



Scour and fill

in the Swift Creek

(Ngarradj) catchment

Results of scour chains for the
1998/1999, 1999/2000 and
2000/2001 Wet seasons

Saynor MJ, Erskine WD,
Smith BL, Fox GJ & Evans KG
July 2002



SCOUR AND FILL IN THE SWIFT CREEK (NGARRADJ) CATCHMENT: RESULTS OF SCOUR CHAINS FOR THE 1998/1999, 1999/2000 AND 2000/2001 WET SEASONS

**MJ Saynor^{1,2}, WD Erskine^{3,4}, BL Smith¹,
GJ Fox¹ & KG Evans¹**

1 Hydrological and Ecological Processes
Environmental Research Institute of the Supervising Scientist
Supervising Scientist Division
GPO Box 461
Darwin NT 0801

2 Department of Geography
University of Western Australia
Nedlands WA 6907

3 Office of the Supervising Scientist
Supervising Scientist Division
GPO Box 461
Darwin NT 0801

4 Division of Geography
School of Geosciences
University of Sydney
Sydney NSW 2006

July 2002



Contents

1 Introduction	1
2 Methods	4
2.1 Scour chains	4
2.2 Chain installation	4
2.3 Annual relocation and reinstallation of scour chains	7
2.4 Scour and fill calculations	8
3 Results	9
3.1 Tributary North	9
3.2 Tributary Central	15
3.3 East Tributary	20
3.4 Upper Swift Creek	27
3.5 Swift Creek	35
4 Scour and fill in the Swift Creek catchment	48
5 Conclusions and recommendations	49
6 References	50

Figures

Figure 1 The Swift Creek catchment showing the Jabiluka Mineral Lease, gauging stations and local creek names	3
Figure 2 Diagrammatic representation of the full range of scour chain behaviour when there was net scour depicted by the middle option in figure 3	5
Figure 3 Three options of net channel bed change during the Wet season detected by scour chains	6
Figure 4 Location of the cross sections on Tributary North	9
Figure 5 Scour Chain at TN02 on 24 October 2000	10
Figure 6 Scour Chain at TN07 on 13 November 2001	12
Figure 7 Scour Chain at TN09–1 on 24 October 2000	14
Figure 8 Location of cross sections on Tributary Central	16

Figure 9 Tributary Central cross section 11 (TC11) looking upstream in 1998, showing a low cambered point bar on the left bank or the right side of the plate	18
Figure 10 Tributary Central cross section 11 (TC11) looking upstream in 2001 showing the high cambered sandy point bar that had accreted markedly during 2000/2001 Wet season	18
Figure 11 Upstream-directed scour chain at TC03 on 24 October 2000	19
Figure 12 Location of the cross sections in the East Tributary gauging reach	20
Figure 13 Scour chain at ET01 on 23 October 2000	21
Figure 14 Scour chain at ET01 (2000) directed towards the left bank	23
Figure 15 Scour chain at ET07 angled downstream in 1999	24
Figure 16 Scour chain at ET08 (1999) pointing upstream	25
Figure 17 Location of the cross sections in the Upper Swift Creek gauging reach	27
Figure 18 Scour Chain UM02–1 (2000) pointing towards the left bank	28
Figure 19 Horizontal links of the scour chain at UM02–2 (2 November 1999)	29
Figure 20 Scour Chain UM05–1 (1999)	30
Figure 21 Scour Chain UM05–1 (2001)	31
Figure 22 Scour Chain UM07 (2000)	33
Figure 23 Location of the cross sections in the Swift Creek gauging reach	35
Figure 24 Scour chain SM05–1 (1999)	36
Figure 25 Scour chain SM05–2 had been totally dislodged during the 1998/1999 Wet season	38
Figure 26 Scour chain SM05–3 (2000)	38
Figure 27 Plastic scour chain at SM05–P2 (2000)	40
Figure 28 Scour chain SM02–3 (2000)	42
Figure 29 Plastic scour chain SM02–P2 (2000)	43
Figure 30 Scour Chain SM08–1 (2000)	44

Tables

Table 1 Number of scour chains installed in each river reach	7
Table 2 Scour and fill on Tributary North	15
Table 3 Scour and fill on Tributary Central	19
Table 4 Scour and fill at the East Tributary gauging station	26

Table 5 Scour and fill in Upper Swift Creek	34
Table 6 Scour and fill in Swift Creek	47
Table 7 Mean values of net change in scour (negative values) and fill (positive values) and the standard error of estimate for each reach in which scour chain measurements were made for each Wet season	48

Scour and fill in the Swift Creek (Ngarradj) catchment: Results of scour chains for the 1998/1999, 1999/2000 and 2000/2001 Wet seasons

MJ Saynor, WD Erskine, BL Smith, GJ Fox & KG Evans

1 Introduction

Initial field inspections were conducted in the Swift Creek (Ngarradj¹) catchment during the Dry season of 1998 (September) to identify reaches in which channel erosion rates could be measured as part of a sediment budget to determine the possible effects of the Jabiluka mine on sediment generation, storage and transport rates (Saynor 2000, Erskine et al 2001). Swift Creek is a sand-bed stream which, in some reaches, is highly sinuous. During the field observations, various fluvial erosion processes were identified (Erskine et al 2001) with one of these being scour and fill of the sandy creek beds. Bedforms such as dunes, sand sheets, point bars and scour holes were present at the time of the inspection, when the creeks were completely dry and indicated that scour and fill were active processes during the Wet season. To measure this scour and fill, scour chains were recommended for installation in the creeks (Saynor 2000, Erskine et al 2001).

Following the initial field reconnaissance, three gauging stations were installed in the Ngarradi catchment (figure 1) during November 1998 at the following sites:

- The main channel of Ngarradj upstream of all mine influences (herein called Upper Swift Creek — UM).
- The main channel of Ngarradj (herein called Swift Creek — SC) downstream of the Jabiluka mine and downstream of the junction of the tributaries on both the right and left banks between the two gauging stations on Swift Creek.
- The main right bank tributary (herein called East Tributary — ET) that flows into Swift Creek between the upstream and downstream gauging stations on Swift Creek. There is no mining activity in this catchment.

These three gauging stations were installed to measure rainfall, stream height, turbidity, pH and electrical conductivity at 6 minute intervals (Saynor et al 2001a, Erskine et al 2001). In addition, suspended sediment and bed load transport are also measured less frequently at the same sites (Saynor 2000, Erskine et al 2001).

There are three smaller left bank tributaries, Tributaries North, Central and South, between the two gauging stations, UM and SC, on Swift Creek. The Jabiluka mine is located in the catchments of Tributary North and Tributary Central and the mining company installed

¹ The name Swift Creek is used in this report for the river that drains the catchment in which the Jabiluka Mine is located and that flows into the Magela Creek wetlands. Ngarradj is the Aboriginal name for this stream system. The full term is Ngarradj Warde Djobkeng and is the site where the cockatoo vomited on and split the rocks to form the creek known as Ngarradj. It is one of several dreaming (Djang) sites on or adjacent to the Jabiluka mine lease (A Ralph, Gundjehmi Aboriginal Corporation, 2001).

gauging stations on these streams for the 1998/99 Wet season. Figure 1 shows the location of the gauging stations and the various tributaries in the Swift Creek catchment. Tributary West is the largest of the left bank tributaries, draining the southern part of the catchment and has a discontinuous channel with large swampy areas. Additional information about the nature of the creeks is contained in Erskine et al (2001).

Erskine et al (2001, p4) made various recommendations for determining the physical impacts of uranium mining on the channel network of Swift Creek, with one of these being the 'Installation of scour chains in each gauging station reach as well as in the mine site tributaries, to determine the maximum depth of bed scour or reworking of channel-bed sediments during each Wet season.'

To gain an understanding of baseline conditions in the Swift Creek catchment it is important to determine what the present rates of erosion are within the various reaches of the Swift Creek catchment. This has been done using a combination of techniques including:

- the repeated measurement of the amount of exposure of erosion pins,
- the installation and resurvey of permanently marked cross sections, and
- installation and re-excavation of scour chains during each Dry season (Saynor 2000, Saynor et al 2001b, 2002, Erskine et al 2001).

The work reported here refers to the third dot point above, the amount of scour and fill that occurs during each Wet season as determined by scour chains using the methods of Emmett (1965) and Leopold et al (1966). Other channel erosion issues in the Swift Creek catchment are discussed in a series of internal reports (for example, Saynor 2000, Saynor et al 2001b, 2002). Erskine et al (2001) recommended that all projects should be reviewed after three years to assess the impact of the mine and to determine whether any of the projects should continue. The present report presents the results of this review.

Changes in river bed elevation during the passage of a flood are commonly called scour and fill (Lane & Borland 1954, Colby 1964, Andrews 1979). Scour refers to the erosion of the river bed and the consequent lowering of bed levels to below their pre-flood position. Fill refers to the deposition of sediment on the river bed and the consequent raising of bed levels to above the position eroded by scour during a flood. At Swift Creek, in the seasonally wet tropics, only maximum scour depth and subsequent fill during a Wet season can be measured. Stream bed inundation prevents excavation between flood events during each Wet season. Roberts (1991) also used scour chains to measure scour and fill during the 1986/1987 Wet season at two sites on the anabranching Magela Creek near gauging station 8210009. The mean scour depth was 239 mm which approximately equalled the mean fill depth of 247 mm. Roberts (1991) interpreted scour as being related to one-half of the maximum dune amplitude.

It is essential to determine depths of scour and fill on the rivers draining the Jabiluka mine site because sandy sediment generated on the mine site will be first stored temporarily in the downstream channels (Erskine et al 2001). There is also a conflict in the literature as to the nature of scour and fill. Some researchers maintain that flood scour is very localised and matched by simultaneous fill elsewhere (for example, Lane & Borland 1954, Colby 1964). Others maintain that scour and subsequent fill occur simultaneously throughout long reaches of river and involve large volumes of sediment (Emmett & Leopold 1963). Ariizumi & Kondo (1963) used a density meter of a gamma-ray back-scattering type to determine that scour occurred on the rising limb of the flood hydrograph and fill on the recession. The fill material had a low density that increased over time as it compacted. The dynamics of scour and fill during the Wet season at each gauging station have also been measured and will be reported subsequently to complement this report.

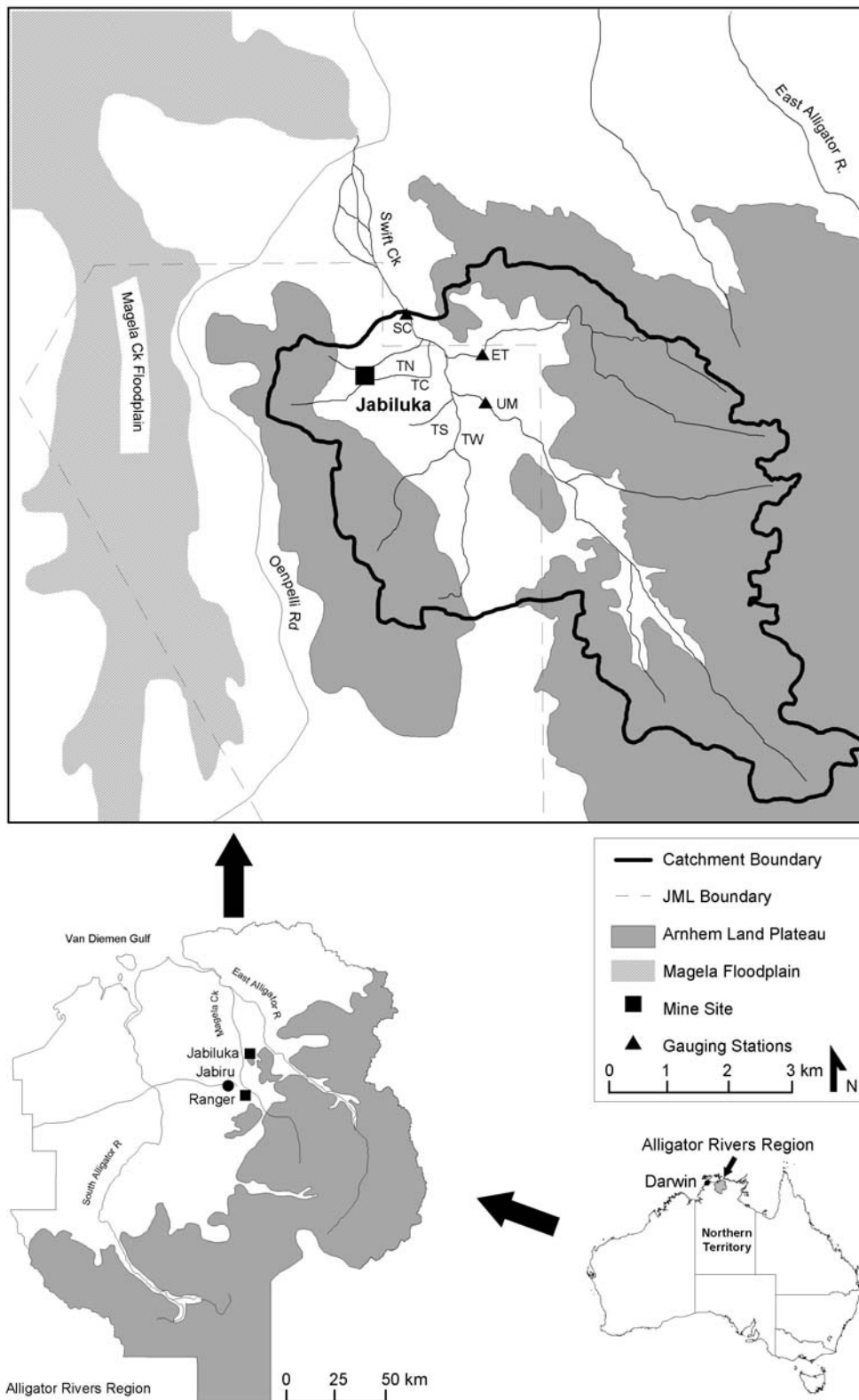


Figure 1 The Swift Creek catchment showing the Jabiluka Mineral Lease, gauging stations and local creek names. SC refers to Swift Creek gauging station, TN Tributary North, ET East Tributary gauging station, TC Tributary Central, TS Tributary South, TW Tributary West and UM Upper Swift Creek gauging station.

2 Methods

During each Wet season, the various grain size fractions of the bed material of Swift Creek and its tributaries are reworked and transported downstream at various rates to a number of sediment storages. Although the bed-material fluxes have been measured during the Wet season (Erskine et al 2001), it is also important to know the depth to which the bed is scoured and/or aggraded each Wet season. Repeated surveys of permanently marked cross sections, as reported by Saynor et al (2001b, 2002), only measure the net change between successive Wet seasons. The actual depths of scour and fill during the Wet season are usually much greater. Furthermore, the channels will be one of the first temporary stores to receive sediment, if any is generated by mining activities (Erskine et al 2001).

