Part 3: Jabiluka

Contents[1]

[1] List of papers grouped by Key Knowledge Need.

Monitoring sediment movement at Jabiluka

D Moliere, M Saynor & K Evans

Introduction

The Jabiluka uranium deposit is located in the catchment of Ngarradj (Swift) Creek in the wet-dry tropics of the Northern Territory, Australia (Fig 1). Ngarradj is a major downstream right-bank tributary of Magela Creek, which flows directly into the Magela Creek floodplain. The Ngarradj catchment will be the first to be affected should any impact occur as a result of mining operations at Jabiluka. In 1998 a stream gauging network was established to determine the pre-mining hydrological and suspended sediment transport characteristics of the Ngarradj catchment. Stream gauging stations were installed upstream (Upper Main – UM; East Tributary – ET) and downstream (Swift Creek – SC) (Fig 1) of Jabiluka (Erskine et al 2001).

Fine suspended-sediment[1] transport is monitored at the stations using field-calibrated turbidimeters. Moliere et al (2005, 2006a) has used an event-based Before-After-Control-Impact, paired difference design (BACIP) (Stewart-Oaten et al 1986, 1992, Humphrey et al 1995) approach for impact assessment using event mud loads derived from mud concentration data collected by the turbidimeter during 2003–04 and 2004–05. In this case, an event-based BACIP design where SC and the combination of UM and ET are treated as paired sites and the comparison of ratios is used to assess impact. Event load data collected during 2005–06 have now been added to the previous pool (Moliere et al 2005, 2006a) of BACIP analyses.

Progress to date

During the three year monitoring period (2003–06) there were 34 events with complete event load data collected at all three (SC, UM, ET) stations. The ratio of SC mud load to UM + ET mud load for these 34 events is not normally distributed and, therefore, we have used percentiles to assess the data. The events of 'interest' are those that lie greater than the 95th percentile of the mud load ratios because these are events where significantly elevated mud loads are measured at SC relative to the combined load at UM and ET. The event-based BACIP analysis indicates that only one such event has occurred throughout the three-year period (Fig 2).

The event that lies above the 95th percentile of the mud load ratios on Figure 2 occurred on 10 March 2006. Peak runoff associated with this event was the highest for 2005–06 at SC and UM (and fourth largest at ET) (Moliere et al 2006b). The total mud load for this event was 15% of the total annual load at SC and only 9% and 4% of the total annual load at UM and ET respectively. Hence, it is possible that the contribution of mud load at SC from the ungauged tributaries within the western part of the Ngarradj catchment may have been relatively high during this runoff event. This highlights the need to monitor flow and mud concentration on these western tributaries to better able to attribute source of elevated mud loads observed downstream of Jabiluka compared to the upstream stations, particularly if mining should proceed at Jabiluka.

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[1] Fine suspended-sediment is the mud (silt+clay) component of sediment transported in the water column, ie. that portion < 63 μm, > 0.45 μm diameter.

