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Cross section, scour chain and particle size data in Gulungul Creek for 2002 to 2004

MJ Saynor, BL Smith, G Fox & KG Evans

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(Release status – unrestricted)

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Contents

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1 Introduction

Ranger uranium mine lies partly within the catchment of Gulungul Creek, a small left bank tributary of Magela Creek (see figure 1). Current mine infrastructure in the catchment includes part of the tailings dam and minor road works and the final rehabilitated landform will also lie partly within the catchment. A review of the literature found that there is limited data on the geomorphology of Gulungul Creek (Crossing 2002).

A program of geomorphic research and monitoring in Gulungul Creek is required both to assess any current mine impact on the stream system, with particular reference to channel stability and sediment load, and to determine a baseline and assessment strategy for future monitoring of the final rehabilitated landform. A research program similar to that proposed by Erskine et al (2001) for the Ngarradj catchment was established in Gulungul Creek.

Initial field inspections were conducted in the Gulungul Creek catchment during the dry season of 2002. In order to measure the amount of large-scale bank erosion along Gulungul Creek, permanently marked channel cross sections were established (figure 2). Bulk bed material samples at each of the cross sections were collected and scour chains were used at some of the cross sections to measure scour and fill. The initial set up of cross sections and survey data are described in Crossing (2002).

Data for the annual cross section surveys, bulk bed material samples and scour chain measurements for the dry seasons of 2003 and 2004 are presented in this report. Annual data reports (Internal Reports) will be produced so that a record of the data is retained. Analysis of the data will be presented in refereed documents at a later date.

2 Methods

2.1 Cross Section survey

Twelve cross sections were surveyed along Gulungul Creek at different sites between the upstream lease boundary and the junction with Baralil Creek (a few hundred metres downstream of the Arnhem Highway (fig 1)). The location of these sections is shown in figure 2. These sections were installed and surveyed in the 2002 dry season and will be surveyed on an annual basis to provide a baseline for monitoring change in the channel banks and bed over time.

The cross-sections were surveyed into two concrete plinths, one either side of the main channel. Some channels were surveyed only between these two plinths, while others extended away from the channel beyond one or both plinths, using the same instrument set up. A star picket was used to mark the end of the cross-section in these cases. UG01 is a longer section with 5 plinths, and involved three instrument setups. Details of survey setup points are given in table 1. Table 1 is sourced from Crossing (2002) with some changes to the table to correct

transcription errors. Section UG01 is located through the proposed location of an upstream gauging station (fig 1). A temporary gauging station was installed prior to the 2003–04 wet season and stage-discharge gauging measurements were carried out during the wet season. The sections immediately upstream and downstream of UG01 (UG02, 03 and 04) were chosen to ensure the channel reach around the gauging station is adequately characterised.

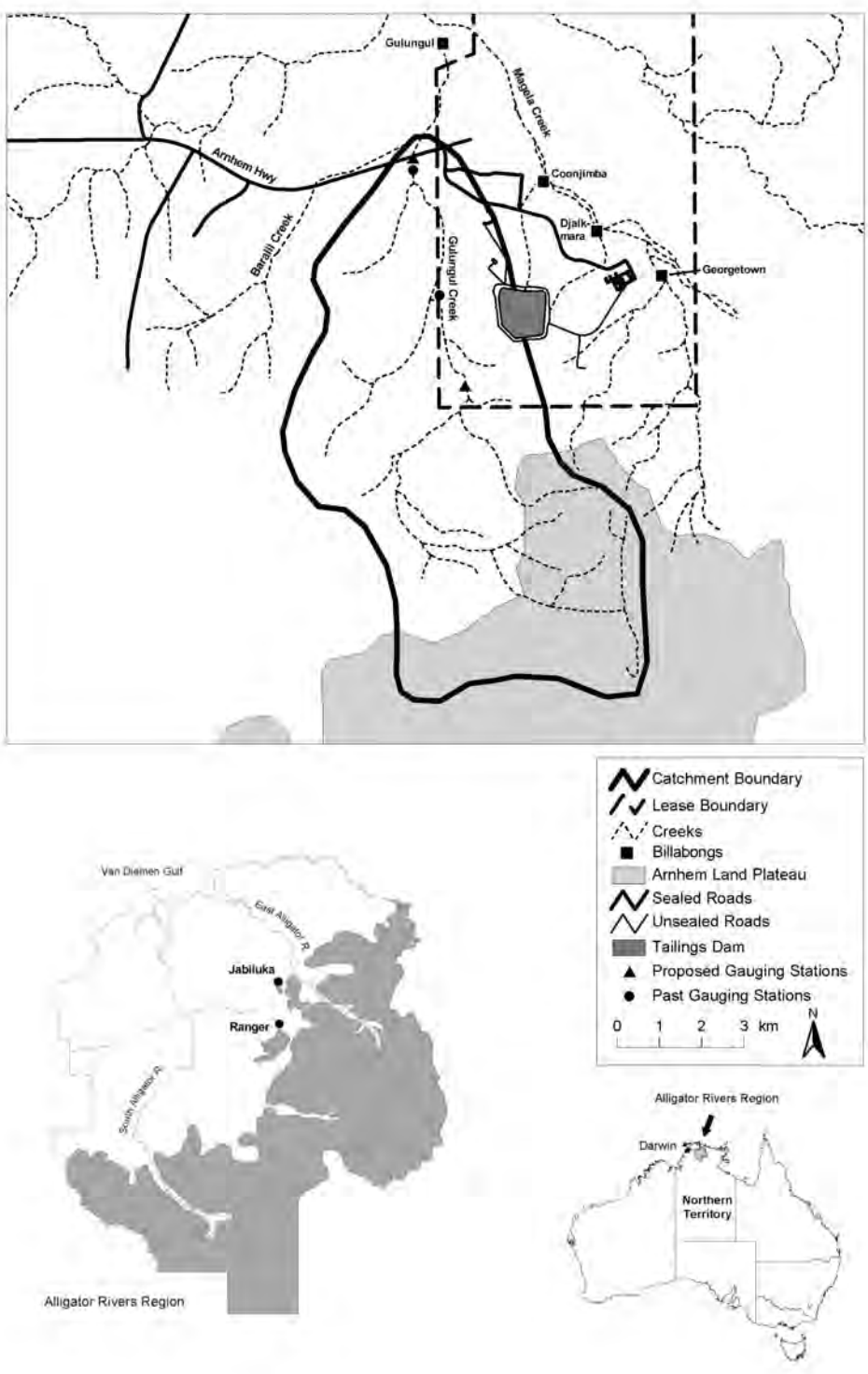


Figure 1 Gulungul Creek catchment showing the main creeks and tributaries, Ranger Mineral Lease and mine infrastructure, gauging stations and the Arnhem Land Plateau. Sourced from Crossing (2002).

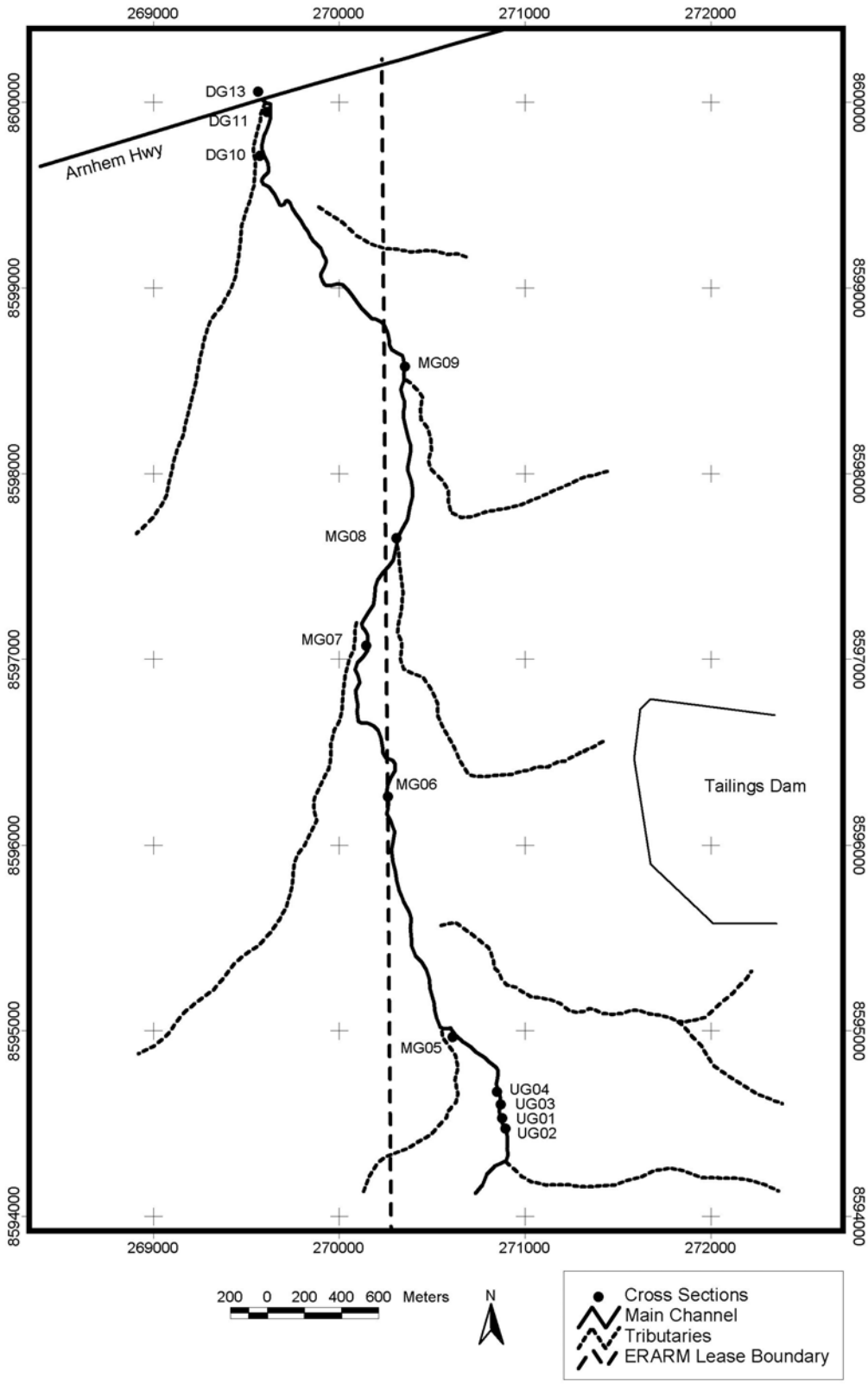


Figure 2 Gulungul Creek showing location of cross sections. Sourced from Crossing (2002).

It is proposed that a gauging station is installed downstream of the mine approximately 200 m upstream from the culverts on the Arnhem Highway prior to the 2004–05 wet season. No cross section has been surveyed at this location, as the culverts are a permanent man-made structure rather than a natural stream channel. When required, a survey can be undertaken once the gauging station is installed. Sections DG11 and DG13 have been surveyed upstream and downstream of the culverts to ensure the channel reach around this gauging station is also adequately characterised.

Table 1 Details of the cross-section surveys carried out in the 2002 dry season. This information should be used whenever the cross-sections are re-surveyed.

Section	Instrument set up	Arbitrary coordinates (m) [a]			Sighted to	Sighting angle (degrees)
		North	East	Height		
UG01 - A	Plinth 1 (RB)	5000	2000	50	Plinth 3	270
UG01 - B	Plinth 3	1864.60	5000	50.43	Plinth 1	90
UG01 - C	Plinth 4	1747.45	5000	49.88	Plinth 3	Approx. 90 [b]
UG02	RB plinth	3000	1000	50	LB plinth	270
UG03	RB plinth	3000	1000	50	LB plinth	270
UG04	RB plinth	3000	1000	50	LB plinth	270
MG05	RB plinth	3000	1000	50	LB plinth	270
MG06	RB plinth	3000	1000	50	LB plinth	270
MG07	LB plinth	3000	1000	50	RB plinth	90
MG08	LB plinth	3000	1000	50	RB plinth	90
MG09	RB plinth	3000	1000	50	LB plinth	270
DG10	RB plinth	3000	1000	50	LB plinth	270
DG11	RB plinth	3000	1000	50	LB plinth	270
DG13	RB plinth	3000	1000	50	LB plinth	270

a The coordinates for Plinth 3 and 4 on cross-section UG01 are not arbitrary, and were measured from the coordinates at Plinth 1 on cross-section UG01. It should be noted that apart from these cross sections, no other cross sections can be related to each other.

b The backsight for Section UG01 – C was sighted on Plinth 3, but rather than specifying a sighting angle, the coordinates of Plinth 3 were entered.

Plots of the cross section surveys are contained in section 3 and the survey data are shown in Appendix A. Hydraulic Geometry calculations will be made when several more annual surveys have been completed.

2.2 Bed material field collection for particle size analysis

Bulk samples of specific depositional environments are the accepted method of sampling fluvial sediments. This involves the collection of all material from a predetermined volume within a specific depositional or geomorphic environment (Kellerhals & Bray 1971). Where collection of all sediment from a specific depositional environment is impossible because the mass is too large for collection, transport and/or analysis, sub-sampling is practised. Nevertheless, there are potential problems with bulk sampling that must be recognised. Very large sample masses are required to obtain reproducible measures of the grain size distributions of samples containing individual large clasts or gravels (de Vries 1970, Church et al 1987, Gale & Hoare 1992, Ferguson & Paola 1997). Recommended minimum sample mass also depends on sediment sorting or the dispersion of the grain size distribution (Gale & Hoare 1994, Ferguson & Paola 1997). For a particular depositional environment, poorly sorted sediments, such as found in mixed sand-bed and gravel-bed rivers, require larger

masses than better sorted samples (Gale & Hoare 1994, Ferguson & Paola 1997). Bulk sampling is also usually restricted to small areas that may not be representative of all of a specific depositional environment (Wolman 1954, Muir 1969). This is a major concern on large rivers with spatially variable depositional environments (Mosley & Tindale 1985) but is not a problem on the smaller channels in the Gulungul Creek catchment.

During the dry seasons of 2002 and 2003, a total of 24 bed material samples were collected (12 each year) from each of the cross sections. Bulk bed material samples were collected by a trowel or small spade from at least 3 (usually 6) equally spaced points across the stream bed and then combined into a single sample for each section.

2.3 Particle size analysis laboratory methods

All bulk bed-material samples were oven dried at 105°C for 24 hours before being subjected to particle size analysis. Initial field observations indicated that there was little mud (ie< 0.063 mm in diameter) present. The phi (ϕ) notation system is often used to describe the grain size of clastic sediment by sedimentologists. It is a logarithmic scale in which each grade limit is twice as large as the next smaller grade limit (Folk 1974) and is denoted by:

$$\phi = -\log_2 d \qquad (1)$$

where d is the grain diameter in mm.

Any gravel fraction of the samples was manually sieved in its entirety at $\phi/2$ intervals. If the fraction less than 2 mm in diameter (fine earth fraction) was greater than 150 g it was passed through a riffle box to obtain a sample of approximately 100 g to ensure that the analytical stainless steel sieves were not damaged by excessive loading. This sub-sample was then dry sieved through a nest of stainless steel sieves at $\phi/2$ intervals using a 15 minutes shake time. For the fine earth fraction sample masses less than 150 g, the sample was sieved in its entirety.

Given the relatively small amounts of material less than 0.063 mm that were generally obtained, four samples (UG03, UG06, MG09 & DG13) were selected from the 2003 samples and subjected to a simplified particle size analysis according to the sieve and hydrometer method of Gee and Bauder (1986). The detail of this method is contained in Saynor et al (2004). The results are shown in section 4.