2.1 Scour chains

Depths of scour and fill can be determined using scour chains and are described by Emmett & Leopold (1963) and Emmett (1965). Scour chains (interlocked metal chains placed vertically into the bed sediment during the Dry season) are the best means of measuring total scour depths (Emmett & Leopold 1963, Emmett 1965, Leopold et al 1966). These chains were installed in various reaches of the Swift Creek catchment (Saynor et al 2001b), as outlined below. After single or multiple flow events, the elevation of the streambed is resurveyed and the bed is excavated until the chain is exposed. If scour has occurred, a part of the chain will be lying horizontally (figure 2). The difference between the existing bed elevation and the horizontal chain is the depth of fill (figure 2). If no scour has occurred, the amount of fill is the depth of sediment above the top of the buried chain. If the amount of fill equals the scour then there will be no net change in bed level although scour and fill have occurred.

Some shortcomings of chains according to Emmett and Leopold (1963) and Emmett (1965) are:

- that the timing of scour and fill at a chain is unknown; and
- that the synchronicity of scour and fill between chains is unknown.

Foley (1978) reported that laboratory flume experiments showed that scour chains will fall straight downstream (figure 2) when exposed by scour only during flows in the upper flow regime (ie flow was supercritical or the Froude Number was > 1). Chains exposed by the downstream migration of small and large scale ripples become tangled by secondary flows and separation envelopes in the trough between successive ripples. As a result, chains are rarely found lying horizontal but are more commonly inclined downstream or occasionally inclined upstream.

2.2 Chain installation

To install the scour chains, a plastic collar either 0.17 m or 0.32 m long was used at the top of the hole to prevent the dry sand from filling the auger hole as it was being excavated. Generally the auger was able to retain the sand until the water table was reached. The water table was typically at a depth of 1 m by November of each year. However, at East Tributary, the auger retained samples to depths of 2.5 to 3.0 m, due to the higher clay content. The material that was excavated from the auger hole was placed in sequence on a plastic sheet. This was described briefly in the field in terms of sand size and colour. Where one could be confident that the same layer was present in terms of these properties, the collected sample was bulked. Samples were bagged, labelled and transported back to *eriss* for further analyses. More detailed laboratory analyses according to the methods recommended by McDonald and Isbell (1990) will be conducted at a later date.

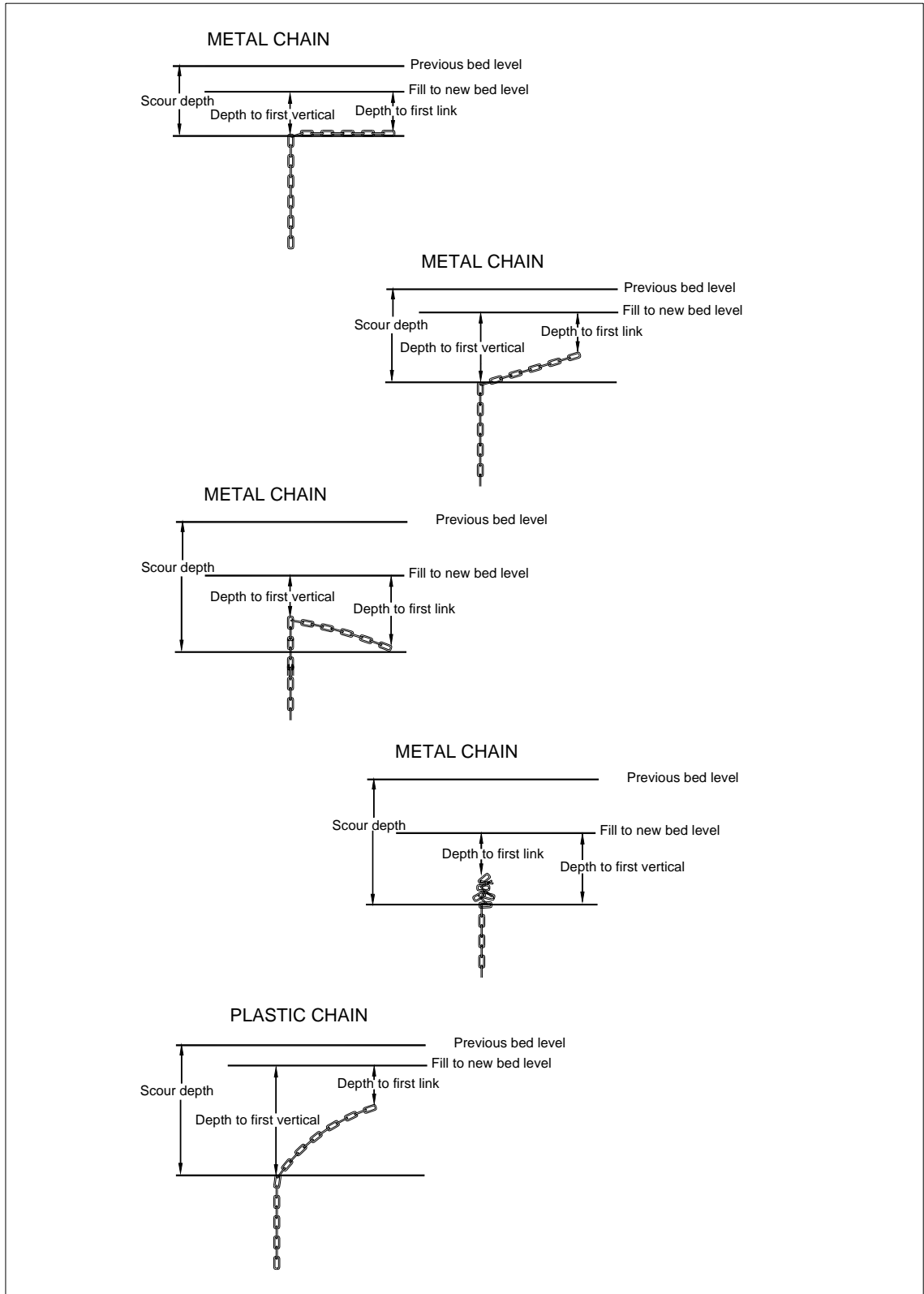


Figure 2 Diagrammatic representation of the full range of scour chain behaviour when there was net scour depicted by the middle option in figure 3 (over page). Net fill is shown by the top option in figure 3 and no change, by the lower option in figure 3.

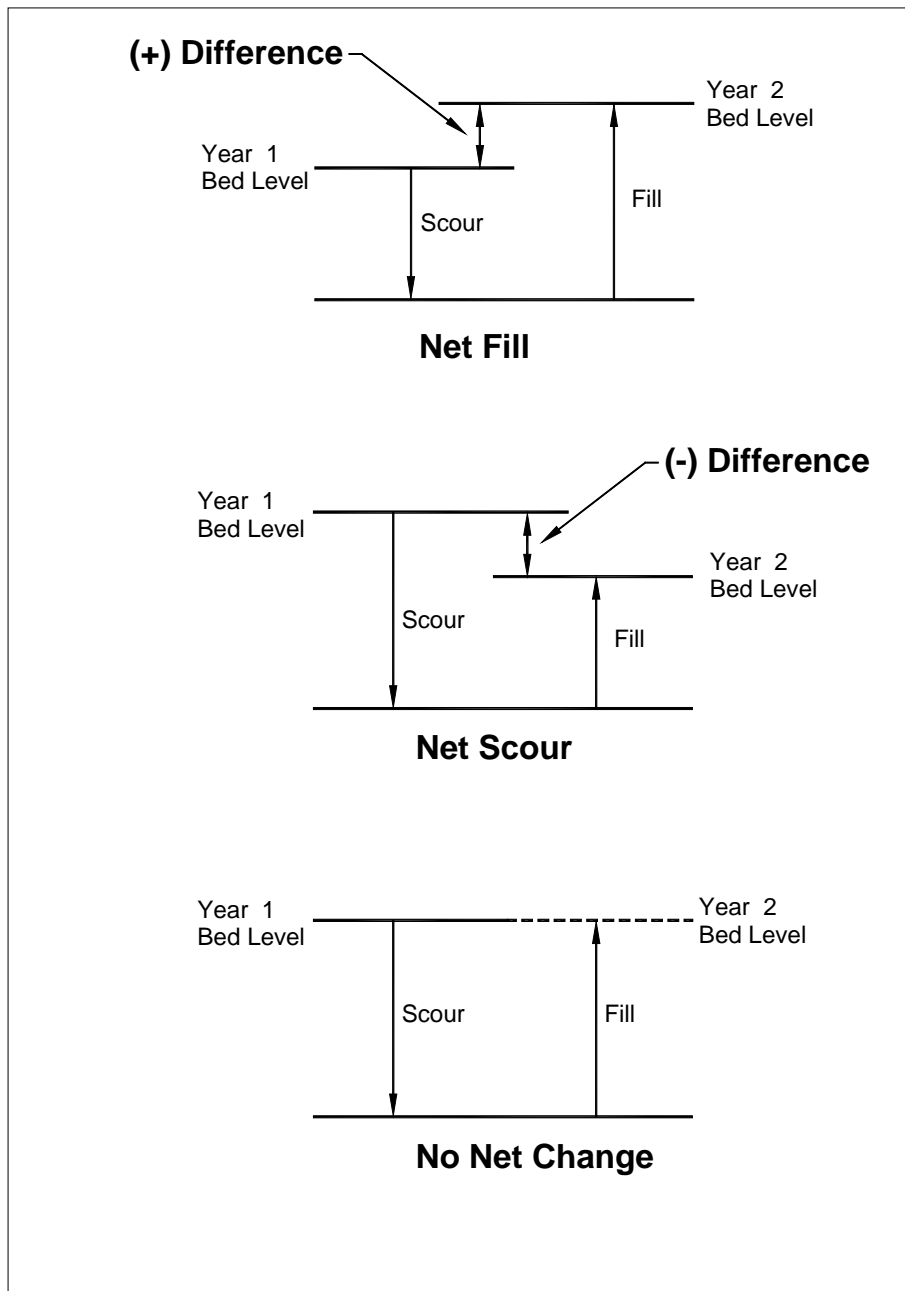


Figure 3 Three options of net channel bed change during the Wet season detected by scour chains. Net fill occurs when the bed level for the 2nd year is higher than for the 1st (top). Net scour occurs when the bed level for the 2nd year is lower than for the 1st (middle). No net change occurs when the bed level for the 1st and 2nd years is the same (bottom).

When there was no recovery from the auger hole due to bedrock refusal or saturation, a scour chain was installed. Six mm metal galvanised chain was used and was cut to a length determined by the depth of the hole so that all the links remained vertical. The chain was then carefully lowered into the hole and held at the top of the excavated hole by a long steel rod. A length of string was tied to the top link to prevent the chain from dropping down the hole which was then carefully backfilled with the material from the auger hole and compacted to try and ensure that the chains were held firmly in place. A 0.5–0.6 m length of bright orange flagging tape was tied to the top link to assist with the relocation of the chain after the Wet season. The location of each scour chain was precisely measured. A diagram was constructed

of the location and distances to the chains from recovery marks and were recorded as shown in Saynor et al (2001b). The top of the chain is the zero datum for the measurements taken during the following Wet season.

Scour chains were originally installed in each gauging station reach and on Tributary Central. The onset of flow during December 1998 prevented the installation of more chains. However, additional chains were installed in Swift Creek and Tributary North at the end of the 1999 Dry season. On Swift Creek, an additional cross section (SM02) had scour chains installed during the 1999 Dry season. Plastic scour chains were installed on each of the three measured sections at the Swift Creek gauging stations in 1999 as an experiment to see if they behaved the same as the metal chains. Scour chains were also installed on Tributary North in 1999. In Tributaries North and Central the channel was only wide enough to install one scour chain in the channel bed. Table 1 contains information on the number and timing of scour chains installed in each reach and a diagram showing their location is included at the beginning of each result section.

Table 1 Number of scour chains installed in each river reach

Location	No. of cross sections with scour chains	Year of initial installation	Total number of scour chains in each reach
Swift Creek	3	1998 and 1999	15
East Tributary	4	1998	5
Upper Swift Creek	3	1998	6
Tributary North	5	1999	7
Tributary Central	3	1998 and 1999	3

Emmett and Leopold (1963) and Emmett (1965) refer to occasional ‘chain sagging’ into the initial excavated hole. Chain sagging was observed at several sites after the first Wet season (1998/99). In the Swift Creek catchment chain sagging occurred when the auger holes were deep (in excess of 1m) and passed through clayey sand into white kaolinitic clay. When the chain had been installed it was difficult to completely fill the hole and, as a result, the chain collapsed into the auger hole due to poor compaction. This was a problem at sites on East Tributary and Tributary Central and did not occur after the first year once experience had been gained with the technique. Where sagging occurred, the values are not used in the calculations of scour and fill.

2.3 Annual relocation and reinstallation of scour chains

Late in each Dry season, the scour chains were relocated using the diagrams and measurements in Saynor et al (2001b) and, more importantly, a metal detector. The metal detector was particularly effective in locating the chains. The measurements of the depth to the scour chain and the bed surface level were left until later in the Dry season so that the water table level was at its lowest. Measurements were made after the first rains to help with the consolidation of the sandy material but before they had any impact on water table levels.

The approximate location of the scour chain was determined using the metal detector and once either the chain or the flagging tape was located the chain was very carefully excavated. Practice has shown that the chain should be excavated from a downstream direction to leave a good exposure or face that can be measured. Usually the metal tag was found first and then the flagging tape was carefully followed until the top link of the chain was found. The rest of the chain that was not in a vertical position was then very carefully excavated.

A wooden board was positioned over the upstream face of the excavation and all measurements were taken to the bottom of this board which equated to the then current bed level. A photograph was usually taken to show the position of the chain and an indication of the direction of flow was given by a trowel, pen or ruler pointing downstream. As the scoured part of the chain was not always lying horizontal, two measurements were taken to determine the scour depth (figure 2). These were:

- Depth to top of first link (ie the link to which the flagging tape was tied) and
- Depth to the first vertical link.

The orientation of the chain was also noted. After these measurements were made the chain was carefully straightened and then a further measurement made:

- Depth to straightened chain from the base of the wooden board.

All measurements were made as positive values except when the straightened chain was higher than the current bed level (wooden board) when the value was assigned a negative value. These measurements are used to determine scour and fill and are explained in the next section.

Once all the measurements had been made, the chain was reset. If the chain was below the current bed level, the chain was carefully pulled up to the current bed level and the surrounding sediment compacted. If the straightened chain was higher than the current bed level then the chain was carefully pulled out of the hole and reinstalled. The creek bed was then rehabilitated to as close as possible to the pre-excavation state. A new piece of flagging tape (approximately 0.3 m long) was tied to the top link and an aluminum tag tied to the other end. The reset chains determined the datum for the next set of measurements.

