater management objectives is the bioretention cost with the lifecycle cost being $67,000 per hectare.

WSUD Costs (from Table 54)

Item	Costs ($ Au)				
	Total lifecycle	Acquisition	Annual maintenance	Renewal	Decommission
Rainwater tanks (Base Case)	8,800	6,000	175	1,800	1,200
Bioretention systems (incremental cost)	67,237	49,500	488	19,800	19,800
- per hectare	67,237	49,500			
- per lot	67,237	49,500			
Detention storages*	6,640	3,875	155	1,163	775
Overall (WSUD Case)[1]	76,038	55,500			
- per hectare	76,038	55,500			
- per lot	76,038	55,500			

Note: Calculations are based on 1 lot over 1 hectare. * This item is associated with detention storage to meet the waterway stability objective. This objective is not applicable in all instances. Therefore, the costs for this item have not been included in the overall costs.[1] The Overall (WSUD Case) is the sum of the Base Case and Bioretention systems.

The bioretention systems account for 88% of the Overall WSUD Case. Given the style of development the WSUD Case without rainwater tanks has not been calculated.

Case Study 1 Residential greenfield (large) on sloping topography

Element	Option A	Option B
Impervious surface	47% of the site	47% of the site
Rainwater tank	5kL per residence	None
Rainwater tank storage capacity	4.8ML	0
Annual flow	473ML	509ML
Annual flow reduction rainwater tanks	36ML (7%)	0
Detention basins for flood storage	20,000–25,000 m^3	19,000–23,750 m^3
Total bioretention area (0.6m)*	9,848m^2 (1.3% of site area)	10,605m^2 (1.4% of site area)
Detention volume required	14,792 m^3 (195 m^3 per ha)	14,792 m^3 (195 m^3 per ha)
Detention volume – above bioretention	5,909 m^3	6,363 m^3 (7.7% increase)
Detention volume – in bioretention	384m^3	413m^3 (7.6% increase)
Detention volume – in detention basins	8,499 m^3	8,016 m^3 (5.7% reduction)

Note: * indicates average depth of detention area

Element	Lifecycle	Acquisition	Maintenance*
Rainwater tanks[1]	$4,214,208	$2,853,000	$85,590
Bioretention cost – Option A	$3,652,509	$2,609,588	$32,004
Bioretention cost – Option B	$3,933,471	$2,810,326	$34,466
Bioretention cost increase – Option B[2]	$280,962	$200,738	$2,462
Cost saving without rainwater tanks	$3,933,246	$2,652,262	$83,128
Detention storage cost – Option A	$364,085	$212,475	$8,499
Detention storage cost – Option B[3]	$345,881	$201,851	$8,074
Detention storage cost reduction	$18,204	$10,624	$425
Total cost reduction with Option B	$3,951,450	$2,622,886	$83,553

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 8.2% increase in detention capacity. The cost increase due to bioretention systems is 7% (6.7%) of the cost of rainwater tanks i.e. 93% cost saving, without any significant impact on detention costs

[3]based on a 5% size reduction.

Case Study 2 Residential greenfield (small/medium) on flat topography

Element	Option A	Option B
Impervious surface	56% of the site	56% of the site
Rainwater tank	5kL per residence	None
Rainwater tank storage capacity	0.42ML	0
Annual flow	40ML	43ML
Annual flow reduction rainwater tanks	3ML (7%)	0
Detention tanks	450 m^3	430 m^3
Total bioretention area (0.3m)*	824 m^2 (1.3% of site area)	887 m^2 (1.4% of site area)
Detention volume required	1,278 m^3 (202 m^3 per ha)	1,278 m^3 (202 m^3 per ha)
Detention volume – above bioretention	247 m^3	266 m^3 (7.7% increase)
Detention volume – in bioretention	34m^3	37 m^3 (8.8% increase)
Detention volume – in/above u/g tanks	997 m^3	975 m^3 (2.2% reduction)

Note: * indicates average depth of detention area

Element	Lifecycle	Acquisition	Maintenance*
Rainwater tanks[1]	$372,233	$252,000	$7,560
Bioretention cost – Option A	$369,356	$271,920	$2,678
Bioretention cost – Option B	$397,768	$292,837	$2,884
Bioretention cost increase – Option B[2]	$28,412	$20,917	$206
Cost saving without rainwater tanks	$343,821	$231,083	$7,354
Detention storage cost – Option A	$177,966	$148,675	$997
Detention storage cost – Option B[3]	$174,051	$145,404	$975
Detention storage cost reduction	$3,915	$3,271	$22
Total cost reduction with Option B	$347,736	$234,354	$7,376

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 7.8% increase in detention capacity. The cost increase due to bioretention systems is 8% (7.6%) of the cost of rainwater tanks i.e. 92% cost saving, without any significant impact on detention costs

[3] based on a 2.2% size reduction.

Case Study 3 Residential townhouse development

Element	Option A	Option B
Impervious surface	61% of the site	61% of the site
Rainwater tank	3kL per residence	None
Rainwater tank storage capacity	75kL	0
Annual flow	4.57 ML	5.16 ML
Annual flow reduction rainwater tanks	0.59 ML (11%)	0
Detention tanks	79.9 m^3	77.16 m^3
Total bioretention area (0.4m)*	79.9 m^2 (1.2% of site area)	86.6 m^2 (1.3% of site area)
Detention volume required	137.1 m^3 (206 m^3 per ha)	137.1 m^3 (206 m^3 per ha)
Detention volume – above bioretention	32 m^3	34.6 m^3 (7.6% increase)
Detention volume – in bioretention	3 m^3	3.24 m^3 (8% increase)
Detention volume – u/g tanks	79.9 m^3	77.16 m^3 (3.4% reduction)
Surface ponding	22.2 m^3	22.2 m^3

Note: * indicates average depth of detention area

Element	Lifecycle	Acquisition	Maintenance*
Rainwater tanks[1]	$96,998	$62,500	$2,250
Bioretention cost – Option A	$35,815	$26,367	$260
Bioretention cost – Option B	$38,800	$28,564	$282
Bioretention cost increase – Option B[2]	$2,985	$2,197	$12
Cost saving without rainwater tanks	$94,013	$60,303	$2,238
Detention storage cost – Option A	$28,389	$24,526	$102
Detention storage cost – Option B[3]	$27,424	$23,692	$99
Detention storage cost reduction	$965	$834	$3
Total cost reduction with Option B	$94,978	$61,137	$2,241

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 8.1% increase in detention capacity. The cost increase due to bioretention systems is 3% of the cost of rainwater tanks i.e. 97% cost saving. Detention cost reduction is 3.4% (based on lifecycle cost).

[3] based on a 3.4% size reduction.

Case Study 4 Urban Renewal

Element	Option A	Option B
Impervious surface	81% of the site	81% of the site
Rainwater tank	1kL - 800 dwellings	None
Rainwater tank storage capacity	0.8ML	0
Annual flow	117ML	130ML
Annual flow reduction rainwater tanks	13ML (10%)	0
Detention tanks	948 m^3	802 m^3
Total bioretention area (1m)*	2,100m^2 (1.5% of site area)	2,240m^2 (1.6% of site area)
Detention volume required	3,140 m^3 (224 m^3 per ha)	3,140 m^3 (224 m^3 per ha)
Detention volume – above bioretention	2,100 m^3	2,240 m^3 (6.7% increase)
Detention volume – in bioretention	93 m^3	99 m^3 (6.7% increase)
Detention volume – in detention tanks	943 m^3	802 m^3 (14% reduction)

Note: * indicates average depth of detention area

Element	Lifecycle	Acquisition	Maintenance*
Rainwater tanks[1]	$645,062	$500,000	$7,500
Bioretention cost – Option A	$941,320	$693,000	$6,825
Bioretention cost – Option B	$1,004,075	$739,200	$7,280
Bioretention cost increase – Option B[2]	$62,755	$46,200	$455
Cost saving without rainwater tanks	$582,307	$453,800	$7,045
Detention storage cost – Option A	$325,549	$284,400	$948
Detention storage cost – Option B[3]	$275,412	$240,600	$802
Detention storage cost reduction	$50,430	$43,800	$146
Total cost reduction with Option B	$632,737	$497,600	$7,191

Note: * refers to the annual maintenance cost across the site.

[1] this is also the cost reduction associated with the no rainwater tank option i.e. Option B.

[2] Equates to an 4.6% increase in detention capacity. The cost increase due to bioretention systems is 10% of the cost of rainwater tanks i.e. 90% cost saving. Detention cost reduction is 15.4% (based on lifecycle cost).

[3] based on a 15% size reduction.

Appendix F

TWCMP and USQMP

Appendix F TWCMP and USQMP

Total Water Cycle Management Planning

The Water EPP 2009 requires a Total Water Cycle Management Plan (TWCMP) to be prepared for each local government area with a population greater than 10,000 people.

A TWCMP is about the integration of water use and includes the collection, treatment and recycling of; waste water, stormwater, ground water, and other water sources.

Total Water Cycle Management Plan Framework

The development of the Total Water Cycle Management Plan, as required under the EPP Water 2009 (August 2009), has been endorsed by TCC through the WAC process and subsequently by CEO/Directors. Integrated Sustainability Services (ISS) will lead the development process.

The process has commenced and initial arrangements have been made to put a project management team (steering group) in place based on assumed responsibility by the Executive Managers of the relevant TCC departments. The current structure of the steering group and general responsibilities are illustrated below.

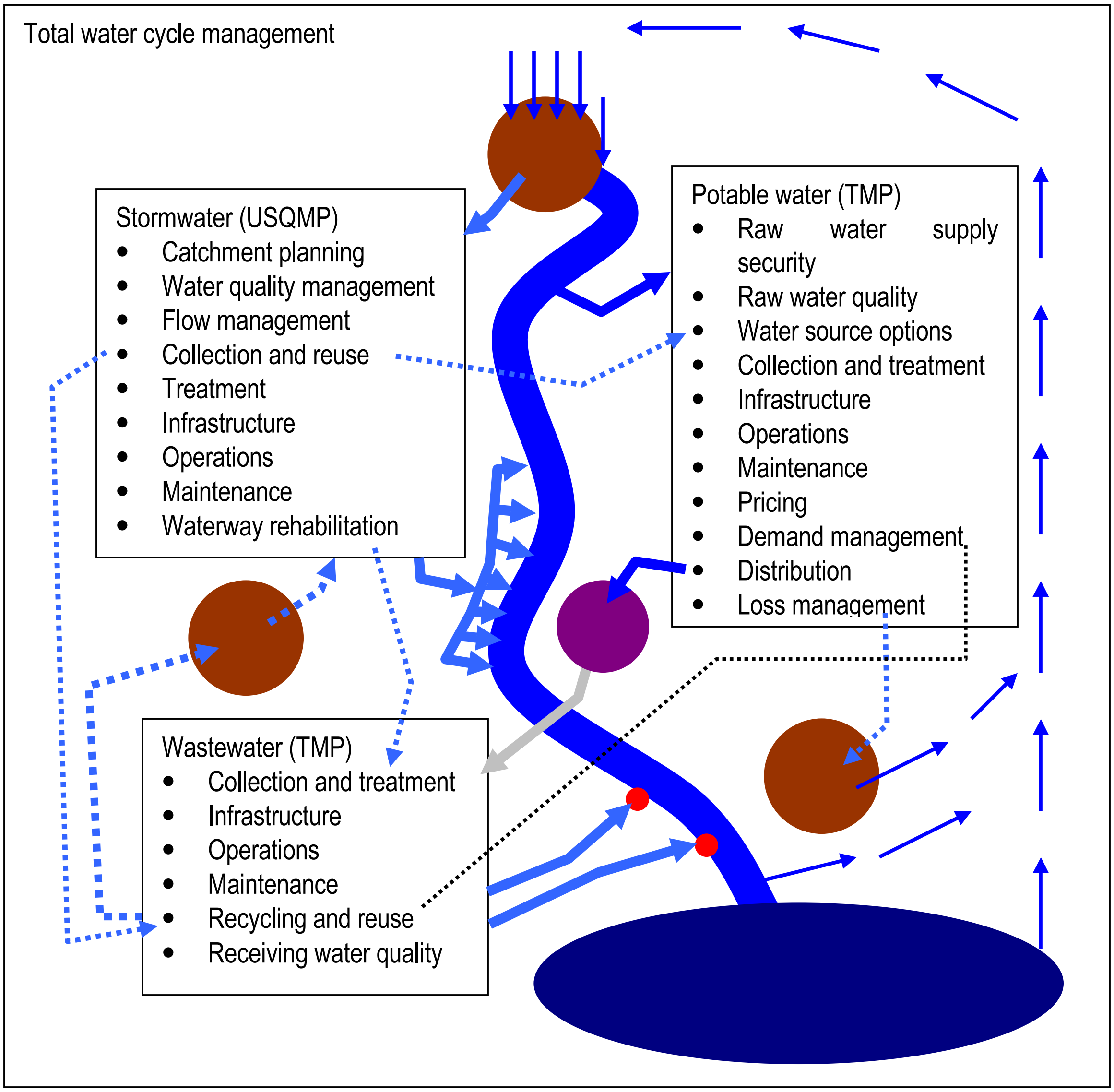
Table 1 Initial steering group

Responsibility area	Lead	Responsible person	Delegated responsibility	Assisting
Overall coordination	ISS	Greg Bruce	Chris Manning	All listed
			tba (demographics)	
USQMP	C and M	Brendan Quabba	tba	
			Chris Manning	ISS
			Graham Anderson	SP
	(d), (e)			(a), (b)
TMP (incorporating SMP)	TWater	Pedro Mediolea	Mark Tartellin	
			tba (water supply)	SP
	(a),(b),(c),(f)			(d), (e)
Natural areas – waterways and wetlands	ISS	Greg Bruce	Jason Lange	
			tba	Parks
			tba	C and M
				(d), (e)

Notes: Integrated Sustainability Services is ISS (with Creek to Coral as the coordination vehicle), C and M is Construction and Maintenance, SP is Strategic Planning, TWater is Townsville Water, Strategic Planning includes City Plan). TMP is Total Management Plan. Letters in brackets refer to the components for consideration in Table 2.

Total water cycle management plans (TWCMP) are inclusive of the former urban stormwater management plans (USQMPs) (provisions about stormwater quality management to improve the quality and flow of stormwater in ways that protect the environmental values of waters affected by the local government's urban stormwater system) and sewage management plans (SMPs). A TWCMP must include provisions about the collection, treatment and recycling of wastewater, stormwater, ground water and other water sources; and the integration of water use in its area.

If a local government is required to develop a TWCMP, or other environmental plan (apart from a trade waste management plan), it must develop and start implementing the plan within two years after the commencement of the Water EPP 2009. The plan is to be reviewed and revised after five years.



The Total Management Plan (TMP) approach for management of water and sewerage services has been in existence since the early 1990s when the water reform agenda started in earnest. Total management planning promotes best practice planning and least cost outcomes for water supply and sewerage planning. The guidelines prepared by the Department of Natural Resources and Water (now part of DERM) were updated in March 2002, and an NRW approved TMP was a pre-requisite for a local government to receive maximum subsidy from the state government.

In terms of total water cycle management plans, the various sub plans and components of a TMP for water can be adapted to meet the requirements of the EPP Water 2009. In some cases the sub plans may be directly translatable into the TWCMP.

USQMP Objectives and principles

Urban drainage systems are often designed and built specifically to move stormwater away from developed areas to minimise the threat of flooding. Stormwater drains traditionally lead to local waterways without any form of treatment of the stormwater, meaning a range of pollutants such as sediment; nutrients, oil and rubbish are entering our waterways. Physical changes such as waterway channel erosion can also occur due to the increase of run-off from impervious urban areas. If stormwater is not managed, pollution and physical changes caused by stormwater can result in substantial damage to the environment in and around our local waterways.

To achieve best practice in the environmental management of stormwater, it is important that catchment management and local government activities are guided by a stormwater quality management plan (USQMP). Urban stormwater quality management primarily involves the protection of the environmental values of the receiving waters that are influenced by run-off from urban stormwater systems. Urban stormwater management however encompasses a broader range of objectives and principles including those listed below.

- Protection of the environmental values of waterways and waters;
- Minimised ecological impacts on waters;
- Maintenance of ecosystem services;
- Minimised contamination of waters by stormwater in accordance with design objectives for the area;
- Contaminants removed from the stormwater;
- Maximised infiltration of water into the ground;
- Reduced velocity of stormwater flow;
- Protection from flooding;
- Public safety;
- Use of stormwater for recycling and water conservation;
- Use of drainage corridors for improved recreational opportunities;
- Re-established riparian vegetation and environments in degraded drainage corridors;
- Integration of USQMP with catchment-based and land-use planning.

The USQMP process

The urban stormwater quality management planning process is outlined in the Draft Urban Stormwater Queensland Best Practice Environmental Management Guidelines (DERM 2009). The main activities as suggested by DERM (2009) are listed in the text box below. The activities listed are similar in many respects to the steps used to develop the Townsville (Black Ross) WQIP, as both are based on the National Water Quality Management Strategy (NWQMS).

Scoping the preparation of a USQMP for the new Townsville City local government area takes into account the work involved in preparing the Townsville WQIP and the necessity to use an adaptive planning and management approach to enable information gaps to be filled while continuing to progress the overall development of the USQMP.

