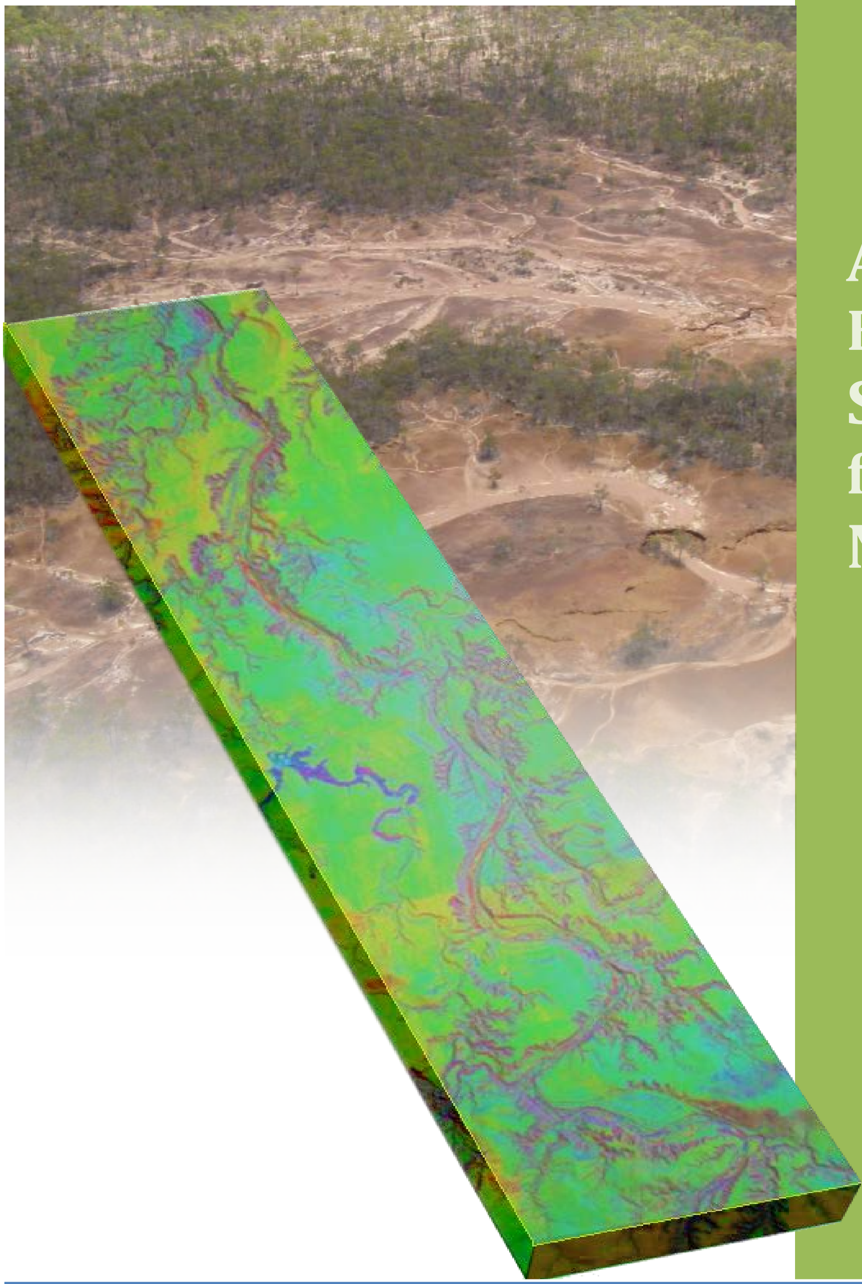

An Empirically-based Sediment Budget for the Normanby Basin

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Appendix 02: Literature Review – Water Quality and Quantity in the Normanby Basin

Griffith UNIVERSITY

CARING FOR OUR COUNTRY

Appendix to the Final Report prepared for the Australian Government's Caring for our Country - **Reef Rescue initiative**

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CAPE YORK WATER QUALITY

Appendix 02 Literature Review – Water Quality (Suspended Sediments and Turbidity) in the Normanby Catchment

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1. Water Quality Monitoring

The Australian Institute of Marine Science (AIMS) monitored wet season turbidity and water levels at Kalpowar Crossing between 1997–2000. The turbidity data was converted to total suspended sediments and has been utilised by AIMS to produce estimates of sediment loads discharging into Princess Charlotte Bay. A total of 29 nutrient and TSS samples were also collected during the 1999 and 2000 wet seasons as part of the AIMS monitoring program (Furnas, 2003).