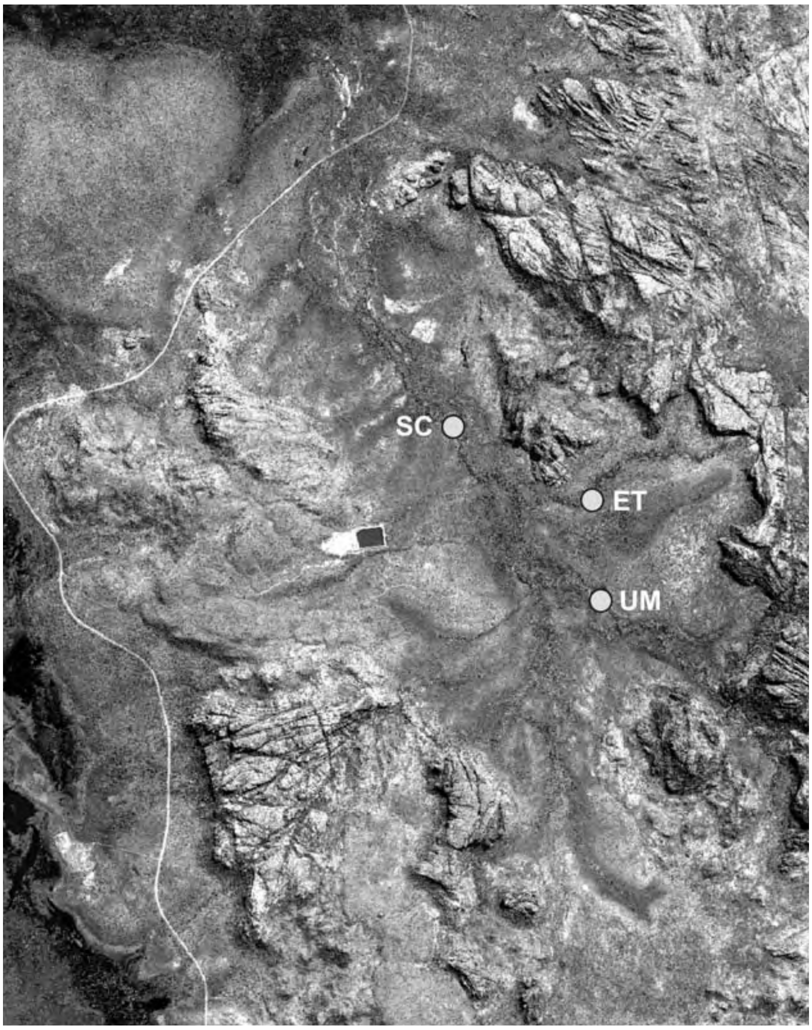

Figure 1 Location of gauging stations along Ngarradj

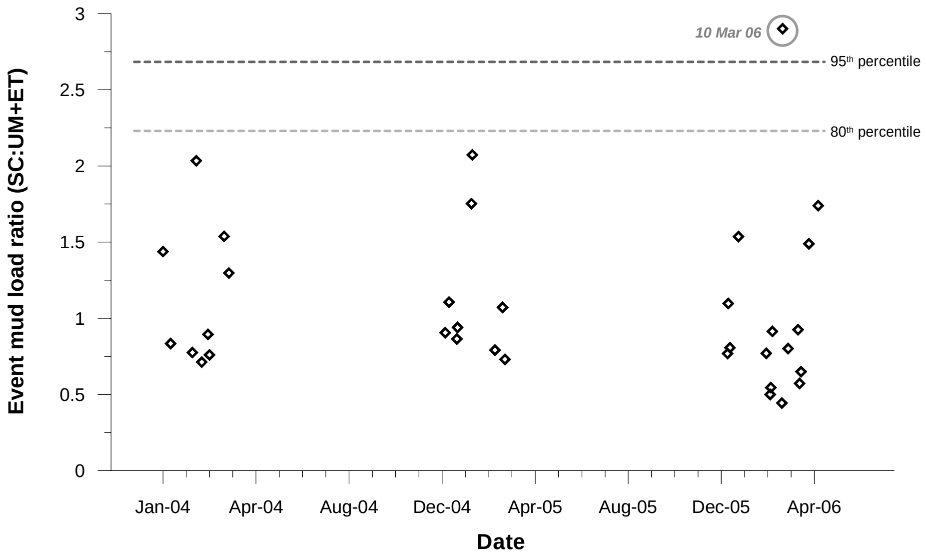

Figure 2 Temporal variation of the ratio of event mud loads measured at SC to that at UM and ET during 2003–04, 2004–05 and 2005–06 (indicated as◇). The 80th and 95th percentiles of the event mud load ratios are also shown.

Cyclone Monica

Cyclone Monica moved through the Ngarradj catchment early on 25 April 2006 (by this time it had reduced to a category 3 cyclone). Substantial tree fall occurred throughout the catchment as a result of this event, particularly the riparian vegetation along the Ngarradj channel (Moliere et al 2006b). As a result of the treefall, significant changes could occur to the hydrology, sediment transport and channel stability characteristics within the Ngarradj catchment compared with pre-cyclone conditions. These changes would occur as a result of (1) increased availability of sediment for erosion throughout the catchment as a result of treefall, and (2) a change in channel alignment and channel cross section as erosion around fallen trees occurs (particularly around root balls). It is essential that hydrology and sediment transport data are collected during the 2006-07 wet season to be in a better position to assess the changes to the catchment conditions as a result of the cyclone. If significant changes have occurred to the hydrology, sediment transport and channel stability characteristics, several more years of post-cyclone data may need to be collected within the catchment to revise the pre-mining catchment conditions.