While the preparation and implementation of the USQMP is laid out as a number of stages and a series of steps the process is not necessarily linear. Adaptability is therefore a prerequisite of the planning process to ensure satisfactory progress is made to complete the USQMP in a reasonable timeframe. As the USQMP is a key component of the Total Water Cycle Management Plan (TWCMP) adaptability will also be necessary to integrate the USQMP with the other components of the TWCMP.

[1] With guidance from Chapter 3: Stormwater management planning – regional and local in Draft Urban Stormwater Queensland Best Practice Environmental Management Guidelines 2009 Review Draft (DERM 30 August 2009)

USQMP Stages and Activities (DERM 2009)

Stage 1 Preliminary activities
1.1 Establish commitment to the project
1.2 Agree project framework and scope
1.3 Define problems and information requirements:

- catchments, drainage system, receiving environments
- land-use patterns, land-use activities
- pollutants.

Stage 2 Risk assessment
2.1 Consider stormwater threats
2.2 Identify environmental values and design objectives (WSUD)
2.3 Produce a list of issues/activities in order of importance (i.e. threat × value = priority)

Stage 3 Development of USQMP
3.1 Consider options for action
3.2 Develop a list of recommendations based on cost effectiveness, capability, opportunity
3.3 Establish implementation responsibility, costs, monitoring and review

Stage 4 Implementing the USQMP
4.1. Develop implementation strategy
4.2. Establish performance review and improvement programs
4.3. Undertake water quality monitoring and review (p.44)

A summary of the activities necessary to develop the Townsville City USQMP to meet the requirements of the *Environmental Protection (Water) Policy 2009* (EPP Water) are outlined in section 2.8.3 with additional detail for some of the processes provided below.

The activities suggested by DERM in the *Draft Urban Stormwater Queensland Best Practice Environmental Management Guidelines* (2009) have been adapted to suit the local Townsville environment and incorporate the work already completed as part of the development of the Townsville WQIP. Text in italics has been extracted from the DERM (2009) guidelines.

[Stage 1 Preliminary Activities]
Step 4 Review of management practices and processes

The review should cover planning, regulation, education, enforcement and operations as well as any existing structural approaches to managing stormwater impacts.

- Planning: Regional plans, planning scheme, planning policies, permit conditions
- Operations: Specifications for service delivery (e.g. waste collections), asset maintenance activities, depot operation
- Regulation: Integration between policy, planning controls, local laws and enforcement activities

- Education: Programs aimed at those involved in activities with potential to affect the stormwater system
- Infrastructure: Incorporation of structural measures into buildings, roads and drainage systems to reduce environmental impacts

The majority of the review will focus on Council management practices associated with planning, construction and maintenance of public infrastructure and open space, training and education programs and processes including induction of new employees. The non-Council management practices and processes that have the potential to impact stormwater quality and flow also need to be reviewed. This includes state government agencies e.g. Qrail and Main Roads, industry e.g. Townsville Port and Airport and land developers, commercial premises and the average householder (collectively accounting for the majority of the urban area).

Stage 2 Risk assessment

Purpose: To identify and rank the values of receiving environments and the threats posed by urban stormwater pollutants and/or flows
Outputs: Agreed ratings or rankings of stormwater threats and receiving environment values
Process:

- *Review of existing information (including from stage 1);*
- *Site assessments;*
- *Consultation (various);*
- *Stakeholder workshop to confirm results.*

The risk management approach is based on assessing the risk or likelihood of losing significant values of receiving environments due to the impacts of urban stormwater, and identifying areas where the risk of damage is greatest.

The risk of those environmental values being lost depends on two main factors:

- The scale or severity of the stormwater threat, and
- The sensitivity of the receiving environment to that threat.

The two main tasks are to:

- *Identify the environmental values of receiving waters and assign scores or rankings to the various environments or receiving waters;*
- *Identify the nature and source of stormwater threats to receiving water and assign numerical values to indicate the size of the threat / risk of damage due to stormwater flows or pollution.*

The steps involved in assessing the risk to the receiving waters are outlined below. This may not be a strictly linear process.

For the receiving waters potentially affected by urban stormwater, environmental values (EVs) and water quality objectives (WQOs) should be identified with a description of the existing qualities, characteristics and resilience of the aquatic environment. The intent is to characterise the receiving waters including EVs, WQOs and the current and required levels of ecosystem protection.

Step 1 Compilation of available data to determine draft Environmental Values (human use and aquatic ecosystem) for waterways and waterbodies impacted by urban stormwater

Identifying the Environmental Values will commence with a review of information from Stage 1 and will include a variety of information sources and information gathering methods including:

- *National Water Quality Management Strategy* and *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)*;
- *Queensland Water Quality Guidelines 2009*;
- *Directory of Important Wetlands Australia*;
- *Environmental Protection (Water) Policy 2009*;
- *DERM publications and guidelines*;
- Black Ross WQIP results and documents (especially EVs, WQOs and WQ Targets Report);
- Former CoT and TCC USQMPs and other relevant studies and reports;
- Technical Working Group;
- Stakeholder consultation (a consultation strategy will need to be developed based on engaging the community in designated priority catchments and sub catchments).

The type of information that will be used to inform the identification of Environmental Values associated with urban and peri-urban waterways is listed in Table 1.

Table 1 Information for assessing the values of receiving environments

Value	Category	Examples of attributes
Amenity - recreational and landscape attributes	Significance	Extent of open space associated with the receiving environment, extent of facilities such as trails, car parks, picnic areas, areas for canoe or boat launching, extent and continuity of public access, visual attractiveness
	Use	Visitor numbers, level of active water-based recreation or passive non-contact recreation, number of associated recreation events held at a site
Cultural		Association with known sites of cultural and heritage significance
Economic - benefits derived from water environments	Direct	Water-use, fishing or aquaculture, tourism, transport (e.g. ferry services)
	Indirect	Property values
Environment - physical and ecological attributes of waterways	Significance	Biodiversity, significant species (e.g. rare or threatened), treaties, protection agreements, listings, sites of significance
	Intactness or Integrity	Size of intact area (e.g. continuity of habitat), remnant vegetation, level of invasion by exotic species
Hydraulic		Extent to which the environment contributes to the protection of property and public safety from flooding
Resource - urban (potable and non-potable), industrial and agricultural water usage		Quality of untreated water, degree of treatment required to achieve the required water quality Water abstraction licences may indicate uses such as stock watering and irrigation

After these environmental values have been determined the values need to be converted into a rating system so that the relative significance of the waterways can be determined.

The levels of aquatic ecosystem protection (Environment in Table 1) need to be determined as either high ecological value (HEV), slightly disturbed (SD), moderately disturbed (MD) or highly disturbed (HD).

Step 2 Identification of appropriate WQOs for corresponding EVs

Step 3 Comparison of water quality data with WQOs

Step 4 Identify threats to receiving waters from stormwater

Step 5 Rate threats to EVs

Step 6 Site assessments

Step 7 Risk assessment

This stage involves reviewing stormwater related threats to determine the potential risks to the environmental values of local waterways. It should take into account:

- the transmission efficiency of drains carrying the pollution or flow threats;
- the significance of receiving water values (HEVs and human use);
- the sensitivity of those values to the threats identified (sensitivity rating required based on current condition, proximity to source, riparian buffers etc).

Step 8 Stakeholder workshop/s to review findings and amend EVs and threat ratings

The results of the assessment of threats and values should be presented to stakeholders. This can involve presentation of maps, working through the ranking process used and discussion of the results. Participants should be given the opportunity to question the results and add any information that may have been missed during the assessment process. The aim should be to achieve consensus on the rankings of threat and value.

Step 9 Follow up and resolve any significant disagreements

Meet and discuss any conflicts and resolve to the degree possible.

Stage 3 Development of USQMP Management Options and Actions

The USQMP will provide actions and strategies to be undertaken by Townsville City Council, and its partners as appropriate, to meet the agreed objectives and values identified and confirmed in Stage 2. Strategies may be city wide, or specific to a catchment, and within the context of a TWCM Plan (see EPP water 2009). The USQMP will provide the framework within which existing industry, developers of urban land, State and local government agencies, and the general public manage their activities and the stormwater system over differing time periods i.e. immediate to long term.

Step 1 Identify the range of available management options to address issues / threats identified in Stage 2

The risk management approach will include options across a number of disciplines and management areas as outlined in Table 2.

Table 2 Management option considerations

Discipline	Management option considerations
Planning	Planning guidance and controls should be designed to incorporate the potential effects of landuse change and land development on water quality. Planning is also involved in the incorporation of WSUD elements in new developments and identifying retrofit options for established urban areas.
Land management practices	Land management practices influence impacts on water quality especially with regard to maintenance of parks and other open space, drainage lines and waterways, road verges, house yards and gardens, revegetation sites and conservation areas. Land management practices need to be reviewed and issues addressed to protect waterways and water quality
Waste management	The way services such as waste collection are provided by municipalities and the private sector should be reviewed, to ensure that stormwater quality is not being compromised
Education and awareness	Well researched and designed community and business awareness programs may be instrumental in changing behaviours and the way the environment is managed
Infrastructure	Structural treatment measures such as litter traps can be used to capture and retain pollutants. Stormwater may be able to be captured and reused.

Information sources and input:

- Findings from Stage 2
- *Queensland Urban Drainage Manual 2007* (provides information for strategic planning for stormwater management)
- Attachment 1

Step 2 Align potential management options with functional management units, waterways and catchments as appropriate

The focus should be on implementing 'best practice' environmental management within a catchment, targeting the priority issues.

Step 3 Evaluate cost effectiveness of options and prioritise management actions

When considering the application of a range of proposed approaches to the management of stormwater threats, a number of questions should be asked.

- Is the cost of measures to avoid or reduce risks high without sufficient benefit? If so, their **cost-effectiveness** is relatively low.
- Does local government or others have sufficient resources, expertise or powers to implement the measure? If not, their **capability** is low.
- Is it practical to implement the measure? There may be no space for installing a structure to treat stormwater, for example. If so, the **opportunity** is lacking (see Attachment 1).

Step 4 Document USQ Strategies and Management Actions

Step 5 Prepare an Implementation Plan

Stage 4 Implementing the USQMP

Successful implementation of the USQMP will require:

- Commitment of all stakeholders to improved stormwater quality management;
- Incorporation of stormwater quality management objectives (including WSUD design objectives) into the statutory planning framework and other relevant plans, strategies and policies;
- Coordination of planning, operations and maintenance, infrastructure planning and activities, education and training, and enforcement within Council and in association with other agencies;
- Strengthened relationships with State agencies and local Council to deliver coordinated programs;
- Agreed and consistent priorities for action;
- Allocation of resources commensurate with desired outcomes;
- Adaptive planning and management approach to support continuous improvement in operational practices particularly to ensure environmental performance objectives are written into specifications for service delivery.

Management Options (from Attachment 1 (DERM 2009))

USQMP management strategies

Developing suitable urban stormwater management strategies involves confirming risk rankings at a workshop of stakeholders and then identifying and evaluating a range of best practice management options for managing the priority risks. These can include measures related to land-use planning, urban design, land management, operations, enforcement, education and awareness, and infrastructure (stormwater treatment).

Table above Example presentation of opportunities for implementation of management measures

Category	Criteria	Explanation
Effectiveness	Cost	Use approximate cost categories to compare costs. For example: major cost > $500,000 moderate/high $100–$500 k moderate $50–$100 k low<$50 k
	Effectiveness	Assess how well the measure is likely to reduce risk.
	Capability	Is it cost-effective and feasible to manage impacts to the extent required to protect EVs? Do we have enough information to be effective? Are the skills readily available?
Feasibility		Does the technical ability or understanding exist? Are statutory powers available What's our track record like?
	Opportunity	Do others need to be involved and will they agree to it? Is space available where structural measures are proposed? Can the measure be included as part of another project which is to be implemented e.g. drainage system upgrade?

Management options should be evaluated against criteria of cost, effectiveness in protecting or enhancing values (reducing risk), opportunities for implementation and capability of the municipal council or other agencies to implement. Table above provides some examples of how these criteria might be applied.

Risk assessment

For development likely to threaten a particular receiving environment a brief assessment of management measures should be carried out including: land-use planning, urban design, land management, operations, enforcement, education and awareness and stormwater treatment and infrastructure, can be undertaken quickly. As part of this assessment there is a need to compare the effectiveness and feasibility of management options for each priority stormwater risk.

Land-use and planning scheme links

Land-use planning options have major implications for water quality and flows. Council planning schemes should be informed by and linked to the USQMP to ensure:

- Information gathered in developing the USQMP will support the preparation of planning instruments for local areas and planning scheme amendments or a new planning scheme;
- Mapping of stormwater infrastructure and catchments will assist in determining the preferred pattern of settlement;

- Water quality objectives can be used to guide the location of certain developments and the conditions on development approvals;
- Planning policies and codes can be produced based on options for stormwater management developed in waterway action plans (i.e. water sensitive urban design, grassed swales, porous paving);
- Infrastructure charges on development can be used to fund part or all of the stormwater (and the rest of the water cycle) network. Networks so funded can be designed and costed to achieve the environmental values and water quality objectives established in the USQMP;
- Valuable features within a local government area, such as waterways and wetlands, are protected and conserved;
- Environmental information required in development applications (e.g. land capability assessment or master drainage plan) is appropriate including;
    - how EVs of waterways will be protected during both construction and post construction,
    - any likely change to hydrology,
    - the level or load of sediments and nutrients discharged in stormwater from the development site,
    - provision of a stormwater site assessment report and subsequent stormwater management plan,
    - conform with principles of ESD,
    - demonstrate that the development is occurring on the appropriate land capability class,
    - maximise the social value of stormwater and stormwater infrastructure,
    - protect riparian zones from disturbance,
    - adopt water conservation and recycling principles,
    - not cause flooding,
    - cost to the Council of maintaining permanent stormwater infrastructure provided by the developer or Council

Land development controls

Stormwater management options for developing areas include:

- Erosion source control;
- Sediment traps;
- Wetlands for nutrient control;
- Stabilised temporary drainage lines;
- Flow control devices – rate and volume of run-off to approximate predevelopment rates and volumes, including for the one in one year ARI flood recurrence frequency;
- Riparian management – natural vegetation, channel form, stream substrates, and meanders to be preserved where feasible site rehabilitation.

Water sensitive urban design

Water sensitive urban design (WSUD) aims to retain or replicate natural hydrology and channel design, by encouraging infiltration, flow retention or detention, and by minimising impervious areas and the use of rapid-flow and impervious drainage systems (e.g. pipes). WSUD options, and other relevant stormwater principles, should be included in waterway action plans and other USQMP components for all new development. For example:

- Maximising opportunities for using stormwater productively (e.g. water sensitive urban design and constructed stormwater wetlands);
- Maximising opportunities for the enhancement of recreational and visual amenity through the design of drainage corridors and open space;

- Adopting water sensitive urban design in conceptualising, aligning, shaping and sizing stormwater facilities in new urban developments;
- Pre-treating stormwater prior to discharge to surface water as far as possible;
- Minimising hard engineering solutions to riparian management in favour of approaches which preserve natural channel form and riparian vegetation;
- Implementing stormwater infrastructure design approaches which are consistent with the planning scheme objectives and principles.

Source controls

Prevention measures at the source are generally the most effective i.e. prevention being better than rehabilitation. Source control can be implemented in a variety of ways including through planning provisions, physical infrastructure and education and awareness programs. Some options are listed below.

- Land use planning identifying environmentally significant or sensitive land;
- Development controls to protect environmental values especially in areas of environmental significance, sensitivity/susceptibility and low suitability such as;
    - special management of stream vegetation,
    - buffers adjacent to 'essential' vegetation and waterways etc,
    - stream rehabilitation works and maintenance.
- Attaching a resource value to stormwater e.g. aquifer recharge or environmental flows;
- Installing flow control basins, water quality control ponds, polishing wetlands, and aquifer recharge basins;
- Installing litter or oil control devices i.e. stormwater quality improvement devices (SQIDs)
- Minimising the inflow of stormwater to the sewerage system to reduce hydraulic load and minimise the risk of system overflow, and minimizing the inflow of sewer overflows into the stormwater system
- Design guidance for developments to address more frequent storms rather than the infrequent larger storms;
- Planning approvals conditions requiring land developers to prepare, submit and implement site Stormwater Quality Management Plans (SQMPs) for specific sites.

Existing urban areas

USQMPs and components should address improved stormwater management in existing areas including options for:

- Oil pollution control – storage bunding, oil arresters;
- Litter capture – trash racks;
- Sediment capture – sediment traps;
- Nutrient reduction – constructed wetlands (can tie in with parkland/open space plans);
- Street sweeping programs – (targeted source areas);
- Industrial land first flush systems – (e.g. collection and reuse of first 20mm of run-off);
- Infiltration techniques – e.g. construction of grassed swales, infiltration channels/basins;
- Stream rehabilitation – restoration of naturally vegetated channels and increase the width of riparian corridors;
- Labelling and identifying stormwater culverts.

Open space and drainage corridors

Examples of controls and improvements include:

- Wetlands as landscape features;
- Multiple use facilities – tennis courts and playing fields as dry sediment basins and flow retardation basins;
- Drainage corridors as walking/bicycle/fitness tracks, or communication corridors;
- Riparian zones and vegetated drainage corridors as wildlife corridors;
- Water in a landscape – rated among the most desirable features in a recreational/landscape setting and development proposals should be encouraged to reflect this.