The Queensland Department of Environment and Resource Management (DERM) has monitored water flow, suspended sediments and nutrient concentrations at Kalpowar Crossing since 2006 as part of the Great Barrier Reef Catchment Monitoring (GBR I5) program. DERM has also monitored a wide range of water quality parameters at gauging stations across the Catchment since the late 1960's, with extensive monitoring conducted through 1988. Monitoring has continued at select gauging stations on an irregular basis and now forms an extensive dataset.

Monthly monitoring of river water quality at 10 freshwater and estuary locations across the catchment was conducted by CYMAG Environmental Inc. between 2006– 2010 (Howley, 2010a).

2. Basic Water Chemistry

During the 2006 – 2010 CYMAG monitoring period, temperatures in the Laura & Normanby Rivers ranged from 19.6°C to 36.3°C. Salinity within the estuary ranged from 0.4 ppt during freshwater events to a maximum of 39.7 ppt measured at the end of the dry season. Salinity at freshwater sites ranged from 0.0 – 0.9 ppt, while conductivity ranged from 0.053 mS/cm – 1.715 mS/cm mS/cm. The Laura River generally had higher conductivity than the Normanby River, most likely due to saline soils. Estuary pH values ranged 7.06 to 8.17 and freshwater pH values ranged from 6.51 to 9.01. Laura–Normanby freshwater dissolved oxygen levels ranged from 36.5% – 166.6%, with median (year-round) values of 82.3% (Laura River) and 77.9 % (Normanby River). Dissolved oxygen levels below 50% were relatively common during the dry season periods of low flow and high algal growth (Howley, 2010b).

3. Turbidity/ Suspended Sediments

Monitoring by CYMAG measured maximum turbidity values of 258 NTU at Carroll's Crossing on the Laura River, 193 NTU at Broken Dam Station (Lakeland) and 168 NTU at Battle Camp Crossing on the Normanby River after heavy wet season rains in January 2010 and November 2008 (Howley, 2010b). Grab samples collected for this project during the 2010/2011 wet season floods recorded maximum turbidity and SSC levels of >1000 NTU (1013 mg/L) on the Laura River at Crocodile Station, 857 NTU (1064 mg/L) at Broken Dam Station and 204 NTU (121 mg/L) at the East Normanby River.

TSS concentrations measured by AIMS in the Normanby River (Kalpowar Crossing) during the wet season range from 50 mg/L to 300 mg/L, with a mean value of 108 mg/L. DERM wet season suspended sediment concentrations measured at Kalpowar Station between 2006- 2010 had a similar range (0.5 – 266 mg/L) and a mean value of 40 mg/L (DERM, unpublished data). The maximum concentrations are significantly lower than those from the Burdekin or Fitzroy rivers, which can range between 1 and 3 g/L at the peak of large flood events (Furnas, 2003). The Normanby data represent moderate flood event concentrations. Total suspended sediment concentrations measured by AIMS and DERM at Kalpowar Crossing are presented in Table 1.

Table 1 TSS Concentrations Measured by AIMS and DERM at the Normanby River, Kalpowar Crossing

Sampling Program		TSS (mg/l)
AIMS[1] 1999-2000 n=29	Min- Max	50- 300
	Mean	108
DERM[2] 2006- 2010 n = 155	Min- Max	0.5-266
	Mean	37

1. AIMS unpublished data (TSS), primarily wet season data
2. DERM unpublished data; primarily wet season data

4. Discharge to PCB and GBR

A number of published studies and reports have claimed that the Normanby is a significant exporter of sediments to the reefs due primarily to the size of the catchment and the volume of discharge. It has been ranked as having the third largest average annual discharge out of 35 rivers draining into the GBR (Furnas, 2003). Large GBR catchments such as the Normanby have high sediment loads due to the amount of discharge but generally generate the lowest yields per area of catchment (Joo et al., 2012b)

5. Sediment Loads Estimates

A number of loads estimates have been calculated for the Normanby based on the AIMS and DERM flood event monitoring data from Kalpowar Crossing and using SedNet/ ANNEX models. Sediment exports have also been calculated from the estimated accumulation of sediment in the coastal sediment wedge (Belperio, 1983). Discharge-export relationships derived from the AIMS monitoring data have been used to estimate sediment exports (Furnas, 2003). SedNet and the associated ANNEX models have been widely used to estimate loads from the Normanby river, and these modeled loads are cited as the current best estimates (Brodie et al 2003, McKergow et al, 2005, Kroon et al, 2010; Brodie et al 2010; Kroon et al, 2011).