2.4 Scour and fill calculations

The top of the highest link of each chain is the zero datum for the next Wet season. It is used for all calculations and is the bed level for year 1. The values are all made to this datum even though some of the measurements are made to the bed level for year 2. Once the scour chains are reset the datum is then also reset and the bed level is called Year 1 for the following year.

As noted above, two measurements are taken to determine the scour depth:

- Depth to top or first link
- Depth to the first vertical link

The maximum value (F_M) is the actual fill during the Wet season. The depth to the straightened chain (DSC) is used in equation 1 to determine the maximum scour (S_M) and it is essential to keep the mathematical signs as shown in figure 3.

$$S_M = F_M - DSC \quad (\text{Eq.1})$$

The net change in bed level (BL_N) is determined by equation 2:

$$BL_N = F_M - S_M \quad (\text{Eq.2})$$

A positive value indicates net fill from year 1 to year 2 and a negative value, net scour. This convention of positive values for fill and negative values for scour has been used, among others, by Emmett (1965), Leopold et al (1966), Roberts (1991), Fowler and Wilson (1995) and Locher (1997). Figure 3 shows the three situations that are possible, net fill, net scour and no net change.

3 Results

3.1 Tributary North

Chains were installed in the late Dry season of 1999 on five cross sections, with cross section TN07 having a chain installed on both the main and tributary channels (figure 4). The following cross sections had a single chain installed in the middle of the channel: TN02, TN04, TN05, TN07 (main channel), and TN07 (tributary channel). The most downstream cross section, TN09, had two chains installed in the bed. Scour chain results are described below for the cross sections in downstream order. The location of the cross sections is shown in figure 4.

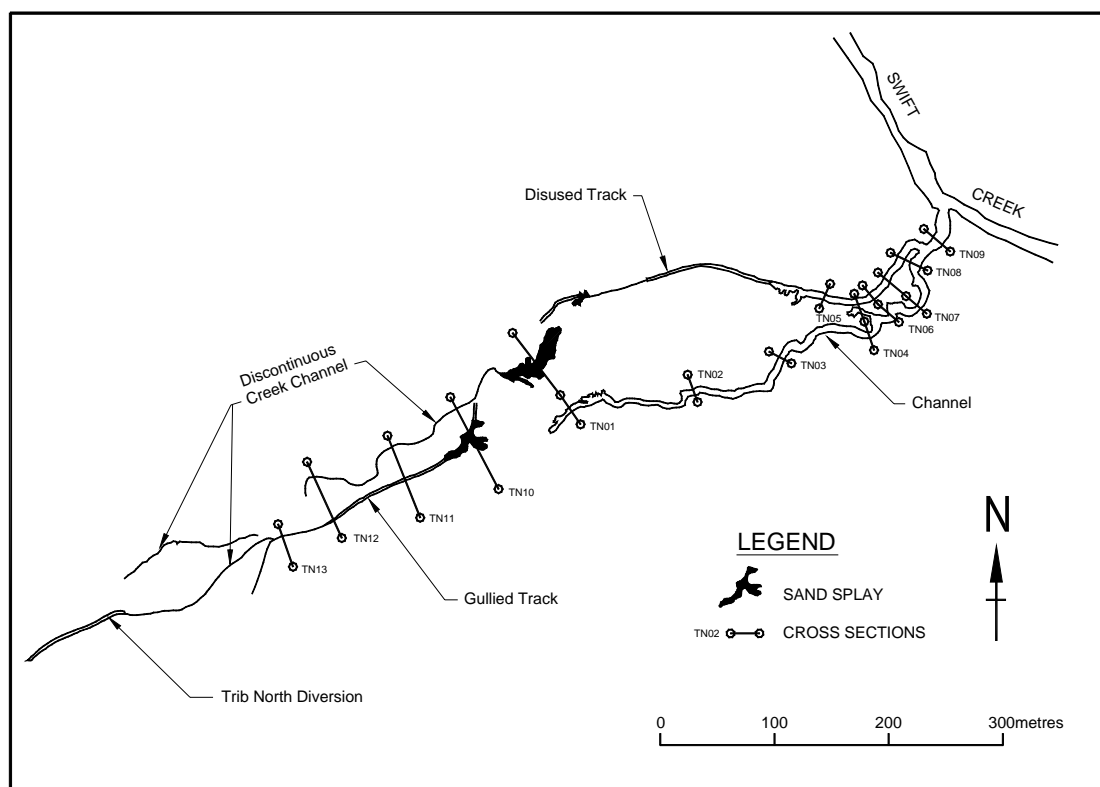


Figure 4 Location of the cross sections on Tributary North

3.1.1 Tributary North cross section 2 (TN02)

There is one chain located in the middle of the channel which was found on 24 October 2000. The chain was pointing downstream (figure 5).

- Depth to first link 131 mm
- Depth to first vertical link 169 mm
- Depth to straightened chain -50 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 219 mm below the 1999 bed level, and then there was subsequent deposition of 169 mm which aggraded the bed to its 2000 level. The bed level in 2000 was 50 mm lower than it was in 1999.

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 102 mm
- Depth to first vertical link 112 mm
- Depth to straightened chain -74 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 186 mm below the 2000 bed level, and then there was subsequent fill of 112 mm which aggraded the bed to its 2001 level. The bed level in 2001 was 74 mm lower than it was in 2000 which, in turn, was 50 mm lower than in 1999.



Figure 5 Scour chain at TN02 on 24 October 2000 orientated downstream. Arrow shows flow direction.

3.1.2 Tributary North cross section 4 (TN04)

There was one chain in the middle of the main channel which was found on 24 October 2000. The chain was located approximately 60 mm below the surface with all the links still vertical. This indicates that only deposition occurred during the 1999/2000.

- Depth to first link 60 mm
- Depth to first vertical link 60 mm
- Depth to straightened chain 60 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was not scoured as all the chains remained vertical. There was 60 mm of fill and the 2000 bed level was 60 mm above the 1999 level.

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 69 mm
- Depth to first vertical link 69 mm
- Depth to straightened chain -41 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 110 mm below the 2000 bed level, and then there was subsequent fill of 69 mm to aggrade the bed to its 2001 level. The bed level for 2001 was 41 mm lower than in 2000.

3.1.3 Tributary North cross section 5 (TN05)

Tributary North cross section 5 (TN05) is located on the tributary channel and has one chain located in the middle of the channel. This chain was located on 24 October 2000. The chain exhibited several links which had collapsed onto themselves.

- Depth to first link 67 mm
- Depth to first vertical link Not able to be determined
- Depth to straightened chain 32 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a depth of 35 mm below the 1999 bed level, and then there was subsequent fill of 67 mm which aggraded the bed to its 2000 level. The bed level in 2000 was 32 mm higher than the 1999 bed level.

The chain was located on 13 November 2001.

- Depth to first link 14 mm
- Depth to first vertical link 14 mm
- Depth to straightened chain 14 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was not scoured and that there was 14 mm of fill to aggrade the bed to its 2001 level. The bed level for 2001 was 14 mm higher than the 2000 bed level.

3.1.4 Tributary North cross section 7 (TN07)

Cross section 7 is located across both the main channel and the tributary channel (figure 4). A single scour chain was installed in each channel.

3.1.4.1 Tributary North Cross Section 7 (TN07– main channel)

This chain was located in the middle of the bed and was found on 24 October 2000. The top link was pointing downstream.

- Depth to first link 70 mm
- Depth to first vertical link 56 mm
- Depth to straightened chain 32 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a depth of 38 mm below the 1999 bed level, and then there was subsequent fill of 70 mm to aggrade the bed to its 2000 level. The bed level for 2000 was 32 mm higher than the 1999 bed level.

The chain was located on 13 November 2001 and was pointing downstream (figure 6).

- Depth to first link 80 mm
- Depth to first vertical link 104 mm
- Depth to straightened chain 22 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a depth of 82 mm below the 2000 bed level, and then there was subsequent fill of 104 mm to aggrade the bed to its 2001 level. The bed level for 2001 was 22 mm higher than the 2000 bed level.



Figure 6 Scour chain at TN07 on 13 November 2001 showing that the orientation of the chain is generally downstream. The pen cap indicates flow direction.

3.1.4.2 Tributary North Cross Section 7 (TN07– tributary)

This chain was located in the middle of the tributary channel and was found on 24 October 2000. The top link of the chain was vertical indicating that there had been no scour.

- Depth to first link 40 mm
- Depth to first vertical link 40 mm
- Depth to straightened chain 40 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was not scoured but that there had been 40 mm of fill which aggraded the bed to 40mm above the 1999 level.

The chain was located on 13 November 2001 and was pointing almost downstream.

- Depth to first link 0 mm
- Depth to first vertical link 15 mm
- Depth to straightened chain -75 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a depth of 90 mm below the 2000 bed level, and then there was subsequent fill of 15 mm. The bed level for 2001 was 75 mm lower than the 2000 bed level.

3.1.5 Tributary North cross section 9 (TN09)

Cross section 9 has two scour chains that were installed late in 1999. This cross section is located on the main channel downstream from the confluence with the left bank tributary but upstream of the junction with Swift Creek (figure 4).

3.1.5.1 Scour chain 1 (TN09-1)

Scour chain 1 is located towards the left bank and was found on 24 October 2000. The chain was located with the top link vertical indicating that there had been no scour (figure 7).

- Depth to first link 74 mm
- Depth to first vertical link 74 mm
- Depth to straightened chain 74 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was not scoured but that there had been fill of 74 mm. The 2000 bed level was 74 mm higher than the 1999 bed level.

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 24 mm
- Depth to first vertical link 43 mm
- Depth to straightened chain 18 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 25 mm below the 2000 bed level, and then there was subsequent fill of 43 mm to aggrade the bed to its 2001 level. The bed level for 2001 was 18 mm higher than the 2000 bed level.

3.1.5.2 Scour chain 2, (TN09-2)

Scour chain 2 is located towards the right bank of cross section 9 and was found on 23 October 2000. The chain was located with the top link slightly angled, suggesting minimal scour or fill.

- Depth to first link 0 mm
- Depth to first vertical link 15 mm
- Depth to straightened chain 0 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured slightly to a depth of 15 mm below the 1999 bed level, and then there was subsequent fill of 15 mm. The 2000 bed level was the same as the 1999 bed level.

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 0 mm
- Depth to first vertical link -15 mm
- Depth to straightened chain -15 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a depth of 15 mm and then there was no subsequent fill. The bed level for 2001 was 15 mm lower than the 2000 bed level.



Figure 7 Scour chain at TN09-1 on 24 October 2000 showing that the top link was still orientated vertically and hence had not been scoured during the 1999/2000. Arrow points downstream.

For Tributary North Cross Section 9 the average scour for the 1999/2000 Wet season was 8 mm and the average fill was 45 mm. The average scour for the 2000/2001 Wet season was 20 mm and the average fill 22 mm. These results suggest that there was not much activity at this section because the cross section is probably backwater affected at high flows.

3.1.6 Tributary North scour and fill

During the Wet seasons of 1999/2000 and 2000/2001 Tributary North experienced both scour and fill. From the scour chain data for 1999/2000, there was net fill at five chains and net scour at only one chain. The 2000/2001 data indicate that four chains had net scour and three chains had net fill. Table 2 shows the mean scour and fill at each section and gives the average scour and fill for the tributary reach.

Table 2 Scour and fill on Tributary North. The standard error of estimate is also shown for the averages. All units are in mm.

Cross Section	1999/2000			2000/2001		
	Scour	Fill	Net Change	Scour	Fill	Net Change
TN02	219	169	-50	186	112	-74
TN04	0	60	60	110	69	-41
TN05	35	67	32	0	14	14
TN07 Main Channel	38	70	32	82	104	22
TN07 Tributary	0	40	40	90	15	-75
TN09 Average	8	45	37	20	22	2
Average	50 ± 34	75 ± 19	25 ± 16	81 ± 27	56 ± 18	-25 ± 19

The net change in bed level for Tributary North is determined by subtracting the scour from the fill. A positive value indicates net fill and a negative value indicates net scour. For Tributary North (table 2) there was an average net fill of 25 mm for the 1999/2000 Wet season and an average net scour of 25 mm for the 2000/2001 Wet season. Therefore, there was no net change over the two years of measurement. However, bed levels varied during each Wet season with the bed being reworked to average depths of up to 81 mm and maximum depths of up to 219 mm. The greatest depths of scour and fill occurred at cross section TN02 which is the closest, at which a scour chain had been installed, to the headcut on the lower gullied reach (Erskine et al 2001).

3.2 Tributary Central

A single scour chain was located on each of three cross sections on Tributary Central before the 1998/99 Wet season. These cross sections were TC09, TC11 and TC03 (figure 8). Bedrock and clay are often exposed in the bed of Tributary Central (Erskine et al 2001), restricting the number of cross sections suitable for the installation of scour chains. The scour chain information is described below for the cross sections in downstream order. Occasional ‘chain sagging’ into the initial excavated hole was recorded during the first year at TC09 and TC11. Thereafter, the sand was more compacted around the chains and, as a result, sagging was not a problem.

3.2.1 Tributary Central cross section 9 (TC09)

There is one chain located in the middle of the channel which was found on 9 November 1999. The flagging tape was visible on the surface. Gravels with a b-axis diameter of 25 mm were lying on the flagging tape. All links were orientated vertically.

- Depth to first link 150 mm
- Depth to first vertical link 150 mm
- Depth to straightened chain 150 mm (1998 bed level)

The links were all orientated vertically with the gravels lying on the flagging tape. It is probable that the chain subsided or sagged down the initial auger hole. Hence these results over estimate fill and, for this reason, the 1998/1999 results will not be used for TC09.

The chain was located on 24 October 2000 and was pointing downstream.