Waterway action plans

Preparing specific waterway action plans is a USQMP option that can be applied to individual catchments or the whole local government area. A waterway action plan may be prepared for priority catchments to achieve specific environmental objectives, or more broadly to address land use based water quality impacts. Waterway action plans should be designed to address the range of USQMP issues associated with:

- Stormwater quality especially relating to sediments, turbidity, nutrients and litter, and as appropriate, oil, pesticides and coliform count. Design objectives for many of these indicators need to be developed;
- Stormwater flows as they affect downstream erosion potential, stormwater volume and velocity, environmental flow requirements, or flooding. Design objectives for flow frequency and waterway stability should be confirmed;
- Local groundwater hydrology, e.g. aquifer storage, quality and use;
- Landscape values of local drainage lines, creeks, stormwater control ponds, basins and wetlands;
- Water habitats including stream and streamside vegetation, stream/basin morphology, and potential barriers to fish passage;
- Health and safety aspects including mosquito breeding potential and accidental drowning.

The waterway action plan should also be developed in consideration of environmental planning and land-use issues. Examples include:

- Inherent features of the catchment that may impose constraints or provide opportunities for land use including topography, soil type and erodability, water bodies (including both hydrology and water quality), habitats (including aquatic, bushland and wetlands), or any other natural asset
- Information available in relation to the relevant processes and interactions which link features in the catchment. Is this information adequate to enable a reasonably accurate assessment of the environmental impacts of various catchment land-use development scenarios? If it is, what are the likely impacts on such processes and interactions? What trade-offs are acceptable where resource management objectives may be in conflict? Are there issues such as World Heritage Areas that warrant a precautionary principle approach to development?
- Present river flows and water resource uses and how these impact on environmental values and water quality
- Land capability and suitability for the proposed use (taking into account stormwater pre-treatment measures)
- Council capability to maintain any permanent stormwater pollution control facilities (e.g. flow retention basins, gross pollutant traps and water quality control ponds), which may be necessary to control the long-term environmental impacts of stormwater.

Appendix G

Riparian Vegetation GIS Analysis

Quantifying Riparian Vegetation Extent

The extent of remnant riparian vegetation was calculated using GIS buffering along the waterways of the Black Ross WQIP area. The results of the assessment are provided in the tables below in alphabetical order by waterway name (Table A) and by sub basin groupings (Table B).

Table A Remnant riparian vegetation by waterway

Catchment	Waterway Length of Catchment		Total Riparian Area		Total Area (hectares)		NR/R	Total Length (metres)		NR/R
	River System (m)	km	m²	hectare	Remnant	Non remnant	%	Remnant	Non remnant	%
Alice River	109,513	110	2,795,034	280	258.8	20.7	8.0	202,460	16,565	8.2
Alligator Creek	148,837	149	3,966,130	397	297.7	65.8	22.1	226,783	51,116	22.5
Antill Plains Creek	86,918	87	2,265,393	227	168.0	40.7	24.2	133,170	29,664	22.3
Arcadia	1,583	2	40,051	4	2.6	1.0	39.0	2,048	804	39.3
Black River	162,429	162	4,367,123	437	387.7	41.8	10.8	287,969	32,262	11.2
Bluewater Creek	95,588	96	2,578,300	258	241.5	11.7	4.9	181,291	7,167	4.0
Bohle River	132,944	133	3,529,547	353	274.0	47.5	17.3	209,611	38,103	18.2
Bohle River 2	157,171	157	4,086,355	409	307.8	100.8	32.8	238,354	75,987	31.9
Cape Cleveland	16,374	16	411,592	41	40.3	0.0	0.0	31,881	0	0.0
Cassowary Creek	11,995	12	299,814	30	28.6	0.8	2.9	22,847	640	2.8
Cocoa Creek	19,464	19	500,711	50	44.1	0.0	0.0	34,861	0	0.0
Crocodile Creek	86,438	86	2,468,337	247	197.9	3.9	2.0	140,134	3,036	2.2
Crystal Creek	103,951	104	2,775,366	278	256.8	15.8	6.2	194,327	10,804	5.6
Deep Creek	81,790	82	2,097,836	210	178.2	26.4	14.8	139,359	21,070	15.1
Hencamp Creek	36,783	37	918,415	92	72.0	17.2	23.9	57,603	13,812	24.0
Horseshoe Bay	7,893	8	197,619	20	18.3	1.5	8.1	14,602	1,166	8.0
Leichhardt Creek	51,878	52	1,387,095	139	123.9	9.7	7.9	93,345	7,562	8.1
Lorna Creek	9,669	10	242,073	24	17.1	7.0	40.8	13,758	5,503	40.0
Mt Stuart	33,463	33	914,126	91	60.4	11.6	19.2	47,751	7,366	15.4
Mundy Creek	7,303	7	182,816	18	1.3	16.9	1,283.7	1,000	13,573	1,357.8
Nelly Bay	2,981	3	74,976	7	4.7	2.3	49.2	3,722	1,832	49.2
Offshore	4,018	4	122,736	12	2.8	0.2	7.8	2,163	192	8.9
Ollera Creek	60,221	60	1,639,719	164	146.7	12.2	8.3	108,455	8,859	8.2
Pallarenda	3,229	3	81,003	8	7.8	0.2	3.0	6,204	171	2.8
Picnic Bay	1,774	2	44,825	4	2.4	1.8	74.3	1,873	1,399	74.7
Rollingstone Creek	72,166	72	1,879,584	188	169.5	13.7	8.1	131,701	9,916	7.5

Ross Creek	16,690	17	415,549	42	0.0	40.2	100.0	0	32,315	100.0
Ross River (atd)	293,341	293	7,791,062	779	695.1	36.3	5.2	532,945	25,719	4.8
Ross River (btdam)	93,505	94	2,596,384	260	162.5	70.5	43.4	114,769	55,505	48.4
Sachs Creek	38,915	39	1,041,590	104	58.0	26.6	45.9	46,599	19,765	42.4
Saltwater Creek	50,793	51	1,298,396	130	123.0	3.6	2.9	96,731	2,698	2.8
Sandfly Creek	40,496	40	1,088,911	109	76.8	30.4	39.6	56,052	23,953	42.7
Scrubby Creek	18,149	18	453,418	45	32.4	11.9	36.7	25,742	9,594	37.3
Shelly Beach	5,519	6	138,289	14	13.8	0.0	0.0	11,038	0	0.0
Six Mile Creek	61,581	62	1,686,456	169	100.5	17.2	17.1	80,558	12,704	15.8
Sleeper Log Creek	69,262	69	1,815,230	182	160.9	14.0	8.7	123,327	10,973	8.9
Station Creek	11,236	11	280,722	28	27.4	0.6	2.2	21,879	489	2.2
Stuart Creek	50,577	51	1,382,288	138	118.9	19.0	16.0	89,061	11,845	13.3
Surveyors Creek	25,192	25	630,023	63	43.8	17.5	39.9	35,166	13,876	39.5
Toonpan Lagoon	156,127	156	3,982,684	398	321.7	71.9	22.4	253,954	55,396	21.8
Two Mile Creek	12,341	12	307,920	31	28.3	2.3	8.1	22,680	1,766	7.8
Unamed	1,551	2	39,193	4	3.7	0.1	1.8	2,899	50	1.7
West Coast	13,119	13	329,231	33	31.3	1.5	4.7	24,898	1,154	4.6
Wild Boar Creek	5,273	5	131,742	13	12.4	0.3	2.6	9,861	250	2.5
Totals		2,466		6,515	5,319	835	16	4,073,272	636,427	16

Notes: Length of non-remnant plus length of remnant plus length of water is equivalent to 2 times the length of waterways

Table B Remnant riparian vegetation by basin and sub basin grouping

Catchment	Waterway Length of Catchment		Total Riparian Area		Total Area (hectares)		NR/R	Total Length (metres)		NR/R
	River System (m)	km	m²	hectare	Remnant	Non remnant	%	Remnant	Non remnant	%
Crystal Creek Sub Basin										
Crystal Creek	103,951	104	2,775,366	278	256.8	15.8	6.2	194,327	10,804	5.6
Lorna Creek	9,669	10	242,073	24	17.1	7.0	40.8	13,758	5,503	40.0
Ollera Creek	60,221	60	1,639,719	164	146.7	12.2	8.3	108,455	8,859	8.2
Scrubby Creek	18,149	18	453,418	45	32.4	11.9	36.7	25,742	9,594	37.3
Hencamp Creek	36,783	37	918,415	92	72.0	17.2	23.9	57,603	13,812	24.0
Sub Basin Totals	**228,772**	**229**	**6,028,991**	**603**	**525**	**64**	**12.2**	**399,885**	**48,572**	**12.1**
Rollingstone Creek Sub Basin										
Rollingstone Creek	72,166	72	1,879,584	188	169.5	13.7	8.1	131,701	9,916	7.5
Unamed	1,551	2	39,193	4	3.7	0.1	1.8	2,899	50	1.7
Surveyors Creek	25,192	25	630,023	63	43.8	17.5	39.9	35,166	13,876	39.5
Wild Boar Creek	5,273	5	131,742	13	12.4	0.3	2.6	9,861	250	2.5
Station Creek	11,236	11	280,722	28	27.4	0.6	2.2	21,879	489	2.2
Saltwater Creek	50,793	51	1,298,396	130	123.0	3.6	2.9	96,731	2,698	2.8
Cassowary Creek	11,995	12	299,814	30	28.6	0.8	2.9	22,847	640	2.8
Leichhardt Creek	51,878	52	1,387,095	139	123.9	9.7	7.9	93,345	7,562	8.1
Sub Basin Totals	**230,084**	**230**	**5,946,569**	**595**	**532**	**46**	**8.7**	**414,429**	**35,481**	**8.6**
Bluewater Creek Sub Basin										
Sleeper Log Creek	69,262	69	1,815,230	182	160.9	14.0	8.7	123,327	10,973	8.9
Two Mile Creek	12,341	12	307,920	31	28.3	2.3	8.1	22,680	1,766	7.8
Bluewater Creek	95,588	96	2,578,300	258	241.5	11.7	4.9	181,291	7,167	4.0
Deep Creek	81,790	82	2,097,836	210	178.2	26.4	14.8	139,359	21,070	15.1
Sub Basin Totals	**258,981**	**259**	**6,799,286**	**681**	**609**	**54**	**8.9**	**466,657**	**40,976**	**8.8**
Black River Sub Basin										
Black River	162,429	162	4,367,123	437	387.7	41.8	10.8	287,969	32,262	11.2
Alice River	109,513	110	2,795,034	280	258.8	20.7	8.0	202,460	16,565	8.2
Sub Basin Totals	**271,942**	**272**	**7,162,157**	**717**	**647**	**63**	**9.7**	**490,429**	**48,827**	**10.0**

Catchment	Waterway Length of Catchment		Total Riparian Area		Total Area (hectares)		NR/R	Total Length (metres)		NR/R
	River System (m)	km	m²	hectare	Remnant	Non remnant	%	Remnant	Non remnant	%
Bohle River Sub Basin										
Bohle River	132,944	133	3,529,547	353	274.0	47.5	17.3	209,611	38,103	18.2
Bohle River 2	157,171	157	4,086,355	409	307.8	100.8	32.8	238,354	75,987	31.9
Shelly Beach	5,519	6	138,289	14	13.8	0.0	0.0	11,038	0	0.0
Sub Basin Totals	**295,634**	**296**	**7,754,191**	**776**	**596**	**148**	**24.9**	**459,003**	**114,090**	**24.9**
Lower Ross River Sub Basin										
Pallarenda	3,229	3	81,003	8	7.8	0.2	3.0	6,204	171	2.8
Mundy Creek	7,303	7	182,816	18	1.3	16.9	1,283.7	1,000	13,573	1,357.8
Ross Creek	16,690	17	415,549	42	0.0	40.2	100.0	0	32,315	100.0
Ross River (btd)	93,505	94	2,596,384	260	162.5	70.5	43.4	114,769	55,505	48.4
Sub Basin Totals	**120,727**	**121**	**3,275,752**	**328**	**172**	**128**	**74.5**	**121,973**	**101,564**	**83.3**
Upper Ross River Sub Basin										
Ross River (atd)	293,341	293	7,791,062	779	695.1	36.3	5.2	532,945	25,719	4.8
Six Mile Creek	61,581	62	1,686,456	169	100.5	17.2	17.1	80,558	12,704	15.8
Toonpan Lagoon	156,127	156	3,982,684	398	321.7	71.9	22.4	253,954	55,396	21.8
Antill Plains Creek	86,918	87	2,265,393	227	168.0	40.7	24.2	133,170	29,664	22.3
Sachs Creek	38,915	39	1,041,590	104	58.0	26.6	45.9	46,599	19,765	42.4
Mt Stuart	33,463	33	914,126	91	60.4	11.6	19.2	47,751	7,366	15.4
Sub Basin Totals	**670,345**	**670**	**17,681,311**	**1,768**	**1,404**	**204**	**14.6**	**1,094,977**	**150,614**	**13.8**
Stuart Creek Sub Basin										
Stuart Creek	50,577	51	1,382,288	138	118.9	19.0	16.0	89,061	11,845	13.3
Sandfly Creek	40,496	40	1,088,911	109	76.8	30.4	39.6	56,052	23,953	42.7
Sub Basin Totals	**91,073**	**91**	**2,471,199**	**247**	**196**	**49**	**25.2**	**145,113**	**35,798**	**24.7**
Alligator Creek Sub Basin										
Alligator Creek	148,837	149	3,966,130	397	297.7	65.8	22.1	226,783	51,116	22.5
Crocodile Creek	86,438	86	2,468,337	247	197.9	3.9	2.0	140,134	3,036	2.2
Cocoa Creek	19,464	19	500,711	50	44.1	0.0	0.0	34,861	0	0.0
Cape Cleveland	16,374	16	411,592	41	40.3	0.0	0.0	31,881	0	0.0
Sub Basin Totals	**271,113**	**271**	**7,346,770**	**735**	**580**	**70**	**12.0**	**433,659**	**54,152**	**12.5**

Catchment	Waterway Length of Catchment		Total Riparian Area		Total Area (hectares)		NR/R	Total Length (metres)		NR/R
	River System (m)	km	m²	hectare	Remnant	Non remnant	%	Remnant	Non remnant	%
Magnetic Island Sub Basin										
West Coast	13,119	13	329,231	33	31.3	1.5	4.7	24,898	1,154	4.6
Picnic Bay	1,774	2	44,825	4	2.4	1.8	74.3	1,873	1,399	74.7
Nelly Bay	2,981	3	74,976	7	4.7	2.3	49.2	3,722	1,832	49.2
Arcadia	1,583	2	40,051	4	2.6	1.0	39.0	2,048	804	39.3
Horseshoe Bay	7,893	8	197,619	20	18.3	1.5	8.1	14,602	1,166	8.0
Sub Basin Totals	**27,350**	**27**	**686,702**	**68**	**59**	**8**	**13.7**	**47,143**	**6,355**	**13.5**
WQIP Area Totals		2,466		6,515	5,319	835	16	4,073,272	636,427	16

Table C Remnant and non remnant riparian vegetation percentages by basin and sub basin grouping

Catchment	Riparian Vegetation by Area (hectares)					Riparian Vegetation by Bank Length (metres)				
	Total	Remnant	%	Non remnant	%	Total	Remnant	%	Non remnant	%
Crystal Creek Sub Basin										
Crystal Creek	272.6	256.8	94.2	15.8	5.8	205,131	194,327	94.7	10,804	5.3
Lorna Creek	24.1	17.1	71.0	7	29.0	19,261	13,758	71.4	5,503	28.6
Ollera Creek	158.9	146.7	92.3	12.2	7.7	117,314	108,455	92.4	8,859	7.6
Scrubby Creek	44.3	32.4	73.1	11.9	26.9	35,336	25,742	72.8	9,594	27.2
Hencamp Creek	89.2	72	80.7	17.2	19.3	71,415	57,603	80.7	13,812	19.3
Sub Basin Totals	**589.1**	**525**	**89.1**	**64**	**10.9**	**448,457**	**399,885**	**89.2**	**48,572**	**10.8**
Rollingstone Creek Sub Basin										
Rollingstone Creek	183.2	169.5	92.5	13.7	7.5	141,617	131,701	93.0	9,916	7.0
Unamed	3.8	3.7	97.4	0.1	2.6	2,949	2,899	98.3	50	1.7
Surveyors Creek	61.3	43.8	71.5	17.5	28.5	49,042	35,166	71.7	13,876	28.3
Wild Boar Creek	12.7	12.4	97.6	0.3	2.4	10,111	9,861	97.5	250	2.5
Station Creek	28	27.4	97.9	0.6	2.1	22,368	21,879	97.8	489	2.2
Saltwater Creek	126.6	123	97.2	3.6	2.8	99,429	96,731	97.3	2,698	2.7
Cassowary Creek	29.4	28.6	97.3	0.8	2.7	23,487	22,847	97.3	640	2.7
Leichhardt Creek	133.6	123.9	92.7	9.7	7.3	100,907	93,345	92.5	7,562	7.5
Sub Basin Totals	**578.6**	**532**	**92.0**	**46**	**8.0**	**449,910**	**414,429**	**92.1**	**35,481**	**7.9**
Bluewater Creek Sub Basin										
Sleeper Log Creek	174.9	160.9	92.0	14	8.0	134,300	123,327	91.8	10,973	8.2
Two Mile Creek	30.6	28.3	92.5	2.3	7.5	24,446	22,680	92.8	1,766	7.2
Bluewater Creek	253.2	241.5	95.4	11.7	4.6	188,458	181,291	96.2	7,167	3.8
Deep Creek	204.6	178.2	87.1	26.4	12.9	160,429	139,359	86.9	21,070	13.1
Sub Basin Totals	**663.3**	**609**	**91.8**	**54**	**8.2**	**507,633**	**466,657**	**91.9**	**40,976**	**8.1**
Black River Sub Basin										
Black River	429.5	387.7	90.3	41.8	9.7	320,231	287,969	89.9	32,262	10.1
Alice River	279.5	258.8	92.6	20.7	7.4	219,025	202,460	92.4	16,565	7.6
Sub Basin Totals	**709**	**647**	**91.2**	**63**	**8.8**	**539,256**	**490,429**	**90.9**	**48,827**	**9.1**
Black Basin Totals	**2,540**	**2312.7**	**91.1**	**227.3**	**8.9**	**1,945,256**	**1,771,400**	**91.1**	**173,856**	**8.9**