2.4 Sediment texture

The sediment textural classification used for all fluviatile samples is that of Folk (1954, 1974) for unconsolidated materials and is based on a ternary diagram showing the proportions of gravel, sand and mud on separate axes (figure 3). This texture triangle is split into 15 groups and the median diameter is determined, where possible, for each component fraction. Each sediment fraction can be expressed in terms of one of the Wentworth size classes (table 2). To place a sample into one of the 15 major groups, only two properties need to be determined, namely the gravel percentage (boundaries at 80, 30, 5 and a trace or 0.01 %) and the ratio of sand to mud with boundaries at 9:1, 1:1 and 1:9 (Folk 1954, 1974). The gravel content is partly a function of the highest current velocity and the maximum grain size of the supplied sediment. The sand:mud ratio reflects the amount of winnowing (washing away of fine sediment) that has occurred. For samples lacking gravel, a further ternary diagram (figure 4) is used which expands the bottom tier of figure 3. It is based on the proportions of sand, silt and clay (see Folk 1954, 1974).

Table 2 The Wentworth grain size scale for sediments (after Folk 1974)

Finest Grain Size (mm)	Finest Grain Size (ϕ)	Wentworth Size Class
256	-8	Boulder
64	-6	Cobble
4	-2	Pebble
2	-1	Granule
1.00	0	Very coarse sand
0.50	1	Coarse sand
0.25	2	Medium sand
0.125	3	Fine sand
0.0625	4	Very fine sand
0.031	5	Coarse silt
0.0156	6	Medium silt
0.0078	7	Fine silt
0.0039	8	Very fine silt
0.00006	14	Clay

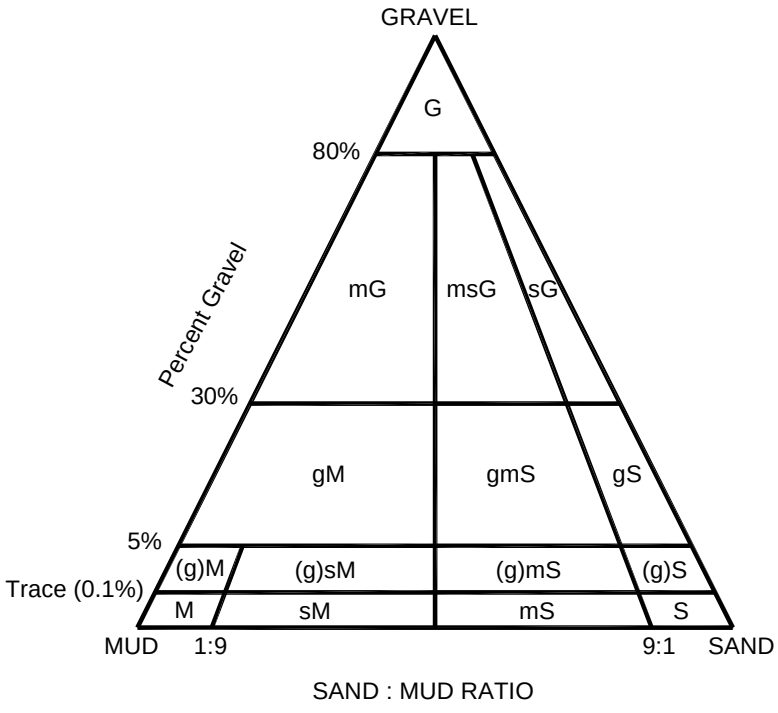


Figure 3 Folk's (1974) textural groups. G is gravel; sG sandy gravel; msG muddy sandy gravel; mG muddy gravel; gS gravelly sand; gmS gravelly muddy sand; gM gravelly mud; (g)S slightly gravelly sand; (g)mS slightly gravelly muddy sand; (g)sM slightly gravelly sandy mud; (g)M slightly gravelly mud; S sand; mS muddy sand; sM sandy mud; M mud.

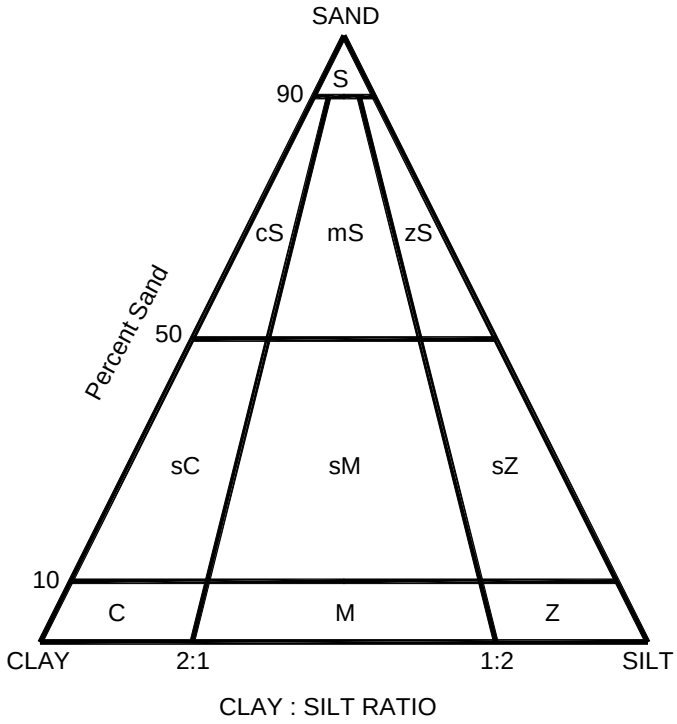


Figure 4 Folk's (1974) expansion of the bottom tier of figure 5 to show textural classes for sediments lacking gravel. S is sand; zS silty sand; mS muddy sand; cS clayey sand; sZ sandy silt; sM sandy mud; sC sandy clay; Z silt; M mud; and C clay

2.5 Scour Chains

Depths of scour and fill can be measured by scour chains, as described by Emmett and Leopold (1963) and Emmett (1965). Scour chains were installed in various reaches of the Gulungul Creek catchment (table 3) during the late dry season of 2002. Table 3 contains information on the number of scour chains installed and at which cross sections. The scour chains were always located on a surveyed cross section. After each wet season, the elevation of the stream bed was resurveyed and the bed was excavated until the chain was exposed (figure 5). The difference between the existing bed elevation and the horizontal chain was the depth of fill. If no scour had occurred, the amount of fill was the depth of sediment above the top of the buried chain. If the amount of fill equalled scour, there was no net change in bed level although scour and fill had occurred.

Table 3 Number of scour chains installed and on which cross sections in Gulungul Creek

Cross Section name	No. of scour chains	Cross Section name	No. of scour chains
UG02	**2**	**MG08**	**3**
UG03	**3**	**DG10**	**2**
MG06	**3**	**DG11**	**2**

Figure 5 Scour chain orientated essentially downstream at MG08-3 on 24 November 2004. Arrow marked on paper indicates flow direction.

Late in each dry season when the water table was at its lowest, the scour chains were relocated using the diagrams and measurements in Appendix C, more importantly, a metal detector. Measurements of the depth to the scour chain and the bed surface level were then obtained. 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 bed level. A photograph was taken to show the position of the chain and the direction of flow was indicated by an arrow marked on paper or by a trowel, pen or ruler pointing downstream (figure 5). As the scoured part of the chain was not always lying horizontal, two measurements were taken to determine the scour depth (figure 6):

- depth to top of first link.
- depth to the first vertical link.

After these measurements were made the chain was carefully straightened vertically and then the depth to the top of the straightened chain from the base of the wooden board was measured.

All measurements were made as positive values except when the straightened chain was higher then the current bed level (in this case, the value was a negative value). These measurements were used to determine scour and fill, which is explained in the next section. Once all the measurements had been made, the chain was reset so that the top link was level with the channel bed.

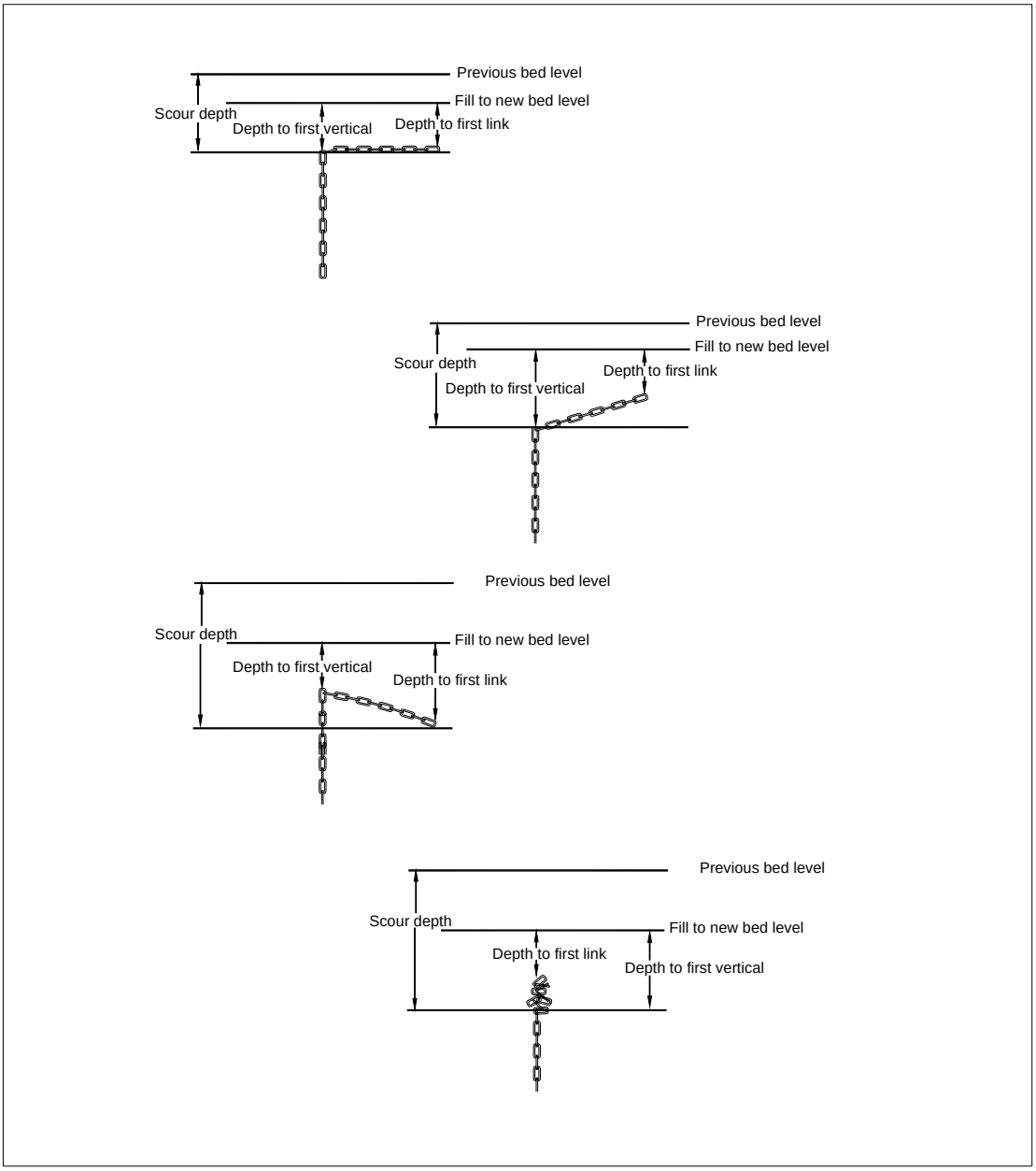


Figure 6 Diagrammatic representation of the full range of scour chain behaviour when there was net scour depicted by the middle example in figure 7. Net fill is shown by the top example in figure 7 and no change, by the lower example in figure 7.

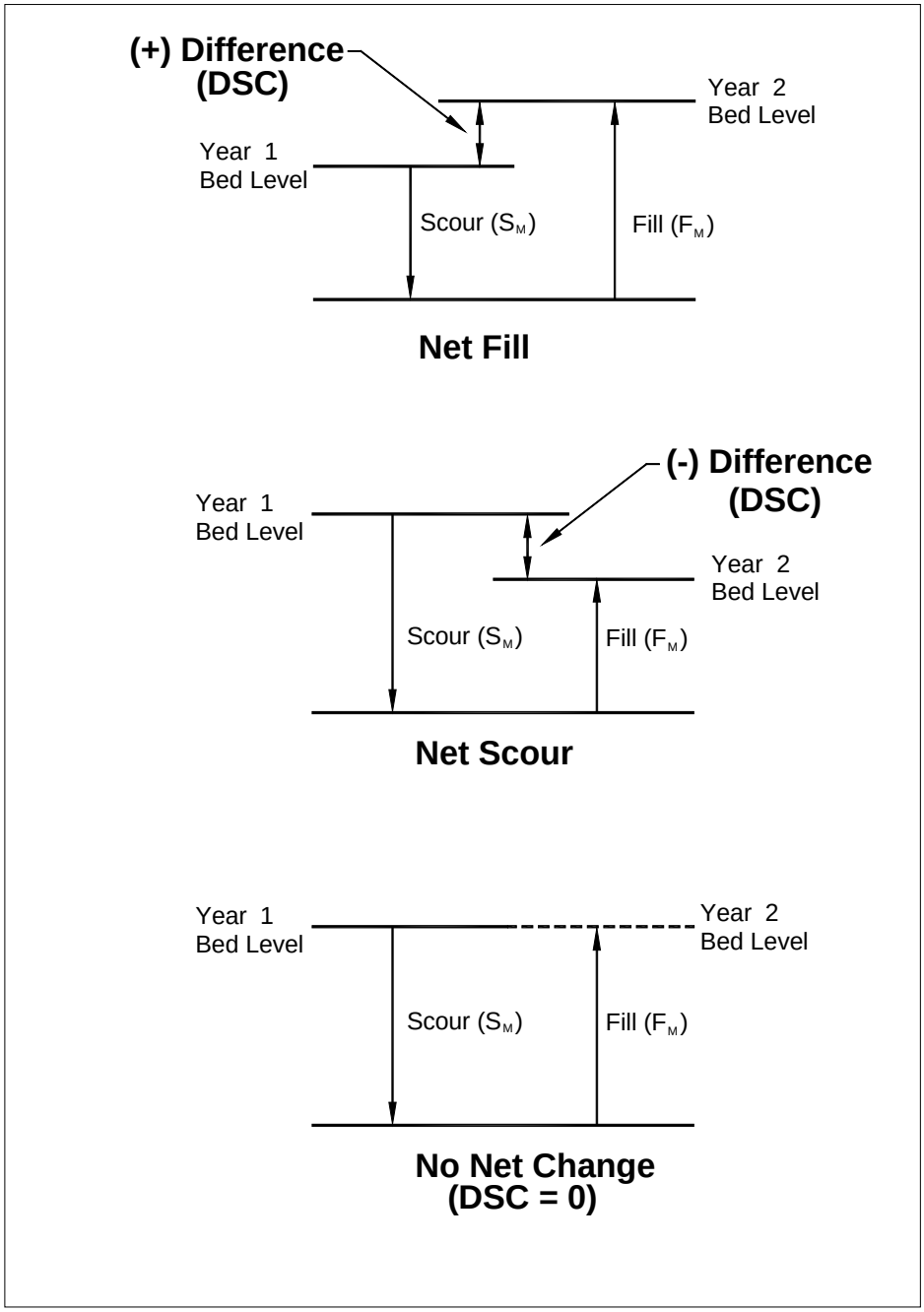


Figure 7 Three examples of net channel bed change during the wet season measured by scour chains. Net fill occurs when the bed level for the 2nd year is higher than for the 1st (top). Net scour occurs when the bed level for the 2nd year is lower than for the 1st (middle). No net change occurs when the bed level for the 1st and 2nd years is the same (bottom).