- Depth to first link 40 mm
- Depth to first vertical link 25 mm
- Depth to straightened chain 0 mm (1999 bed level)

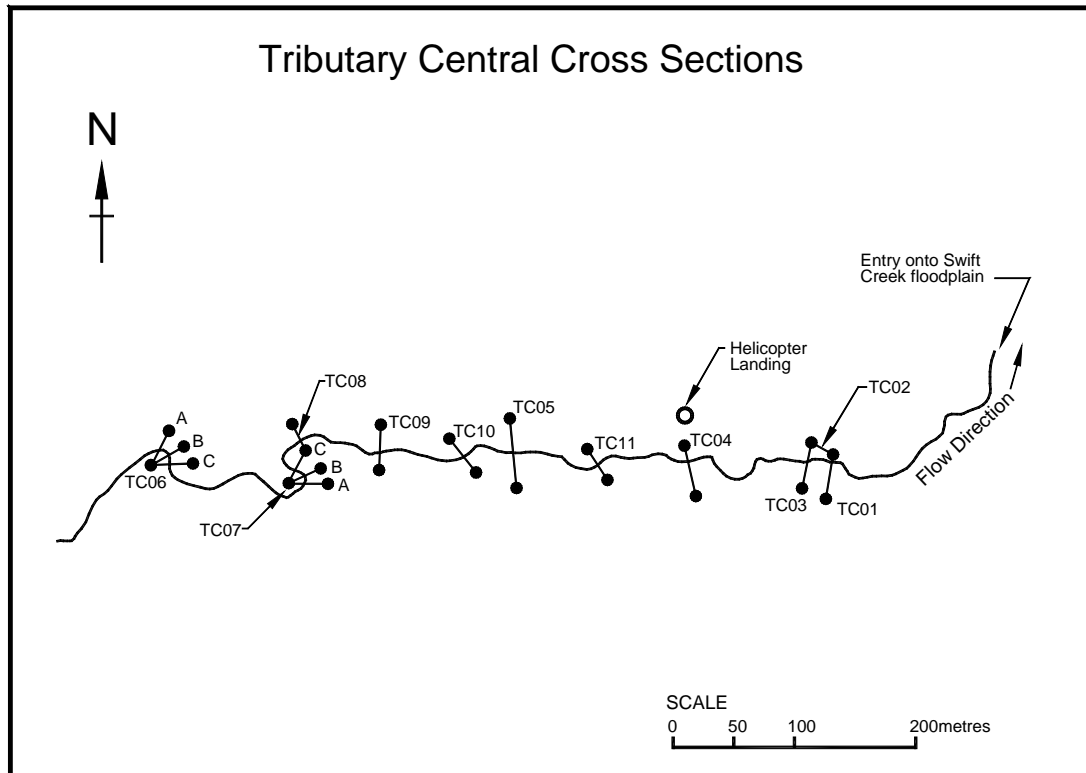


Figure 8 Location of cross sections on Tributary Central

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 40 mm below the 1999 bed level, and then there was fill of 40 mm. The bed level for 2000 was the same as in 1999.

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 13 mm
- Depth to first vertical link 12 mm
- Depth to straightened chain 0 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 13 mm and then there was 13 mm of fill. The bed level for 2001 is the same as it was in 2000 which is also the same as in 1999.

3.2.2 Tributary Central cross section 11 (TC11)

There is one chain located in the middle of the channel which was found on 9 November 1999. There is a gravel armoured sand bar at this location. The links and flagging tape were orientated vertically.

- Depth to first link 251 mm
- Depth to first vertical link 251 mm
- Depth to straightened chain 251 mm (1998 bed level)

The links were all orientated vertically and it is probable that the chain sagged down the initial auger hole. Hence these results over-estimate fill and, for this reason, the 1998/1999 results will not be used.

The chain was located on 24 October 2000 and was pointing downstream.

- Depth to first link -50 mm
- Depth to first vertical link 11 mm
- Depth to straightened chain -50 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 61 mm below the 1999 bed level, and then there was subsequent fill of 11 mm. The bed level for 2000 was 50 mm below the 1999 bed level.

The chain was located on 16 November 2001 and was pointing downstream.

- Depth to first link 300 mm
- Depth to first vertical link 340 mm
- Depth to straightened chain 280 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 60 mm below the 2000 bed level and then there was subsequent fill of 340 mm. The bed level for 2001 was 280 mm higher than it was in 2000. The cross section is located on a bend and there was point bar accretion during the 2000/2001 Wet season. The chain was very difficult to locate and figures 9 and 10 show the point bar development that has occurred at this cross section. The point bar accreted markedly during the 2000/2001 Wet season.

3.2.3 Tributary Central cross section 3 (TC03)

There is one chain located in the middle of the channel which was found on 9 November 1999. The links were lying in a pile with no preferred orientation.

- Depth to first link 293 mm
- Depth to first vertical link 324 mm
- Depth to straightened chain 75 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 249 mm below the 1998 bed level, and then there was subsequent fill of 324 mm to aggrade the bed to its 1999 level. The 1999 bed level is 75 mm higher than the 1998 bed level.

The chain was located on 24 October 2000 and was pointing upstream (figure 11).

- Depth to first link 178 mm
- Depth to first vertical link 173 mm
- Depth to straightened chain 30 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 148 mm below the 1999 bed level, and then there was subsequent fill of 178 mm to aggrade the bed to its 2000 level. The 2000 bed level is 30 mm higher than the 1999 bed level.

This chain was located on 13 November 2001 and was pointing in a semi circle towards the left bank.

- Depth to first link 135 mm
- Depth to first vertical link 156 mm
- Depth to straightened chain 12 mm (2000 bed level)



Figure 9 Tributary Central cross section 11 (TC11) looking upstream in 1998, showing a low cambered point bar on the left bank or the right side of the plate. Compare with figure 10.



Figure 10 Tributary Central cross section 11 (TC11) looking upstream in 2001 showing the high cambered sandy point bar that had accreted markedly during 2000/2001 Wet season. Compare with figure 9.



Figure 11 Upstream-directed scour chain at TC03 on 24 October 2000

These measurements show that during the 2000/2001 Wet season the bed was scoured to a depth of 144 mm below the 2000 bed level, and then there was fill of 156 mm to aggrade the bed to its 2001 level. The 2001 bed level is 12 mm higher than the 2001 bed level.

3.2.4 Tributary Central scour and fill

During the Wet seasons of 1998/1999, 1999/2000 and 2000/2001 Tributary Central experienced both scour and fill. For 1998/1999, only one chain had reliable results (cross section TC03) and it experienced net fill of 75 mm. For 1999/2000, one chain recorded no net change, one chain net fill and one chain net scour. For 2000/2001 one chain recorded no net change and two chains net fill. Table 3 shows the mean scour and fill at each section and for the Tributary Central reach.

Table 3 Scour and fill on Tributary Central. The standard error of estimate is also shown for the averages. All units are in mm.

Cross Section	1998/1999			1999/2000			2000/2001		
	Scour	Fill	Net Change	Scour	Fill	Net Change	Scour	Fill	Net Change
TC09				40	40	0	13	13	0
TC11				61	11	-50	60	340	280
TC03	249	324	75	148	178	30	144	156	12
Average	N/A	N/A	N/A	83 ± 33	76 ± 52	-7 ± 23	72 ± 38	170 ± 95	97 ± 91

The net change in bed level is determined by subtracting the scour from the fill with a positive value indicating net fill and a negative value indicating net scour. For Tributary Central there were not enough data to make any conclusions for the 1998/1999 Wet season. For the 1999/2000 Wet season there was average net scour of 7 mm and for the 2000/2001 Wet season there was average net fill of 98 mm. Although there is only limited data on scour and fill for Tributary Central, it is more active at the scour chain cross sections than Tributary North.

3.3 East Tributary

Scour chains were installed at four cross sections at the East Tributary gauging station before the 1998/99 Wet season. Two chains were located on cross section ET01 and one chain was located on ET04, ET07 and ET08. The location of the cross sections is shown in figure 12.

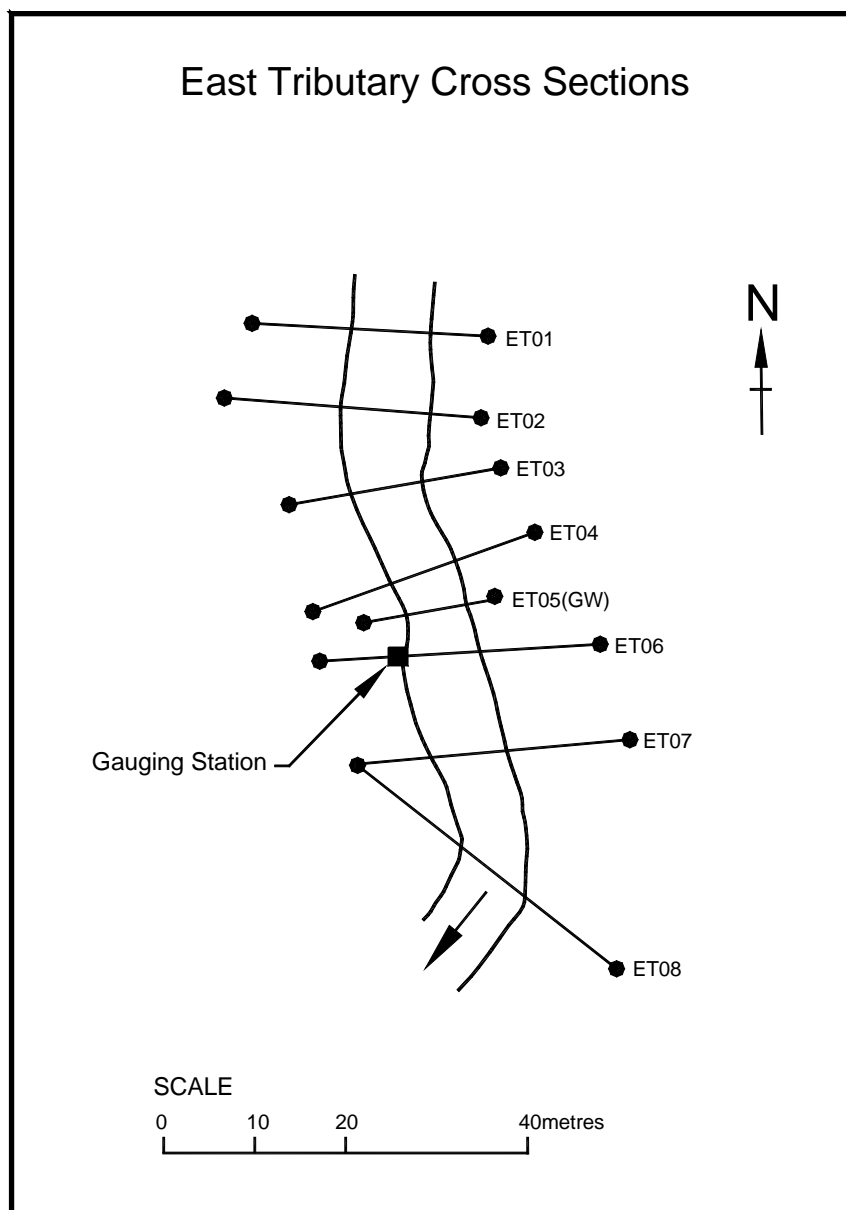


Figure 12 Location of the cross sections in the East Tributary gauging reach

3.3.1 East Tributary cross section 1 (ET01)

East Tributary cross section 1 has two scour chains that were installed late in 1998 (figure 12).

3.3.1.1 Chain 1 (ET0-1)

Scour chain 1 is located towards the left bank and was found on 2 November 1999. The entire chain was vertical but had been buried.

- Depth to first link 350 mm
- Depth to first vertical link 350 mm
- Depth to straightened chain 350 mm (1998 bed level)

It is probable that the chain sagged down the initial auger hole and hence these results over-estimate fill. For this reason the 1998/1999 results will not be used.

The chain was located on 23 November 2000 and was pointing downstream but slightly towards the right bank (figure 13).

- Depth to first link 160 mm
- Depth to first vertical link 156 mm
- Depth to straightened chain 53 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 107 mm below the 1999 bed level, and then there was subsequent fill of 160 mm. The 2000 bed level is 53 mm above the 1999 level.



Figure 13 Scour chain pointing essentially downstream at ET01 on 23 October 2000

The chain was located on 13 November 2001 and was pointing downstream similar to 2000 (see figure 13).

- Depth to first link 167 mm
- Depth to first vertical link 190 mm
- Depth to straightened chain 46 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 144 mm below the 2000 bed level and then there was subsequent fill of 190 mm. The bed level for 2001 was 46 mm higher than the 2000 bed level.

3.3.1.2 Chain 2 (ET01-2)

This chain was found on 2 November 1999 and was located towards the right bank. The chain was buried and was pointing upstream.

- Depth to first link N/A
- Depth to first vertical link 470 mm
- Depth to straightened chain 120 mm (1998 bed level)

The measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 350 mm and then there was subsequent fill of 470 mm. The bed level for 1999 was 120 mm higher than the 1998 bed level.

The chain was located on 23 October 2000 and was pointing towards the left bank (figure 14)

- Depth to first link 153 mm
- Depth to first vertical link 163 mm
- Depth to straightened chain -215 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 378 mm below the 1999 bed level, and then there was subsequent fill of 163 mm. The 2000 bed level was 215 mm below the 1999 level.

The chain was located on 13 November 2001 and was pointing towards the left bank similar to 2000 (see figure 14).

- Depth to first link 185 mm
- Depth to first vertical link 207 mm
- Depth to straightened chain 26 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 181 mm and then there was subsequent fill of 207 mm. The bed level for 2001 was 26 mm higher than the 2000 bed level.

For East Tributary Cross Section 1 the 1999 scour and fill was not able to be determined due to chain subsidence or sagging. After the 1999/2000 Wet season, the average scour was 243 mm and the average fill was 162 mm. During the 2000/2001 Wet season the average scour was 163 mm and the average fill was 199 mm.



Figure 14 Scour chain at ET01 (2000) directed towards the left bank. Flow direction shown by arrow.

3.3.2 East Tributary cross section 4 (ET04)

There is one chain in the middle of the channel which was located on 3 November 1999. All links of the chain were vertical.

- Depth to first link 141 mm
- Depth to first vertical link 141 mm
- Depth to straightened chain 141 mm (1998 bed level)

It is probable that the chain subsided or sagged down the initial auger hole and hence these results over estimate fill. For this reason, the 1998/1999 results will not be used.

The chain was located on 24 October 2000 and was pointing downstream.

- Depth to first link 95 mm
- Depth to first vertical link 108 mm
- Depth to straightened chain 0 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 108 mm below the 1999 bed level, and then there was subsequent fill of 108 mm. The 2000 bed level is at the same level as in 1999.

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 73 mm
- Depth to first vertical link 100 mm
- Depth to straightened chain -30 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 130 mm and then there was fill of 100 mm. The bed level for 2001 was 30 mm lower than it was in 2000.

3.3.3 East Tributary cross section 7 (ET07)

There is one chain located in the middle of the channel which was located on 3 November 1999 pointing downstream but angled towards the right bank (figure 15).

- Depth to first link 255 mm
- Depth to first vertical link 255 mm
- Depth to straightened chain 96 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 159 mm below the 1998 bed level, and then there was subsequent fill of 255 mm to raise the bed to its 1999 level. The 1999 bed level was 96 mm higher than the 1998 bed level.