Catchment	Riparian Vegetation by Area (hectares)					Riparian Vegetation by Bank Length (metres)				
	Total	Remnant	%	Non remnant	%	Total	Remnant	%	Non remnant	%
Bohle River Sub Basin										
Bohle River	321.5	274	85.2	47.5	14.8	247,714	209,611	84.6	38,103	15.4
Bohle River 2	408.6	307.8	75.3	100.8	24.7	314,341	238,354	75.8	75,987	24.2
Shelly Beach	13.8	13.8	100.0	0	0.0	11,038	11,038	100.0	0	0.0
Sub Basin Totals	**743.9**	**596**	**80.1**	**148**	**19.9**	**573,093**	**459,003**	**80.1**	**114,090**	**19.9**
Lower Ross River Sub Basin										
Pallarenda	8	7.8	97.5	0.2	2.5	6,375	6,204	97.3	171	2.7
Mundy Creek	18.2	1.3	7.1	16.9	92.9	14,573	1,000	6.9	13,573	93.1
Ross Creek	40.2	0	0.0	40.2	100.0	32,315	0	0.0	32,315	100.0
Ross River (btd)	233	162.5	69.7	70.5	30.3	170,274	114,769	67.4	55,505	32.6
Sub Basin Totals	**299.4**	**172**	**57.3**	**128**	**42.7**	**223,537**	**121,973**	**54.6**	**101,564**	**45.4**
Upper Ross River Sub Basin										
Ross River (atd)	731.4	695.1	95.0	36.3	5.0	558,664	532,945	95.4	25,719	4.6
Six Mile Creek	117.7	100.5	85.4	17.2	14.6	93,262	80,558	86.4	12,704	13.6
Toonpan Lagoon	393.6	321.7	81.7	71.9	18.3	309,350	253,954	82.1	55,396	17.9
Antill Plains Creek	208.7	168	80.5	40.7	19.5	162,834	133,170	81.8	29,664	18.2
Sachs Creek	84.6	58	68.6	26.6	31.4	66,364	46,599	70.2	19,765	29.8
Mt Stuart	72	60.4	83.9	11.6	16.1	55,117	47,751	86.6	7,366	13.4
Sub Basin Totals	**1,608**	**1,404**	**87.3**	**204**	**12.7**	**1,245,591**	**1,094,977**	**87.9**	**150,614**	**12.1**
Stuart Creek Sub Basin										
Stuart Creek	137.9	118.9	86.2	19	13.8	100,906	89,061	88.3	11,845	11.7
Sandfly Creek	107.2	76.8	71.6	30.4	28.4	80,005	56,052	70.1	23,953	29.9
Sub Basin Totals	**245.1**	**196**	**79.8**	**49**	**20.2**	**180,911**	**145,113**	**80.2**	**35,798**	**19.8**
Alligator Creek Sub Basin										
Alligator Creek	363.5	297.7	81.9	65.8	18.1	277,899	226,783	81.6	51,116	18.4
Crocodile Creek	201.8	197.9	98.1	3.9	1.9	143,170	140,134	97.9	3,036	2.1
Cocoa Creek	44.1	44.1	100.0	0	0.0	34,861	34,861	100.0	0	0.0
Cape Cleveland	40.3	40.3	100.0	0	0.0	31,881	31,881	100.0	0	0.0
Sub Basin Totals	**649.7**	**580**	**89.3**	**70**	**10.7**	**487,811**	**433,659**	**88.9**	**54,152**	**11.1**
Ross Basin Totals	**3,546.1**	**2,946.6**	**83.1**	**599.5**	**16.9**	**2,710,943**	**2,254,725**	**83.2**	**456,218**	**16.8**

Catchment	Riparian Vegetation by Area (hectares)					Riparian Vegetation by Bank Length (metres)				
	Total	Remnant	%	Non remnant	%	Total	Remnant	%	Non remnant	%
Magnetic Island Sub Basin										
West Coast	32.8	31.3	95.4	1.5	4.6	26,052	24,898	95.6	1,154	4.4
Picnic Bay	4.2	2.4	57.1	1.8	42.9	3,272	1,873	57.2	1,399	42.8
Nelly Bay	7	4.7	67.1	2.3	32.9	5,554	3,722	67.0	1,832	33.0
Arcadia	3.6	2.6	72.2	1	27.8	2,852	2,048	71.8	804	28.2
Horseshoe Bay	19.8	18.3	92.4	1.5	7.6	15,768	14,602	92.6	1,166	7.4
Sub Basin Totals	**67.4**	**59**	**88.0**	**8**	**12.0**	**53,498**	**47,143**	**88.1**	**6,355**	**11.9**
WQIP Area Totals	**6,153**	**5,319**	**86.4**	**835**	**13.6**	**4,709,697**	**4,073,268**	**86.5**	**636,429**	**13.5**

Appendix H

Riparian Condition Assessment

C and R Consulting Stage 1 and Stage 2 Riparian Condition Assessment Report extracts

The source of this information is *Assessment of Selected Riparian Systems of the Ross and Black River Basins Townsville / Thuringowa Region* (C and R Consulting 2007) and *Assessment of Selected Riparian Systems of the Ross and Black River Basins and Selected Other Drainage within the Townsville / Thuringowa Region Stage 2* (C and R Consulting 2008).

The Black and Ross Basin were divided into sub basins and catchments and where appropriate, each catchment is subdivided into sections, predominantly according to topography (e.g. upper reaches), and/or geographic peculiarity (e.g. Lake Ross surrounds).

The following colour legends are used in all maps:

GREEN	Estuarine/mangrove systems.
YELLOW	Sand dune wetlands and associated riparian zones.
ORANGE	Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.
PINK	Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.
BLACK	Areas of non-remnant vegetation.
BLUE	The creek system under analysis.

Methodology

Creeks and rivers within the study area have been evaluated using the minimal buffer width required by the current Vegetation Management Act (2004). However, the requirements of the Vegetation Management Act are, by necessity, generalised and predominantly based on climates considerably different to the tropical, seasonally arid, climate of the Townsville / Thuringowa region.

In recognition of these differences, the riparian zone has been extended to encompass a buffer zone recommended by Geosciences Australia (see Table A). This includes vegetation communities that would not traditionally be considered riparian communities, but which exist in all major drainage areas of the study area and whose value is equally important for bank stability and buffering capacity.

Where the high bank cannot be clearly identified, the centre line of the major drainage channel has been used in accordance with the recommendations in the Geosciences Australia topographic data suite. A larger buffer width has been used in these cases to overcome the inability to assess the high bank.

Table A GIS Buffer Widths Used

	Recommended riparian vegetation widths	
Stream Order	**Vegetation Management Act**	**Geoscience Australia**
1st and 2nd	50m from each high bank	75m from each high bank
3rd and 4th	100m from each high bank	150m from each high bank

Additionally, the full extent of riparian vegetation has also been displayed. Riparian areas outside the 150m buffer zones are also displayed to demonstrate the full extent of relevant riparian regional ecosystems.

Riparian vegetation condition ratings are summarised in Table B.

Table B Riparian Condition Ratings by Sub Basin and Waterway

Focus Area	Rating	Summary Comments on Condition
Crystal Creek Sub Basin		
Crystal Creek Upper Reaches	Moderate-Good	1st and 2nd order streams are generally in good condition. Threats to bank stability occur on alluvial sections mainly due to a combination of: • Disturbance from agricultural practices, and • Removal of remnant vegetation in buffer zones.
Crystal Creek Lower Reach	Moderate	Moderately modified remnant condition. With significant clearing next to 3rd and 4th order streams. Major threats from: • Disturbance from agricultural practices, • Removal of remnant vegetation in buffer zones, and • The presence of sodic and erodible soils.
Lorna Creek	Moderate-Good	Clearing for agriculture in upper reaches.
Creek 1	Good	Minimal clearing only around highway.
Creek 2	Moderate	Fully cleared in middle reaches on erodible sodic soils. Upper and lower reaches have good condition with fully intact riparian zones.
Ollera Creek Upper Reaches	Good	Little to no clearing has taken place within the upper granitic slopes of Ollera Creek.
Ollera Creek Mid Reaches	Moderate	Variable condition with different channels having different riparian condition. Some channels are totally cleared on erodible sodic soils.
Ollera Creek Lower Reaches	Good	Lower reaches are in good condition with minimal disturbance around transport corridors.
Scrubby Creek	Poor	Little to no native vegetation exists within the designated buffer width along the majority of the creek.
Creek 3	Moderate-Poor	Two major channels have a very varied condition ranging from full coverage within the designated buffer zone to no riparian coverage at the high bank.
Hencamp Creek Upper Reaches	Moderate-Good	Little to no clearing has taken place within the upper granitic slopes of Hencamp Creek.
Hencamp Creek Lower Reaches	Moderate-Poor	Variable condition with different channels having different riparian condition. Some channels are totally cleared on erodible sodic soils.
Rollingstone Creek Sub Basin		
Rollingstone Creek Upper Reaches	Good	The upper granitic slopes are in pristine condition with little to no incursion into the designated buffer zone. The alluvial flats are in relatively good condition however there is some incursion into the designated buffer zone.
Rollingstone Creek Lower Reaches	Moderate	Clearing has occurred to the high bank. Adjacent land uses within this area are currently agricultural lands and degraded agricultural/pastoral lands.
Unnamed Creek (Creek 4)	Poor	Over half of the Creek has been cleared to the high bank with adjacent land uses being current agricultural or previous agricultural/pastoral lands.

Focus Area	Rating	Summary Comments on Condition
Surveyors Creek	**Moderate-Poor**	Variable condition with different channels having different riparian condition. Some channels are totally cleared on erodible sodic soils.
Creek 5	**Good**	Good condition with minimal incursion into the designated buffer zone.
Wild Boar Creek	**Good**	Good condition with minimal incursion into the designated buffer zone.
Station Creek	**Good**	Good condition with minimal incursion into the designated buffer zone.
Creek 6	**Good**	Good condition with minimal incursion into the designated buffer zone.
Saltwater Creek Upper Reaches	**Good**	Good condition with minimal incursion into the designated buffer zone.
Saltwater Creek Lower Reaches	**Good-Moderate**	Breaches of the designated buffer zone include road and rail corridors and some minor clearing for unknown purposes and for aquaculture.
Cassowary/Camp Oven Creek	**Good**	Good condition with minimal incursion into the designated buffer zone.
Lillypond Creek	**Moderate**	A large section of non-remnant vegetation exists between the rail and road corridor. This area is degraded agricultural/pastoral land, which is starting to regrow. Contains a mixture of native and invasive species.
Leichhardt Creek Upper Reaches	**Good**	Minimal clearing has occurred with only one breach into the designated buffer zone for property access on the alluvial plains.
Leichhardt Creek Mid Reaches	**Moderate**	Disturbances in the upper part of this reach seem to be in relation to an old quarrying operation.
Leichhardt Creek Lower Reaches	**Moderate**	Disturbances between the Bruce Highway and the railway corridor are extensive with the northern bank completely cleared between these two points.
Bluewater Creek Sub Basin		
Sleeper Log /Christmas Creeks Upper Reaches	**Moderate**	Clearing in the southern section on the alluvial plains can be attributed to agricultural purposes and possibly an old WW2 airstrip.
Sleeper Log /Christmas Creeks Lower Reaches	**Moderate-Good**	Breaches of the designated buffer zone include road and rail corridors and some minor clearing for unknown purposes, and for aquaculture.
Two Mile Creek	**Good**	The only breach of the designated buffer zone is for road and rail corridors and some minor clearing for aquaculture purposes in the estuarine/sand dune zone.
Creek 7	**Good**	Creek 7 has pristine riparian vegetation with only one breach within the designated buffer being the railway corridor.
Creek 8	**Good**	The only breach of the designated buffer zone is for road and rail corridors.
Bluewater Creek Upper Reaches	**Good**	There is minimal disturbance at the base of the scarp with some minor encroachments into the riparian vegetation

Focus Area	Rating	Summary Comments on Condition
Bluewater Creek Middle Reaches	Poor	This reach is highly modified with major breaches into the designated buffer zone. This poor condition is mainly due to residential properties on the northern side and pastoral uses on the southern bank.
Deep/ Althaus/ Healy Creeks Upper Reaches	Moderate	Several 1st and 2nd order streams have little to no riparian vegetation within the designated buffer zone. The majority of clearing within this reach has been for cattle grazing.
Deep/ Althaus/ Healy Creeks Lower Reaches	Poor-Moderate	Significant areas adjacent to 3rd and 4th order streams are cleared within the designated buffer zone, however little of this clearing is directly adjacent to the channel.
Black River Sub Basin		
Black River Upper Reaches (to confluence with Alice River)	Moderate-Good	The majority of the area is in good condition with minimal incursion into the recommended buffer zone.
Black River Mid Reaches (to Black River Bridge)	Poor	Adjacent areas have been highly modified with significant reaches in both 1st /2nd order streams and 3rd/4th order rivers having little to no remnant riparian vegetation. Significant stretches directly adjacent to the rivers are currently used for cattle grazing, small crops farming and rural residential.
Black River Lower Reaches	Poor-Moderate	Significant areas adjacent to 1st/2nd and 3rd/4th streams cleared to the high bank.
Bohle River Sub Basin		
Bohle River Upper Reaches	Poor- Moderate	Large areas adjacent to 1st and 2nd order streams with little to no buffering capacity.
Bohle River Mid Reaches	Poor- Moderate	Highly modified with significant reaches having little to no remnant riparian vegetation, including areas adjacent to grazing lands. No recognisable riparian vegetation units buffering the Bohle Industrial Area. Significant para grass infestations do occur within these areas, offering some bank stability and erosion protection.
Bohle River Lower Reaches	Poor-Good	Highly variable area including the Bohle and Louisa Creek Industrial Areas which have zones of little to no remnant or natural riparian vegetation remaining. Other areas in the lower reaches of the Bohle and Town Common area have well-established riparian features of national significance.
Lower Ross River Sub Basin		
Ross River (Dam wall to Black Weir)	Moderate - Very Poor	Negative Causes: • Residential development. • Continued riparian vegetation clearance. • Annual burn-off. Positive Causes: • “Special Usage” Zone within Army Reserve. • Well-managed park lands between Apex Park and Loam Island.

Focus Area	Rating	Summary Comments on Condition
Ross River (Black Weir to Aplins Weir)	Poor	Heavily modified for residential development.
Ross River Lower Reaches (Below Aplins)	Poor - Good	Riparian condition ranges from poor to excellent. Area between Townsville Golf Course and Rooneys Bridge is in particularly poor condition.
Ross Creek	Poor	Modified native vegetation remaining above and adjacent to, Woolcock Street crossing. Minor native riparian vegetation remaining below the crossing with a sharp decrease, to total removal of native vegetation, with proximity to CBD and the Port.
Upper Ross River Sub Basin		
Ross River Upper reaches east of Lake Ross	Poor-Moderate	Large areas adjacent to major drainage lines have no remnant riparian vegetation. Catchment soils are highly dispersive and erodible.
Lake Ross	Poor-Moderate	Highly modified system with no remnant vegetation present within the whole of the system. However, within this zone there is a modified zone with significant buffering capacity and habitat value.
Ross River Upper reaches west of Lake Ross	Moderate-Good	Relatively good condition. Majority of the inflowing rivers have adequate vegetation buffer zones. Major impact within this zone is quarrying activities.
Mt Stuart Upper Reaches	Moderate-Good	Small first order creeks within the Mt Stuart Training Area have poor vegetation cover, erodible and dispersive soils, and may also traverse through old munitions dumps.
Stuart Creek Sub Basin		
Stuart Creek Upper Reaches	Good	Little clearing within the designated buffer zone maintaining natural riparian values from the high bank.
Stuart Creek Mid Reaches	Poor	Significant clearing has occurred within the designated buffer zone, with major impacts coming from quarrying and industrial activities within these areas.
Stuart Creek Lower Reaches	Moderate-Good	Lower reaches have extensive estuarine riparian zones.
Alligator Creek Sub Basin		
Alligator Creek Upper Reaches	Moderate	All the areas within the Bowling Green Bay National Park are in pristine condition with only minimal incursion into the designated buffer zone. Riparian condition is compromised in the western anabranches with unconfirmed land use and cattle grazing taking place within this part of the catchment.
Alligator Creek Mid Reaches	Poor	Disturbance from grazing and rural residential purposes has resulted in little to no natural riparian vegetation along large areas in both 1st/2nd order streams, and 3rd/4th order streams.
Alligator Creek Lower Reaches	Good	The majority of the reach is bordered with mangroves grading to sparsely vegetated estuarine salt flats. This is the natural condition of the area.