2.5.1 Scour and fill calculations

The top of the highest link of each chain is the zero datum for the next wet season. The values are all made to this datum even though some of the measurements are made to the bed level for year 2 (figure 7). Once the scour chains are reset the datum is then also reset and the bed level is called Year 1 for the following year (figure 7).

Maximum scour (S_M) is determined as

$$S_M = F_M - DSC \qquad (2)$$

where F_M is the maximum amount of fill during a wet season and DSC is the vertical distance from the year 2 bed level to the top of the straightened chain. It is essential that the mathematical signs in figure 7 are used.

A positive value of DSC indicates net fill from year 1 to year 2 and a negative value indicating net scour (figure 7). This convention of positive values for fill and negative values for scour has been used by, among others, Emmett (1965), Leopold et al (1966), Roberts (1991), Fowler & Wilson (1995) and Locher (1997). Figure 7 shows the three possible situations, net fill, net scour and no net change.

3 Results

3.1 Annual cross section

The plots of the 12 cross sections for 2002, 2003 and 2004 are shown in figs 8–19. The location of the cross sections is shown in figure 2. The cross section survey data for all sections for 2003 and 2004 are contained in Appendix A. Cross section survey data for 2002 is contained in Crossing (2002).

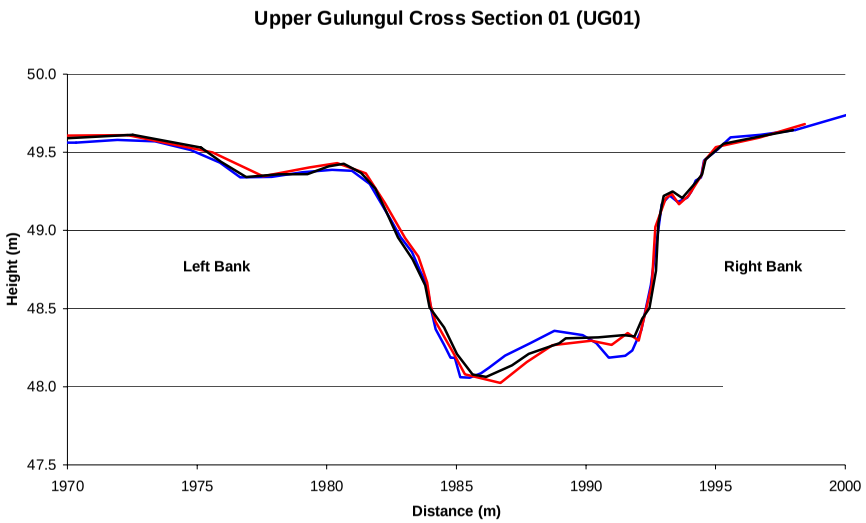


Figure 8 Cross section plot of upper Gulungul Cross section 01 for 2002, 2003 & 2004

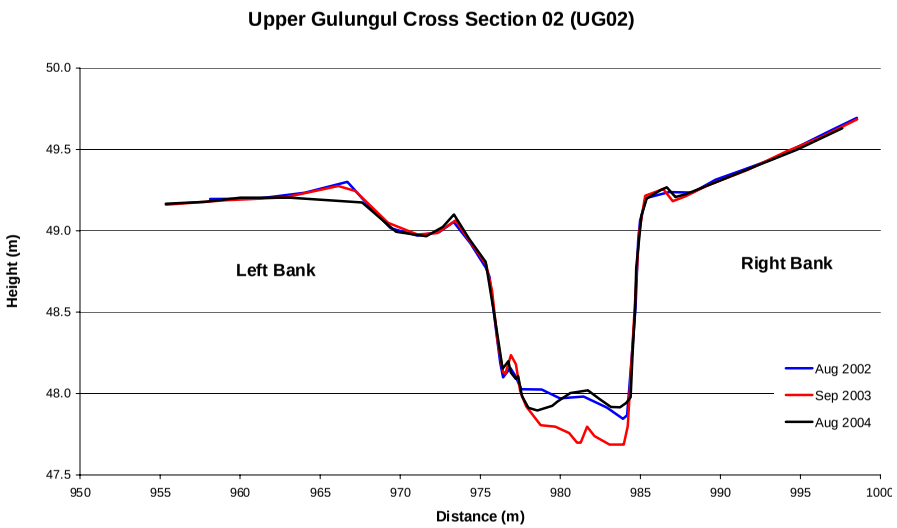


Figure 9 Cross section plot of upper Gulungul Cross section 02 for 2002, 2003 & 2004

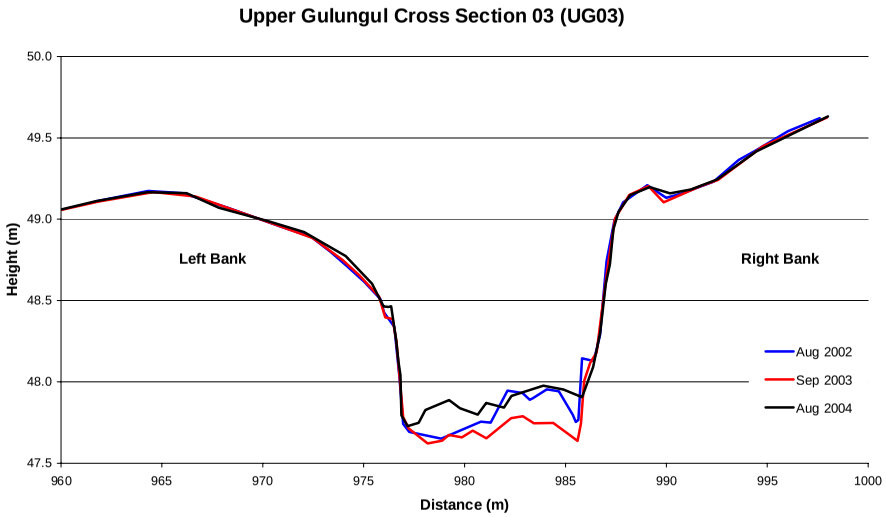


Figure 10 Cross section plot of upper Gulungul Cross section 03 for 2002, 2003 & 2004

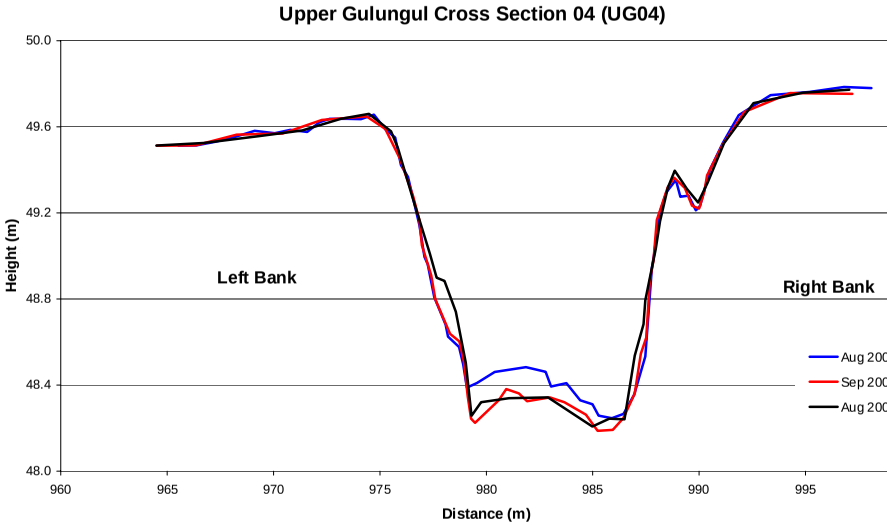


Figure 11 Cross section plot of upper Gulungul Cross section 04 for 2002, 2003 & 2004

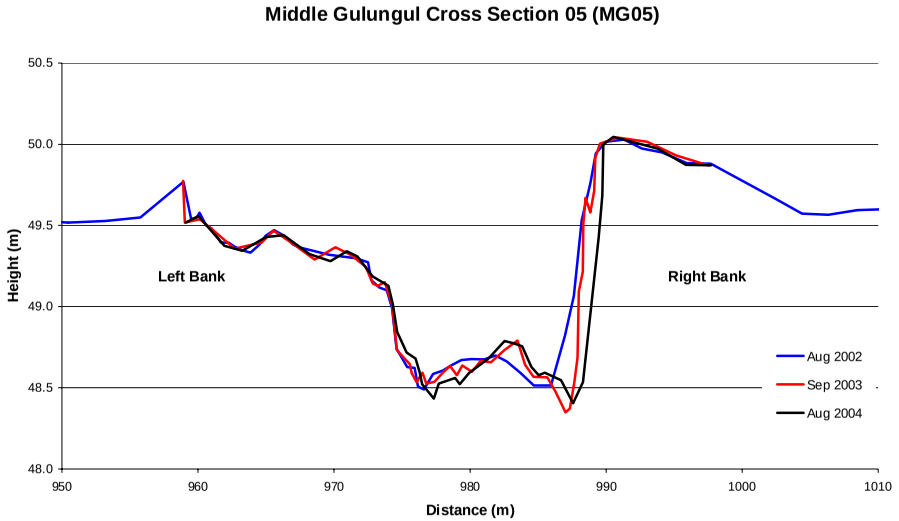


Figure 12 Cross section plot of Middle Gulungul Cross section 05 for 2002, 2003 & 2004

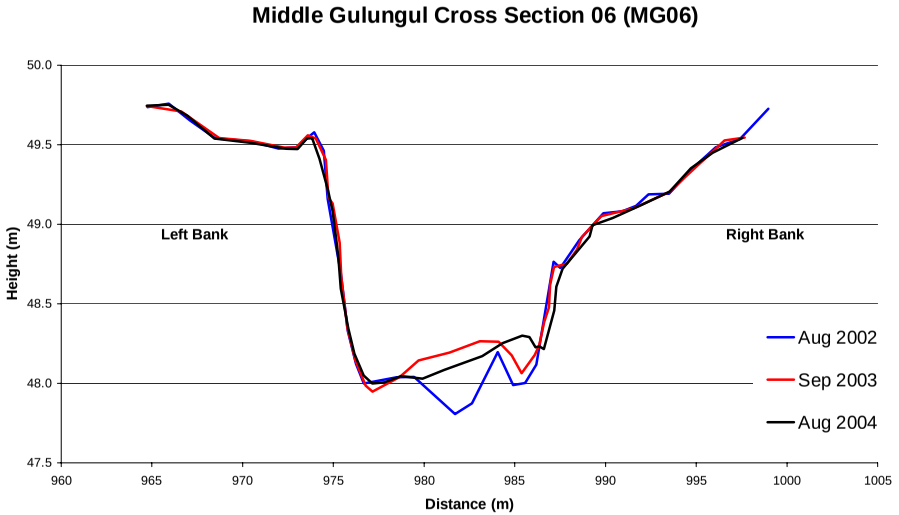


Figure 13 Cross section plot of Middle Gulungul Cross section 06 for 2002, 2003 & 2004

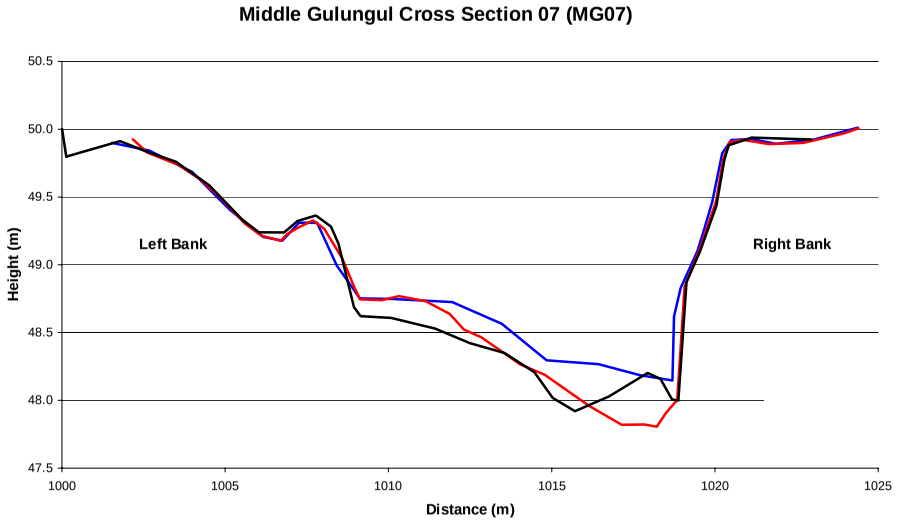


Figure 14 Cross section plot of Middle Gulungul Cross section 07 for 2002, 2003 & 2004

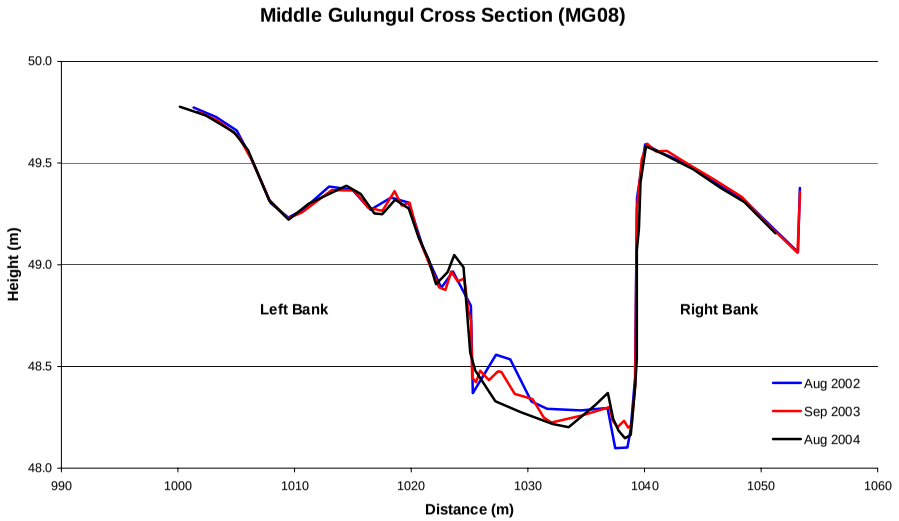


Figure 15 Cross section plot of Middle Gulungul Cross section 08 for 2002, 2003 & 2004

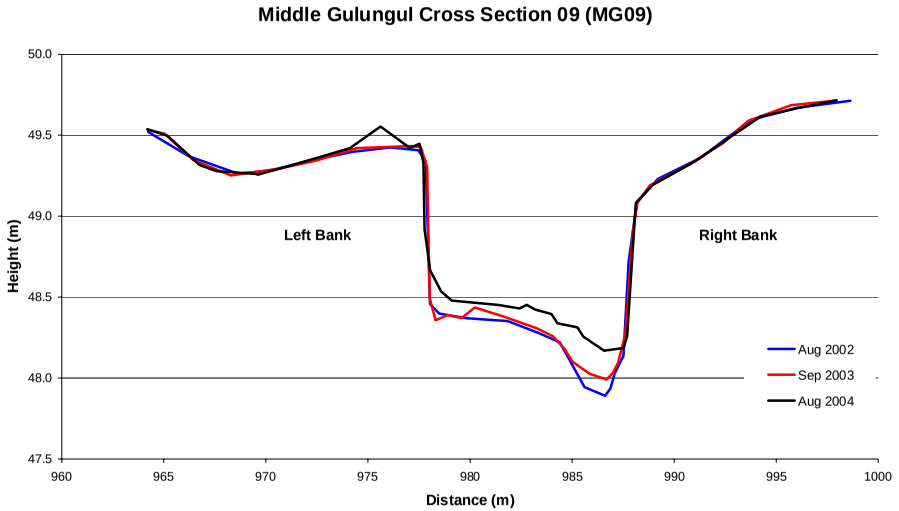


Figure 16 Cross section plot of Middle Gulungul Cross section 09 for 2002, 2003 & 2004