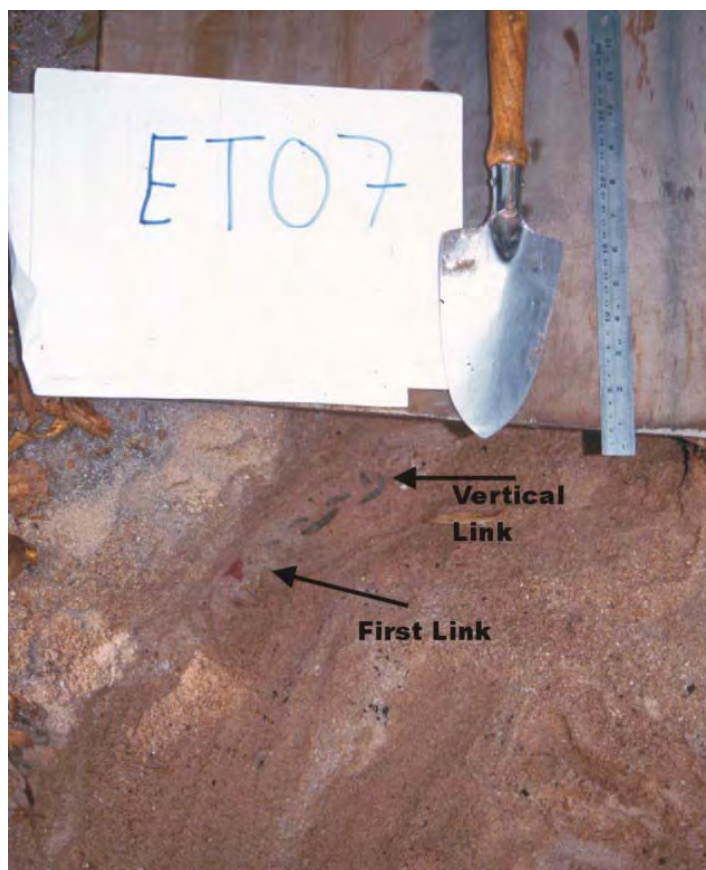


Figure 15 Scour chain at ET07 angled downstream in 1999

The chain was located on 23 October 2000 and was pointing downstream but angled towards the right bank (see figure 15).

- Depth to first link 298 mm
- Depth to first vertical link 295 mm
- Depth to straightened chain 0 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 298 mm below the 1999 bed level, and then subsequent fill of 298 mm resulted in the bed returning to the same level as at the end of the 1999/2000 Wet season.

The chain was located on 13 November 2001 and was pointing upstream

- Depth to first link 240 mm
- Depth to first vertical link 255 mm
- Depth to straightened chain 0 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 255 mm below the 2000 bed level and then there was subsequent fill of 255 mm. The bed level for 2001 was the same as in 2000.

3.3.4 East Tributary cross section 8 (ET08)

There is one chain located near the thalweg on the outside of the point bar towards the left bank. The chain was located on 3 November 1999 and was pointing upstream (figure 16).

- Depth to first link 105 mm
- Depth to first vertical link 150 mm
- Depth to straightened chain -120 mm (i.e. 120 mm above 1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 270 mm below the 1998 bed level, and then there was subsequent fill of 150 mm. The bed level for 1999 was 120 mm lower than the 1998 bed level.



Figure16 Scour chain at ET08 (1999) pointing in an upstream direction. The top link has the flagging tape attached to it.

The chain was located on 23 October 2000 and was pointing downstream.

- Depth to first link 53 mm
- Depth to first vertical link 111 mm
- Depth to straightened chain -35 mm (i.e. 35 mm above 1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 146 mm and then there was subsequent fill of 111 mm. The 2000 bed level was 35 mm lower than the 1999 bed level.

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 95 mm
- Depth to first vertical link 107 mm
- Depth to straightened chain 0 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 107 mm below the 2000 bed level and then there was fill of 107 mm. The bed level for 2001 was the same as in 2000.

3.3.5 East Tributary scour and fill

During the Wet seasons of 1998/1999, 1999/2000 and 2000/2001, the bed of East Tributary experienced both scour and fill. From the scour chain data for 1998/1999 three of the five chains exhibited sagging, one chain showed net fill and the other chain showed no net change. The problem of sagging is due to the initial excavation of the sand auger through finer textured sediment than the sandy bed material at depth and the backfilling of the hole with uncompacted sand below the water table. As a result, the sand compacted over time and the chain collapsed *in situ* as the sediment increased in density. It was not a problem after the first year because the chain was not disturbed to the same extent and hence the sandy backfill remained compacted. During 1999/2000, two chains were stable, two showed net scour and one showed net fill. During 2000/2001, one chain was stable, two chains exhibited net fill and two chains exhibited net scour. Table 4 shows the mean scour and fill at each section and lists the average scour and fill.

Table 4 Scour and fill at the East Tributary gauging station. The standard error of estimate is also shown for the averages. All units are in mm.

Cross Section	1998/1999			1999/2000			2000/2001		
	Scour	Fill	Net Change	Scour	Fill	Net Change	Scour	Fill	Net Change
ET01	350*	470*	120	243	162	-81	163	199	36
ET04				108	108	0	130	100	-30
ET07	159	255	96	298	298	0	255	255	0
ET08	270	150	-120	146	111	-35	107	107	0
Average	260 ± 55	292 ± 94	32 ± 76	199 ± 50	170 ± 51	-29 ± 22	164 ± 38	165 ± 43	2 ± 16

* Determined only from ET01–2

From table 4, there was net fill of 32 mm for the 1998/99 Wet season and there was net scour of 29 mm for the 1999/2000 Wet season. There was 2 mm of fill during the 2000/2001 Wet season indicating essentially no net change. While the net change was small, substantial scour and fill occurred during each Wet season at each cross section.

3.4 Upper Swift Creek

Scour chains were installed at three cross sections at the Upper Swift Creek (UM) gauging station before the 1998/99 Wet season. Two chains were located on cross sections UM02, UM05 and UM07. The cross sections are shown in figure 17.

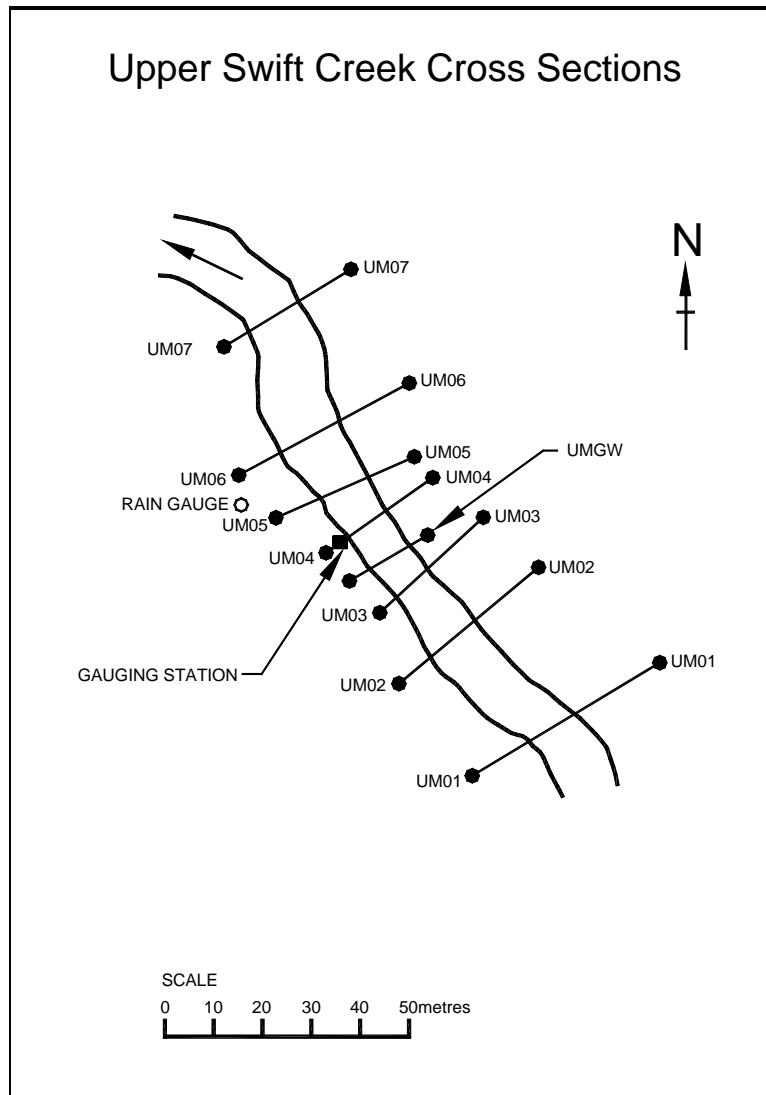


Figure 17 Location of the cross sections in the Upper Swift Creek gauging reach

3.4.1 Upper Swift Creek cross section 2 (UM02)

Cross section 2 has two scour chains that were installed in late 1998. Chain 1 is located closer to the left bank and chain 2, closer to the right bank.

3.4.1.1 Chain 1 (UM02-1)

This chain was located on 2 November 1999 and was pointing mainly downstream but angled towards the left bank.

- Depth to first link 360 mm
- Depth to first vertical link 345 mm
- Depth to straightened chain 222 mm (1998 bed level)

These measurements show that during the 1998/1999 Wet season the bed was scoured to a maximum depth of 138 mm and then there was subsequent fill of 360 mm. The 1999 bed level was 222 mm above the 1998 level.

The chain was located on 24 October 2000 and was pointing towards the right bank (figure 18).

- Depth to first link 258 mm
- Depth to first vertical link 269 mm
- Depth to straightened chain 0 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 269 mm and then there was subsequent fill of 269 mm to aggrade the bed to the same level as in 1999.



Figure 18 Scour chain UM02-1 (2000) pointing towards the left bank. The flagging tape is attached to the top link.

The chain was located on 13 November 2001 and was pointing mainly downstream.

- Depth to first link 252 mm
- Depth to first vertical link 271 mm
- Depth to straightened chain 11 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 282 mm below the 2000 bed level and then there was subsequent fill of 271 mm. The bed level for 2001 was 11 mm higher than in 2000.

3.4.1.2 Chain 2 (UM02–2)

This chain was located on 2 November 1999 and was lying in a semi-circular pattern across the bed and orientated downstream (figure 19). The chain had been dislodged from its original position. When this scour chain was installed, only 350mm of chain could be inserted into the bed due to the large gravels and weathered bedrock that were encountered at depth.

- Depth to first link 420 mm
- Depth to first vertical link No vertical links
- Depth to straightened chain Not able to be determined.

These measurements indicate that during the 1998/99 Wet season the bed was scoured to a depth sufficient to remove the chain. The amount of fill at this chain was 420 mm. The chain was lying horizontally after the 1998/99 Wet season and therefore, the 1998 bed level could not be determined. A new chain was installed at this time.

The chain was located on 24 October 2000 and was pointing downstream.

- Depth to first link 255 mm
- Depth to first vertical link 263 mm
- Depth to straightened chain 19 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 244 mm and then there was subsequent fill of 263 mm. The 2000 bed level was 19 mm higher than the 1999 bed level.

The chain was located on 13 November 2001 and was pointing upstream.

- Depth to first link 286 mm
- Depth to first vertical link 260 mm
- Depth to straightened chain 12 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 274 mm and then there was subsequent fill of 286 mm. The bed level for 2001 was 12 mm higher than it was in 2000.

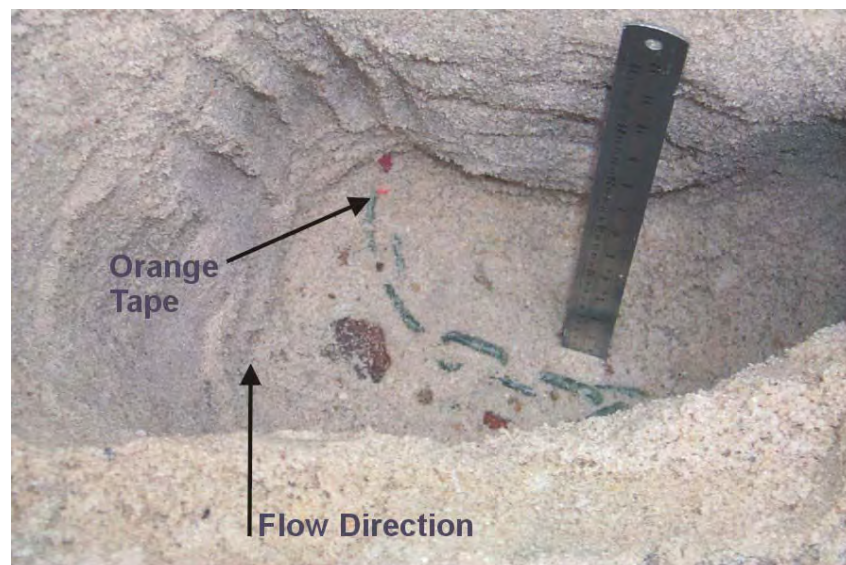


Figure 19 Horizontal links of the scour chain at UM02–2 (2 November 1999). The chain can be seen amongst large gravels (lag deposit) and the pink flagging tape is just visible towards the top of the picture.

For Upper Swift Creek Cross Section 2, the 1999 scour was 138 mm at chain 1 and the fill was 390 mm. Chain 2 had been dislodged. After the 1999/2000 Wet season, the average scour was 257 mm and the average fill was 266 mm. For the 2000/2001 Wet season the average scour was 278 mm and the average fill was 279 mm.

3.4.2 Upper Swift Creek cross section 5 (UM05)

Cross section 5 has two scour chains that were installed late in 1998. Chain 1 is located closer to the left bank and chain 2 closer to the right bank.

3.4.2.1 Chain 1 (UM05-1)

This chain was located on 2 November 1999 and was pointing towards the right bank (figure 20).

- Depth to first link 226 mm
- Depth to first vertical link 240 mm
- Depth to straightened chain 147 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 93 mm below the 1998 bed level and then there was subsequent fill of 240 mm. The 1999 bed level was 147 mm above the 1998 bed level.