Appendix I

Rural Management Practice Costs

Rural management practice costs

The following information is taken from the report *The economic and social impacts of protecting environmental values in Great Barrier Reef catchment waterways and the reef lagoon* (Marsden Jacob Associates 2010) prepared for the Department of Environment and Resource Management.

Tully Murray WQIP

The cost of riparian rehabilitation varies significantly based on the location, vegetation, condition, slope and the opportunity cost. Previous research[1] has found **riparian rehabilitation costs** can range from **$5,000 to $50,000 per kilometre** in rural areas, with rehabilitation in tropical climates being closer to the top end of this spectrum due to vegetation types.

Source: [1]WBM Oceanics, 2005, *Diffuse Source Best Management Practices: Review of Efficacy and Costs.*

(MJA 2010, Tully Murray WQIP section 9.5.2. Riparian rehabilitation, p.134)

Mackay Whitsunday WQIP

For sugar cane production cost estimates of up-front capital investments were:

- $35,000 to move from level C to level B; and
- $62,000 to move from level B to level A.

Limited access to capital could significantly constrain landowners' ability to accelerate adoption of best practice where there are up front' capital costs or time lags between implementation and productivity benefits. Some form of transitional funding or risk sharing would, therefore, be appropriate. One option worth considering is to provide financial incentives for capital equipment in the form of structural adjustment loans, with repayments more closely aligned to enhancements in cashflow.

(MJA 2010, Mackay Whitsunday WQIP section 6.5.2. Rural diffuse loads — specific sugar industry issues, p.82)

The key costs to the grazing sector were assessed, based on a 200 hectare property. These costs include:

- A grazing land management plan, at around $4,500;
- Pasture and stock monitoring at three sites, at around $9,000;
- A nutrient management plan, including five soil tests, at around $2,500;
- Five kilometres of fencing, at around $18,000; and
- Two watering points, at around $20,000.

While the cost of developing a grazing land management plan and nutrient management plan probably do not vary greatly between landholders, the other costs will vary significantly. In addition, the actual net private benefits and costs of undertaking the other actions will vary significantly between enterprises.

(MJA 2010, Mackay Whitsunday WQIP section 6.5.4. Rural diffuse — specific grazing industry issues, p.83)

Fitzroy Basin Association [Fitzroy WQIP]

Assuming that FBA are able to target and achieve changes in average cover from 55% to 70%, MJA estimate that the potential cost of achieving FBA's target **reduction in sediment loads** of 750,000 tonnes **per annum** is on the order of $36–51m, or around **$48-68 per tonne**. This estimate incorporates:

- the opportunity cost (essentially the gross margin foregone) over a 20-year period as a proxy of costs to landholders
- program administration costs.

The analysis demonstrates a significant cost in achieving the sediment reduction targets. However, analysis by Donaghy et al. indicates that the long term costs and benefits of managing for target groundcover levels vary significantly depending on the starting pasture condition. That research indicated that there was likely to be a potential optimal pasture utilisation rate in the long run. Utilisation rates above that level were actually detrimental to farm financial performance and ultimately the value of the farm asset.
Donaghy found that:

By lowering the pasture utilization rate from 60% to 50% utilization, the land holder…will achieve a significant reduction in sediment of… 40% over 20 years. This implies an opportunity cost of only $3 per tonne…

Donaghy, P., Rolfe, J. & Gaffney, J., 2007, *Unravelling the economic and environmental tradeoffs of reducing sediment movement from grazed pastures*. Paper presented to the 51st AARES Conference. Queenstown. p.12.
(MJA 2010, Fitzroy Basin section 5.5.1. Rural diffuse impacts, pp.58-9)

Appendix B (extract from MJA 2010, pp.164-176)

Indicative cost schedule – water quality improvement associated activities (site acquisition, rehabilitation, ongoing management and administration)

Cost item/unit	Lower $	Medium $	Upper $
Secure covenant (per land parcel)		120	
Purchasing beef land (opportunity cost per ha)	0	27	110
[1]Purchase partial land rights FNQ (cost per ha)	544	12,406	71,825
Legal costs (per land parcel)	555	2,223	3,889
[2]Search/negotiation/site plan establishment (small—medium size project) (per land parcel)	3,065	9,196	15,327
[3]Search/negotiation/site plan establishment (large size project) (per land parcel)	166,659	361,095	555,531
Detailed site assessments (vegetation focus) and site management plan establishment (per 20 -100 ha land parcel)	2,000	2,500	3,000
Cursory site assessments (vegetation focus) and site management plan establishment (per land parcel)	153	307	1, 226
4WWTP upgrades - reducing nitrogen to 2 mg/L ($/tonne/year)	200,000	500,000	800,000
4WWTP upgrades - reducing phosphorus to 2 mg/L ($/tonne/year)	35,000	55,000	75,000
4WWTP upgrades - reducing phosphorus to 5 mg/L ($/tonne/year)	150,000	230,000	380,000
5Water quality abatement (cost per kg of nitrogen)	600	800	1,200
6 Revegetation (total cost per hectare)	905	2,809	8,474
6 Weed eradication (per hectare)	15	1,528	4,000
7 Chemical control of weeds by beef industry (cost per hectare)	1	1	1
7 Chemical control of weeds by sugar industry (cost per hectare)	104	108	112
7 Chemical control of weeds by fruit industry (cost per hectare)	93	190	287
7 Chemical control of weeds by vegetable industry (cost per hectare)	92	179	265
6 Pest eradication/management (cost per hectare)	10	148	500
8 Establishing replacement wetlands—small (cost per hectare)	800,000	900,000	1,000,000
9 Establishing replacement wetlands—medium to large (cost per ha)	275,130	349,913	412,696
6 Fencing to exclude stock and pests (per kilometre of fence)	1,350	2,810	6,175
10 Establishing watering points (per watering point)	3,758	4,175	4,593
11 Gully treatment to reduce erosion (per kilometre of treatment)	5,000	27,500	50,000
Weed management (per hectare) following ‘eradication’	30	135	240
12 Fire management (per kilometre)	200	250	300
Destocking beef (annual opportunity cost per hectare)	0	2	6
13 Carbon sequestration (cost per tonne)	12.30	12.40	12.55
Contract compliance management (per offset transaction)	6,144	7,680	9,216
14 Program management (% of program ongoing funding)	6%	10%	14%

Notes: [1] Source: Comerford, E. PhD thesis 2006. Based on the average funded bids for the Vegetation Incentives Program. These are the lowest, highest and mean bids submitted to the VIP—the successful bids were substantially lower at an average of $151/ha.

[2] Source: EPA, based on experience with nature refuge program. Estimates based on top of a PO4 salary and a multiplier of 2 (to ensure consistency with in-kind valuations for NHT and other external programs). These numbers are supported by the Catchment Care auction which paid $85/hr to contractors to negotiate and implement their site visits, plans etc. Their grant process took 14hrs/funded property and the grant process 26hrs/funded property, including negotiation, plan, site inspection and mapping (Source: Bryan et al, 2005, Catchment Care—–developing an auction process for biodiversity and water quality gains).

[3] Source: EPA, based on experience with mine offset project. Estimates based on top of a PO4 salary and a multiplier of 2 (to ensure consistency with in-kind valuations for NHT and other external programs).

4 BDA group.

5 Source: Melbourne Water http://wsud.melbournewater.com.au/content/stormwater_quality_offsets/stormwater_quality_offsets.asp.

6 Source: Schirmer, J. and Field, J., 2000, The cost of revegetation.

7 Source: Sinden, J. et al, 2005, The economic impact of weeds in Australia.

8 Source: CRC Catchment hydrology. Inputs for MUSIC model.

9 Source: Lloyd, S.D, Wong, T, Chesterfield, C, 2002, WSUD: A stormwater management perspective. Plus establishment cost of $738,607.

10 Source: Sillard and Associates, 1999, Cost–benefit study of Riparian Restoration in the Mary River.

11 Source: WBM Oceanics, 2005, Diffuse Source Best Management Practices: Review of Efficacy and Costs.

12 Source: QP&WS estimates. Includes construction and maintenance of fire beaks using a bulldozer.

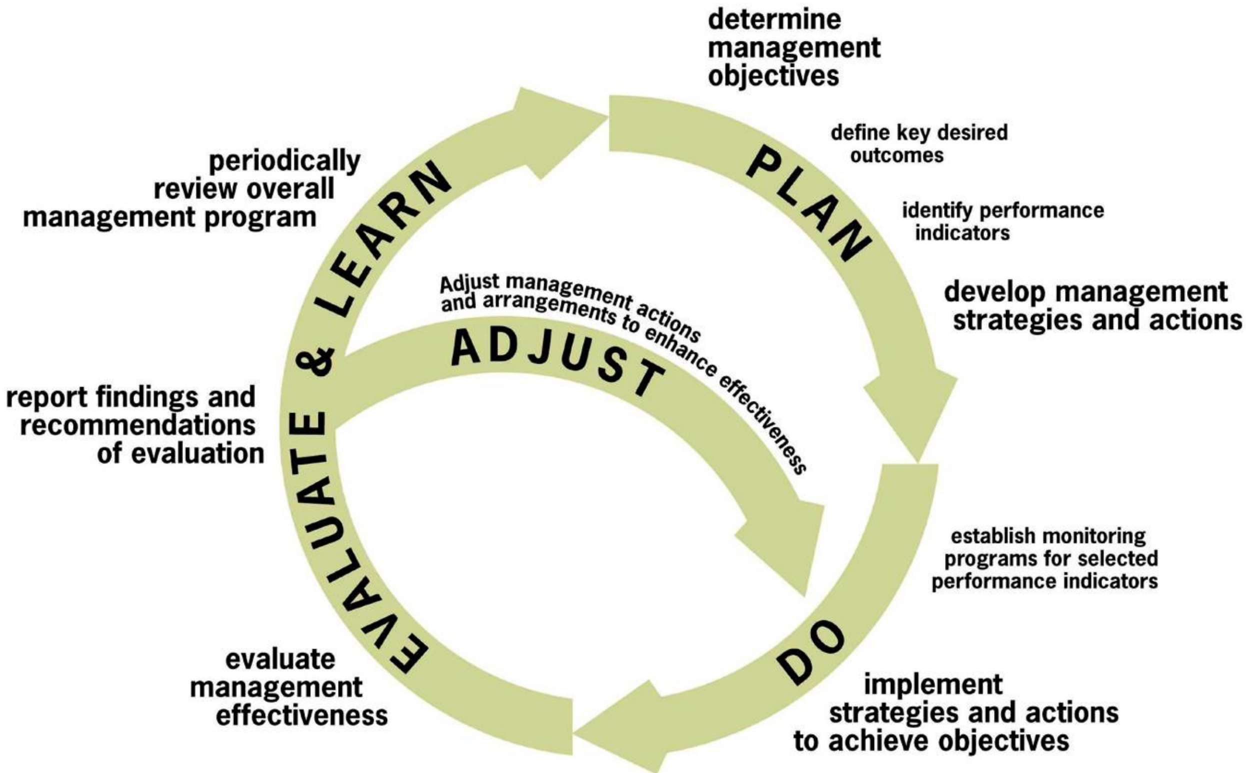
13 Source: Katoomba Ecosystem Marketplace, http://ecosystemmarketplace.com/pages/marketwatch.overview.aggregate.php?market_id=14. http://www.ecosystemmarketplace.com/pages/dynamic/marketwatch.landing_page.php

14 Source: Patrick, I. and Wise, R., 2005, *Technical, Economic and Institutional Assessment Of Environmental Offsets to Reduce Saline Water Discharge*, University of New England.

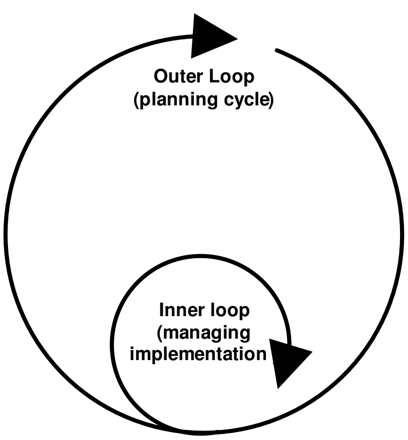
Appendix J

Adaptive Management

Double loop model of adaptive management



The detailed concept of a double loop model of adaptive management (Source: CSIRO) in Eberhard et al (2008, p.5)



"The inner loop of the cycle represents feedback and adaptive implementation of the current management plan (i.e. the WQIP). The outer loop represents the review and revision of the WQIP itself. Adaptive management involves both the refinement of the current plan through testing and revision of approaches, and anticipating the revision of the plan and the strategies and actions that may be considered at that time" (Eberhard et al 2008, pp.5-6).

Benefits of adaptive management strategies

The purpose of an adaptive management strategy is to:

- Identify explicit, timely and cost-effective opportunities for improvement in plan implementation; and
- Minimise the risk of failure to achieve the plan objectives, and therefore provide assurance to stakeholders and investors.

Management effectiveness will be improved through maximising the opportunities to test and refine actions. For example, an adaptive management strategy might include:

- Monitoring performance measures at a range of scales to provide early feedback on the likelihood of successful outcomes;
- Experimental research on the water quality benefits of specific agricultural management practices;
- Evaluation of the effectiveness of various mechanisms to facilitate uptake of improved agricultural practices;
- Processes to establish and support effective partnership arrangements to provide clear communication pathways for constructive feedback.

Investors and institutional partners will benefit from an explicit adaptive management strategy that demonstrates that the risk associated with uncertainty is acknowledged and proactively managed through measures to address critical areas of uncertainty.

For community stakeholders, an adaptive management strategy can provide confidence that strategies will be evaluated and modified in a predictable, transparent and objective manner. For example, an adaptive management strategy would:

- Utilise risk assessment criteria to prioritise actions;
- Provide clear expectations of outcomes over time through performance measures; and
- Articulate roles and responsibilities for responding to feedback.

(Eberhard et al 2008, pp.7-8)

Protocol checklist

The following checklist summarises the essential elements of an adaptive management strategy for GBR WQIPs.

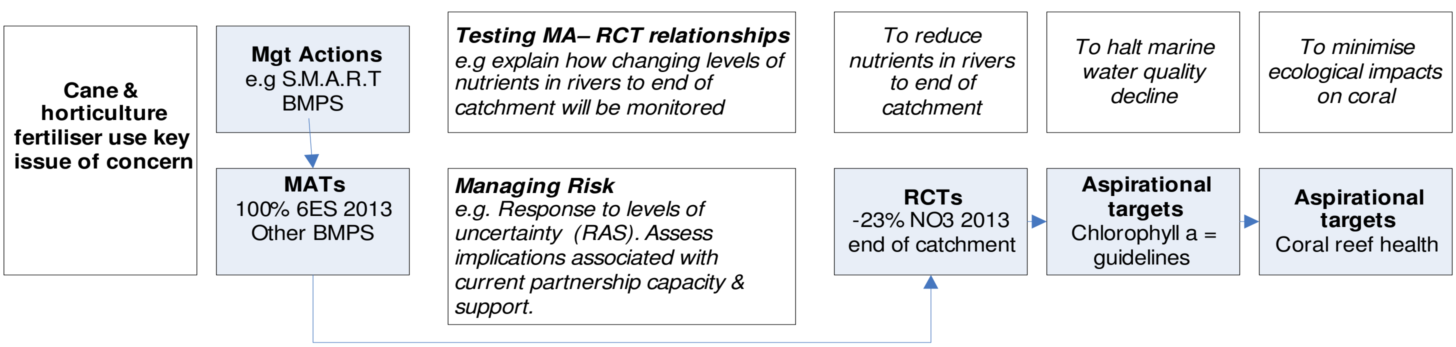
1. A ***conceptual model*** or program logic that identifies how the WQIP plans to address priority water quality issues. The conceptual model should:
    - Identify key process steps and cause-effect relationships from actions to outcomes.
    - Initial steps should show the (major) actions taken by the regional body and partners in delivering the WQIP.
    - Intermediate steps should reflect the management objectives (management action targets) for the WQIP.
    - Final steps should reflect the expected outcomes (resource condition targets).
    - The conceptual model should summarise the major thrust of the WQIP (not the detail).
    - The conceptual model should be agreed by the major stakeholders.

2. ***Learning objectives*** that address key uncertainties within the conceptual model. Learning objectives should:
    - Describe responses to major uncertainties.
    - Will often question cause-effect relationships e.g. how an action achieves practice change, or how practice delivers an intermediate resource condition outcome.
    - Articulate management questions i.e. answering the question would have a clear link to a management response.
    - Identify objectives for investigation, assessment or research.

3. ***Performance trajectories*** that describe progress towards management objectives (targets) over time. Trajectories should:
   - Articulate expectations of performance against targets over time.
   - Be based on the best available science and expert judgement and may be highly uncertain (particularly at the resource condition end of the model).
   - Inform key milestones or trigger points for review and response

4. ***Feedback loops*** that describe how performance measures and learning objectives will be monitored, assessed and communicated. The feedback loops should:
   - Articulate the roles and responsibilities for data collection and assessment.
   - Describe the communication products or process, and timing for these.
   - Be agreed by key stakeholders, including those undertaking the assessment, and those whose actions will be assessed (directly and indirectly).