More recently, Joo et al. (2012a) calculated Normanby River annual discharge loads from three years of flow, sediment monitoring data collected by DERM at Kalpowar Station. The annual suspended sediment loads for 2006/2007, 2007/2008 and 2008/2009 wet seasons ranged from 59 ktonnes to 211 ktonnes. These estimates are between 5 to 10 times less than the values estimated by SedNet. River discharge during the three monitoring years ranged from 1762 GL to 3646 GL, which represent low to average rainfall years.

Sediment loads calculated based on both AIMS and DERM monitoring data are significantly lower than those determined by the SedNet/Annex models. Significant error is however, associated with the empirical load estimates due to the fact that the Kalpowar gauge only represents around 50% of the total catchment area discharging into PCB, and it is not known what the loads are in the ungauged tributaries or what additional inputs there are downstream of Kalpowar. Furthermore, Wallace et al., (2012) estimated that the Kalpowar gauge on the Normanby is underestimating flows (and hence sediment load calculations) by at least 43% due to ungauged bypass flows. This is in addition to the ~50% of the catchment that is currently ungauged. So there is a huge potential disparity between sediment loads estimated from the Kalpowar gauge and what is actually exported from the four main rivers that discharge into PCB.

There has also been no accurate assessment of how much of the current load is caused by land-use change such as grazing, roads and horticulture. The SedNet model predictions (Brodie et al., 2003) of a 5 fold increase in sediment yield from the catchment in the post-European period is largely due to assumed differences in vegetation cover (i.e. the C Factor in the RUSLE model) and assumes that most of the sediment is sourced from hillslope erosion. The SedNet model predictions contrast markedly with the assessment of Furnas (2003), who states that "The largely dry Normanby River basin on Cape York Peninsula provides the best example of what sediment exports from dry catchments might have been like prior to 1850".

Sediment load estimates (both current and pre-European) from various studies are presented in Table 2.

Table 2 Sediment and Nutrient Loads Estimates for the Normanby River

Source	Estimate Method	Estimate time fram	TSS (kt/yr)
Belperio 1983[1]	Shelf sed accumulation	Current (80s)	2590
(NLWRA, 2001)[2]	Sednet/ Annex	Current	1620
		Pre-1850's	540
(Furnas, 2003)	Simple Model based on AIMS data	Current	500
(Brodie et al., 2003)	Sednet/ Annex	Current	1093
		Natural	184
(McKergow et al., 2005)	Sednet/ Annex (modified)	Current	1093
		Pre-1850	--
(Kroon et al., 2010)	Sednet/ Annex	Current best	1093
		Pre-1850	184
	LRE from DERM data w/ correction	Current estimate from limited data	137
(Brodie et al., 2010a)	Sednet/ Annex	Current Best estimate	1100[3]
	Flow weighted mean annual load[4]	2006/2007	166
(Kroon et al., 2012)	Survey of available estimates	Current	1100[3]
		Pre-1850	180
(Joo et al., 2012b) [5]		2006-2009 DERM data	59 to 211
DNRM 2012[6]	Source Catchments	1983-2009	620

1. Reported in Brodie et al., (2010b)
2. NLWRA 2001 *Australian Agriculture Assessment 2001* (www.anra.gov.au/topics/water/pubs/national/agriculture_basin_budgets.html
3. Brodie et al. (2003): some monitoring data validation
4. Values averaged from Brodie et al., (2003), and Furnas, (2003): little or no monitoring data validation, major assumptions made (Brodie et al., 2010b)
5. Calculated from 2006/2007 DERM monitoring data (Kalpowar Crossing)
6. Unpublished Source Catchments Model data 2012 (based on revised RUSLE values + the same bank and gully erosion data as used in Brodie et al., (2003).)

6. Sources of Suspended Sediments

Brodie et al. (2010b) determined that the current (i.e. 2009) best load estimate for Normanby River suspended sediments was 1100 k tonnes/annum; of which grazing land-use was estimated to contribute 1042 ktonnes/annum, with the remainder contributed from forested and “other” lands. Grazing was also the primary source of all particulate and dissolved nitrogen and phosphorous species; contributing between 82 to 97% of total nutrient loads. These source contributions were taken from the Brodie et al., (2003) SedNet/ ANNEX model calculations.