References

ANZECC (Australian and New Zealand Environment and Conservation Council) & ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand) 2000. *Australian Guidelines for Water Quality Monitoring and Reporting*. National Water Quality Management Strategy, No. 7, Canberra. 6-17 to 6-21.

Erskine WD, Saynor MJ, Evans KG & Boggs GS 2001. Geomorphic research to determine the off-site impacts of the Jabiluka Mine on Swift (Ngarradj) Creek, Northern Territory. Supervising Scientist Report 158, Supervising Scientist, Darwin NT.

Humphrey CL, Faith DP & Dostine PL 1995. Baseline requirements for assessment of mining impact using biological monitoring. *Australian Journal of Ecology* 20, 150–166.

Moliere DR, Saynor MJ & Evans KG 2006a. Monitoring suspended sediment at Jabiluka: 2003–2005. In ***eriss** research summary 2004–2005*, eds Evans KG, Rovis-Hermann J, Webb A & Jones DR, Supervising Scientist Report 189, Supervising Scientist, Darwin NT, 127–129.

Moliere DR, Saynor MJ, Evans KG & Smith BL 2006b. Hydrology and suspended sediment of the Ngarradj catchment, Northern Territory: 2005–2006 wet season monitoring. Internal Report (in prep), Supervising Scientist, Darwin. Unpublished paper.

Moliere DR, Saynor MJ, Evans KG & Smith BL 2005. Hydrology and suspended sediment of the Ngarradj catchment, Northern Territory: 2004–2005 wet season monitoring. Internal Report 504, August, Supervising Scientist, Darwin. Unpublished paper.

Stewart-Oaten A, Murdoch WW & Parker KR 1986. Environmental impact assessment: ‘Pseudoreplication’ in time? *Ecology* 67, 929–940.

Stewart-Oaten A, Bence, JR & Osenberg CW 1992. Assessing effects of unreplicated perturbations: No simple solutions. *Ecology* 73, 1396–1404.

Stream bedload characterisation: Ngarradj catchment

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Introduction

A stream-monitoring program was implemented in the Ngarradj catchment in the late dry season of 1998 and prior to the 1998–1999 wet season (Erskine et al 2001). Rainfall, stream suspended mud concentration, suspended bedload, solutes, EC, turbidity and stream discharge data were collected for the wet seasons 1998–1999 to 2004–2005, inclusive. Transported bedload samples were collected for the wet seasons 1998–1999 to 2001–2002, inclusive. The data have allowed (1) determination of baseline characteristics for the measured sediment parameters in the catchment and (2) assessment of impact on water quality resulting from construction of the Jabiluka project site site. The work discussed here focuses on water, solute and sediment yields for the East Tributary catchment (Figure 1).

Progress to date

East Tributary is a small sand-bed stream which is a right bank tributary of Ngarradj Creek. The total catchment area of East Tributary is 10.3 km^2, of which 8.5 km^2 drains to the gauging station. The gauging station is located in the Forested Meandering Reach (Erskine et al 2001), of the Tributary. This is characterised by a sinuous planform (sinuosity > 1.5) and by steep, well-vegetated banks (monsoonal vine forest dominated by *Allosyncarpia ternata*). The East Tributary gauging station is fitted with a stilling well, an optical shaft encoder and pressure transducer, data logger, stage-activated automatic pump sampler (APS) with a fixed level inlet, rain gauge and gauging wire. Data have been collected for the 7 wet seasons between late 1998 and mid-2005.

Water samples collected by the APS were downloaded on a weekly or fortnightly basis. The water samples were processed in the ***eriss*** laboratory using standard sediment filtering and water chemistry techniques after Eaton et al (1995) and described in Evans et al. (2004). Parameters measured included concentration of sand (> 63 μm diameter); mud or silt and clay (< 63 μm and > 0.45 μm diameter) and solutes (< 0.45 μm diameter). The lower limit of detection for mud concentration was 3 mg/L (Evans et al 2004). Bed-load transport samples were collected by a Helley-Smith bedload sampler for most of the times the site was visited to download data.