5. ***Scenarios and responses*** that describe alternative actions based on anticipated feedback scenarios. Scenarios and responses should:
   - Describe Responses i.e. 'What if… and then?' Discuss with key stakeholders and document. (Eberhard et al 2008, p.31)



Example of conceptual adaptive management model for nitrate issues and responses in Tully catchment p.30

	Management Actions	Management Action Targets	Resource Condition Targets
What	Actions delivered Outputs achieved	Adoption rates	Plot and paddock-scale trials Monitoring sub-catchment and catchment nitrate loads
Learning objectives	To test action suitability or effectiveness	To test delivery strategies	To test conceptual model
When	annual review	2 or 5 yearly	2 years & 5 years
How	output reporting grower feedback focus groups	BMP uptake survey (cane, GBR-wide) RAS, financial budgeting	Investigative trials of key practices Event-based monitoring Ambient monitoring Report on web
Who's responsible	Regional NRM Body & WQIP Committee	program deliverers e.g. Canegrowers	DPI&F with partners, NRW for water quality

Examples of feedback loops and responses for Step 4

Appendix K

Other Programs and Initiatives

Burdekin Dry Tropics Regional NRM Plan

The Burdekin Dry Tropics (BDT) Natural Resource Management (NRM) regional group developed a Natural Resource Management Plan (NRM Plan) and a Regional Investment Strategy (RIS) to guide the investment of NRM funds within the BDT region for the period 2005-2009. Townsville City is part of the Burdekin Dry Tropics NRM region and the Black Ross WQIP area is wholly within the BDT NRM region.

A significant component of the regional NRM Plan for the Burdekin Dry Tropics involved water quality and the management of land management practices to reduce adverse impacts on receiving waters. Urban stormwater quality was largely ignored in the regional NRM Plan and as such was not directly addressed in management actions. Regardless of this anomaly Creek to Coral continues to work with NQ Dry Tropics in an effort to integrate urban stormwater quality management with the more extensive water quality management initiatives outlined in the regional NRM Plan and the more recently developed Burdekin Water Quality Improvement Plan (WQIP).

Coastal Catchments Initiative

The Coastal Catchments Initiative (CCI) was a Commonwealth government program delivered prinjcipally through regional natural resource management (NRM) groups in the Great Barrier Reef Catchments.

The original CCI application for the Burdekin NRM region was developed with urban, grazing and cropping components. The application was rejected due to a perceived funding shortfall. The advice from CCI was that the urban component would have to be removed. Burdekin Dry Tropics Board (now NQ Dry Tropics) then submitted a separate application based on grazing and cropping only. This application was approved and activities are now underway to deliver outcomes of the Burdekin WQIP.

Another application for funding under the CCI from Creek to Coral was submitted at short notice on advice that funding was available for the ‘urban’ component. Subsequent funding saw Creek to Coral develop a separate urban based WQIP for the Townsville region.

Coastal Catchments Wetlands Program

Another Commonwealth government program developed to support the Reef Water Quality Protection Plan. Conservation Volunteers Australia were contracted to deliver the Burdekin Dry Tropics component of the program. Previous project areas are in the Burdekin Shire.

Reef Plan

The Reef Water Quality Protection Plan (Reef Plan) is the overarching strategy designed to coordinate efforts of government, industry and community to achieve improved water quality outcomes for the Great Barrier Reef. A significant proportion of the delivery of Reef Plan rests with regional NRM groups such as NQ Dry Tropics. Programs such as the Coastal Catchments Initiative and Coastal Catchments Wetlands Program were designed to assist in achievement of Reef Plan objectives. Reef Plan was revised in 2009.

Reef Water Quality Partnership

Under the Reef Plan, a Reef Water Quality Partnership was established to help coordinate and support the water quality target-setting, monitoring and modelling and reporting components. This Partnership formalised the ongoing collaboration between Australian and Queensland Government agencies, local government and regional natural resource management bodies of the Great Barrier Reef catchments. The partnership went into hiatus following the change of government (2007) and revision of NRM programs in 2008.

Caring for Our Country

The Caring for Our Country program is the 'new' Australian Government NRM funding vehicle, which took over from the Natural Heritage Trust, the National Action Plan for Salinity and Water Quality and other NRM funding bases from 1 July 2008.

The goal of Caring for Our Country is to have an environment that is healthy, better-protected, well-managed, resilient, and that provides essential ecosystem services in a changed climate.

Caring for Our Country includes the Great Barrier Reef Rescue package and its various components. Funding for implementation of the urban water quality improvement was not included in the Reef Rescue package.

Reef Guardian Councils

The Reef Guardian Council Program is an initiative of the Great Barrier Reef Marine Park Authority (GBRMPA). The program seeks to engage local communities through their local council, in the protection and sustainable use of the Great Barrier Reef (GBR). The program recognises the existing work of local councils in contributing to reef protection and sustainable use, while also encouraging the development of new initiatives for inclusion in future work plans.

The Reef Guardian Councils program aims to influence five target areas of local government activity:

- Partnerships: Develop partnerships with Local Government, at the individual and Regional Organisations of Council level.
- Planning: Ensure implementation of appropriate planning requirements that reflect the significance of adjacent environments.
- Management: Manage impacts on coastal, marine and local ecosystems through plans to maintain biodiversity and ecosystem integrity.
- Community: Influence and involve the community through on-ground actions, education and information to promote and facilitate the protection of coastal, marine and adjacent environments.
- Monitoring: Look to maintain ecosystem integrity by monitoring outcomes from actions that address catchment-based pollution sources.

Townsville City Council, in partnership with the GBRMPA has compiled a list of its activities that may be recognised under the Reef Guardian Council Program. Many of these activities are complimentary with the objectives of Creek to Coral and the Black Ross WQIP, particularly with regard to new initiatives and future on-ground works.

Urban Stormwater Quality Management Plan

It is a requirement of local government under the Environmental Protection Act 1994 subordinate legislative to develop Urban Stormwater Quality Management Plans (USQMP) for areas that have constructed stormwater management systems. This applies to most urban and developing areas covered by the Black Ross WQIP.

The current USQMPs components developed for the previous Townsville and Thuringowa City Council areas are dated (1999 and 2001) and in need of review.

The Black Ross WQIP implementation process provides a logical vehicle for the review and amalgamation of the two former Council USQMPs, and an extension of the scope of the USQMP framework to include non-regulatory stormwater management across the new Townsville City local government area in keeping with the Stormwater Management Framework (Earth Environmental 2005) prepared for Citiworks (Townsville City Council) and emerging legislation.

Creek to Coral

The Creek to Coral program has an ongoing role in total water cycle management in the Townsville region including through community education and involvement and partnering with other organisations and individuals interested in catchment and waterway management. Creek to Coral also makes linkages between the water cycle and water and energy conservation, sustainability and urban nature.

Appendix L

Bayesian Belief Networks

About Bayesian Belief Networks

Bayesian networks (BNs) are graphical models that are ideal for aiding decision making in natural resource management (NRM). BNs are probabilistic models that can be used to represent complex natural systems, integrate different sources and types of information, and investigate alternative management and system change scenarios to assist decision-making processes. Being probabilistic, BNs are able to represent uncertainties (including natural variability and knowledge gaps) and they can be readily updated. These features make them ideal for NRM applications.

Increasingly, BNs are being used in NRM applications in Australia, including water and climate related issues. They also have a long history of being applied in other fields, such as medicine and engineering.

The process used to develop BNs is known to provide benefits in systems thinking and process understanding.
Source: The Fenner School of Environment and Society, ANU Australian National University College of Science, APPLICATION OF BAYESIAN NETWORKS IN NATURAL RESOURCE MANAGEMENT (course brochure).

Bayesian Belief Networks (BBNs) are emerging as valuable tools for investigating complex ecological problems. In a BBN, the important variables in a problem are identified and causal relationships are represented graphically.

Underpinning this is the probabilistic framework in which variables can take on a finite range of mutually exclusive states. Associated with each variable is a conditional probability table (CPT), showing the probability of a variable attaining each of its possible states conditioned on all possible combinations of its parents. Whilst the variables (nodes) are connected, the CPT attached to each node can be quantified independently.

This allows each variable to be populated with the best data available, including expert opinion, simulation results or observed data. It also allows the information to be easily updated as better data become available.
Source: Hamilton, G., Alston, C., Chiffings, T., Abal, E., Hart, B. and Mengersen, K., Integrating Science through Bayesian Belief Networks: Case study of Lyngbya in Moreton Bay (unnamed publication, pp.392-9)

Black Ross WQIP and Application of BBN

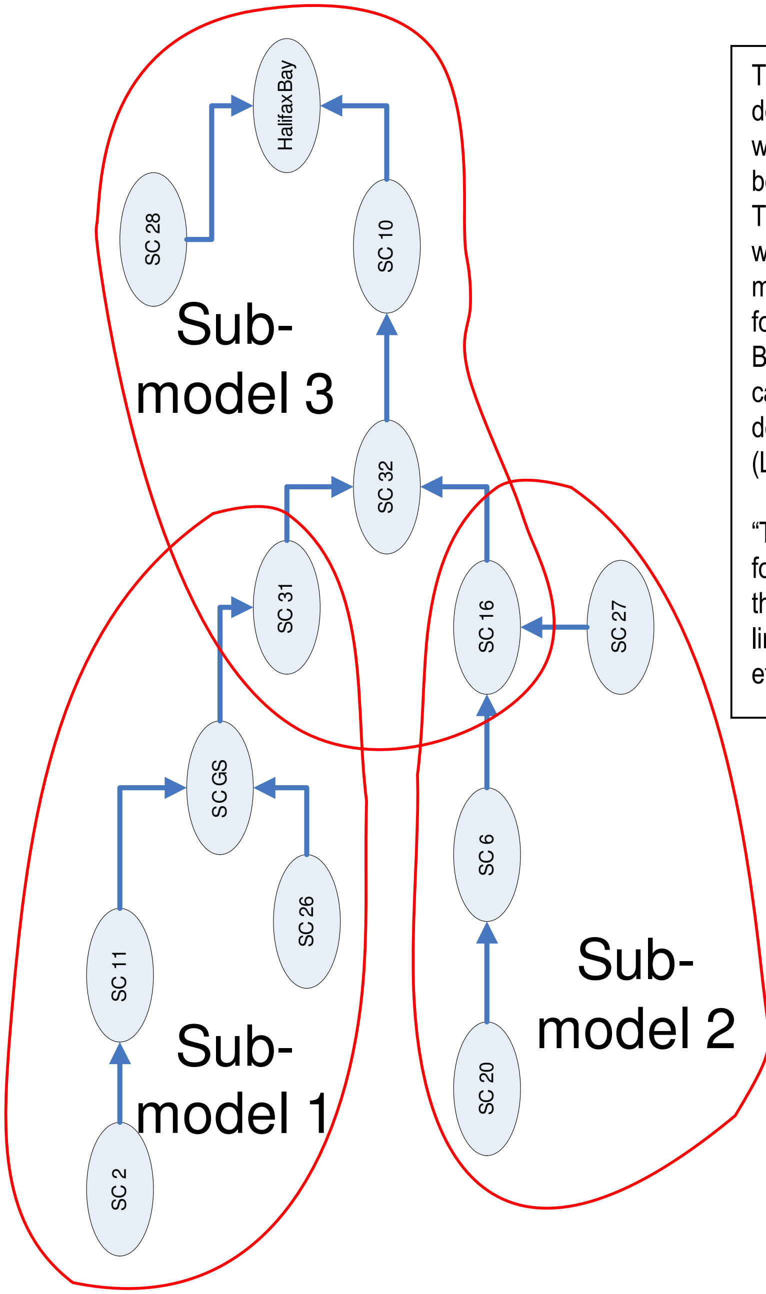
As part of the process of developing a water quality improvement plan (WQIP) for the catchments in the Townsville region Creek to Coral in comjunction with CSIRO sought to explore the utility of a Bayesian Belief Network (BBN) to support the adaptive management approach to water quality improvement adopted by Creek to Coral. In the project the BBN is used as a representation of the knowledge of pollutant loads held by natural resource managers as well as the beliefs of these managers as to how their actions are likely to influence pollutant loads usually indirectly through actions they take to influence the actions of those directly affecting pollutant loads. The Bohle catchment was selected to test the BBN modelling approach.

“The project comprised two elements; 1) the development and use of a BBN modelling based approach to water quality management; and 2) the analysis of the relative contributions of different elements of the process (of BBN model development and use) and BBN itself to learning by the team involved in the process.” (Lynam et al 2008, pp.1 and 3)

"To explore and analyse the estimated relative sediment contributions of each sub-catchment unit and of the whole catchment 10,000 random variates were generated from each sub-catchment unit node using the built in Netica function ("Simulate cases"). Separate nodes were built into the model to estimate the endogenous sediment production for each node that also received exogenous sediment.

To explore and analyse the relative contributions of each land use to overall sediment production 10,000 random variates were simulated from each TSS coefficient node and each of these were then multiplied by the total area of the associated land use in the whole Bohle catchment." (Lynam et al 2008, pp.17-18)

Figure A Bohle River Catchment BBN model at December 2008 (Lynam et al 2008, p.18)



The [Bohle River] BBN was developed to ensure consistency with the E2 and MUSIC modelling being carried out for Creek to Coral. The spatial units used in the BBN were identified by these other modelling activities and were used for the purpose of developing the BBN. Twelve spatial units, or sub-catchments (SC), excluding the total delivery to Halifax Bay, were used". (Lynam et al 2008, p.14)

"The BBN model became too large for successful compilation and was therefore subdivided into three linked parts or sub-models". (Lynam et al 2008, p.18)

Next Steps for Townsville – Social Learning and BBN (extract from the draft BBN report Lynam et al 2008)

"*The work presented so far is incomplete. Much needs to be done and learnt in order to effectively enhance our ability to support managers in the adaptive management of water quality. We need to learn more about how people learn so that we can support their learning more effectively. We also need to learn more about learning in different social contexts; small groups that are directly involved in building models are likely to need different approaches compared to groups that are not involved in model development but need to use the models or model outputs. How can we learn from and support the learning of such groups?*

Important next steps have already been identified for the social learning component of the project:

- *The participation of additional key groups in future BBN model activities and their role in enhancing learning.*
- *Transferring the learning that occurs 'in the backroom' (by primarily technical experts refining the BBN model with additional technical and mathematical expertise) to non-technical participants involved in the development and implementation of the BBN.*
- *Adapting and applying key findings of learning around the development of the BBN model to the implementation phase of the BBN model.*
- *Learning about how to best communicate the BBN tool's role and contribution as part of an adaptive management strategy.*

Looking at the development and use of the BBN there remains a great deal to be done to support decision making and learning in the face of very large uncertainties. We already know that runoff and consequently flow through the river systems is an important determinant of pollutant load delivery to and through the river systems. Including flow estimates will be an important next step that will enable the exploration of pollutant concentrations in each of the sub-catchment units and as delivered to Halifax Bay.

With flow included, the next major steps will be to explore the options available to TCC to reduce end of catchment sediment loads. Three intervention points present themselves and each of these will need to be explored in terms of their technical, social, and economic feasibility. The first is through altering the areas of each land use in each catchment unit. Changes in the areas of different land uses will happen as part of the projected development of Townsville in the Bohle region. The projected changes need to be incorporated into the BBN to enable the council to explore the likely implications of these changes on sediment loads.

The second intervention point is associated with altering the per hectare sediment production relationships for each land use. This activity is likely to be an iterative investigation of scenarios of land use change in each sub-catchment unit with explorations of feasible options for reducing sediment production from the land uses in the sub-catchments. The relative cost of achieving a desired load reduction is likely to play an important part in these analyses. The current model identified which land uses and which sub-catchment units are important. Not all need to be treated in the same way.

The third intervention point is in relation to the inter-sub-catchment transfers of sediment. Can sediment be trapped in certain sub-catchments to prevent its delivery to Halifax Bay?

A number of potentially large sources of uncertainty in our knowledge of sediment production and delivery relationships need to be addressed. Already mentioned is the between sub-catchment transfer of sediments. How much of the sediment generated in one catchment unit is reaching Halifax Bay in any one year? A second major uncertainty is associated with the roles of the wetlands at the mouth of the Bohle catchment (SC10 and SC32). Under what conditions are they sinks versus sources of sediment?

Our ability to learn is fundamentally constrained by the lack of empirical data to support confronting our beliefs (as captured in the BBN) with reality. We acknowledge that it is unlikely that we will ever have sufficient knowledge to be certain about the relationships that are being managed by TCC. Decisions will still need to be made in the face of considerable uncertainties. The BBN was developed with this in mind, but we need to actively seek ways of confronting our beliefs with empirical reality. We should not underestimate the difficulty of developing confidence in our ability to effectively predict the consequences of TCC actions to achieve water quality goals.

Looking at the data for Halifax Bay it should be clear that a very large range of sediment load values are likely given current land use and land use practices. It is highly unlikely that the TCC could identify changes in loads as a consequence of their actions without decades of data; the intrinsic variability in loads due to factors like variance in rainfall far outweighs the possible effect of actions taken by TCC. Nonetheless decisions need to be made and actions need to be taken with reasonable assurance that the actions taken will result in end of catchment loads that are within the target range. The BBN approach should support this sort of learning. An important additional next step, however, will be to identify what combination of monitored data (type, location, and time) will maximally inform the BBN and hence the TCC as to progress to achieving goals.