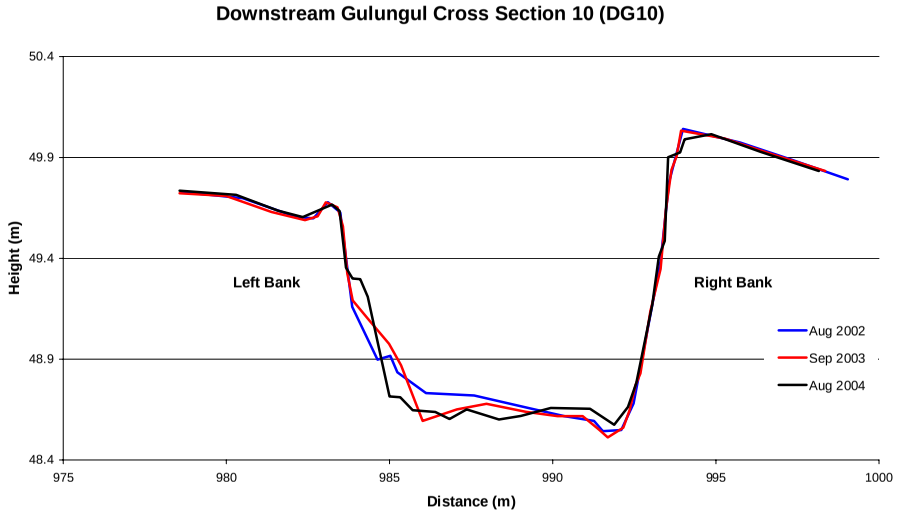


Figure 17 Cross section plot of Downstream Gulungul Cross section 10 for 2002, 2003 & 2004

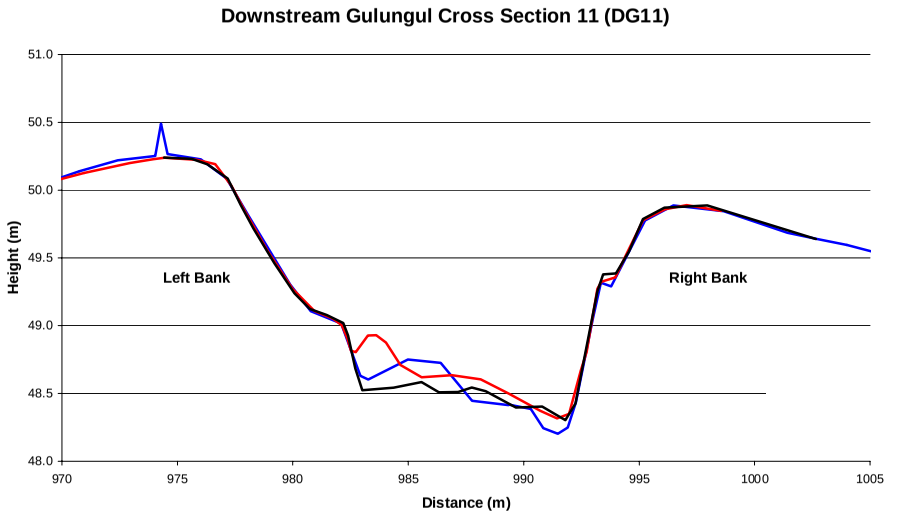


Figure 18 Cross section plot of Downstream Gulungul Cross section 11 for 2002, 2003 & 2004

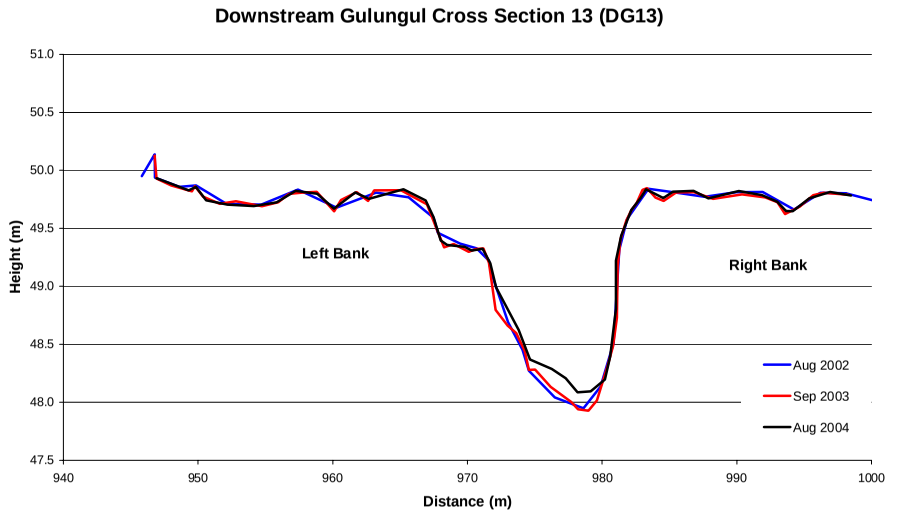


Figure 19 Cross section plot of Downstream Gulungul Cross section 13 for 2002, 2003 & 2004

3.2 Particle size analysis

Figure 2 shows the location of the channel cross sections at which the bed material was bulk sampled. Sample masses for each year are summarised in table 4. From the criteria of de Vries (1970), Church et al (1987) and Gale & Hoare (1992), the sample masses were adequate to obtain reproducible measures of the grain size distribution for these bed-material sediments.

Table 4 Summary of oven dry bulk bed-material sample masses collected on Gulungul Creek for each year of the sediment program.

Sample Mass	**2002**	**2003**	**2004**
Mean (g)	1523.3	2197.8	2634.0
Standard Error of Estimate (g)	113.7	103.8	176.7
Minimum (g)	1104.5	1459.9	1664.7
Maximum (g)	2486.5	2859.8	3582.1

To investigate the mud content of the bed material, four of the 2002 samples were dispersed and wet sieved through a 63 μm sieve. The percentage of the samples <63 μm were as follows:

- cross section UG03 – 2.19%,
- cross section MG06 – 1.63%,
- cross section MG09 – 1.29%
- cross section DG13 – 3.57%.

As all four samples had less than 5 % mud, bed-material samples were oven dried and dry sieved in subsequent years. Of the 36 samples collected on Gulungul Creek there was only 1 sample with greater than 5% mud.

The cumulative frequency grain size distributions and Folk (1954, 1974) texture group for every sediment sample collected on Gulungul Creek are contained in Appendix B, tables B1 to B3.

3.3 Gulungul scour chain

Scour chains were installed during the late dry season of 2002 at six cross sections. The following cross sections had three chains installed in the bed: UG03, MG06 and MG08, while only two chains were installed at: UG02, DG10 and DG11 due to the narrow bed width at these sections. The location of the cross sections is shown in figure 2. Appendix C has schematic diagrams that can be used to assist with locating the scour chains.

3.3.1 Upper Gulungul cross section (UG02)

There were two chains located across the bed of the channel at UG02.

UG02-1

This chain was found on 19 November 2003 and was located toward the right bank. The chain was buried and orientated diagonally upstream and towards the right bank.

- Depth to first link……..225 mm
- Depth to first vertical link…….220 mm
- Depth to straightened chain……..-185 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a maximum depth of 410 mm and then filled by 225 mm over the remaining wet season. The 2003 bed level was 185 mm below the 2002 bed.

The chain was located on 26 October 2004 and was buried and oriented diagonally upstream towards the left bank.

- Depth to first link……..500 mm
- Depth to first vertical link…….487 mm
- Depth to straightened chain……..280 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 220 mm and then filled by 500 mm over the remaining wet season. The 2004 bed level was 280 mm above the 2003 bed.

UG02-2

This chain was found on 19 November 2003 and was located toward the left bank. The chain was buried and oriented diagonally upstream towards the left bank.

- Depth to first link……..62 mm
- Depth to first vertical link…….55 mm
- Depth to straightened chain……..-180 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 242 mm and filled by 62 mm over the remaining wet season. The 2003 bed level was 180 mm below the 2002 bed.

The chain was located on 26 October 2004 and was buried and orientated across towards the right bank.

- Depth to first link……..175 mm
- Depth to first vertical link…….200 mm
- Depth to straightened chain……..150 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 50 mm and then filled by 200 mm over the remaining wet season. The 2004 bed level was 150 mm above the 2003 bed.

At Upper Gulungul Cross section 2 (UG02) the average scour for the 2002–2003 wet season was 326 mm and the average fill was 144 mm. The average scour for the 2003–2004 wet season was 135 mm and the average fill was 350 mm.

3.3.2 Upper Gulungul cross section (UG03)

There were three chains located across the bed of the channel at UG03.

UG03-1

The chain was found 19 November 2003 and was located towards the right bank. The chain was buried and orientated slightly upstream and towards the left bank.

- Depth to first link……..420 mm
- Depth to first vertical link…….420 mm
- Depth to straightened chain……..-120 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 540 mm and filled by 420 mm over the remaining wet season. The 2003 bed level was 120 mm below the 2002 bed.

The chain was located on 23 November 2004 and was buried and orientated upstream towards (at 45°) the left bank.

- Depth to first link……..700 mm
- Depth to first vertical link…….770 mm
- Depth to straightened chain……..160 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 610 mm and then filled by 770 mm over the remaining wet season. The 2004 bed level was 160 mm above the 2003 bed.

UG03-2

The chain was found 19 November 2003 and was located in the middle of the bed and was pointing towards the right bank.

- Depth to first link……..290 mm
- Depth to first vertical link…….310 mm
- Depth to straightened chain……..-195 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 505 mm and filled by 310 mm over the remaining wet season. The 2003 bed level was 195 mm below the 2002 bed.

The chain was located on 23 November 2004 and was buried and orientated upstream towards (at 45°) the right bank.

- Depth to first link……..490 mm
- Depth to first vertical link…….485 mm
- Depth to straightened chain……..185 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 305 mm and then filled by 490 mm over the remaining wet season. The 2004 bed level was 185 mm above the 2003 bed.

UG03-3

The chain was found 19 November 2003 and was located toward the left bank and was pointing towards the right bank.

- Depth to first link……..297 mm
- Depth to first vertical link…….286 mm
- Depth to straightened chain……..0 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 297 mm and filled by the same amount over the remaining wet season. The 2003 bed level was the same as the 2002 bed.

The chain was located on 26 October 2004 and was buried and orientated across towards the right bank.

- Depth to first link……..505 mm

- Depth to first vertical link…….515 mm
- Depth to straightened chain……..175 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 340 mm and then filled by 515 mm over the remaining wet season. The 2004 bed level was 175 mm above the 2003 bed.

At Upper Gulungul Cross section 3 (UG03) the average scour for the 2002–2003 wet season was 447 mm and the average fill was 342 mm. The average scour for the 2003–2004 wet season was 418 mm and the average fill was 592 mm.

3.3.3 Mid Gulungul cross section (MG06)

There were three chains located across the bed of the channel.

MG06-1

The chain was found on 19 November 2003 located toward the right bank. The chain was orientated towards the left bank and then downstream.

- Depth to first link……..730 mm
- Depth to first vertical link…….730 mm
- Depth to straightened chain……..140 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 590 mm and filled by 730 mm over the remaining wet season. The 2003 bed level was 140 mm higher than the 2002 bed.

The chain was located on 26 October 2004 and was buried and orientated towards the right bank.

- Depth to first link……..930 mm
- Depth to first vertical link…….920 mm
- Depth to straightened chain……..Not anchored (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to an unknown depth as there were no vertical links in the chain. There was 930 mm of fill over the chain however the relationship of the 2003 to 2004 bed level is not known.

MG06-2

The chain found on 19 November 2003 was located in the middle of the bed. The chain was pointing towards the right bank.

- Depth to first link……..740 mm
- Depth to first vertical link…….740 mm
- Depth to straightened chain……..400 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 340 mm and filled by 740 mm over the remaining wet season. The 2003 bed level was 400 mm higher than the 2002 bed.

The chain was located on 26 October 2004 and was buried at depth however no links were anchored as the chain was not that long. A longer 1 m chain was installed and driven into the clay bed below the sand.

- Depth to first link……..720 mm

- Depth to first vertical link…….680 mm
- Depth to straightened chain…….. Not anchored (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a n unknown as there were no vertical links in the chain. There was 720 mm of fill over the chain however the relationship of the 2003 to 2004 bed level is not known.

MG06-3

The chain was found on 19 November 2003 located toward the left bank. The chain was pointing towards the right bank and then downstream.

- Depth to first link……..105 mm
- Depth to first vertical link…….140 mm
- Depth to straightened chain……..5 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 135 mm and filled by 140 mm over the remaining wet season. The 2003 bed level was 5 mm higher than the 2002 bed.

The chain was located on 26 October 2004 and was buried and orientated across towards the right bank and slightly upstream.

- Depth to first link……..160 mm
- Depth to first vertical link…….175 mm
- Depth to straightened chain……..0 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 175 mm and then filled by 175 mm over the remaining wet season. The 2004 bed level was the same level as the 2003 bed.

At Mid Gulungul Cross section 6 (MG06) the average scour was for the 2002–2003 wet season was 355 mm and the average fill was 537 mm. The average scour for the 2003–2004 wet season was not able to be determined due to no vertical links in the chain at MG08-1 & M08-2. The average fill was 608 mm.

3.3.4 Mid Gulungul cross section (MG08)

There were three chains located across the bed of the channel.

MG08-1

The chain found on 19 November 2003 and was located toward the right bank. The chain was buried and orientated upstream and then toward the left bank.

- Depth to first link……..570 mm
- Depth to first vertical link…….590 mm
- Depth to straightened chain……..25 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 565 mm and filled by 590 mm over the remaining wet season. The 2003 bed level was 25 mm higher than the 2002 bed.

The chain was located on 24 November 2004 and was buried and orientated towards the left bank and slightly upstream.

- Depth to first link……..800 mm

- Depth to first vertical link…….750 mm
- Depth to straightened chain……..30 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 770 mm and then filled by 800 mm over the remaining wet season. The 2004 bed level was 30 mm above the 2003 bed.

MG08-2

The chain was found on 19 November 2003 located in the middle of the bed. The chain was buried and orientated diagonally upstream toward the left bank.

- Depth to first link……..445 mm
- Depth to first vertical link…….425 mm
- Depth to straightened chain……..0 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 445 mm and filled by the same amount over the remaining wet season. The 2003 bed level was the same as the 2002 bed.

The chain was located on 24 November 2004 and was buried and orientated essentially upstream.

- Depth to first link……..600 mm
- Depth to first vertical link…….580 mm
- Depth to straightened chain……..0 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 600 mm and then filled by 600 mm over the remaining wet season. The 2004 bed level was the same as the 2003 bed.

MG08-3

The chain was found on 19 November 2003 located toward the left bank. The chain was buried and orientated diagonally upstream towards the right bank.

- Depth to first link……..225 mm
- Depth to first vertical link…….255 mm
- Depth to straightened chain……..-100 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 355 mm and filled by 255 mm over the remaining wet season. The 2003 bed level was 100 mm below the 2002 bed.

The chain was located on 24 November 2004 and was buried and orientated essentially downstream.

- Depth to first link……..400 mm
- Depth to first vertical link…….425 mm
- Depth to straightened chain……..-30 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 455 mm and then filled by 425 mm over the remaining wet season. The 2004 bed level 30 mm lower than the 2003 bed.

At Mid Gulungul Cross section 8 (MG08) the average scour for the 2002–2003 wet season was 455 mm and the average fill was 430 mm. The average scour for the 2003–2004 wet season was 608 mm and the average fill was 608 mm.

3.3.5 Downstream Gulungul cross section (DG10)

There were two chains located across the bed of the channel.

DG10-1

The chain was found on 19 November 2003 located toward the right bank. The chain was buried and orientated slightly upstream and then diagonally downstream toward the left bank.