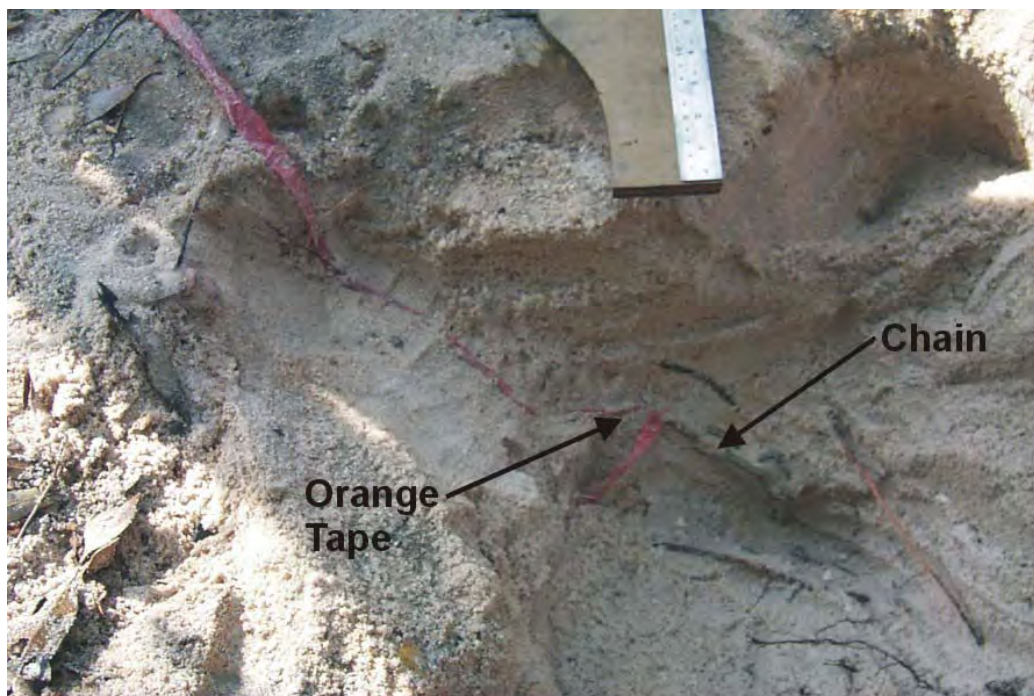


Figure 20 Scour chain UM05-1 (1999) can be seen in the centre right of the picture. The orange flagging tape can be seen lying across the bed. Flow direction is indicated by the steel rule.

The chain was located on 24 October 2000 and was pointing downstream.

- Depth to first link 166 mm
- Depth to first vertical link 193 mm
- Depth to straightened chain 25 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 168 mm below the 1998 bed level and then there was subsequent fill of 193 mm to aggrade the bed to its 2000 level. The 2000 bed level is 25 mm higher than the 1999 bed level.

The chain was located on 13 November 2001 and was pointing towards the right bank (figure 21).

- Depth to first link 116 mm
- Depth to first vertical link 117 mm
- Depth to straightened chain 0 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 117 mm below the 2000 bed level and then there was subsequent fill of 117 mm. The bed level for 2001 was the same level as in 2000.



Figure 21 Scour chain UM05-1 (2001) pointing towards the right bank

3.4.2.2 Chain 2 (UM05-2)

This chain was located on 29 October 1999 with 2-3 links lying on top of one another in a pile suggesting that the bed had scoured and the chain had fallen under its own weight to create the pile.

- Depth to first link 120 mm
- Depth to first vertical link 125 mm
- Depth to straightened chain 30 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 95 mm below the 1998 bed level and then there was subsequent fill of 125 mm. The 1999 bed level was 30 mm above the 1998 bed level.

The chain was located on 24 October 2000 and was pointing downstream.

- Depth to first link 60 mm
- Depth to first vertical link 77 mm
- Depth to straightened chain 13 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 64 mm below the 2000 bed level and then there was subsequent fill of 77 mm. The 2000 bed level was 13 mm higher than the 1999 bed level.

The chain was located on 13 November 2001 and was pointing towards the left bank.

- Depth to first link 110 mm
- Depth to first vertical link 123 mm
- Depth to straightened chain 43 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 80 mm below the 2000 bed level and then there was subsequent fill of 123 mm. The bed level for 2001 was 43 mm higher than the 2000 bed level.

For Upper Swift Creek Cross Section 5, the 1998/1999 Wet season average scour was 94 mm and the average fill was 183 mm. After the 1999/2000 Wet season, the average scour was 116 mm and the average fill was 135 mm. For the 2000/2001 Wet season, the average scour was 99 mm and the average fill was 120 mm.

3.4.3 Upper Swift Creek cross section 7 (UM07)

Cross section 7 has two scour chains that were installed late in 1998. Chain 1 is located closer to the left bank and chain 2 closer to the right bank.

3.4.3.1 Chain 1 (UM07-1)

This chain was located on 2 November 1999 and was pointing mainly downstream but slightly towards the right bank. Gravels up to 40 mm in b axis diameter were resting on the chain, indicating that these gravels had moved during the Wet season but were deposited at the maximum scour depth.

- Depth to first link 227 mm
- Depth to first vertical link 238 mm
- Depth to straightened chain 94 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 144 mm below the 1998 bed level and then there was fill of 238 mm. The 1999 bed level was 94 mm above the 1998 bed level.

The chain was located 24 October 2000 and was pointing towards the right bank (figure 22).

- Depth to first link 135 mm
- Depth to first vertical link 120 mm
- Depth to straightened chain 38 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 97 mm below the 1999 bed level, and then there was subsequent fill of 135 mm. The 2000 bed level was 38 mm above the 1999 bed level.



Figure 22 Scour chain UM07 (2000) pointing towards the right bank

The chain was located on 13 November 2001 and was pointing downstream.

- Depth to first link 180 mm
- Depth to first vertical link 211 mm
- Depth to straightened chain 17 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 194 mm below the 2000 bed level and then there was fill of 211 mm. The bed level for 2001 was 17 mm higher than the 2000 bed level.

3.4.3.2 Chain 2 (UM07-2)

This chain was located on 2 November 1999, however, no indication of the direction was recorded in the field notes.

- Depth to first link 306 mm
- Depth to first vertical link 365 mm
- Depth to straightened chain 135 mm (1998 bed level)

During each of the three Wet seasons there was net fill or aggradation, The greatest net fill (142 mm) occurred during the 1998/98 Wet season. During the 1999/2000 Wet season, net fill was 21 mm and during the 2000/2001 Wet season net fill was 10 mm. The maximum mean scour depth was 278 mm during the 2000/2001 Wet season and maximum fill was 360 mm during the 1998/1999 Wet season.

3.5 Swift Creek

Scour chains were installed at two cross sections at the Swift Creek gauging station before the 1998/99 Wet season. Three chains were located on cross sections SM05 and SM08. Additional chains were located on cross section SM02 before the 1999/2000 Wet season and plastic chains were also installed at each of the cross sections with metal chains to determine if they behaved the same as the metal chains. The location of the cross sections is shown in figure 23.

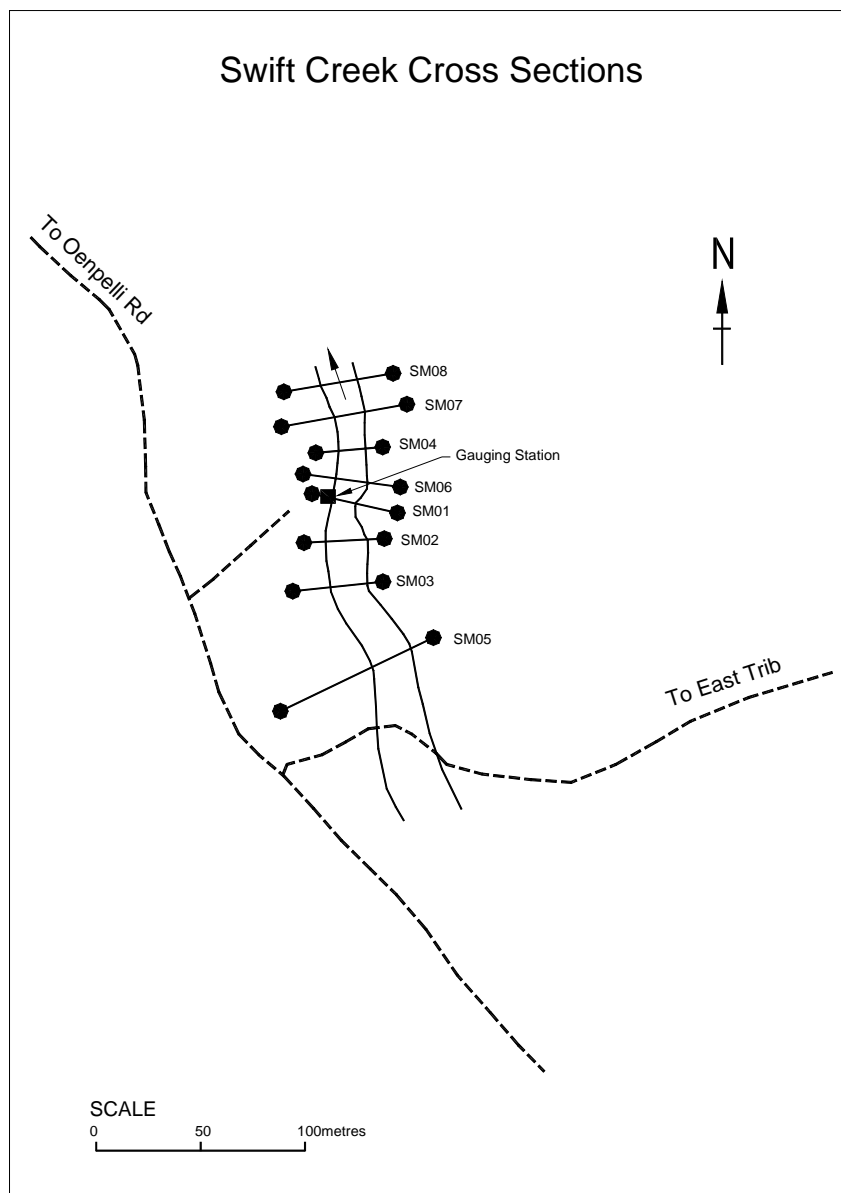


Figure 23 Location of the cross sections in the Swift Creek gauging reach

3.5.1 Swift Creek cross section 5 (SM05)

Three metal chains were installed at Swift Creek cross section 5 before the 1998/99 Wet season. Two additional plastic chains were installed between the metal scour chains before the 1999/2000 Wet season.

3.5.1.1 Chain 1 (SM05-1)

The chain was located on 3 November 1999 and was pointing upstream (figure 24).

- Depth to first link 323 mm
- Depth to first vertical link 301 mm
- Depth to straightened chain 55 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 268 mm below the 1998 bed level, and then there was subsequent fill of 323 mm. The 1999 bed level was 55 mm higher than the 1998 bed level.

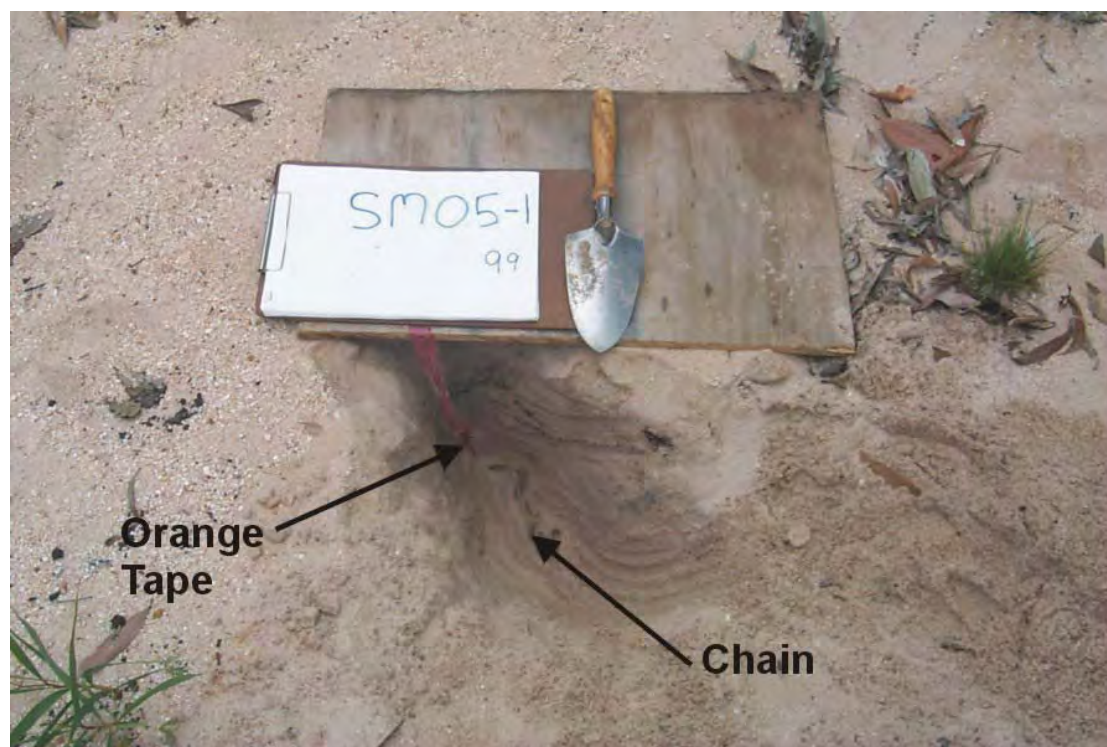


Figure 24 Scour chain SM05-1 (1999) with the flow direction indicated by the trowel. The chain is orientated upstream, implying scour by upstream-directed flow or a reverse current.

The chain was located on 23 October 2000 and was pointing towards the right bank.

- Depth to first link 335 mm
- Depth to first vertical link 355 mm
- Depth to straightened chain 52 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 303 mm below the 1999 bed level, and then there was subsequent fill of 355 mm. The 2000 bed level was 52 mm higher than the 1999 bed level.

The chain was located on 16 November 2001 and was pointing across the channel towards the right bank. The chain was almost at the water table.

- Depth to first link 400 mm
- Depth to first vertical link 530 mm
- Depth to straightened chain 25 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 505 mm below the 2000 bed level and then there was subsequent fill of 530 mm. The bed level for 2001 was 25 mm higher than the 2000 bed level.

3.5.1.2 Chain 2 (SM05-2)

This chain was located on 3 November 1999 and was pointing upstream. The chain was initially installed with 2 links (60 mm) lying on the stream bed surface pointing downstream.

- Depth to first link 451 mm
- Depth to first vertical link 433 mm
- Depth to straightened chain 32 mm (1998 bed level)

As two links were not buried, 60 mm must be added to the straightened chain measurement to determine the difference between the 1998 and 1999 bed levels. Therefore, the 1998 bed was 92 mm below the 1999 level. During the 1998/99 Wet season the bed was scoured to a maximum depth of 359 mm below the 1998 bed level, and then there was subsequent fill of 451 mm. The 1999 bed level was 92 mm higher than the 1998 bed level.

The chain was located on 23 October 2000 and was pointing downstream.

- Depth to first link 340 mm
- Depth to first vertical link 360 mm
- Depth to straightened chain 35 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 325 mm below the 1999 bed level, and then there was subsequent fill of 360 mm. The 2000 bed level was 35 mm higher than the 1999 bed level.

The chain was located on 16 November 2001 and was pointing upstream. All the links were lying horizontally and the chain was below the water table (figure 25).

- Depth to first link 530 mm
- Depth to first vertical link N/A
- Depth to straightened chain N/A

This chain had been dislodged and was below the water table. It was not possible to determine the amount of fill apart from the depth at which the chain had been found because it had been totally removed from its original position.

3.5.1.3 Chain 3 (SM05-3)

This chain was located on 3 November 1999 and was pointing upstream (figure 26). The chain was initially installed with 1 link (30 mm) lying on the stream bed surface pointing in a downstream direction.