Finally it will be important for us to learn how best to institutionalise the learning developed through this BBN centred process (or any other process used by the TCC) to ensure what is learnt by this group is readily available to the next generation of water quality managers. This is a challenge yet to be addressed."
(Lynam et al 2008, pp. 30-33)

Appendix M

ABCD Management Practice Framework

Urban landuse management practice framework (ABCD) and characteristics for the Black Ross (Townsville) WQIP

Urban ABCD framework principles

A	***Advanced or 'cutting edge' practices – some of which haven't yet been invented***
	• Effectively 0-5% directly connected impervious surfaces; • Natural flows mimicked through capture, treatment and release of water over time; • Nutrient and chemical levels entering waterways are equivalent to or less than natural levels.
B	***Better practices – where we want to be to meet our water quality targets***
	• <10% directly connected impervious surfaces to stormwater.
C	***Common practices – where we are now i.e. common or 'normal' practice***
	• 10-40% directly connected impervious surfaces to stormwater.
D	***Degrading practices – what we know not to do***
	• High % of directly connected impervious surfaces (>50% impervious surfaces); • No mitigated flows.

Diffuse sources of pollutants from urban land uses (developing) (draft)

This ABCD management practice framework is relevant to development occurring in locations where land use changes from agricultural, minimal use or natural areas to an urban, commercial or industrial land use resulting in an intensification of land use (generally in peri-urban areas). Development activities include new, infill and retrofit development. This stage includes the transition of urban land use from 'developing' to 'developed'.

1. This classification is relevant until the transfer of stormwater quality assets and other management responsibilities to Council or other appropriate managing authority ('the responsible body'). The timing and terms of the handover to be negotiated with the 'responsible body'.
2. This classification is relevant to the specified reporting spatial unit (e.g. sub catchment) and relates in some instances to a percent coverage of management practice across that spatial unit.
3. Management practices predominantly focus on erosion control and the reduction of sediment movement (sediment and attached nutrients).

ABCD management practice framework for developing urban areas

Class	Management practices for water quality improvement
A	1. Individual Site Based Stormwater Management Plan (SBSMP) developed, implemented and audited for all new, infill and retrofit development. 2. Erosion and Sediment Control Plans (ESCP) developed, implemented and audited for all new, infill and retrofit development. 3. Water Sensitive Urban Design (stormwater) treatment system established in 100% of all new, infill and retrofit development. 4. Water Sensitive Urban Design (stormwater) measures designed to exceed locally specific design objectives for treatment effectiveness (in terms of load reductions) and receiving water quality meets WQ objectives/guidelines. 5. Land clearing prior to construction does not occur at all during the wet season. 6. Regular/comprehensive water quality monitoring is undertaken prior to, during and after construction activities including both stormflow and baseflow monitoring. 7. Regular monitoring of the effectiveness of treatment measures is undertaken to ensure treatment effectiveness of the asset is maintained over its lifecycle.

	8. Comprehensive records kept including water quality data, management measure effectiveness, maintenance records and costs. Records are made available. 9. Adaptive management principles utilised in all master-planned or staged developments to help ensure continuous improvements in practices over time, commensurate with the level of data collected. 10. Industry ensures it is trained in current best practice with respect to all aspects of stormwater quality improvement. 11. Industry provides demonstration sites and allows data records to be made available for the purpose of continuous improvement of practice adoption and effectiveness. 12. Industry engages Council in discussions over maintenance and asset handover early in the development cycle. 13. Industry voluntarily provide data to allow reporting to community on performance, including any non-compliances.
B	1. Individual Site Based Stormwater Management Plan (SBSMP) developed and implemented for all new, infill and retrofit development (>1 ha sites) 2. Erosion and Sediment Control Plans (ESCP) developed and implemented for all new, infill and retrofit development. 3. Water Sensitive Urban Design (stormwater) treatment system established in >50% of all new, infill and retrofit development across the landscape. 4. Water Sensitive Urban Design (stormwater) measures designed to meet locally specific design objectives for treatment effectiveness (in terms of load reductions) and receiving water quality meets WQ objectives/guidelines 75% of the time. 5. Incremental land clearing occurs no earlier than two weeks prior to construction activities occuring during the wet season. 6. Water quality monitoring undertaken prior to, during and after construction activities including both stormflow and baseflow monitoring. 7. Monitoring of the effectiveness of treatment measures is undertaken to ensure treatment effectiveness of the asset is maintained over its lifecycle. 8. Records kept including water quality data, management measure effectiveness, maintenance records and costs. 9. Adaptive management principles utilised in all master-planned or staged developments to help ensure continuous improvements in practices over time, commensurate with the level of data collected. 10. Industry undertakes some training in current best practice with respect to all aspects of stormwater quality improvement. 11. Industry considers providing demonstration sites and allows data records to be made available for the purpose of continuous improvement of practice adoption and effectiveness. 12. Industry engages Council in discussions over maintenance and asset handover early in the development cycle. 13. Industry voluntarily reports performance including any non-compliances to regulators.
C	1. Individual Site Based Stormwater Management Plan (SBSMP) developed for all new and some infill and retrofit development (>1 ha sites). 2. Erosion and Sediment Control Plans (ESCP) developed for all new, infill and retrofit development. 3. Water Sensitive Urban Design (stormwater) treatment system established in >5% of all new, infill and retrofit development across the landscape. 4. Water Sensitive Urban Design (stormwater) measures designed to meet locally specific design objectives for treatment effectiveness (in terms of load reductions) and receiving water quality meets WQ objectives/guidelines 50% of the time.

	5. Land clearing prior to construction occurs during the wet season without regard for timing of construction and with limited mitigation measures. 6. Minimal water quality monitoring undertaken prior to, during or after construction activities. 7. Very limited monitoring of the effectiveness of treatment measures is undertaken. 8. Very limited records kept including water quality data, management measure effectiveness, maintenance records and costs. 9. Adaptive management principles not utilised in relevant development situations to improve practices over time, often associated with a lack of monitoring data. 10. Industry undertakes limited training in current best practice with respect to all aspects of stormwater quality improvement. 11. Industry does not provide demonstration sites and no data records are made available for the purpose of continuous improvement of practice adoption and effectiveness. 12. Industry engages Council in discussions over maintenance and asset handover only as required by legislation and regulations. 13. Industry provides limited reports on specific performance and only includes any non-compliance reports to regulators when required by legislation.
D	1. No individual Site Based Stormwater Management Plan (SBSMP) prepared for development. 2. No erosion and Sediment Control Plans (ESCP) prepared for development. 3. No Water Sensitive Urban Design (stormwater) treatment systems established as a component of development. 4. Locally specific design objectives for stormwater treatment effectiveness (in terms of load reductions) not met and receiving water quality meets WQ objectives/guidelines <50% of the time. 5. Extensive land clearing occurs at any time of the year including during the wet season and there is no regard for the timing and sequencing of clearing and construction. 6. No water quality monitoring undertaken associated with the development. 7. No monitoring of the effectiveness of treatment measures is undertaken. 8. No records are kept including water quality data, management measure effectiveness, maintenance records and costs. 9. No continuous improvement or adaptive management principles incorporated in the development process. 10. Industry does not encourgae training in current best practice with respect to stormwater quality management and improvement. 11. Industry does not assist with activities to improve stormwater quality practices e.g. demonstration sites and data sharing. 12. Council is forced to engage Industry in discussions over maintenance and asset handover. 13. Industry does not provide data/reports on specific performance or any non-compliances unless by specific request of the regulator.

Diffuse sources of pollutants from urban land uses (developed) (draft)

This ABCD management practice framework is relevant to urban areas after the 'greenfield' stage of development (intensification of land use) is completed. This follows the land use transition from 'developing' to 'developed'.

1. This classification is relevant to the Council or other appropriate managing authority ('the responsible body') as well as the wider community occupying and 'managing' urban areas.
2. This classification is relevant to the specified reporting spatial unit (e.g. sub catchment) and relates in some instances to a percent coverage of management practice across that spatial unit.
3. Management practices predominantly focus on nutrient reduction strategies.

Class	Management practices for water quality improvement
A	1. The operational phase of any Water Sensitive Urban Design (WSUD) stormwater treatment systems continue to be maintained to ensure they exceed locally specific design objectives for treatment effectiveness in terms of load reductions, and receiving water quality meets or exceeds water quality objectives (WQO) or guidelines (WQG). 2. Retrofit and upgrade opportunities for WSUD management measures investigated regularly and systematically implemented across the urban water cycle (stormwater, potable water and wastewater). 3. Regular/comprehensive water quality monitoring continues in selected locations within the urban footprint as deemed appropriate in the Urban Stormwater Quality Management Plan (USQMP) with monitoring to include both stormflow and baseflow monitoring. 4. Comprehensive monitoring and analysis is undertaken to determine treatment effectiveness of WSUD assets and to ensure effectiveness is maintained over the lifecycle of WSUD assets. 5. Comprehensive records are kept and collated including for water quality data, management measure effectiveness, maintenance records and costs. Records are made available. 6. Adaptive management principles are utilised to help ensure continuous improvements in practices over time, commensurate with the level of data collected. 7. Responsible bodies ensure they are trained in current best practice with respect to all aspects of stormwater quality improvement. 8. Responsible bodies continue to maintain any demonstration sites (if applicable) and allow data records to be made available for the purpose of continuous improvement of practice adoption and effectiveness. 9. Responsible bodies voluntarily provide data to allow reporting to community on performance, including any non-compliances. 10. >70% of residents, businesses and industries undertake best practices for water quality improvement in their homes and workplaces. 11. New development areas (catchments) automatically integrated into the USQMP as a process within the USQMP adaptive management framework. 12. Responsible bodies review and update the USQMP regularly to ensure it reflects emerging best practice, locally relevant data, information and learnings in an adaptive management framework.
B	1. The operational phase of any Water Sensitive Urban Design (WSUD) stormwater treatment systems continue to be maintained to ensure they meet locally specific design objectives for treatment effectiveness in terms of load reductions, and receiving water quality meets or exceeds water quality objectives (WQO) or guidelines (WQG) at least 75% of the time. 2. Regular water quality monitoring continues in selected locations within the urban

	footprint as deemed appropriate in the Urban Stormwater Quality Management Plan (USQMP) with monitoring to include both stormflow and baseflow monitoring. 3. On-going monitoring and analysis is undertaken to determine treatment effectiveness of WSUD assets and to ensure effectiveness is maintained over their lifecycle. 4. Records are kept including for water quality data, management measure effectiveness, maintenance records and costs. Records are made available. 5. Adaptive management principles are utilised to help ensure continuous improvements in practices over time, commensurate with the level of data collected. 6. Responsible bodies ensure they are trained in current best practice for stormwater quality improvement. 7. Responsible bodies continue to allow data records to be made available for the purpose of continuous improvement of practice adoption and effectiveness. 8. Responsible bodies voluntarily provide data to allow reporting to community on performance. 9. >40% of residents, businesses and industries undertake best practices for water quality improvement in their homes and workplaces. 10. New development areas are integrated into existing USQMP as part of the USQMP update process. 11. Responsible bodies review and update the USQMP in accordance with regulatory requirements to ensure it reflects emerging best practice, locally relevant data, information and learnings in an adaptive management framework.
C	1. The operational phase of any Water Sensitive Urban Design (WSUD) stormwater treatment systems (if present) are maintained to ensure they meet locally specific design objectives for treatment effectiveness in terms of load reductions and receiving water quality meets or exceeds water quality objectives (WQO) or guidelines (WQG) at least 50% of the time. 2. Some water quality monitoring continues in selected locations within the urban footprint as deemed appropriate in the Urban Stormwater Quality Management Plan (USQMP) with monitoring to include both stormflow and baseflow monitoring. 3. Limited monitoring and analysis undertaken to determine treatment effectiveness of WSUD assets and to ensure effectiveness is maintained over their lifecycle. 4. Limited records are kept including for water quality data, management measure effectiveness, maintenance records and costs. 5. A piecemeal approach is utilised to support continuous improvements in practices over time, commensurate with the level of data available. 6. Responsible bodies ensure they have some training in current best practice for stormwater quality improvement. 7. Responsible bodies allow uncollated data records to be made available for the purpose of continuous improvement of practice adoption and effectiveness. 8. Responsible bodies voluntarily provide limited data for reporting to the community on performance. 9. <40% of residents, businesses and industries undertake best practices for water quality improvement in their homes and workplaces. 10. New development areas integrated into existing USQMP irregularly. 11. Responsible bodies review and update the USQMP when prompted by the agency administering the relevant legislation.
D	1. The operational phase of Water Sensitive Urban Design (WSUD) stormwater treatment systems (if any) are not adequately maintained to meet locally specific design objectives for treatment effectiveness in terms of load reductions and receiving water quality seldom meets water quality objectives (WQO) or guidelines. 2. No regular water quality monitoring is undertaken in urban catchments.

	3. No monitoring of the treatment effectiveness of WSUD assets (if any) is undertaken. 4. Incomplete or inadequate records kept including for water quality data, management measure effectiveness, maintenance records and costs. 5. Adaptive management approach not utilised for continuous improvements in urban stormwater management practices over time. 6. Responsible bodies do not offer or undertake training in current best practice for stormwater quality improvement. 7. Responsible bodies do not collect or provide data records for the purpose of continuous improvement of practice adoption and effectiveness or reporting to the community on performance. 8. <10% of residents, businesses and industries undertake best practices for water quality improvement in their homes and workplaces. 9. Responsible bodies develop, review and update the USQMP only when the agency administering the relevant legislation demands that the responsible body does so.

Diffuse sources of pollutants from peri-urban land uses (draft)

This ABCD management practice framework is relevant to peri-urban areas after initial and/or 'intensive' development of properties has occurred. This follows the land use transition from 'developing' to 'developed'. In general terms the ABCD management practice framework for developing urban areas could also be applied to developing peri-urban areas.

Note: Peri-urban areas are broadly defined as groupings of properties greater than 1 hectare and less than 300 hectares in size in transition zones between urban and rural land uses.

1. This classification is relevant to the Council or other appropriate managing authority ('the responsible body') as well as the wider community occupying and 'managing' peri-urban areas.
2. This classification is relevant to the specified reporting spatial unit (e.g. sub catchment) and relates in some instances to a percent coverage of management practice across that spatial unit.
3. Management practices focus on both sediment and nutrient reduction strategies as well as vegetation, habitat and biodiversity protection and management.

Class	Management practices for water quality improvement
A	1. Sustainable property management plans (SPMP) are developed, implemented and routinely audited. 2. All existing native vegetation is protected and managed in accordance with the SPMP. Both voluntary and regulated conservation instruments may be applied to properties as part of the SPMP. 3. Vegetation clearing is limited to areas required for dwellings, associated infrastructure and to ensure the safety of residents and their property in accordance with development approvals and conservation instruments. 4. Rehabilitation and revegetation of any degraded areas is undertaken in accordance with SPMPs and is consistent with regional conservation strategies and natural resource management (NRM) plans. 5. Intensive land uses such as horticulture and extractive industries occur only in appropriate areas as defined by legislation through regional and local planning instruments. Intensive land use activities are managed appropriately. 6. Where available dwelling properties are connected to reticulated sewerage systems otherwise septic tanks and other wastewater treatment systems are maintained adequately and upgraded or replaced as required to maintain environmentally safe discharges. 7. Natural overland flow paths are protected with all water storage and treatment measures constructed 'offline' from natural overland flow paths. 8. Water quality monitoring is undertaken (where relevant) where an intensive land use occurs or with proposed intensification of land use. 9. Comprehensive records are kept including water quality data, management measure effectiveness, maintenance records and costs. Records are publicly available on request. 10. >70% of residents, businesses and industries undertake best practices for water quality improvement in their homes, workplaces and properties. 11. Responsible bodies regularly review and update the relevant planning and regulatory mechanisms to ensure they reflect emerging best practice, locally relevant data, information and learnings in an adaptive management framework. 12. Pest/weed management plans are a component of SPMPs. Individual SPMPs are consistent with any regional pest management plans, strategies and legislation. 13. Fire management planning is a component of SPMPs and appropriate fire regimes are utilised.
B	1. Property management plans (PMP) are developed and implemented. 2. Native vegetation is protected and managed consistent PMPs.