Rainfall is highly seasonal in the East Tributary catchment with monthly totals greater than 150 mm being recorded at the peak of the wet season between December and March. During the period of this study rainfall normally commenced in October and persisted until April/May (Table 1). Mean and median monthly values are generally similar for the 7 years of data reported here. As a consequence of the distinct wet season period, streamflow is also highly seasonal.

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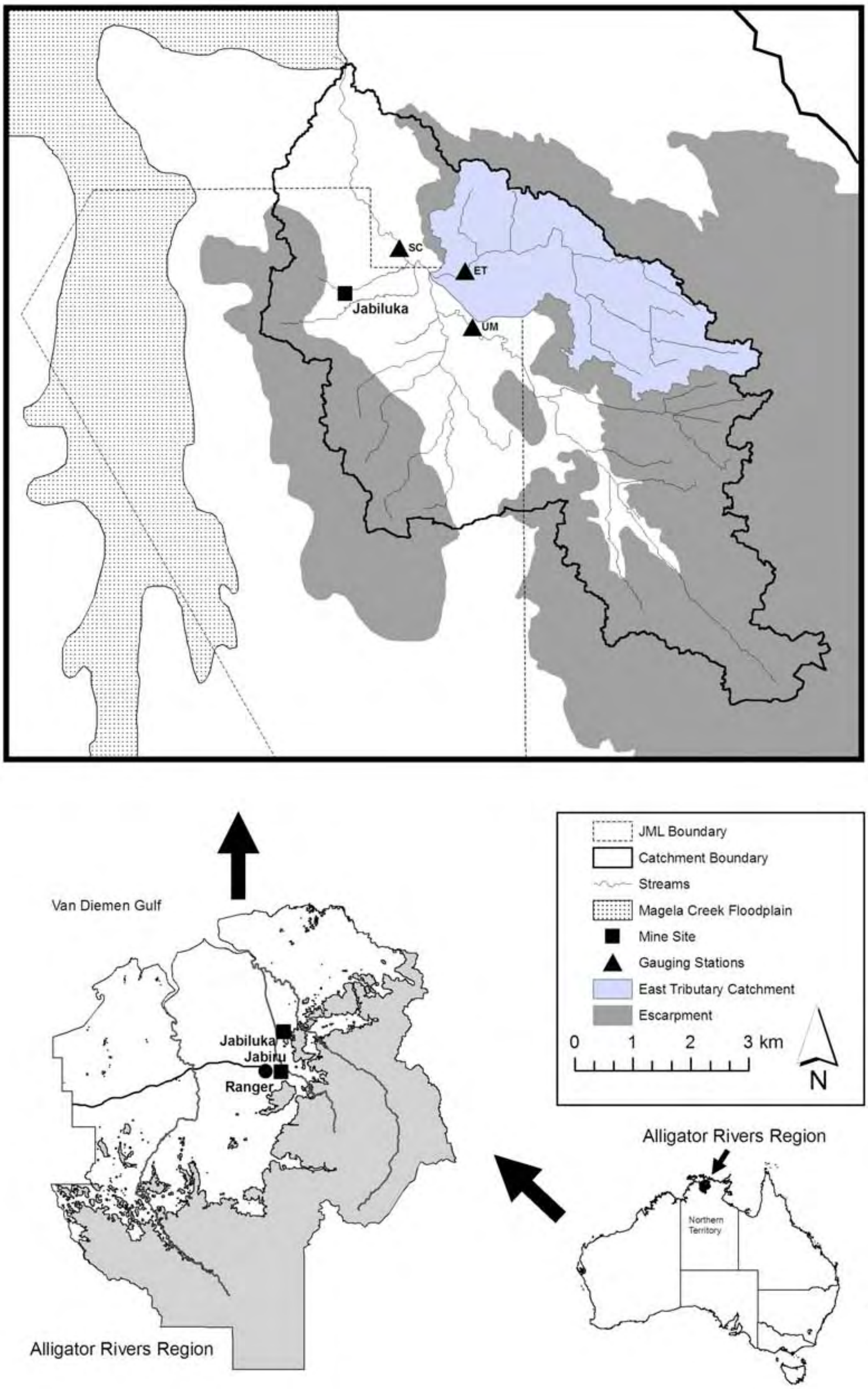