- Depth to first link……..245 mm
- Depth to first vertical link…….245 mm
- Depth to straightened chain……..0 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 245 mm and filled by the same amount over the remaining wet season. The 2003 bed level was the same as the 2002 bed.

The chain was located on 24 November 2004 and was buried and orientated across toward the left bank.

- Depth to first link……..145 mm
- Depth to first vertical link…….160 mm
- Depth to straightened chain……..0 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 160 mm and then filled by 160 mm over the remaining wet season. The 2004 bed level is at the same level as the 2003 bed.

DG10-2

The chain was found on 19 November 2003 located toward the left bank. The chain was buried and orientated across the bed toward right bank.

- Depth to first link……..210 mm
- Depth to first vertical link…….187 mm
- Depth to straightened chain……..-70 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 280 mm and filled by 210 mm over the remaining wet season. The 2003 bed level was 70 mm lower than the 2002 bed.

The chain was located on 24 November 2004 and was buried and orientated across toward the right bank.

- Depth to first link……..155 mm
- Depth to first vertical link…….160 mm
- Depth to straightened chain……0 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 160 mm and then filled by 160 mm over the remaining wet season. The 2004 bed level was the same level as the 2003 bed.

At downstream Gulungul Cross section 10 (MG10) the average scour for the 2002–2003 wet season was 263 mm and the average fill was 228 mm. The average scour for the 2003–2004 wet season was 160 mm and the average fill was 160 mm.

3.3.6 Downstream Gulungul cross section (DG11)

There were two chains located across the bed of the channel.

DG11-1

The chain was located on 19 November 2003 and was buried and orientated towards the right bank.

- Depth to first link……..280 mm
- Depth to first vertical link…….290 mm
- Depth to straightened chain……..130 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 160 mm and filled by 290 mm over the remaining wet season. The 2003 bed level was 130 mm higher than the 2002 bed.

The chain was located on 24 November 2004 and was buried and orientated towards the right bank.

- Depth to first link……..380 mm
- Depth to first vertical link…….270 mm
- Depth to straightened chain……35 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 345 mm and then filled by 380 mm over the remaining wet season. The 2004 bed level 35 mm higher than the 2003 bed.

DG11-2

The chain was located on 19 November 2003 and was buried and orientated upstream against the flow.

- Depth to first link……..170 mm
- Depth to first vertical link…….160 mm
- Depth to straightened chain……..-60 mm (2002 bed level)

These measurements show that during the 2002–2003 wet season the bed was scoured to a depth of 230 mm and filled by 170 mm over the remaining wet season. The 2003 bed level was 60 mm lower than the 2002 bed.

The chain was located on 24 November 2004 and was buried and orientated in an upstream direction.

- Depth to first link……..355 mm
- Depth to first vertical link…….320 mm
- Depth to straightened chain…..…-90 mm (2003 bed level)

These measurements show that during the 2003–2004 wet season the bed was scoured to a maximum depth of 445 mm and then filled by 355 mm over the remaining wet season. The 2004 bed level 90 mm lower than the 2003 bed.

At downstream Gulungul Cross section 11 (MG11) the average scour for the 2002–2003 wet season was 195 mm and the average fill was 230 mm. The average scour for the 2003–2004 wet season was 395 mm and the average fill was 368 mm.

4 Conclusions and recommendations

The channel cross sectional data collected by ***eriss*** on Gulungul Creek have been presented in this report as survey data (appendix A). There are now 13 permanently monumented (marked) cross sections installed on Gulungul Creek following the Vigil Network method of the US Geological Survey developed for the International Hydrological Decade. These cross sections have been surveyed during the dry seasons of 2002, 2003 and 2004 to determine baseline characteristics of Gulungul Creek. Bulk bed material grab samples were collected each year at each of the cross sections to characterise the sediments using particle size analysis. Scour chains have been installed at some of the cross sections which provide information about the scour and fill that occurs during each wet season.

Continued monitoring of the cross sections, bed material samples and scour chains is recommended prior to the rehabilitation of the Ranger mine to determine/establish the baseline characteristics. This will provide an excellent "baseline data set against which any impacts of the minesite rehabilitation can be evaluated.

5 References

Church MA, M^{c}Lean DG & Wolcott JF 1987. River bed gravels: sampling and analysis. In *Sediment transport in gravel-bed rivers*. eds CR Thorne, JC Bathurst & RD Hey, Wiley, Chichester, 43–88.

Crossing KS 2002. Geomorphology and hydrology of Gulungul Creek. Internal Report 398, November, Supervising Scientist, Darwin. Unpublished paper.

de Vries M 1970. On the accuracy of bed-material sampling. *Journal of Hydraulic Research* 8, 523–533.

Emmett WW & Leopold LB 1963. Downstream pattern of riverbed scour and fill. In *Proceedings of the Federal Interagency Sedimentation Conference.* United States Department of Agriculture Agricultural Research Service, Miscellaneous Publication 970, 399–409.

Emmett WW 1965. The Vigil network: Methods of measurement and a sampling of data collected. *International Association of Hydrological Sciences* Publ. No. 66, 89–106.

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.

Ferguson RI & Paola C 1997. Bias and precision of percentiles of bulk grain size distributions. *Earth Surface Processes and Landforms* 22, 1061–1077.

Folk RL 1954. The distinction between grain size and mineral composition in sedimentary – rock nomenclature. *Journal of Geology* 62, 345–251.

Folk RL 1974. *Petrology of sedimentary rocks*. Hemphill, Austin.

Fowler KK & Wilson JT 1995. Characteristics, and yield of sediment in Juday Creek, St. Joseph County, Indiana, 1993-94. Water Resources Investigations Report: 95-4135, Denver.

Gale SJ & Hoare PG 1992. Bulk sampling of coarse clastic sediments for particle-size analysis. *Earth Surface Processes and Landforms* 17, 729–733.

Gale SJ & Hoare PG 1994. Reply: Bulk sampling of coarse clastic sediments for particle-size analysis. *Earth Surface Processes and Landforms* 19, 263–268.

Gee GW & Bauder JW 1986. Particle size analysis. In *Methods of soil analysis Vol. 1, Physical and mineralogical methods*, ed A Klute, American Society of Soil Agronomy and Soil Science Society of America, Madison, 357–376.

Kellerhals R & Bray DI 1971. Sampling procedures for coarse fluvial sediments. *Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers* 97, 1165–1180.

Leopold LB, Emmett WW & Myrick RM 1966. *Channel and hillslope processes in a semiarid area New Mexico*. US Geological Survey Profession Paper 352-G, 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.

Mosley MP & Tindale DS 1985. Sediment variability and bed material sampling in gravel-bed rivers. *Earth Surface Processes and Landforms* 10, 465–482.

Muir TC 1969. Sampling and analysis of coarse riverbed sediments. In *Proceedings 4th Mississippi Water Resources Conference*, Water Resources Research Institute, Mississippi State University, State College, Mississippi, 73–83.

Roberts RG 1991. Sediment budgets and quaternary history of the Magela Creek catchment, Tropical Northern Australia. Open file record 80, Supervising Scientist for the Alligator Rivers Region, Canberra. Unpublished paper.

Saynor MJ, Smith BL, Erskine WD & Evans KG 2004. Bed-material grain size data for the Ngarradj catchment between 1998 and 2003. Internal Report 392, July, Supervising Scientist, Darwin. Unpublished paper.

Wolman MG 1954. *The natural channel of Brandywine Creek, Pennsylvania*. US Geological Survey Profession Paper 271, Washington DC.

Appendix A

Survey data for each cross section for 2002 and 2003 dry seasons

This appendix contains the survey data for each cross section for the 2002 and 2003 dry seasons. The sections are listed in increasing numerical order which does not always correspond to their location in downstream sequence. Refer to the relevant diagrams in Section 3 to determine where they are located.

The datum used for each section is an assumed datum with a horizontal angle of either 0°, 90°, 180°, 270° so that there is a distance (chainage) and a height for each survey point. All measurements are in metres and each cross section is independent of each other cross section. The assumed datum is often different between cross sections.

The location of the data files on SSD explorer is in the following directories:

\\Landscape Characterisation and Monitoring\Gulungul Creek\Sediment transport in Gulungul Creek catchment\Data\xsections

Gulungul Creek Cross sections 2003							
UG02 Distance (m)	**3-Sep-03 Assumed Height (m)**	**UG01 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**UG03 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**UG04 Distance (m)**	**3-Sep-03 Assumed Height (m)**
955.222	49.392	1961.783	49.837	958.662	49.277	964.347	49.739
955.227	49.392	1961.776	49.837	958.651	49.276	964.341	49.739
955.366	49.16	1961.893	49.569	958.833	49.024	964.503	49.512
959.131	49.188	1965.094	49.588	961.832	49.108	966.332	49.514
962.819	49.206	1968.495	49.605	964.586	49.167	968.265	49.564
966.13	49.275	1972.33	49.61	966.679	49.139	970.424	49.569
967.194	49.244	1975.592	49.499	968.575	49.056	972.274	49.632
969.239	49.049	1977.545	49.347	970.64	48.966	974.368	49.648
971.065	48.977	1979.335	49.403	972.487	48.884	975.251	49.59
972.323	48.986	1980.4	49.431	973.965	48.749	975.939	49.451
973.461	49.064	1981.506	49.366	974.799	48.653	976.557	49.277
974.571	48.904	1982.253	49.174	975.766	48.524	976.854	49.166
975.373	48.794	1983.019	48.952	976.064	48.397	976.977	49.049
975.739	48.632	1983.536	48.833	976.437	48.387	977.414	48.91
976.088	48.327	1983.871	48.668	976.618	48.249	977.607	48.798
976.419	48.135	1984.011	48.52	976.957	47.785	978.302	48.638
976.569	48.122	1984.187	48.42	977.227	47.715	978.73	48.603
976.915	48.236	1984.875	48.217	978.169	47.622	978.956	48.507
977.231	48.18	1985.327	48.08	978.88	47.639	979.127	48.349
977.5	48.015	1986.698	48.024	979.224	47.674	979.282	48.244
977.867	47.922	1987.716	48.159	979.861	47.659	979.471	48.225
978.77	47.806	1988.707	48.266	980.406	47.701	980.584	48.329
979.68	47.797	1990.2	48.294	981.08	47.654	980.937	48.381
980.551	47.757	1990.989	48.268	982.308	47.777	981.528	48.361
981.053	47.699	1991.611	48.344	982.888	47.79	981.914	48.325
981.273	47.699	1992.032	48.295	983.431	47.746	982.984	48.343
981.678	47.797	1992.535	48.652	984.4	47.748	983.663	48.32
982.133	47.739	1992.679	49.023	985.142	47.68	984.685	48.262
983.078	47.686	1993.073	49.206	985.6	47.638	985.233	48.187
983.962	47.686	1993.304	49.234	985.763	47.744	985.952	48.192
984.209	47.8	1993.585	49.167	985.932	48.005	986.444	48.247
984.928	48.989	1993.962	49.223	986.217	48.116	986.979	48.361
985.303	49.215	1994.463	49.355	986.538	48.181	987.257	48.546
986.438	49.257	1994.564	49.444	986.797	48.43	987.523	48.621
987.023	49.182	1995.008	49.534	987.113	48.725	987.682	48.884
987.817	49.211	1996.676	49.593	987.458	49.004	987.857	48.979
989.19	49.278	1998.436	49.68	988.167	49.149	988.017	49.167
991.713	49.375			989.113	49.203	988.523	49.319
994.141	49.488			989.865	49.104	988.829	49.363

Gulungul Creek Cross sections 2003							
UG02 Distance (m)	**3-Sep-03 Assumed Height (m)**	**UG01 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**UG03 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**UG04 Distance (m)**	**3-Sep-03 Assumed Height (m)**
996.325	49.577			991.673	49.202	989.331	49.316
998.545	49.685			992.557	49.241	989.667	49.233
				994.788	49.449	989.999	49.22
				997.964	49.625	990.249	49.299
						990.379	49.374
						991.099	49.515
						992.127	49.669
						994.28	49.757
						997.205	49.753

Gulungul Creek Cross sections 2003							
MG05 Distance (m)	**3-Sep-03 Assumed Height (m)**	**MG06 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**MG07 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**MG08 Distance (m)**	**3-Sep-03 Assumed Height (m)**
958.908	49.774	964.572	49.984	1024.529	50.244	1053.34	49.359
958.909	49.773	964.57	49.985	1024.533	50.244	1053.337	49.359
959.04	49.518	964.721	49.743	1024.393	50.007	1053.128	49.059
960.135	49.538	966.616	49.709	1023.957	49.969	1050.45	49.207
961.168	49.467	968.707	49.543	1022.71	49.9	1048.334	49.335
962.702	49.356	970.456	49.524	1021.663	49.889	1045.867	49.423
964.694	49.395	972.301	49.482	1020.847	49.922	1043.539	49.502
965.55	49.467	972.937	49.483	1020.445	49.904	1041.918	49.56
966.905	49.392	973.592	49.56	1020.253	49.781	1040.985	49.558
968.571	49.289	974.025	49.54	1020.036	49.469	1040.241	49.596
970.101	49.365	974.585	49.405	1019.557	49.132	1039.768	49.52
971.257	49.318	974.729	49.167	1019.068	48.839	1039.334	49.272
972.328	49.246	974.96	49.131	1018.841	48.003	1039.2	48.408
972.85	49.142	975.348	48.884	1018.504	47.909	1038.904	48.213
973.22	49.128	975.435	48.67	1018.219	47.806	1038.606	48.199
973.724	49.15	975.768	48.354	1017.838	47.822	1038.239	48.233
974.267	49.011	976.203	48.148	1017.143	47.819	1037.703	48.201
974.616	48.732	976.772	47.986	1016.154	47.958	1037.277	48.234
975.573	48.645	977.148	47.947	1014.791	48.188	1037.017	48.301
975.696	48.592	978.662	48.04	1014.042	48.265	1034.624	48.259
976.074	48.535	979.693	48.144	1012.836	48.467	1032.018	48.225
976.502	48.593	981.395	48.193	1012.313	48.523	1031.377	48.249
976.78	48.526	983.074	48.265	1011.874	48.638	1030.403	48.34
977.387	48.537	984.097	48.262	1011.132	48.732	1028.879	48.365
977.972	48.592	984.823	48.176	1010.322	48.769	1027.733	48.473
978.529	48.634	985.373	48.063	1009.795	48.739	1027.429	48.476
979.021	48.577	986.099	48.178	1009.129	48.745	1026.663	48.433
979.427	48.637	986.341	48.239	1008.951	48.838	1025.908	48.479
980.144	48.599	986.619	48.385	1008.582	49.048	1025.553	48.423
980.775	48.666	986.879	48.478	1008.032	49.265	1025.23	48.446
981.536	48.657	986.941	48.62	1007.695	49.327	1025.138	48.724
982.528	48.732	987.158	48.732	1007.266	49.278	1024.889	48.774
983.493	48.791	987.866	48.751	1006.893	49.227	1024.554	48.933
984.039	48.642	988.424	48.841	1006.707	49.177	1023.99	48.918
984.657	48.567	988.694	48.921	1006.108	49.214	1023.421	48.967
985.67	48.565	989.769	49.052	1005.608	49.304	1022.937	48.876
986.262	48.477	991.548	49.1	1004.779	49.514	1022.386	48.889
987.012	48.349	993.518	49.203	1004.236	49.63	1021.571	49.001