	3. Remnant vegetation clearing is limited to areas required for dwellings, associated infrastructure and to ensure the safety of residents and their property in accordance with development approvals. 4. Revegetation activities occur consistent with PMPs. 5. Intensive land uses such as horticulture and extractive industries occur only in appropriate areas as defined by legislation through regional and local planning instruments. 6. Where available dwelling properties are connected to reticulated sewerage systems otherwise septic tanks and other wastewater treatment systems are maintained adequately and upgraded or replaced as required to maintain environmentally safe discharges. 7. Natural overland flow paths are generally protected with water storage and treatment measures constructed in a manner sensitive to protecting natural overland flow paths. 8. Water quality monitoring is undertaken (where relevant) where an intensive land use occurs or with proposed intensification of land use. 9. Records are kept including for water quality data, management measure effectiveness, maintenance records and costs. 10. 40% to 70% of residents, businesses and industries undertake best practices for water quality improvement in their homes, workplaces and properties. 11. Responsible bodies semi-regularly review and update the relevant planning and regulatory mechanisms to ensure they reflect emerging best practice, locally relevant data, information and learnings in an adaptive management framework. 12. Pest/weed management plans developed and implemented as a component of PMPs. Individual plans are consistent with any regional pest management plans, strategies and legislation. 13. Fire management planning is undertaken as a component of PMPs and appropriate fire regimes are utilised.
C	1. Limited property management planning occurs and is often not effectively documented. 2. Vegetation, including remnant vegetation is protected and maintained only as required by legislation. 3. Land clearing activities are relatively un-managed except as required by legislation. 4. Revegetation activities are generally uncoordinated and may only occur when required by legislation. 5. Intensive land uses such as horticulture and extractive industries occur in appropriate areas only as defined by legislation through local planning instruments. 6. Septic tanks are generally maintained to minimise on property usage issues. 7. Water storage and treatment measures are constructed with little emphasis on protecting overland flow paths. 8. Limited water quality monitoring is undertaken (where relevant). 9. Very limited records are kept including for water quality data, management measure effectiveness, maintenance records and costs. 10. <40% of residents, businesses and industries undertake best practices for water quality improvement in their homes, workplaces and properties. 11. Responsible bodies review and update the relevant planning and regulatory mechanisms only as required by legislation. 12. Pest/weed management plans may be developed and individual plans may be consistent with any regional pest management plans, strategies and legislation. 13. Limited fire management planning is undertaken and appropriate fire regimes may not be utilised.
D	1. No property management planning occurs. 2. Vegetation, including remnant vegetation is not protected and maintained. 3. Land clearing activities occur in an un-managed manner and may not comply with relevant legislation.

	4. Revegetation activities only occur if enforced by legislation. 5. Intensive land uses such as horticulture and extractive industries undertaken with little regard for social and environmental considerations. 6. Septic tanks are not maintained adequately or replaced when necessary. 7. Water storage and treatment measures are constructed with no regard for protecting overland flow paths. 8. No water quality monitoring is undertaken. 9. No records are kept including for water quality data, management measure effectiveness, maintenance records and costs. 10. <10% of residents, businesses and industries undertake best practices for water quality improvement in their homes, workplaces and properties. 11. Responsible bodies do not review and update relevant planning and regulatory mechanisms except when prompted by the relevant regulatory agency. 12. Pest/weed management plans are not developed. 13. No fire management planning is undertaken and fire regimes are usually inappropriate.

Point sources of pollutants from developed sites (draft)

This ABCD management practice framework is relevant to developed sites with point source discharges. The principal point source discharge activity in Townsville is associated with wastewater treatment plants.

1. This classification is relevant to the Council or industry conducting environmentally relevant activities (ERA) involving point source discharge.
2. This classification is relevant to specific sites with reporting and compliance as required by ERA permit conditions.
3. Management practices focus principally on nutrient reduction strategies.

Class	Management practices for water quality improvement
A	1. Wastewater Treatment Plants (WWTPs) and other ERA activities never exceed licence conditions. 2. Discharges from ERA activies, other than WWTPs, are connected to an approved reticulated wastewater treatment plant, or if wastewater is treated on site it is treated in accordance with best practice water quality improvement standards. 3. Treated wastewater is reused and recycled with <10% of the volume of treated wastewater discharged to receiving waters.
B	1. WWTPs and other ERA activities rarely exceed licence conditions (1 in 10 years) and then exceedance is only minor and/or due to external factors. 2. Treated wastewater is reused and recycled with <50% of the volume of treated wastewater discharged to receiving waters.
C	1. WWTPs and other ERA activities occasionally exceed licence conditions (1 in 3 years). 2. Less than 10% of treated wastewater is reused or recycled with the majority of treated wastewater discharged to receiving waters.
D	1. WWTPs and other ERA activities often exceed licence conditions (annually). 2. All treated wastewater is discharged to receiving waters.

Extracts from the Mackay Whitsunday WQIP (Drewry et al 2008)
ABCD Management Practice Framework for Horticulture and Sugar Cane

Table 40 (p.61) Soil management practices for horticulture classified in the ABCD framework.

D Class Horticulture Soil Management	**C Class Horticulture Soil Management**
Description: 1. Cultivated bare fallow 2. Cultivated annual crop or cultivated establishment phase for plantation and tree crops 3. Interrows cultivated for plantation and tree crops.	Description: 1. Minimum till bare fallow or legume fallow 2. Same as Class D 3. Interrows bare for plantation and tree crops.
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Records kept in head	Planning and record keeping: 1. Develop basic Soil Management Plan 2. Keep basic records
Machinery: 1. Standard equipment	Machinery: 1. Same as Class D
B Class Horticulture Soil Management	**A Class Horticulture Soil Management**
Description: 1. Controlled traffic permanent beds 2. Strategic or zonal till fallow, establishment and cropping 3. Interrows grassed or mulched for plantation and tree crops 4. Headlands, drains and waterways managed as filter strips	Description: 1. Controlled traffic permanent beds with GPS guidance of establishment, cropping and harvesting operations 2. - 4. Same as Class B
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Identify soil types and productivity zones for each paddock 2. Develop Soil Management Plan using soil mapping 3. Keep records (including timing of operations) 4. Adjust soil management for next year if required.	Planning and record keeping: 1. Identify soil types and productivity zones for each paddock using GPS mapping 2. Develop GPS based Soil Management Plan using soil mapping and remote sensing 3. Automatic record keeping in computer database 4. Same as Class B
Machinery: 1. Standard wheel spacing on all equipment, Bed Former, Zonal Tillage Equipment, Minimum Till Seed/Seedling Planter, Sprayer and Harvester	Machinery: 1. Standard wheel spacing and GPS Guidance (with variable rate screen) on all equipment, Bed Former, Zonal Tillage Equipment, Minimum Till Seed/Seedling Planter, Sprayer and Harvester

Table 41 (p.62) Nutrient management practices for horticulture classified in the ABCD framework

D Class Horticulture Nutrient Management	**C Class Horticulture Nutrient Management**
Description: 1. One rate for whole crop 2. Application rates based on historic application rates or rules of thumb	Description: 1. Soil testing 2. One or two rates for each crop 3. Application based on old industry recommendations
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Records kept in head	Planning and record keeping: 1. Conduct soil tests 2. Develop basic Nutrient Management Plan 3. Keep basic records
Machinery costs: 1. Surface or sub-surface fertiliser box	Machinery costs: 1. Same as Class D
B Class Horticulture Nutrient Management	**A Class Horticulture Nutrient Management**
Description: 1. Variable rate between paddocks 2. Application rates based on latest industry recommendations 3. Timing nutrient applications with respect to crop stage, irrigation and rainfall	Description: 1. Variable rate within paddocks 2. Application rates based on specialist interpretation of the latest industry recommendations 3. Same as Class B
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Identify soil types/productivity zones for each paddock 2. Develop Nutrient Management Plan using yield, soil mapping and latest industry recommendations 3. Change fertiliser rates between paddocks 4. Attend nutrient management training 5. Conduct soil tests and leaf analysis 6. Keep records (including timing, rates, product and yield) 7. Adjust nutrient rates for next year if required	Planning and record keeping: 1. Identify soil types/productivity zones within each paddock using GPS yield and soil mapping 2. Develop GPS based Nutrient Management Plan using yield, soil mapping and specialist interpretation of latest industry recommendations 3. Apply variable fertiliser rates within paddocks 4 – 5. Same as Class B 6. Automated record keeping in computer database 7. Same as Class B
Machinery: 1. Variable rate application of granular sub-surface or liquid surface with manually controlled rate and/or variable rate fertigation equipment	Machinery: 1. Variable rate application of granular sub-surface or liquid surface with remote/automatic controlled rate and GPS guidance and/or variable rate fertigation equipment

Table 42 (p.63) Pesticide management practices for horticulture classified in the ABCD framework

D Class Horticulture Pesticide Management	**C Class Horticulture Pesticide Management**
Description: 1. One herbicide strategy for each crop based on historic application rates or rules of thumb 2 Often uses maximum label rate residual and knockdown products irrespective of weed pressure	Description: 1. One or two herbicide strategies for each crop 2. Often uses residual and knockdown products at rates appropriate to weed pressure
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Records kept in head	Planning and record keeping: 1. Develop basic Herbicide Management Plan 2. Keep basic records
Machinery costs: 1. Standard spray equipment	Machinery costs: 1. Same as Class D
B Class Horticulture Pesticide Management	**A Class Horticulture Pesticide Management**
Description: 1. Implementation of new application technology for improved placement and timing to improve application efficiency, accuracy and to extend the window of opportunity 2. Knockdown herbicides replace residual herbicides where practical (strategic residual herbicides use) 3. Timing herbicide applications with respect to crop stage, irrigation and rainfall 4. Variable herbicide strategies between paddocks	Description: 1 – 3. Same as Class B 4. Variable herbicide strategies within paddocks.
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Identify – weed types/pressure, soil types and productivity zones for each paddock 2. Develop Herbicide Management Plan using pest pressure, soil types, crop stage and yield mapping 3. Change herbicide strategy between paddocks 4. Attend herbicide management course 5. Monitor pest pressure 6. Keeps Material Safety Data Sheets (MSDSs) and first aid procedures 7. Keep records (including wind speed, time of spraying, products and block rate) 8. Adjust herbicide strategy for next year if required	Planning and record keeping: 1. Identify – weed types/pressure, soil types and productivity zones within each paddock using GPS yield and soil mapping 2. Develop GPS based Herbicide Management Plan using pest pressure, soil types, crop stage and yield mapping 3. Apply variable herbicide strategies within paddocks 4 – 6. Same as Class B 7. Automated record keeping in computer database 8. Adjust herbicide strategy for whole of crop cycle
Machinery: 1. Hooded sprayers, more accurate nozzles (matched to job), multiple tank setups and high clearance tractors with manual rate control	Machinery: 1. Hooded sprayers, more accurate nozzles (matched to job), multiple tank setups and high clearance tractors with remote/ automatic rate control and GPS guidance with variable rate screen

Table 37 (p.55) Soil management practices for cane classified in the ABCD framework.

D Class Cane Soil Management	**C Class Cane Soil Management**
Description: 1. Cultivated bare fallow or plough out/replant 2. Cultivated plant cane 3. Cultivated ratoons	Description: 1. Minimum till bare fallow 2. Cultivated plant cane 3. Zero till ratoons
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Records kept in head	Planning and record keeping: 1. Develop basic Soil Management Plan 2. Keep basic records
Machinery: 1. Standard equipment	Machinery: 1. Standard equipment
B Class Cane Soil Management	**A Class Cane Soil Management**
Description: 1. Controlled traffic permanent beds maintained by zonal tillage with GPS guidance of bed-forming and harvesting operations 2. Strategic or zonal tillage plant cane and rotational crops managed for green manure or grown to harvest 3. Zero till ratoons 4. Drains and waterways managed as filter strips 5. Headlands widened and smoothed to reduce soil compaction of row ends 6. Harvester modifications to accommodate wide rows (includes harvester front, automatic base cutter height control, roller train optimisation, and elevator extensions)	Description: 1. Controlled traffic permanent beds with GPS guidance of all operations including planting zonal tillage and spraying 2.-5. Same as Class B 6. Harvester modifications to accommodate wide rows (includes harvester front, automatic base cutter height control, roller train optimisation, automatic primary extractor fan speed control, and elevator extensions) 7. Haulout modifications to accommodate wide rows (includes rear wheel steering and GPS guidance)
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Identify soil types and productivity zones for each block using existing farm maps 2. Develop Soil Management Plan (includes Harvest Management Plan) using existing paddock scale soil and yield mapping techniques. 3. Keep records (including timing of operations and harvest cane loss assessments) 4. Adjust soil management for next year if required	Planning and record keeping: 1. Identify soil types and productivity zones for each block using GPS mapping 2. Develop GPS based Soil Management Plan (includes Harvest Management Plan) using new within paddock scale soil and yield mapping techniques (link to mill data) 3. Automatic record keeping in computer database 4. Same as Class B
Machinery: 1. Standard wheel spacing on all equipment and GPS Guidance of bed former and harvester, yield monitor on harvester. 2. Other machinery includes zonal tillage equipment, minimum till seed planter, minimum till cane planter. 3. Harvester modifications to accommodate wide rows (includes harvester front, automatic base cutter height control, roller train optimisation, and elevator extensions).	Machinery: 1. Standard wheel spacing and GPS Guidance (with variable rate screen) on all equipment, yield monitor on harvester. 2. Same as class B 3. Harvester and haulout modifications to accommodate wide rows (includes harvester front, automatic base cutter height control, roller train optimisation, automatic primary extractor fan speed control, elevator extensions, haulout GPS guidance and rear wheel steering)

Table 38 (p.56) Nutrient management practices for cane classified in the ABCD framework

D Class Cane Nutrient Management	**C Class Cane Nutrient Management**
Description: 1. One rate for whole farm 2. Application rates based on historic application rates or rules of thumb	Description: 1. Some soil testing 2. One or two rates for the whole farm 3. Application based on old industry recommendations
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Records kept in head	Planning and record keeping: 1. Conduct soil tests 2. Develop basic Nutrient Management Plan 3. Keep basic records
Machinery costs: 1. Surface or sub-surface fertiliser box	Machinery costs: 1. Subsurface fertiliser box, or surface applied and irrigated into soil
B Class Cane Nutrient Management	**A Class Cane Nutrient Management**
Description: 1. Soil test fallow blocks each year 2. Variable rate between blocks 3. Application rates based on latest industry recommendations taking mill by-products and fallow history into account 4. Timing nutrient applications with respect to crop stage, irrigation and rainfall	Description: 1. Soil test specific areas within fallow blocks and some ratoon blocks each year. 2. Some plant tissue testing 3. Variable rate within blocks 4. Application rates based on specialist interpretation of the latest industry recommendations taking mill by-products and fallow history into account 5. Timing nutrient applications with respect to crop stage, irrigation and rainfall
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Identify soil types/productivity zones for each block 2. Develop Nutrient Management Plan using yield, soil mapping and latest industry recommendations 3. Change fertiliser rates between blocks 4. Attend nutrient management training 5. Conduct soil tests (and leaf analysis if required) 6. Keep records (including timing, rates, product and yield) 7. Adjust nutrient rates for next year if required	Planning and record keeping: 1. Identify soil types/productivity zones within each block using GPS yield and soil mapping 2. Develop GPS based Nutrient Management Plan using yield, soil mapping and specialist interpretation of latest industry recommendations 3. Apply variable fertiliser rates within blocks 4 – 5. Same as Class B 6. Automated record keeping in computer database 7. Same as Class B
Machinery: 1. Variable rate application of granular sub-surface or liquid surface with manually controlled rate	Machinery: 1. Variable rate application of granular sub-surface or liquid surface with remote/automatic controlled rate and GPS guidance

Table 39 (p.58) Pesticide management practices for cane classified in the ABCD framework

D Class Cane Pesticide Management	**C Class Cane Pesticide Management**
Description: 1. One herbicide strategy for the whole farm based on historic application rates or rules of thumb 2. Often uses maximum label rate residual and knockdown products irrespective of weed pressure	Description: 1. One or two herbicide strategies for the whole farm 2. Often uses residual and knockdown products at rates appropriate to weed pressure
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Records kept in head	Planning and record keeping: 1. Develop basic Herbicide Management Plan 2. Keeps Material Safety Data Sheets (MSDSs) 3. Keep basic records
Machinery costs: 1. Standard spray rig both high and low clearance	Machinery costs: 1. Same as Class D
B Class Cane Pesticide Management	**A Class Cane Pesticide Management**
Description: 1. Implementation of new application technology for improved placement and timing to improve application efficiency, accuracy and to extend the window of opportunity 2. Knockdown herbicides replace residual herbicides where practical (strategic use of residual herbicides in fallow and plant cane to lower overall crop cycle herbicide application and help avoid resistance to knockdown herbicides) 3. Timing herbicide applications with respect to crop stage irrigation and rainfall 4. Variable herbicide strategies between blocks 5. Storage – lockable with bunding and emergency wash down facilities 6. Dispose of used herbicide containers in drum muster	Description: 1 – 3. Same as Class B 4. Variable herbicide strategies within blocks. 5–6. Same as Class B
Resource condition indicators (to be determined)	Resource condition indicators (to be determined)
Planning and record keeping: 1. Identify – weed types/pressure, soil types and productivity zones for each block 2. Develop Herbicide Management Plan using weed pressure, soil types, crop stage which focuses on good weed control in fallow and plant cane stages, and includes strategic residual herbicide use 3. Change herbicide strategy between blocks 4. Attend herbicide training including spray nozzle technology 5. Monitor weed pressure 6. Keeps Material Safety Data Sheets (MSDSs) and first aid procedures 7. Keep records (including wind speed, time of spraying, products and block rate) 8. Adjust herbicide strategy for next year if required	Planning and record keeping: 1. Identify – Weed types/pressure, soil types and productivity zones within each block using GPS weed survey and soil mapping 2. Develop GPS based Herbicide Management Plan using weed pressure, soil types, crop stage which focuses on good weed control in fallow and plant cane stages, and includes strategic residual herbicide use 3. Apply variable herbicide strategies within blocks 4 – 6. Same as Class B 7. Automated record keeping in computer database 8. Adjust herbicide strategy for whole of crop cycle
Machinery: 1. Hooded sprayers, more accurate nozzles (matched to job), multiple tank setups and high clearance tractors with manual rate control	Machinery: 1. Hooded sprayers, more accurate nozzles (matched to job), multiple tank setups and high clearance tractors with remote/ automatic rate control and GPS guidance with variable rate screen