- Depth to first link 529 mm
- Depth to first vertical link 504 mm
- Depth to straightened chain 40 mm (1998 bed level).



Figure 25 Scour chain SM05-2 had been totally dislodged during the 1998/1999 Wet season and was lying below the water table in November 1999

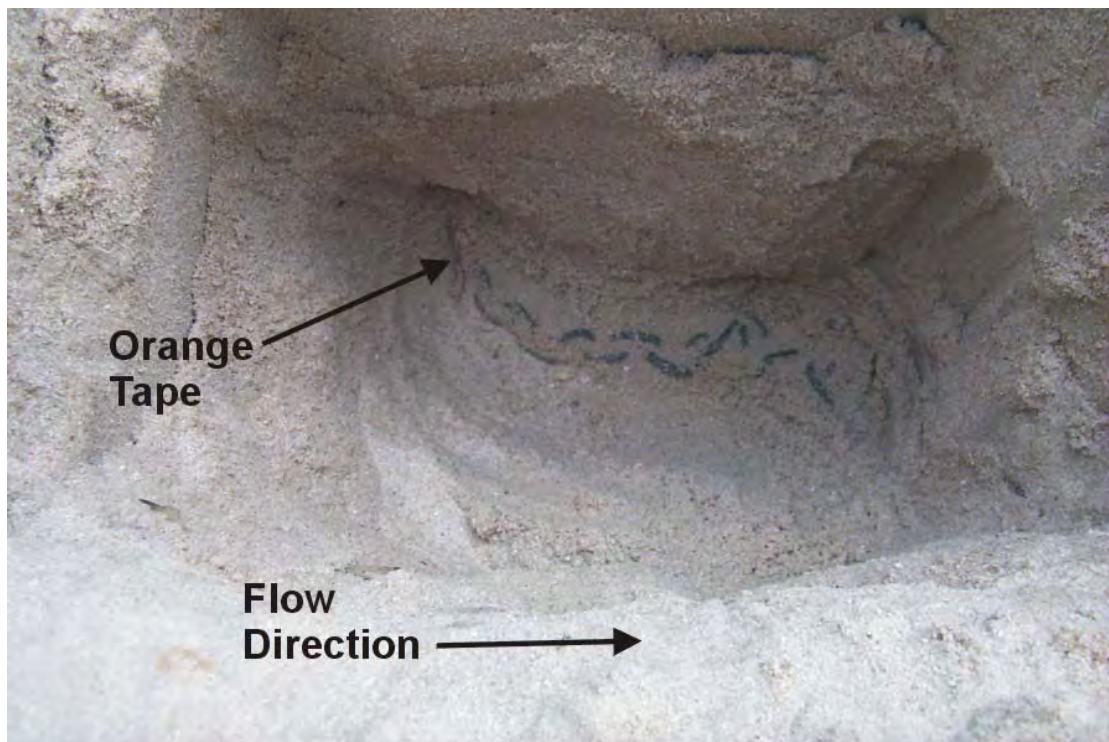


Figure 26 Scour chain SM05-3 (2000) with the top of the first link indicated by the orange flagging tape

The 1998 bed was 70 mm below the 1999 level. These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 459 mm below the 1998 bed level, and then there was subsequent fill of 529 mm.

The chain was located on 23 October 2000 and was pointing upstream as in the previous year (figure 26).

- Depth to first link 475 mm
- Depth to first vertical link 500 mm
- Depth to straightened chain 0 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 500 mm below the 1999 bed level, and then there was subsequent fill of 500 mm. The 2000 bed level is the same as in 1999.

This chain could not be located during the late Dry season of 2001 as the water table was at a level approximately 450 mm below the bed surface and the hole kept collapsing. Given the depth at which the other two chains had been located it was likely that there had been considerable scour and fill at this cross section.

3.5.1.4 Plastic chain 1 (SM05–P1)

This chain was located on 23 October 2000 and was pointing downstream and slightly towards the left bank.

- Depth to first link 174 mm
- Depth to first vertical link 310 mm
- Depth to straightened chain 65 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 245 mm below the 1999 bed level, and then there was subsequent fill of 310 mm. The 1999 bed level was 65 mm higher than the 2000 bed level.

This chain was not searched for during the 2001 Dry season because the metal chains had been extremely difficult to relocate. The plastic chains are also lighter and it is possible that they were totally removed as the only part of the chain that could be detected by the metal detector was the aluminum tag.

3.5.1.5 Plastic chain (SM05–P2)

This chain was located on 23 October 2000 and was pointing mainly downstream and slightly towards the left bank (figure 27).

- Depth to first link 246 mm
- Depth to first vertical link 377 mm
- Depth to straightened chain 0 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 377 mm below the 1999 bed level, and then there was 377 mm of fill. The 2000 bed level was the same as in 1999.

This chain was not searched for in 2001 for the reasons outlined above for chain SM05–P1.

For Swift Creek Cross Section 5 the results for the metal chains for the 1998/1999 Wet season were that the average scour was 362 mm and the average fill was 434 mm. After the 1999/2000 Wet season the average scour was 376 mm and the average fill was 405 mm. During the 2000/2001 Wet season one chain was dislodged completely and another could not be located. Therefore, the scour depth of 505 mm and the fill of 530 mm were based on one chain only. The plastic chains were located after the 1999/2000 Wet season and the average scour was 311 mm and the average fill was 344 mm. The plastic chains were not located after the 2000/01 Wet season. The plastic chains did not exhibit the same behaviour as the metal chains. As the plastic chains were lighter they tended to be found with a curved trajectory

through the sand rather than horizontal which is more characteristic of the metal chains. Also, being lighter, they were, in some cases, dislodged. The plastic chains were more difficult to locate given that they only had the metal tag at the end of the flagging tape that could be found by the metal detector. The results for the plastic chains are shown here but are not included in any of the calculations.



Figure 27 Plastic scour chain at SM05–P2 (2000) pointing almost downstream

3.5.2 Swift Creek cross section 2

At this cross section three metal and two plastic chains were installed at the end of the 1999 Dry season. The two plastic chains are located between each metal chain.

3.5.2.1 Chain 1 SM02–1

This chain was located on 23 October 2000 and was pointing towards the right bank.

- Depth to first link 194 mm
- Depth to first vertical link 223 mm
- Depth to straightened chain -20 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 243 mm below the 1999 level, and then there was subsequent fill of 223 mm. The 2000 bed level was 20 mm below the 1999 bed level.

The chain was located on 16 November 2001 and was pointing almost downstream.

- Depth to first link 105mm
- Depth to first vertical link 115 mm
- Depth to straightened chain -175 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 290 mm below the 2000 bed level and then there was subsequent fill of 115 mm. The bed level for 2001 was 175 mm lower than the 2000 bed level.

3.5.2.2 Chain 2 (SM02-2)

This chain was located on 23 October 2000 and was pointing mainly downstream.

- Depth to first link 180 mm
- Depth to first vertical link 170 mm
- Depth to straightened chain -20 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 200 mm below the 1999 level, and then there was subsequent fill of 180 mm. The 2000 bed level was 20 mm lower than the 1999 bed level.

The chain was located on 16 November 2001 and was pointing downstream.

- Depth to first link 241 mm
- Depth to first vertical link 283 mm
- Depth to straightened chain 174 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 109 mm below the 2000 bed level and then there was subsequent fill of 283 mm. The bed level for 2001 was 174 mm higher than the 2000 bed level.

3.5.2.3 Chain 3 (SM02-3)

This chain was located on 23 October 2000 and was pointing towards the right bank (figure 28).

- Depth to first link 86 mm
- Depth to first vertical link 115 mm
- Depth to straightened chain 5 mm (1999 bed level).

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 110 mm below the 1999 level, and then there was subsequent fill of 115 mm. The 2000 bed level was 5 mm higher than the 1999 bed level.

This chain was located on 16 November 2001 and was pointing downstream.

- Depth to first link 128 mm
- Depth to first vertical link 168 mm
- Depth to straightened chain 5 mm (2000 bed level).

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 163 mm below the 2000 bed level, and then there was subsequent fill of 168 mm. The 2001 bed level was 5 mm higher than the 2000 bed level.



Figure 28 Scour chain SM02–3 (2000) pointing towards the left bank

3.5.2.4 *Plastic chain 1 (SM02–P1)*

This chain was located on 23 October 2000 and was pointing downstream.

- Depth to first link 82 mm
- Depth to first vertical link 126 mm
- Depth to straightened chain 53 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 73 mm and then there was subsequent fill of 126 mm. The 2000 bed level was 53 mm higher than the 1999 bed level.

This chain was searched for and located on 16 November 2001. The chain had been completely dislodged and was found approximately 3m downstream from its installation point. No measurements could be made.

3.5.2.5 *Plastic chain 2 (SM05–P2)*

This chain was located on 23 October 2000 and was pointing towards the left bank (figure 29).

- Depth to first link 115 mm
- Depth to first vertical link 196 mm
- Depth to straightened chain 47 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a depth of 149 mm and then there was subsequent fill of 196 mm. The 2000 bed level was 47 mm higher than the 1999 bed level.

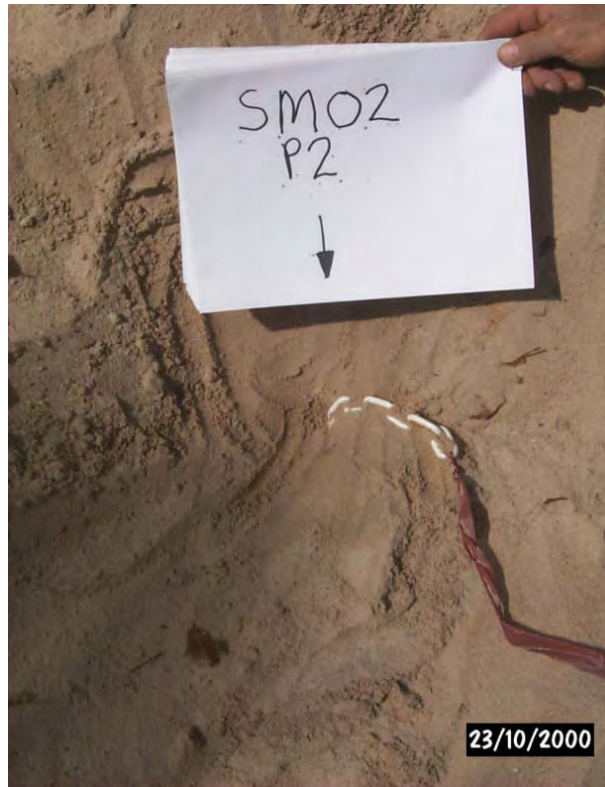


Figure 29 Plastic scour chain SM02–P2 (2000) pointing towards the left bank

This chain was located on 16 November 2001 and was pointing towards the left bank, similar to last year (figure 29).

- Depth to first link 68 mm
- Depth to first vertical link 154 mm
- Depth to straightened chain -25 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a depth of 179 mm and then there was subsequent fill of 154 mm. The 2001 bed level was 25 mm lower than the 1999 bed level.

For Swift Creek Cross Section 2 for the 1999/2000 Wet season the average scour was 184 mm and the average fill was 173mm. The average scour for the 2000/2001 Wet season was 187 mm and the average fill was 189 mm. The plastic scour chains for the 1999/2000 Wet season experienced 111 mm of scour and then 161 mm of fill. For the 2000/2001 Wet season one plastic chain was dislodged completely so average values cannot be calculated.

3.5.3 Swift Creek cross section 8

Three metal chains were installed at Swift Creek cross section 8 before the 1998/99 Wet season. Two additional plastic chains were installed between the metal scour chains before the 1999/2000 Wet season.

3.5.3.1 Chain 1 (SM08-1)

This chain was located on 4 November 1999 and was pointing towards the right bank.

- Depth to first link 400 mm
- Depth to first vertical link 412 mm
- Depth to straightened chain 112 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 300 mm below the 1998 bed level, and then there was subsequent fill of 412 mm. The 1999 bed level was 112 mm higher than the 1998 bed level.

The chain was located on 23 October 2000 and was pointing towards the right bank (figure 30).

- Depth to first link 303 mm
- Depth to first vertical link 295 mm
- Depth to straightened chain 46 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 257 mm and then there was fill of 303 mm. The bed level for 2000 was 46 mm higher than the 1999 bed level.



Figure 30 Scour chain SM08-1 (2000) pointing towards the right bank

This chain was located on 16 November 2001 and was pointing towards the right bank in a similar fashion to that shown in figure 30.

- Depth to first link 398 mm
- Depth to first vertical link 388 mm
- Depth to straightened chain -48 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 446 mm and then there was subsequent fill of 388 mm. The 2001 bed level was 48 mm lower than the 2000 bed level.

3.5.3.2 Chain 2 (SM08-2)

This chain was located on 4 November 1999 and was pointing towards the right bank.

- Depth to first link 280 mm
- Depth to first vertical link 324 mm
- Depth to straightened chain 42 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 282 mm and then there was fill of 324 mm. The 1999 bed level was 42 mm higher than the 1998 bed level.

The chain was located on 23 October 2000 and was pointing towards the right bank.

- Depth to first link 245 mm
- Depth to first vertical link 340 mm
- Depth to straightened chain 35 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 305 mm and then there was subsequent fill of 340 mm. The 2000 bed level was 35 mm higher than the 1999 bed level.

This chain was located on 16 November 2001 and was pointing downstream.

- Depth to first link 247 mm
- Depth to first vertical link 256 mm
- Depth to straightened chain 7 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 249 mm and then there was subsequent fill of 256 mm. The 2001 bed level was 7 mm higher than the 2000 level.

3.5.3.3 Chain 3 (SM08-3)

This chain was located on 4 November 1999 and no notes of the orientation of the chain were made, suggesting that it was not unusual.

- Depth to first link 307 mm
- Depth to first vertical link 300 mm
- Depth to straightened chain 109 mm (1998 bed level)

These measurements show that during the 1998/99 Wet season the bed was scoured to a maximum depth of 198 mm and then there was subsequent fill of 307 mm. The 1999 bed level was 109 mm higher than the 1998 bed level.

The chain was located on 23 October 2000 and was generally pointing downstream.

- Depth to first link 277 mm
- Depth to first vertical link 278mm
- Depth to straightened chain 70 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 208 mm and then there was fill of 278 mm. The 2000 bed level was 70 mm higher than the 1999 bed level.

This chain was located on 16 November 2001 and was pointing towards the right bank.

- Depth to first link 167 mm
- Depth to first vertical link 180 mm
- Depth to straightened chain -35 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 215 mm and then there was subsequent fill of 180 mm. The 2001 bed level was 35 mm lower than the 2000 bed level.

3.5.3.4 *Plastic chain 1 (SM08-P1)*

This chain was located 23 October 2000 and was pointing downstream.