Figure 1 Location of the East Tributary gauging station in northern Australia

On average, flow occurs for approximately 6 months of the year (December to May). Mean annual rainfall (Sept to Aug) was 1662.9 ± 106.2 mm and varied between 1352.8 (2004–05) and 2069.6 mm (1999–2000). Additional rain gauges could not be installed in the upper catchment because the traditional owners valued its cultural significance and did not want any disturbance associated with site visits.

Table 1 Rainfall and runoff from East Tributary catchment for the 7-year study period (1998 to 2005)

Year	Total rainfall (mm) [ARI (y)]	Rainfall period	Antecedent rainfall (mm)	Runoff period	Total runoff (ML) [Peak discharge (m^3s^{-1})]
1998/99	1733.6 [7.5]	20 Sep – 28 Apr	415	9 Dec – 27 May	7621 [8.5]
1999/00	2069.6 [83.3]	14 Oct – 24 May	280	20 Nov – 25 Jun	8532 [8.1]
2000/01	1891.4 [20.4]	14 Oct – 27 Apr	245	28 Nov – 21 May	8275 [8.2]
2001/02	1372.2 [1.8]	17 Oct – 14 Apr	330	28 Dec – 25 Apr	3963 [8.3]
2002/03	1789.8 [10.4]	13 Sep – 1 May	355	1 Jan – 7 May	7249 [8.2]
2003/04	1430.8 [2.1}	7 Oct – 31 May	190	21 Dec – 8 May	5605 [7.8]
2004/05	1352.8 [1.7]	20 Nov – 22 Apr	239	23 Dec – 10 May	4712 [9.0]

Mean annual runoff was 6565 ± 681 ML or 776 ± 81 mm for the 7-year study period. Annual runoff was significantly related to annual rainfall, with, on average, 46.0 ± 0.02% of rainfall being converted to runoff each wet season. Given that there were no rain gauges on the higher elevation Arnhem Land plateau, it is likely that the single rain gauge at the gauging station underestimates catchment rainfall. Therefore, it is likely that no more than 46% of rainfall is converted to runoff. The actual value may be slightly less because rainfall is likely to be greater over the Arnhem Land plateau.

Bankfull discharge occurred at least once during each wet season (Moliere et al 2002). Table 1 shows the peak instantaneous discharge during each wet season and the range (7.8–9.0 m^3/s) is clearly small by southern Australian standards. During the dry season, all channels ceased flowing and the water table dropped to at least 0.5 m below the river bed (Saynor et al 2004).

Solute concentrations were only determined for 2000–01 and 2001–02 wet seasons when a total of 463 water samples were analysed (Evans et al 2004). Mean annual solute yield for 2000 to 2002 was calculated as 118 ± 39 t/yr using method 14 of Phillips et al (1999).

Concentrations of mud (silt and clay) were relatively low between 1998 and 2002 with 339 samples being less than the lower limit of detection of 3 mg/L (Evans et al 2004). The total number of suspended sediment samples analysed for mud concentration was 1340. For the first two wet seasons (1998–99 and 1999–2000), mud concentrations remained constant, decreased in 2000–01 and increased in 2001–02.

Erskine et al (2006) calculated bedload yields by nine different methods for the period 1998–2005. The most reliable bedload rating (based on data from for 52 double traverses)was found to be produced by a least squares linear regression equation of mean bedload flux (Qs) against the mean stream discharge (Q) occurring when the bedload gauging was being done:

$$Qs = 119.38\ Q - 26.604 \qquad (1)$$

The F ratio was 137.11 which has a $\rho < 0.0001$, an adjusted $R^2 = 0.727$ and a standard error = 38.33 g/s. The most reliable estimate of mean annual bedload yield obtained using the above rating was 550 ± 60 t/yr (Erskine et al 2006).