Gulungul Creek Cross sections 2003							
MG05 Distance (m)	**3-Sep-03 Assumed Height (m)**	**MG06 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**MG07 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**MG08 Distance (m)**	**3-Sep-03 Assumed Height (m)**
987.337	48.372	995.05	49.367	1003.567	49.738	1020.636	49.137
987.663	48.534	995.948	49.46	1002.616	49.827	1019.863	49.305
987.893	48.687	996.562	49.527	1002.17	49.925	1019.195	49.291
987.983	49.093	997.67	49.546			1018.563	49.362
988.277	49.215					1017.519	49.265
988.311	49.506					1016.311	49.281
988.487	49.67					1015.097	49.365
988.834	49.579					1013.192	49.367
989.112	49.712					1010.617	49.257
989.201	49.916					1009.428	49.228
989.555	50.004					1007.831	49.319
990.883	50.04					1006.428	49.505
993.024	50.015					1005.19	49.631
995.139	49.932					1003.451	49.707
997.533	49.869					1001.708	49.753

Gulungul Creek Cross sections 2003							
MG09 Distance (m)	**3-Sep-03 Assumed Height (m)**	**DG10 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**DG11 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**DG13 Distance (m)**	**3-Sep-03 Assumed Height (m)**
964.066	49.775	978.426	49.93	974.255	50.488	946.79	50.127
964.069	49.775	978.428	49.93	974.252	50.488	946.773	50.127
964.206	49.533	978.568	49.723	974.255	50.488	946.924	49.929
965.036	49.51	979.995	49.709	974.424	50.244	948.005	49.87
966.444	49.347	981.382	49.63	901.494	50.492	949.534	49.819
968.286	49.251	982.406	49.589	904.704	50.46	949.774	49.863
970.697	49.295	982.793	49.608	905.66	50.372	950.37	49.773
972.446	49.343	983.048	49.677	907.126	50.394	951.61	49.712
974.463	49.42	983.408	49.653	910.651	50.294	952.814	49.734
976.093	49.428	983.572	49.559	913.714	50.232	954.746	49.69
977.109	49.433	983.709	49.326	917.231	50.027	955.961	49.725
977.588	49.427	983.871	49.191	920.635	49.908	956.741	49.796
977.894	49.304	984.401	49.088	923.995	49.823	957.722	49.808
978.019	48.493	984.984	48.976	927.284	49.777	958.806	49.815
978.314	48.357	985.351	48.87	928.569	49.853	960.111	49.646
978.916	48.39	986.013	48.594	929.439	49.77	960.614	49.744
979.574	48.369	987.062	48.651	930.206	49.577	961.782	49.813
980.233	48.436	987.968	48.678	930.616	49.495	962.618	49.736
981.657	48.379	989.176	48.639	932.747	49.518	963.064	49.828
983.248	48.308	990.151	48.617	933.94	49.654	965.054	49.829
984.057	48.258	990.914	48.617	935.419	49.838	966.998	49.707
984.628	48.18	991.425	48.55	937.215	49.917	967.619	49.526
985.03	48.1	991.686	48.512	938.117	49.985	968.261	49.336
985.853	48.026	992.162	48.561	938.558	49.945	968.974	49.365
986.691	47.991	992.355	48.646	939.265	49.777	970.091	49.297
987.014	48.034	992.539	48.773	939.621	49.799	970.647	49.323
987.255	48.096	992.686	48.83	940.086	49.741	971.181	49.327
987.605	48.274	992.992	49.137	941.116	49.814	971.597	49.204
987.965	48.889	993.307	49.347	942.844	49.803	971.742	49.089
988.202	49.085	993.463	49.64	944.378	49.689	972.091	48.796
988.816	49.191	993.642	49.839	945.936	49.749	972.982	48.661
990.657	49.314	993.797	49.906	947.077	49.681	973.629	48.597
992.386	49.451	993.931	50.033	947.077	49.681	974.251	48.442
993.618	49.589	995.262	49.994	947.744	49.634	974.56	48.28
995.725	49.685	996.795	49.912	947.976	49.538	975.028	48.282
997.971	49.714	998.354	49.833	948.502	49.221	976.174	48.132
				948.851	49.119	977.692	48.003
				949.799	49.065	978.214	47.94

Gulungul Creek Cross sections 2003							
MG09 Distance (m)	3-Sep-03 Assumed Height (m)	DG10 Distance (m)	3-Sep-03 Assumed Height (m)	DG11 Distance (m)	3-Sep-03 Assumed Height (m)	DG13 Distance (m)	3-Sep-03 Assumed Height (m)
				950.594	48.898	978.99	47.927
				951.593	48.922	979.611	48.015
				952.55	49.01	980.407	48.315
				953.294	49.042	980.801	48.485
				953.657	49.135	981.102	48.729
				954.327	49.222	981.156	49.175
				955.797	49.403	981.359	49.403
				956.077	49.482	981.789	49.568
				956.632	49.693	982.179	49.659
				957.196	49.785	982.542	49.714
				958.731	49.893	983.008	49.831
				959.696	49.957	983.33	49.846
				961.991	50.034	983.972	49.765
				965.182	49.995	984.563	49.736
				966.595	49.937	985.495	49.81
				968.805	50.03	986.804	49.813
				970.964	50.127	988.245	49.754
				972.944	50.2	990.397	49.792
				973.968	50.228	992.101	49.766
				974.444	50.239	993.016	49.726
				975.84	50.224	993.591	49.623
				976.642	50.191	994.664	49.686
				977.336	50.032	995.672	49.785
				977.94	49.839	996.452	49.805
				978.913	49.55	998.234	49.79
				979.991	49.272		
				980.927	49.109		
				981.741	49.052		
				982.128	49.002		
				982.37	48.904		
				982.518	48.815		
				982.727	48.805		
				983.253	48.928		
				983.616	48.93		
				984.035	48.876		
				984.654	48.71		
				985.579	48.619		
				986.888	48.635		
				988.135	48.604		

Gulungul Creek Cross sections 2003							
MG09 Distance (m)	**3-Sep-03 Assumed Height (m)**	**DG10 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**DG11 Distance (m)**	**3-Sep-03 Assumed Height (m)**	**DG13 Distance (m)**	**3-Sep-03 Assumed Height (m)**
				989.347	48.499		
				990.706	48.373		
				991.449	48.316		
				991.958	48.35		
				992.469	48.668		
				992.727	48.807		
				993.188	49.272		
				993.364	49.325		
				993.965	49.356		
				994.414	49.514		
				995.171	49.778		
				996.117	49.858		
				997.061	49.889		
				998.542	49.847		

Gulungul Creek Cross sections 2004							
UG02 Distance (m)	**16-Aug-04 Assumed Height (m)**	**UG01 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**UG03 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**UG04 Distance (m)**	**16-Aug-04 Assumed Height (m)**
955.236	49.387	1961.787	49.836	958.659	49.274	964.353	49.741
955.155	49.386	1961.781	49.836	958.661	49.274	964.496	49.513
955.23	49.393	1961.898	49.56	958.809	49.024	966.72	49.525
955.358	49.167	1965.085	49.586	961.726	49.111	969.264	49.556
957.814	49.178	1967.621	49.567	964.271	49.166	971.343	49.583
960.029	49.204	1969.807	49.588	966.221	49.16	973.165	49.637
963.107	49.204	1972.515	49.612	967.817	49.07	974.482	49.66
967.625	49.174	1975.156	49.531	970.326	48.986	975.523	49.579
969.743	48.994	1975.148	49.531	972.045	48.921	975.84	49.501
971.631	48.967	1975.927	49.44	974.111	48.774	976.523	49.275
972.657	49.024	1976.89	49.342	975.404	48.605	977.35	49.01
973.36	49.101	1978.134	49.36	975.988	48.464	977.668	48.899
974.324	48.949	1979.25	49.361	976.233	48.461	978.034	48.884
975.341	48.809	1980.077	49.41	976.361	48.465	978.565	48.74
975.891	48.472	1980.66	49.427	976.617	48.252	979.033	48.504
976.403	48.153	1981.322	49.369	976.723	48.122	979.303	48.257
976.757	48.199	1981.87	49.269	976.816	48.042	979.758	48.32
976.907	48.13	1982.274	49.128	976.867	47.795	981.067	48.339
977.224	48.091	1982.744	48.955	977.175	47.728	982.902	48.343
977.373	48.108	1983.308	48.815	977.726	47.749	984.984	48.208
977.611	47.985	1983.797	48.648	978.056	47.827	985.776	48.244
978.016	47.913	1983.969	48.508	979.238	47.889	986.493	48.241
978.564	47.896	1984.531	48.379	979.769	47.838	986.976	48.537
979.496	47.924	1985.019	48.209	980.654	47.799	987.395	48.683
979.829	47.952	1985.621	48.079	981.071	47.871	987.479	48.794
980.619	48.003	1986.147	48.063	981.95	47.842	987.957	49.032
981.727	48.02	1987.146	48.136	982.328	47.914	988.169	49.161
982.442	47.967	1987.794	48.21	983.905	47.977	988.532	49.318
983.169	47.918	1988.962	48.278	984.903	47.954	988.861	49.396
983.741	47.916	1989.221	48.309	985.816	47.906	989.426	49.311
984.11	47.942	1990.47	48.315	986.369	48.091	989.952	49.248
984.391	47.978	1991.45	48.331	986.719	48.301	990.398	49.34
984.523	48.243	1991.869	48.323	986.997	48.602	991.174	49.524
984.681	48.522	1992.172	48.436	987.202	48.723	992.555	49.71
984.748	48.775	1992.443	48.504	987.378	48.939	994.873	49.758
985.078	49.095	1992.699	48.741	987.635	49.046	997.061	49.772
985.39	49.198	1992.794	49.045	988.213	49.148		
986.286	49.252	1992.995	49.221	989.178	49.197		
986.656	49.268	1993.344	49.249	990.184	49.159		
987.192	49.207	1993.707	49.208	991.214	49.183		

Gulungul Creek Cross sections 2004							
UG02 Distance (m)	**16-Aug-04 Assumed Height (m)**	**UG01 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**UG03 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**UG04 Distance (m)**	**16-Aug-04 Assumed Height (m)**
987.856	49.225	1994.257	49.312	992.506	49.243		
989.385	49.285	1994.477	49.36	994.456	49.417		
992.487	49.408	1994.616	49.455	995.633	49.487		
994.786	49.499	1995.303	49.555	998.011	49.632		
997.619	49.63	1997.037	49.612				
		1997.984	49.642				

Gulungul Creek Cross sections 2004							
MG05 Distance (m)	**16-Aug-04 Assumed Height (m)**	**MG06 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**MG07 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**MG08 Distance (m)**	**16-Aug-04 Assumed Height (m)**
958.919	49.775	964.578	49.979	1000	50	999.999	50
958.923	49.774	964.573	49.978	1000.004	50	1000.155	49.777
959.09	49.518	964.718	49.745	1000.134	49.798	1002.4	49.734
960.032	49.558	965.919	49.751	1001.779	49.912	1004.812	49.651
961.947	49.375	966.957	49.683	1002.566	49.837	1006.008	49.564
963.252	49.344	968.444	49.54	1003.49	49.76	1007.819	49.315
965.008	49.428	970.444	49.512	1004.511	49.586	1009.478	49.222
966.304	49.439	972.4	49.475	1005.535	49.331	1011.192	49.3
968.194	49.323	973.026	49.473	1006.03	49.24	1014.439	49.388
969.738	49.28	973.539	49.539	1006.8	49.239	1015.66	49.349
970.94	49.341	973.825	49.542	1007.219	49.324	1016.849	49.252
971.717	49.309	974.242	49.412	1007.774	49.363	1017.512	49.248
972.828	49.186	974.695	49.218	1008.235	49.282	1018.624	49.32
973.999	49.128	974.958	49.082	1008.467	49.156	1019.789	49.276
974.326	49.012	975.179	48.884	1008.942	48.687	1020.613	49.138
974.636	48.843	975.283	48.778	1009.149	48.622	1021.485	49.026
975.336	48.717	975.403	48.595	1010.083	48.608	1022.119	48.905
975.984	48.68	975.825	48.345	1011.436	48.529	1022.731	48.94
976.294	48.597	976.161	48.187	1012.493	48.421	1023.131	48.965
976.477	48.522	976.672	48.05	1013.55	48.35	1023.687	49.048
977.334	48.433	977.14	47.999	1014.467	48.208	1024.484	48.987
977.696	48.526	977.816	48.006	1015.031	48.018	1025.056	48.568
978.895	48.561	978.734	48.046	1015.714	47.92	1025.493	48.48
979.239	48.522	979.919	48.029	1016.749	48.028	1027.211	48.329
979.931	48.592	981.115	48.084	1017.938	48.202	1029.416	48.274
981.354	48.68	983.198	48.171	1018.329	48.159	1032.127	48.217
982.533	48.788	984.323	48.252	1018.686	48.006	1033.486	48.201
983.177	48.774	985.409	48.3	1018.874	47.999	1035.788	48.311
983.824	48.756	985.807	48.291	1018.976	48.341	1036.851	48.37
984.497	48.63	986.136	48.226	1019.127	48.872	1037.322	48.243
985.031	48.577	986.349	48.232	1019.54	49.097	1037.777	48.184
985.49	48.593	986.603	48.215	1020.037	49.432	1038.324	48.147
986.684	48.547	987.168	48.457	1020.29	49.776	1038.818	48.164
987.57	48.405	987.293	48.607	1020.421	49.881	1039.197	48.407
988.289	48.535	987.63	48.72	1021.124	49.938	1039.342	48.54
989.457	49.424	988.584	48.85	1022.945	49.924	1039.336	49.072
989.724	49.685	989.119	48.924			1039.519	49.176
989.794	49.999	989.278	48.994			1039.668	49.405

Gulungul Creek Cross sections 2004							
MG05 Distance (m)	**16-Aug-04 Assumed Height (m)**	**MG06 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**MG07 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**MG08 Distance (m)**	**16-Aug-04 Assumed Height (m)**
990.537	50.045	990.391	49.039			1040.127	49.582
993.798	49.972	992.028	49.124			1041.552	49.546
995.859	49.873	993.532	49.205			1044.164	49.47
997.713	49.87	994.699	49.352			1046.513	49.378
		995.91	49.449			1048.566	49.308
		997.541	49.544			1051.226	49.155

Gulungul Creek Cross sections 2004							
MG09 Distance (m)	**16-Aug-04 Assumed Height (m)**	**DG10 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**DG11 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**DG13 Distance (m)**	**16-Aug-04 Assumed Height (m)**
964.068	49.776	978.426	49.932	974.23	50.493	946.785	50.128
964.192	49.537	978.569	49.735	974.426	50.24	946.92	49.932
965.173	49.497	980.297	49.715	975.62	50.23	949.299	49.828
966.743	49.317	981.588	49.636	976.307	50.19	949.84	49.857
967.577	49.278	982.338	49.604	977.178	50.085	950.591	49.742
969.509	49.261	982.808	49.637	977.736	49.892	952.186	49.703
969.599	49.256	983.237	49.666	978.293	49.719	954.139	49.691
971.575	49.326	983.47	49.635	979.201	49.46	955.828	49.724
974.121	49.42	983.662	49.354	980.074	49.239	957.243	49.823
975.621	49.554	983.869	49.3	980.737	49.124	958.843	49.798
977.053	49.421	984.099	49.297	981.467	49.079	960.102	49.669
977.52	49.447	984.332	49.209	982.186	49.019	961.672	49.81
977.72	49.328	985.002	48.715	982.396	48.928	962.68	49.754
977.771	48.918	985.324	48.711	982.705	48.685	965.251	49.837
978.05	48.666	985.711	48.647	983.011	48.523	966.904	49.741
978.588	48.535	986.4	48.638	984.372	48.543	967.487	49.596
979.102	48.479	986.839	48.603	985.572	48.584	968.014	49.395
981.379	48.451	987.363	48.651	986.329	48.508	968.5	49.357
982.424	48.43	988.349	48.601	987.166	48.511	969.804	49.34
982.757	48.45	989.019	48.618	987.751	48.544	970.323	49.308
982.766	48.453	989.942	48.658	988.35	48.517	971.122	49.324
983.193	48.423	991.144	48.654	989.664	48.396	971.699	49.198
983.988	48.396	991.883	48.575	990.8	48.404	972.126	48.991
984.291	48.338	992.307	48.663	991.802	48.303	973.807	48.623
985.26	48.314	992.557	48.781	992.239	48.425	974.647	48.369
985.545	48.256	993.046	49.17	993.19	49.253	976.266	48.287
986.569	48.169	993.253	49.408	993.442	49.378	977.294	48.207
987.524	48.186	993.43	49.487	993.995	49.385	978.172	48.086
987.699	48.26	993.533	49.901	994.56	49.546	979.153	48.095
988.116	49.079	993.902	49.925	995.169	49.786	980.207	48.197
988.949	49.193	994.044	49.99	996.094	49.87	980.59	48.395
991.002	49.337	994.862	50.016	997.95	49.886	981.03	48.805
992.738	49.487	996.366	49.928	1002.66	49.639	981.027	49.221
994.248	49.616	998.154	49.833			981.412	49.437
996.036	49.668					982.172	49.657
997.957	49.716					982.866	49.764
						983.256	49.837
						984.545	49.761