The disparity between the modelled sediment export estimates from the Normanby Basin, and the (significantly lower) empirical estimates of loads that have been made based on data collected at Kalpowar gauge (see Table 2), highlights some major data and knowledge gaps in this area. Filling these gaps and explaining the disparity between the modelled and empirical load estimates is central to determining the extent to which the Normanby represents a major threat to the reef and to coastal sea grass meadows.

Table 3 Predicted sediment input loads from gully, bank or hillslope erosion sources in the Normanby catchment based on the SedNet/Annex model predictions from Brodie et al. (2003). Note that the gully sources are of the hillslope or colluvial gully form. Note also that the total hillslope erosion value is the amount of sediment predicted by the RUSLE model to be transported off hillslopes before the HSDR is applied – which in this case is assumed to be 10%.

Normanby Sediment Budget Summary (Brodie et al., 2003)		
Source	Suspended Sed Inputs Kt/yr	Bed material Load Inputs Kt/yr
Colluvial gully	173	173
Bank	17.5	17.5
Total Hillslope	15,670	
Hillslope delivered	1,567	0
Total inputs	1,758	190.5
Storage	664	115
Export	1,094	76

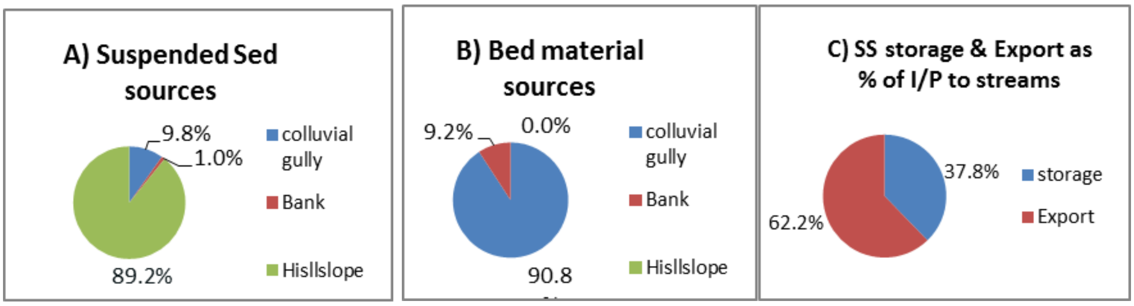

Figure 1 Predicted proportions of suspended and bed material load sediment sources based on the Brodie et al. (2003) SedNet/Annex modelling. Also shown is the predicted proportion of the total suspended load that is stored or exported from the system.

7. Estuary Sediment Transport & Axial Convergence

The Normanby estuary is relatively turbid throughout the year as a result of tidal re-suspension and possibly tidally driven bank erosion, with a median turbidity value of 31.3 NTU compared to a freshwater median of 7.8 NTU (Howley, 2010b). The overall contribution of this bank erosion to Normanby sediment budgets has not been quantified.

A well-developed axial convergence has been documented during flood tides in the Normanby River estuary between 5 and >40 km upstream of the mouth. Ridd et al. (1998) measured SSC, salinity, temperature and currents across vertical and horizontal profiles in order to document the effect of the axial convergence on sediment transport in the estuary under ambient conditions. Only small vertical salinity gradients (0.1 – 0.4 ppt) were present associated with the axial convergence. The highest salinities occurred in mid-stream and were typically 0·2 ppt greater than near the bank. Suspended sediment concentration (SSC) profiles were well-mixed both vertically and laterally, but SSC was generally slightly lower mid-stream than near the banks. The authors concluded that the convergence cells do not have a major influence on sediment transport processes (Ridd et al., 1998).

Bryce et al (1998) studied bedload sediment transport in the Normanby estuary. The tidal current data and estuary sand dune orientation in the main estuarine channel clearly indicated the dominant short- term and net long-term direction of bedload transport is landward. For the mid-estuary site, net landward transport of suspended sediment was calculated at around 1100 tonnes per spring-neap cycle, and 39,000 tonnes per dry season. They documented a lack of terrigenous sand in the lower estuary and adjacent inner shelf and concluded that medium and coarse sands have been trapped in the upper Normanby estuary. Wolanski et al. (1992) also concluded that net transport of fine sediment in the lower and mid-estuary was landward, driven by tidal processes.

Freshwater flood events appear to transport only a small amount of fine sands beyond the mouth of the river. The fine sand deposit seawards of the Normanby mouth has an area of 4.6 km^2. Normanby delta sediments consist of green-grey sandy marine muds, containing approximately 1% terrigenous sand (Bryce et al., 1998).

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Please also see main document, or visit the website: **http://www.capeyorkwaterquality.info**

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