The total terrigenous yield is the sum of the solute, suspended mud, suspended sand and bedload yields and equals 1282 t/yr or 151 t/km^2.yr. The dominant fraction (80.8%) is sand (suspended sand and bedload). Using a bulk density of 1.43 t/m^3 for the Koolpinyah Surface the yield translates to a denudation rate of 0.11 mm/yr. Erskine and Saynor (2000) reported a range of denudation rates for natural or rehabilitated sites in the region of 0.01–1.25 mm/yr and in more recent studies at Tin Camp Creek near Nabarlek, Hancock (pers comm 2007) measured a hillslope denudation rate of 0.46–0.58 mm/yr using ^{137}Cs and 0.98 mm/yr using erosion pins. If a sediment delivery factor of 0.25 is applied to East Tributary then hillslope denudation is 0.42 mm/yr. There is good comparison between the stream sediment transport methods for determining catchment yield presented in this study and hillslope studies in the region which provides good validation of the stream sediment transport methods.

Additional work

Data have been analysed for each of the three gauging stations and two papers (both on East Tributary) prepared for presentation at the 30th Hydrology and Water Resources Symposium, 4–7 December 2006 Launceston, Tasmania.

- Bedload transport, yield and grain size in a seasonal tropical river in northern Australia, WD Erskine, MJ Saynor, DR Moliere & KG Evans
- Water, solute and sediment yields for a seasonal tropical river in northern Australia, MJ Saynor, WD Erskine, DR Moliere & KG Evans

The written papers are independently refereed prior to publication in the conference proceedings.

Analysis is continuing on the data obtained from the other two ***eriss*** gauging stations in the catchment of Ngarradj Creek. It is expected that findings from all three gauging stations will be produced as a Supervising Scientist report and a journal paper.

References

Eaton AD, Clesceri LS & Greenberg AE (eds) 1995. *Standard methods for the examination of water and wastewater*. American Public Health Association, Washington, DC 20005.

Erskine WD & Saynor MJ 2000. *Assessment of the off-site geomorphic impacts of uranium mining on Magela Creek, Northern Territory, Australia*. Supervising Scientist Report 156, Supervising Scientist, Darwin.

Erskine WD, Saynor MJ, Evans KG & Boggs GS 2001. *Geomorphic research to determine the off-site impacts of the Jabiluka Mine on Swift (Ngarradj) Creek, Northern Territory*. Supervising Scientist Report 158, Supervising Scientist, Darwin.

Erskine WD, Saynor MJ, Moliere DR & Evans KG 2006. Bedload transport, yield and grain size in a seasonal tropical river in northern Australia. Paper presented at 30th Hydrology and Water Resources Symposium, 4–7 December 2006, Launceston, Tasmania.

Evans KG, Moliere DR, Saynor MJ, Erskine WD & Bellio MG 2004. Baseline suspended-*sediment, solute, EC and turbidity characteristics for the Ngarradj catchment, Northern Territory, and the impact of mine construction*. Supervising Scientist Report 179, Supervising Scientist, Darwin NT.

Moliere DR, Boggs GS, Evans KG, Saynor MJ & Erskine WD 2002. *Baseline hydrology characteristics of the Ngarradj catchment, Northern Territory*. Supervising Scientist Report 172, Supervising Scientist, Darwin NT.

Phillips JM, Webb BW, Walling DE & Leeks GJL 1999. Estimating the suspended sediment loads of rivers in the LOIS study area using infrequent samples. *Hydrological Processes* 13, 1035–1050.

Saynor MJ, Erskine WD & Evans KG 2004. *Cross-sectional and scour and fill changes in the Ngarradj catchment between 1998 and 2003*. Supervising Scientist Report 181, Supervising Scientist, Darwin NT.

Additional references

Saynor MJ, Smith BL & Erskine WD 2005. Wet season bed-material particle size distribution and statistics for Swift Creek (Ngarradj) catchment between 1998 and 2002. Internal Report 509, September, Supervising Scientist, Darwin. Unpublished paper.

Saynor MJ, Erskine WD & Evans KG 2006. *Bed-material grain size changes in the Ngarradj Creek catchment between 1998 and 2003*. Supervising Scientist Report 188, Supervising Scientist, Darwin NT.