Gulungul Creek Cross sections 2004							
MG09 Distance (m)	**16-Aug-04 Assumed Height (m)**	**DG10 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**DG11 Distance (m)**	**16-Aug-04 Assumed Height (m)**	**DG13 Distance (m)**	**16-Aug-04 Assumed Height (m)**
						985.274	49.816
						986.78	49.823
						987.885	49.758
						990.149	49.822
						991.871	49.785
						992.997	49.729
						993.662	49.649
						994.146	49.648
						995.379	49.758
						996.918	49.814
						998.482	49.782

Appendix B

Cumulative frequency grain size distributions for bulk bed-material samples on Gulungul Creek for the period 2002 to 2004

Table B1 Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2002

Sample	UG02	Gravel Mass = 6.14 g	
Date	01-nov-02	Remaining Mass = 1098.66 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	6.14	0.56
-0.5	1.4 mm	1.31	1.70
0.0	1.0 mm	6.18	5.98
0.5	710 µm	26.48	23.78
1.0	500 µm	76.12	67.31
1.5	355 µm	103.08	90.96
2.0	250 µm	112.64	99.34
2.5	180 µm	113.32	99.94
3.0	125 µm	113.35	99.96
3.5	90 µm	113.36	99.97
4.0	63 µm	113.38	99.99
<4.0	<63 µm	113.39	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Sample	UG01	Gravel Mass = 5.2 g	
Date	01-nov-02	Remaining Mass = 1100.82 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	5.2	0.47
-0.5	1.4 mm	0.15	0.60
0.0	1.0 mm	0.95	1.32
0.5	710 µm	6.80	6.54
1.0	500 µm	49.66	44.81
1.5	355 µm	93.29	83.77
2.0	250 µm	109.81	98.52
2.5	180 µm	111.24	99.79
3.0	125 µm	111.39	99.93
3.5	90 µm	111.44	99.97
4.0	63 µm	111.46	99.99
<4.0	<63 µm	111.47	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	UG03	Gravel Mass = 2.61 g	
Date	01-nov-02	Remaining Mass = 1298.83 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	2.61	0.2
-0.5	1.4 mm	0.4	0.55
0.0	1.0 mm	2.17	2.07
0.5	710 µm	11.24	9.88
1.0	500 µm	54.42	47.08
1.5	355 µm	95.01	82.05
2.0	250 µm	113.92	98.35
2.5	180 µm	115.64	99.83
3.0	125 µm	115.75	99.92
3.5	90 µm	115.8	99.97
4.0	63 µm	115.81	99.97
<4.0	<63 µm	115.84	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	UG04	Gravel Mass = 5.9 g	
Date	01-nov-02	Remaining Mass = 1263.57 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	5.9	0.46
-0.5	1.4 mm	0.68	1.10
0.0	1.0 mm	3.66	3.90
0.5	710 µm	14.88	14.43
1.0	500 µm	59.98	56.74
1.5	355 µm	89.86	84.77
2.0	250 µm	104.58	98.59
2.5	180 µm	105.98	99.90
3.0	125 µm	106.06	99.97
3.5	90 µm	106.07	99.98
4.0	63 µm	106.08	99.99
<4.0	<63 µm	106.09	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Table B1 (Cont.) Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2002

Sample	MG05	Gravel Mass = 6.78 g	
Date	01-nov-02	Remaining Mass = 1744.49 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	6.78	0.39
-0.5	1.4 mm	0.67	1.00
0.0	1.0 mm	3.25	3.38
0.5	710 µm	15.94	15.06
1.0	500 µm	54.14	50.21
1.5	355 µm	84.37	78.03
2.0	250 µm	104.83	96.85
2.5	180 µm	107.89	99.67
3.0	125 µm	108.16	99.92
3.5	90 µm	108.21	99.96
4.0	63 µm	108.23	99.98
<4.0	<63 µm	108.25	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Sample	MG06	Gravel Mass = 2.65 g	
Date	01-nov-02	Remaining Mass = 1593.27 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	2.65	0.17
-0.5	1.4 mm	0.38	0.51
0.0	1.0 mm	2.31	2.28
0.5	710 µm	16.41	15.21
1.0	500 µm	64.64	59.42
1.5	355 µm	92.18	84.66
2.0	250 µm	105.30	96.69
2.5	180 µm	108.18	99.33
3.0	125 µm	108.75	99.85
3.5	90 µm	108.86	99.95
4.0	63 µm	108.89	99.98
<4.0	<63 µm	108.91	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Sample	MG07	Gravel Mass = 4.9 g	
Date	01-nov-02	Remaining Mass = 1782.60 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	4.9	0.27
-0.5	1.4 mm	0.67	0.87
0.0	1.0 mm	2.57	2.58
0.5	710 µm	12.88	11.81
1.0	500 µm	61.20	55.10
1.5	355 µm	94.41	84.84
2.0	250 µm	108.86	97.79
2.5	180 µm	110.92	99.63
3.0	125 µm	111.27	99.95
3.5	90 µm	111.31	99.98
4.0	63 µm	111.32	99.99
<4.0	<63 µm	111.33	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Sample	MG08	Gravel Mass = 6.41 g	
Date	01-nov-02	Remaining Mass = 2480.05 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	6.41	0.26
-0.5	1.4 mm	0.73	0.89
0.0	1.0 mm	2.88	2.70
0.5	710 µm	12.82	11.11
1.0	500 µm	55.38	47.12
1.5	355 µm	94.19	79.97
2.0	250 µm	113.78	96.55
2.5	180 µm	117.41	99.62
3.0	125 µm	117.78	99.93
3.5	90 µm	117.83	99.97
4.0	63 µm	117.84	99.98
<4.0	<63 µm	117.86	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Table B1 (Cont.) Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2002

Sample	MG09	Gravel Mass = 3.77 g	
Date	01-nov-02	Remaining Mass = 1572.54 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	3.77	0.24
-0.5	1.4 mm	0.56	0.78
0.0	1.0 mm	3.04	3.17
0.5	710 µm	16.09	15.73
1.0	500 µm	53.07	51.32
1.5	355 µm	81.82	78.99
2.0	250 µm	100.66	97.12
2.5	180 µm	103.31	99.67
3.0	125 µm	103.55	99.90
3.5	90 µm	103.60	99.95
4.0	63 µm	103.64	99.99
<4.0	<63 µm	103.65	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Sample	DG10	Gravel Mass = 1.48 g	
Date	01-nov-02	Remaining Mass = 1119.25 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	1.48	0.13
-0.5	1.4 mm	0.37	0.47
0.0	1.0 mm	2.05	1.98
0.5	710 µm	12.53	11.44
1.0	500 µm	48.07	43.52
1.5	355 µm	81.80	73.97
2.0	250 µm	106.80	96.53
2.5	180 µm	110.42	99.80
3.0	125 µm	110.61	99.97
3.5	90 µm	110.62	99.98
4.0	63 µm	110.63	99.99
<4.0	<63 µm	110.64	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	DG11	Gravel Mass = 2.34 g	
Date	01-nov-02	Remaining Mass = 1674.65 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	2.34	0.14
-0.5	1.4 mm	0.47	0.57
0.0	1.0 mm	1.89	1.86
0.5	710 µm	10.33	9.52
1.0	500 µm	39.86	36.33
1.5	355 µm	72.79	66.23
2.0	250 µm	105.40	95.84
2.5	180 µm	109.81	99.85
3.0	125 µm	109.96	99.98
3.5	90 µm	109.96	99.98
4.0	63 µm	109.97	99.99
<4.0	<63 µm	109.98	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	DG13	Gravel Mass = 110.98 g	
Date	01-nov-02	Remaining Mass = 1392.06 g	
Phi		Mass (g)	Cumulative %
-3.0	16 mm	0	0.00
-2.5	9.5 mm	35.99	2.39
-2.0	4.0 mm	88.92	5.92
-1.5	2.4 mm	107.27	7.14
-1.0	2.0 mm	110.98	7.38
-0.5	1.4 mm	1.33	8.52
0.0	1.0 mm	2.86	9.84
0.5	710 µm	7.38	13.71
1.0	500 µm	31.02	33.99
1.5	355 µm	56.08	55.48
2.0	250 µm	87.39	82.34
2.5	180 µm	101.54	94.48
3.0	125 µm	105.9	98.22
3.5	90 µm	107.08	99.23
4.0	63 µm	107.59	99.67
<4.0	<63 µm	107.98	100.00

Folk (1974) Texture Group: Slightly pebbly medium sand

Table B2 Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2003

Sample	UG02	Gravel Mass = 12.98 g	
Date	16-Jul-03	Remaining Mass = 2111.78 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	12.98	0.61
-0.5	1.4 mm	0.89	1.39
0.0	1.0 mm	3.32	3.50
0.5	710 μm	13.75	12.58
1.0	500 μm	51.34	45.30
1.5	355 μm	82.22	72.18
2.0	250 μm	102.64	89.95
2.5	180 μm	110.59	96.88
3.0	125 μm	113.00	98.97
3.5	90 μm	113.66	99.55
4.0	63 μm	113.91	99.76
<4.0	<63 μm	114.18	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	UG01	Gravel Mass = 21.84 g	
Date	16-Jul-03	Remaining Mass = 1744.31 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	21.84	1.24
-0.5	1.4 mm	1.75	2.78
0.0	1.0 mm	6.80	7.24
0.5	710 μm	23.32	21.82
1.0	500 μm	61.17	55.24
1.5	355 μm	86.36	77.48
2.0	250 μm	104.00	93.05
2.5	180 μm	110.14	98.47
3.0	125 μm	111.40	99.59
3.5	90 μm	111.67	99.82
4.0	63 μm	111.78	99.92
<4.0	<63 μm	111.87	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Sample	UG03	Gravel Mass = 2.66 g	
Date	16-Jul-03	Remaining Mass = 2248.08 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	2.66	0.12
-0.5	1.4 mm	0.18	0.28
0.0	1.0 mm	1.35	1.35
0.5	710 μm	11.45	10.54
1.0	500 μm	53.47	48.77
1.5	355 μm	87.65	79.87
2.0	250 μm	105.97	96.53
2.5	180 μm	109.38	99.64
3.0	125 μm	109.72	99.95
3.5	90 μm	109.76	99.98
4.0	63 μm	109.77	99.99
<4.0	<63 μm	109.78	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	UG04	Gravel Mass = 3.62 g	
Date	16-Jul-03	Remaining Mass = 1456.29 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	3.62	0.25
-0.5	1.4 mm	0.47	0.66
0.0	1.0 mm	2.03	2.02
0.5	710 μm	9.48	8.54
1.0	500 μm	48.79	42.94
1.5	355 μm	93.22	81.81
2.0	250 μm	111.47	97.78
2.5	180 μm	113.68	99.71
3.0	125 μm	113.94	99.94
3.5	90 μm	113.98	99.97
4.0	63 μm	114.00	99.99
<4.0	<63 μm	114.01	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Table B2 (Cont.) Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2003

Sample	MG05	Gravel Mass = 10.34 g	
Date	16-Jul-03	Remaining Mass = 2329.79 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	10.34	0.44
-0.5	1.4 mm	0.49	0.89
0.0	1.0 mm	2.59	2.83
0.5	710 µm	13.94	13.30
1.0	500 µm	43.96	40.98
1.5	355 µm	66.16	61.45
2.0	250 µm	88.76	82.29
2.5	180 µm	102.01	94.50
3.0	125 µm	106.13	98.30
3.5	90 µm	107.24	99.33
4.0	63 µm	107.63	99.69
<4.0	<63 µm	107.97	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	MG06	Gravel Mass = 4.29 g	
Date	16-Jul-03	Remaining Mass = 2069.15 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	4.29	0.21
-0.5	1.4 mm	0.45	0.61
0.0	1.0 mm	2.18	2.18
0.5	710 µm	10.11	9.35
1.0	500 µm	40.07	36.43
1.5	355 µm	73.92	67.02
2.0	250 µm	100.29	90.86
2.5	180 µm	108.45	98.24
3.0	125 µm	110.06	99.69
3.5	90 µm	110.31	99.92
4.0	63 µm	110.36	99.96
<4.0	<63 µm	110.40	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	MG07	Gravel Mass = 2.2 g	
Date	16-Jul-03	Remaining Mass = 2281.39 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	2.2	0.10
-0.5	1.4 mm	0.17	0.25
0.0	1.0 mm	0.89	0.91
0.5	710 µm	6.98	6.45
1.0	500 µm	36.98	33.77
1.5	355 µm	75.66	68.99
2.0	250 µm	101.52	92.54
2.5	180 µm	108.33	98.74
3.0	125 µm	109.53	99.84
3.5	90 µm	109.64	99.94
4.0	63 µm	109.67	99.96
<4.0	<63 µm	109.71	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	MG08	Gravel Mass = 7.7 g	
Date	16-Jul-03	Remaining Mass = 2330.38 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	7.7	0.33
-0.5	1.4 mm	1.30	1.47
0.0	1.0 mm	5.02	4.72
0.5	710 µm	19.94	17.76
1.0	500 µm	61.01	53.66
1.5	355 µm	93.18	81.78
2.0	250 µm	110.10	96.57
2.5	180 µm	113.52	99.56
3.0	125 µm	113.96	99.95
3.5	90 µm	114.00	99.98
4.0	63 µm	114.01	99.99
<4.0	<63 µm	114.02	100.00