- Depth to first link 232 mm
- Depth to first vertical link 340 mm
- Depth to straightened chain 35 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 305 mm and then there was subsequent fill of 340 mm. The 2000 bed level was 35 mm higher than the 1999 bed level.

This chain was located on 16 November 2001 and was pointing mainly downstream.

- Depth to first link 146 mm
- Depth to first vertical link 308 mm
- Depth to straightened chain -44 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 352 mm and then there was subsequent fill of 308 mm. The 2001 bed level was 44 mm lower than the 2000 bed level.

3.5.3.5 *Plastic chain 2 (SM05-P2)*

This chain located on 23 October 2000 and was pointing downstream.

- Depth to first link 192 mm
- Depth to first vertical link 297 mm
- Depth to straightened chain 72 mm (1999 bed level)

These measurements show that during the 1999/2000 Wet season the bed was scoured to a maximum depth of 225 mm and then there was subsequent fill of 297 mm. The 2000 bed level was 72 mm higher than the 1999 bed level.

This chain was located on 16 November 2001 and was pointing downstream.

- Depth to first link 179 mm
- Depth to first vertical link 246 mm
- Depth to straightened chain -62 mm (2000 bed level)

These measurements show that during the 2000/2001 Wet season the bed was scoured to a maximum depth of 308 mm and then there was subsequent fill of 246 mm. The 2001 bed level was 62 mm lower than the 2000 level.

For Swift Creek Cross Section 8, the 1998/1999 average scour was 260 mm and the average fill was 348 mm. During the 1999/2000 Wet season the average scour was 257 mm and the average fill was 307 mm. The scour chains after the 2000/2001 Wet season recorded 303 mm of scour and 275 mm of fill. The plastic scour chains for the 1999/2000 Wet season experienced 265 mm of scour and then 319 mm of fill. For the 2000/2001 Wet season there was 330 mm of scour and 277 mm of fill.

3.5.4 Swift Creek scour and fill

During the Wet seasons of 1998/1999, 1999/2000 and 2000/2001 the bed at Swift Creek experienced both scour and fill of the sandy bed material. From the scour chain data the stream bed at all six of the metal scour chains installed before the 1998/1999 Wet season exhibited net fill. Before the 1999/2000 Wet season an additional three metal scour chains were installed at cross section SM02. After the 1999/2000 Wet season seven of the nine chain measurements indicated net fill, one exhibited net scour and the other chain exhibited no net change. After the 2000/2001 season four of the nine chains exhibited net fill, three chains exhibited net scour, one chain was dislodged completely and the other chain was not found. Table 6 shows the mean scour and fill at each section and gives the average scour and fill for the Swift Creek gauge reach.

Table 6 Scour and fill in Swift Creek. The standard error of estimate is also shown for the averages. All units are in mm.

Cross Section	1998/1999			1999/2000			2000/2001		
	Scour	Fill	Net Change	Scour	Fill	Net Change	Scour	Fill	Net Change
SM05*	362	434	72	376	405	29	505	530	25
SM02	Not installed			184	173	2	187	189	1
SM08	260	348	88	257	307	50	303	275	-25
Average	311 ± 51	391 ± 43	80 ± 8	272 ± 56	295 ± 67	27 ± 14	332 ± 93	331 ± 102	0 ± 15

* Scour chain SM05-3 was not located in 2000/2001 and SM05-2 was completely dislodged during the 1998/99 Wet season, therefore, the scour was only determined from one chain (SM05-1) and the fill was determined from two chains (SM05-1 & 2).

During the 1998/99 Wet season there was net fill of 80 mm, and there was also net fill during the 1999/2000 Wet season of 27 mm. The 2000/2001 Wet season exhibited no net change. The maximum average scour was 505 mm and the maximum fill was 530 mm.

4 Scour and fill in the Swift Creek catchment

Table 7 shows the average values of net change in scour and fill for each study reach in the Swift Creek catchment for each year of measurement. Scour is denoted by a negative value and fill by a positive value.

Net scour during the 1999/2000 Wet season was exactly matched by net fill during the 2000/2001 Wet season on Tributary North. There are only reliable data for Tributary Central for the 1999/2000 and 2000/2001 Wet seasons due to chain sagging during the first year of measurements. Minor net scour during the 1999/2000 Wet season was replaced by net fill during the 2000/2001 Wet season on Tributary Central. Net fill during the 1998/1999 Wet season was replaced by net scour during the 1999/2000 Wet season on East Tributary. Minor net change (2 ± 16 mm) was recorded during the 2000/2001 Wet season. On Upper Swift Creek net fill was recorded during all three Wet seasons. On Swift Creek net fill was recorded during the first two Wet seasons but no net change was recorded during the last. The results of one year measurements of scour and fill, as carried out by Roberts (1991) on Magela Creek, are likely to yield little information on longer term trends and therefore one year of measurements is not recommended for future use in the Alligator Rivers Region.

Table 7 Mean values of net change in scour (negative values) and fill (positive values) and the standard error of estimate for each reach in which scour chain measurements were made for each Wet season. Results for plastic chains are not included in the data. All units are in mm.

Reach	1998/1999	1999/2000	2000/2001
	Scour/Fill	Scour/Fill	Scour/Fill
Tributary North	Not Installed	25 ± 16	-25 ± 19
Tributary Central	75*	-7 ± 23	97 ± 91
East Tributary	32 ± 76	-29 ± 22	2 ± 16
Upper Swift Creek	142 ± 41	21 ± 7	10 ± 6
Swift Creek	80 ± 8	27 ± 14	0 ± 15
Average	85 ± 26	7 ± 11	17 ± 21

* Based on one chain at one cross section only and was not used in the calculation of the average.

The catchment average net scour and fill was calculated as the arithmetic mean of the averages for each measurement reach (Table 7). Fill dominated in all measurement reaches during the 1998/1999 Wet season, producing a catchment average net fill of 85 ± 26 mm. However, there were no scour chain data for Tributary North and only one scour chain did not sag on Tributary Central. While net fill again dominated during the 1999/2000 Wet season, net scour was recorded on Tributary Central and East Tributary, and the standard error of estimate was large in relation to the mean. Net fill again dominated during the 2000/2001 Wet season but net scour was recorded on Tributary North and essentially no net change was recorded on East Tributary and Swift Creek.

The scour chain measurements indicate that net fill is currently (period 1998 to 2001) occurring in the Swift Creek catchment and hence the bed is an active sand storage. Therefore, it is essential that effective sediment control measures are maintained on the Jabiluka mine site because mine-derived sand will be quickly routed to the channel network where it will be temporarily stored. The scour chain measurements do not indicate that the mine site tributaries (Tributary North and Tributary Central) have been oversupplied with sand derived from the mine site because active bed aggradation is not currently occurring.

The scour and fill results for the plastic scour chains on Swift Creek at the downstream gauging station were compared to the results for the metal chains at the same cross sections for the 1999/2000 and 2000/2001 Wet seasons. The variances of the net change data for both years were not significantly different according to the results of an F test. Therefore, a t test was used to compare the means for the two types of chains. For the 1999/2000 Wet season the mean net change measured by the plastic chains (scour of 45 ± 11 mm) was not significantly different to that measured by the metal chains (scour of 27 ± 14 mm). For the 2000/2001 Wet season the results were again not significantly different (mean fill of 12 ± 26 mm for plastic chains and mean fill of 7 ± 39 mm for metal chains). However, the small sample size for the plastic chains ($n = 6$ for 1999/2000 and $n = 3$ for 2000/2001) cautions against uncritical acceptance of these results. For the same variance and difference in means, a sample size of 16 would yield a significant result at $\rho = 0.05$. However, the maximum number of scour chains installed in any measurement reach is only 15 (Table 1). The present sample sizes are too small to reliably evaluate the performance of the plastic scour chains. Nevertheless, on the basis of field observations of scour chain behaviour outlined in section 3.5, metal chains are believed to be more accurate indicators of scour and fill. Furthermore, as also outlined in section 3.5, it is extremely difficult to relocate plastic scour chains because there is only a relatively small metal tag that can be sensed by the metal detector.

Roberts (1991) interpreted scour depths, as measured by scour chains, as being related to one-half of the maximum dune amplitude. If this interpretation is correct, the range of maximum dune amplitudes for the measured reaches for the two to three measured Wet seasons are:

- 100 ± 68 to 162 ± 54 mm on Tributary North,
- 144 ± 76 to 166 ± 66 mm on Tributary Central,
- 328 ± 76 to 520 ± 110 mm on East Tributary,
- 280 ± 54 to 394 ± 104 mm on Upper Swift Creek, and
- 544 ± 112 to 664 ± 186 mm on Swift Creek.

Field observations of bedform dimensions during each Wet season indicate that these estimated values are in reasonable agreement with measured/estimated maximum values during weekly site visits to the gauging stations. They also indicate that dune dimensions are least on the mine site tributaries (the smallest channels) and greatest at the gauging stations (the largest channels), with the largest bedforms at the Swift Creek gauge which has the greatest catchment area and discharge.

5 Conclusions and recommendations

A total of 36 metal and six plastic scour chains were installed between 1998 and 1999 on Tributary North, Tributary Central, East Tributary and Swift Creek to measure scour and fill during the 1998/1999, 1999/2000 and 2000/2001 Wet seasons. Measurements have been concentrated on the Jabiluka mine site tributaries and in the *eriss* gauging station reaches. Plastic scour chains appear to behave differently to metal chains and are much more difficult to relocate with the metal detector because there is only a relatively small metal tag to assist recovery. Due to the small sample size for plastic chains, no significant difference in net scour or fill was detected between plastic and metal scour chains. However, for the same variance and difference in means, a sample size of only 16 would have yielded a significant difference at $\rho = 0.05$. Therefore, plastic chains are not recommended for future investigations of scour and fill in the Alligator Rivers Region.

Scour and fill are active geomorphic processes in the Swift Creek catchment that result in the reworking of the sandy bed sediment. Mean scour ranging from a minimum of 50 ± 34 mm on Tributary North during the 1999/2000 Wet season to a maximum of 332 ± 93 mm at Swift Creek during the 2000/2001 Wet season was recorded. Mean fill ranging from a minimum of 56 ± 18 mm on Tributary North during the 2000/2001 Wet season to a maximum of 391 ± 43 mm at Swift Creek during the 1998/1999 Wet season were also recorded. Allowing for plus or minus twice the standard error of estimate of the mean, average scour and fill for the metal chains during each Wet season in each measurement reach overlap with each other. This suggests that scour and fill are not significantly different.

Net fill is currently occurring in the Swift Creek catchment and hence the bed is an active sand storage. If any contaminated sandy material was released from the mine site under existing conditions, it would be initially stored in the bed sediments of the mine tributaries and Swift Creek. Therefore, it is essential that the *eriss* monitoring program (Erskine et al 2001) of permanently monumented cross sections (Saynor et al 2002), scour chains and erosion pins (Saynor et al 2001b) is maintained to evaluate the significance of channel erosion as a sediment source in comparison to the Jabiluka mine site. Although the Jabiluka mine is currently in an environmental care and maintenance phase (Energy Resources of Australia Ltd 2002), it is still necessary to determine the geomorphic behaviour of the mine site tributaries in comparison to the remainder of the Swift Creek channel network. It is recommended that the scour chain program is continued for the immediate future because the time and resources involved are relatively minor yet provide valuable information on sediment dynamics that are important for evaluating the impact of the Jabiluka mine and for determining the fate of sandy sediment that may be derived from the mine site.

6 References

- Andrews ED 1979. *Scour and fill in a stream channel, East Fork River, Western Wyoming*. United States Geological Survey Professional Paper 1117, Washington, DC.
- Ariizumi A & Kondo O 1963. Measurement of river-bed variations during a flood. *Proceedings of the Symposium on Application of Radioisotopes in Hydrology, Tokyo, Japan*, International Atomic Energy Agency, Vienna, 237–253.
- Colby BR 1964. *Scour and fill in sand-bed streams*. United States Geological Survey Professional Paper 462–D, Washington, DC.
- Emmett WW 1965. The Vigil network: methods of measurement and a sampling of data collected. *Proceedings of Representative and Experimental Areas from the Budapest Symposium*. Publication 66, IAHS, Wallingford, 89–106.
- Emmett WW & Leopold LB 1963. Downstream pattern of riverbed scour and fill. *Proceedings of the Federal Interagency Sedimentation Conference*. United States Department of Agriculture Agricultural Research Service, Miscellaneous Publication 970, 399–409.
- Energy Resources of Australia Ltd 2002. *2001 Annual Report*. ERA, Sydney.
- 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.
- Foley MG 1978. Scour and fill in steep, sand-bed ephemeral streams. *Geological Society of America Bulletin* 89, 559–570.

- Fowler KK & Wilson JT 1995. Characteristics, transport, and yield of sediment in Juday Creek, St. Joseph County, Indiana, 1993–94. United States Geological Survey Water–Resources Investigations Report 95–4135, Indianapolis, Indiana.
- Lane EW & Borland WM 1954. River-bed scour during floods. *Transactions of the American Society of Civil Engineers* 119, 1069–1079.
- Leopold LB, Emmett WW & Myrick RW 1966. *Channel and hillslope processes in a semi-arid area, New Mexico*. US Geological Survey Professional Paper 352G, Washington, DC.
- Locher H 1997. *Sediment transport in the King River, Tasmania. Mount Lyell Remediation Research and Demonstration Program*. Supervising Scientist Report 120, Supervising Scientist, Canberra.
- McDonald RC & Isbell RF 1990. Soil profile. In *Australian soil and land survey field handbook*, eds RC McDonald, RF Isbell, JC Speight, J Walker & MS Hopkins, Inkata Press, Melbourne, 103–152.
- Roberts RG 1991. Sediment budgets and Quaternary history of the Magela Creek catchment, Tropical Northern Australia. Unpublished PhD thesis, University of Wollongong, NSW.
- Saynor MJ 2000. Hydrology, sediment transport and sediment sources in the Swift Creek catchment Northern Territory: A PhD proposal. Internal Report 339, Supervising Scientist, Darwin. Unpublished paper.
- Saynor MJ, Dawson JC, Smith BL, Crisp E & Moliere DR 2001a. Installation, maintenance and running of gauging stations in the Swift (Ngarradj) Creek catchment, Northern Territory. Internal Report 384, Supervising Scientist, Darwin. Unpublished paper.
- Saynor MJ, Evans KG, Smith BL, Crisp E & Fox G 2001b. Field monitoring information for the Swift (Ngarradj) Creek catchment, Northern Territory. Internal Report 355, Supervising Scientist, Darwin. Unpublished paper.
- Saynor MJ, Erskine WD, Smith BL, Fox GJ, & Evans KG 2002. Cross sectional data and a preliminary assessment of channel changes in the Swift Creek (Ngarradj) catchment between 1998 and 2001. Internal Report 385, Supervising Scientist, Darwin. Unpublished paper.