Folk (1974) Texture Group: Slightly granular coarse sand

Table B2 (Cont.) Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2003

Sample	MG09	Gravel Mass = 5.44 g	
Date	16-Jul-03	Remaining Mass = 2364.62 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	5.44	0.23
-0.5	1.4 mm	0.32	0.52
0.0	1.0 mm	1.68	1.76
0.5	710 µm	9.69	9.08
1.0	500 µm	39.65	36.44
1.5	355 µm	77.35	70.87
2.0	250 µm	102.45	93.80
2.5	180 µm	108.05	98.91
3.0	125 µm	108.99	99.77
3.5	90 µm	109.15	99.92
4.0	63 µm	109.20	99.96
<4.0	<63 µm	109.24	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	DG10	Gravel Mass = 7.12 g	
Date	16-Jul-03	Remaining Mass = 1975.98 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	7.12	0.36
-0.5	1.4 mm	0.65	0.94
0.0	1.0 mm	2.38	2.49
0.5	710 µm	10.29	9.57
1.0	500 µm	40.65	36.74
1.5	355 µm	73.88	66.48
2.0	250 µm	98.89	88.87
2.5	180 µm	107.77	96.81
3.0	125 µm	110.16	98.95
3.5	90 µm	110.73	99.46
4.0	63 µm	110.96	99.67
<4.0	<63 µm	111.33	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	DG11	Gravel Mass = 10.84 g	
Date	16-Jul-03	Remaining Mass = 2848.99 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	10.84	0.38
-0.5	1.4 mm	0.74	1.04
0.0	1.0 mm	3.91	3.89
0.5	710 µm	17.55	16.13
1.0	500 µm	53.19	48.11
1.5	355 µm	82.48	74.39
2.0	250 µm	106.52	95.96
2.5	180 µm	110.71	99.72
3.0	125 µm	110.95	99.94
3.5	90 µm	110.98	99.96
4.0	63 µm	110.99	99.97
<4.0	<63 µm	111.02	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	DG13	Gravel Mass = 39.99 g	
Date	16-Jul-03	Remaining Mass = 2483.66 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	39.99	1.58
-0.5	1.4 mm	0.16	1.74
0.0	1.0 mm	0.73	2.27
0.5	710 µm	3.69	5.06
1.0	500 µm	18.58	19.07
1.5	355 µm	49.06	47.76
2.0	250 µm	86.81	83.29
2.5	180 µm	98.13	93.95
3.0	125 µm	101.55	97.17
3.5	90 µm	102.79	98.33
4.0	63 µm	103.42	98.93
<4.0	<63 µm	104.56	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Table B3 Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2004

Sample	UG02	Gravel Mass = 12.14 g	
Date	13-Jul-04	Remaining Mass = 3569.97 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	12.14	0.34
-0.5	1.4 mm	0.46	0.70
0.0	1.0 mm	1.96	1.88
0.5	710 µm	10.69	8.76
1.0	500 µm	58.05	46.07
1.5	355 µm	99.7	78.87
2.0	250 µm	121.07	95.71
2.5	180 µm	125.4	99.12
3.0	125 µm	126.18	99.73
3.5	90 µm	126.37	99.88
4.0	63 µm	126.46	99.95
<4.0	<63 µm	126.52	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	UG01	Gravel Mass = 5.22 g	
Date	14-Jul-04	Remaining Mass = 2044.77 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	5.22	0.25
-0.5	1.4 mm	0.31	0.52
0.0	1.0 mm	1.32	1.38
0.5	710 µm	6.09	5.43
1.0	500 µm	53.41	45.61
1.5	355 µm	75.21	64.12
2.0	250 µm	106.75	90.90
2.5	180 µm	115.85	98.62
3.0	125 µm	117.16	99.74
3.5	90 µm	117.35	99.90
4.0	63 µm	117.42	99.96
<4.0	<63 µm	117.47	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	UG03	Gravel Mass = 1.84 g	
Date	16-Aug-04	Remaining Mass = 1781.13 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	1.84	0.10
-0.5	1.4 mm	0.19	0.27
0.0	1.0 mm	0.99	0.98
0.5	710 µm	7.12	6.43
1.0	500 µm	39.1	34.87
1.5	355 µm	78.48	69.88
2.0	250 µm	105.87	94.23
2.5	180 µm	111.65	99.37
3.0	125 µm	112.27	99.92
3.5	90 µm	112.33	99.97
4.0	63 µm	112.34	99.98
<4.0	<63 µm	112.36	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	UG04	Gravel Mass = 11.21 g	
Date	16-Aug-04	Remaining Mass = 2546.19 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	11.21	0.44
-0.5	1.4 mm	0.4	0.79
0.0	1.0 mm	1.77	1.98
0.5	710 µm	8.94	8.24
1.0	500 µm	38.4	33.96
1.5	355 µm	73.75	64.83
2.0	250 µm	105.43	92.48
2.5	180 µm	112.95	99.05
3.0	125 µm	113.79	99.78
3.5	90 µm	113.92	99.90
4.0	63 µm	113.98	99.95
<4.0	<63 µm	114.04	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Table B3 (Cont.) Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2004

Sample	MG05	Gravel Mass = 6.47g	
Date	16-Aug-04	Remaining Mass = 2670.42 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	6.47	0.24
-0.5	1.4 mm	0.35	0.57
0.0	1.0 mm	1.6	1.75
0.5	710 µm	9.6	9.30
1.0	500 µm	39.86	37.86
1.5	355 µm	70.05	66.35
2.0	250 µm	96.17	91.01
2.5	180 µm	104.67	99.03
3.0	125 µm	105.58	99.89
3.5	90 µm	105.66	99.96
4.0	63 µm	105.68	99.98
<4.0	<63 µm	105.7	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	MG06	Gravel Mass = 3.14 g	
Date	14-Jul-04	Remaining Mass = 3046.58 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	3.14	0.10
-0.5	1.4 mm	0.13	0.23
0.0	1.0 mm	1.13	1.21
0.5	710 µm	9.68	9.57
1.0	500 µm	41.68	40.85
1.5	355 µm	69.86	68.40
2.0	250 µm	93	91.03
2.5	180 µm	100.52	98.38
3.0	125 µm	101.9	99.73
3.5	90 µm	102.08	99.90
4.0	63 µm	102.14	99.96
<4.0	<63 µm	102.18	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	MG07	Gravel Mass = 10.07 g	
Date	16-Aug-04	Remaining Mass = 2855.25 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	10.07	0.35
-0.5	1.4 mm	0.8	1.07
0.0	1.0 mm	3.65	3.61
0.5	710 µm	16.26	14.86
1.0	500 µm	51.04	45.88
1.5	355 µm	82.41	73.86
2.0	250 µm	105.04	94.05
2.5	180 µm	110.58	98.99
3.0	125 µm	111.53	99.84
3.5	90 µm	111.65	99.95
4.0	63 µm	111.68	99.97
<4.0	<63 µm	111.71	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Sample	MG08	Gravel Mass = 4.9 g	
Date	16-Aug-04	Remaining Mass = 2141.79 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	4.9	0.23
-0.5	1.4 mm	0.3	0.50
0.0	1.0 mm	2.14	2.18
0.5	710 µm	10.93	10.19
1.0	500 µm	43.73	40.08
1.5	355 µm	77.47	70.82
2.0	250 µm	101.76	92.96
2.5	180 µm	107.97	98.61
3.0	125 µm	109.21	99.74
3.5	90 µm	109.42	99.94
4.0	63 µm	109.46	99.97
<4.0	<63 µm	109.49	100.00
Folk (1974) Texture Group: Slightly granular medium sand			

Table B3 (Cont.) Cumulative frequency grain size distributions for bulk bed-material samples on the Gulungul Creek for 2004

Sample	MG09	Gravel Mass =9.08 g	
Date	14-Jul-04	Remaining Mass = 3054.01 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	9.08	0.30
-0.5	1.4 mm	0.54	0.76
0.0	1.0 mm	2.58	2.52
0.5	710 µm	13.58	11.97
1.0	500 µm	50.18	43.45
1.5	355 µm	86.62	74.79
2.0	250 µm	110.42	95.25
2.5	180 µm	114.93	99.13
3.0	125 µm	115.65	99.75
3.5	90 µm	115.8	99.88
4.0	63 µm	115.87	99.94
<4.0	<63 µm	115.94	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	DG10	Gravel Mass = 2.23 g	
Date	19-Aug-04	Remaining Mass = 1662.43 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	2.23	0.13
-0.5	1.4 mm	0.41	0.51
0.0	1.0 mm	1.94	1.92
0.5	710 µm	10.81	10.06
1.0	500 µm	49.51	45.61
1.5	355 µm	84.28	77.54
2.0	250 µm	104.42	96.04
2.5	180 µm	108.28	99.59
3.0	125 µm	108.68	99.95
3.5	90 µm	108.71	99.98
4.0	63 µm	108.72	99.99
<4.0	<63 µm	108.73	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	DG11	Gravel Mass = 3.8 g	
Date	19-Aug-04	Remaining Mass = 3359.12 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	3.8	0.11
-0.5	1.4 mm	0.22	0.31
0.0	1.0 mm	1.14	1.14
0.5	710 µm	7.16	6.53
1.0	500 µm	46.2	41.55
1.5	355 µm	89.64	80.50
2.0	250 µm	108.48	97.40
2.5	180 µm	111.14	99.78
3.0	125 µm	111.32	99.95
3.5	90 µm	111.34	99.96
4.0	63 µm	111.36	99.98
<4.0	<63 µm	111.38	100.00

Folk (1974) Texture Group: Slightly granular medium sand

Sample	DG13	Gravel Mass = 8.11 g	
Date	19-Aug-04	Remaining Mass = 2798.31 g	
Phi		Mass (g)	Cumulative %
-2.0	4.0 mm		
-1.5	2.4 mm		
-1.0	2.0 mm	8.11	0.29
-0.5	1.4 mm	0.51	0.76
0.0	1.0 mm	1.99	2.14
0.5	710 µm	9.82	9.43
1.0	500 µm	41.22	38.66
1.5	355 µm	77.7	72.62
2.0	250 µm	103.44	96.58
2.5	180 µm	106.65	99.57
3.0	125 µm	106.93	99.83
3.5	90 µm	107.02	99.92
4.0	63 µm	107.06	99.95
<4.0	<63 µm	107.11	100.00

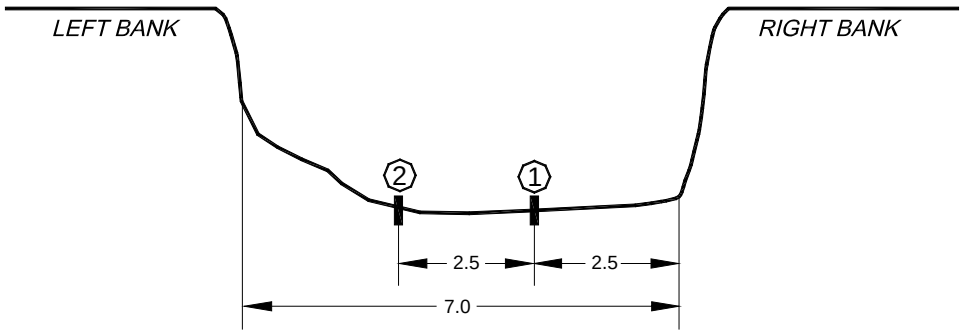
Folk (1974) Texture Group: Slightly granular medium sand

Appendix C

Schematic diagrams to locate the scour chains in Gulungul Creek

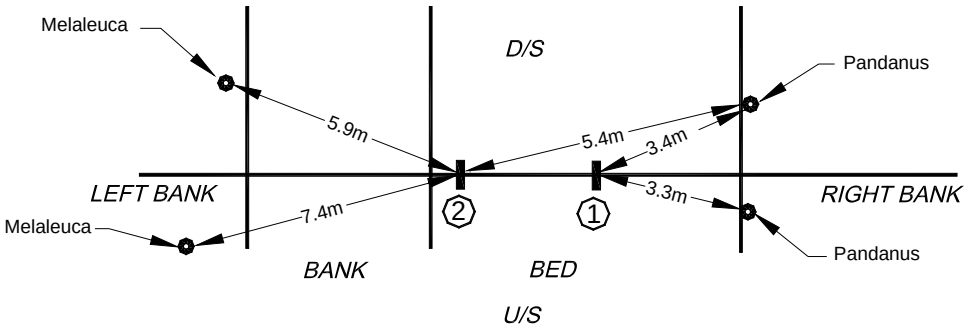
UG02

Chains Initially Installed 30 Oct 02



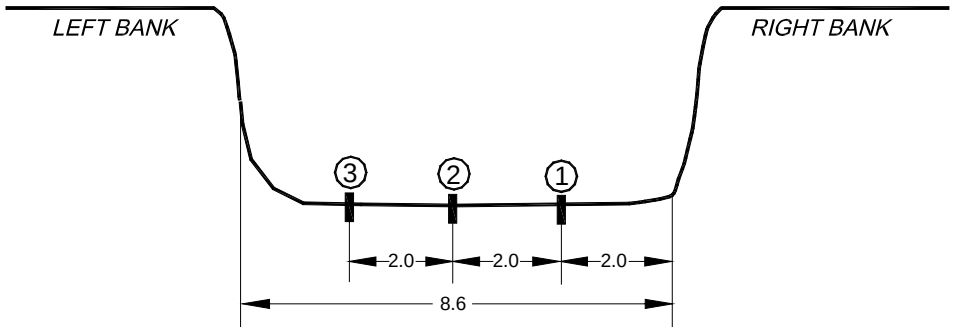
SCOUR CHAIN 1 1.0m All Links Vertical

SCOUR CHAIN 2 1.0m All Links Vertical

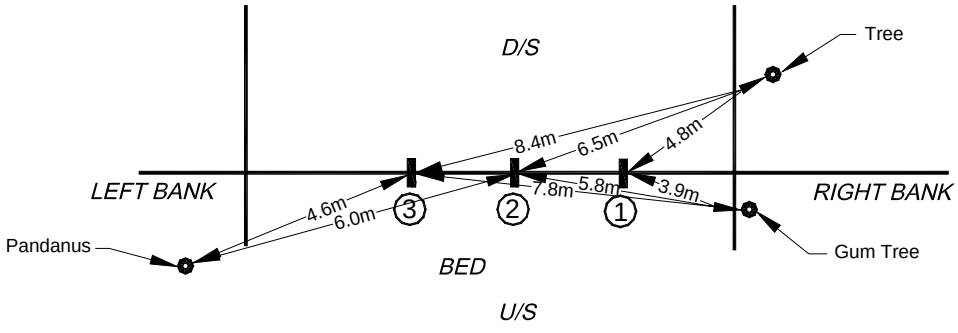


UG03

Chains Initially Installed 30 Oct 02

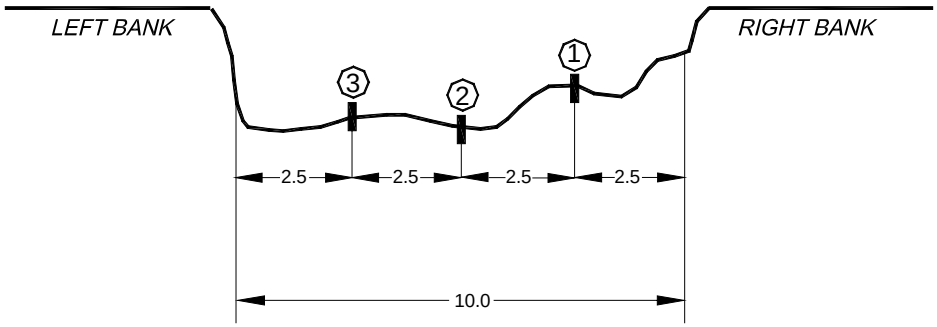


SCOUR CHAIN 1 1.0m All Links Vertical
SCOUR CHAIN 2 1.0m All Links Vertical
SCOUR CHAIN 3 1.0m All Links Vertical

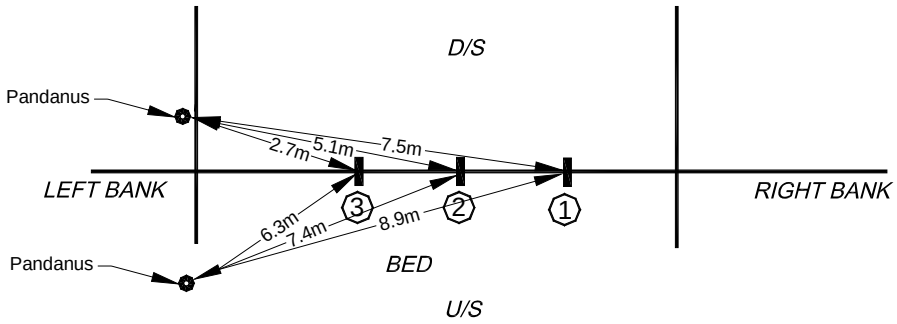


MG06

Chains Initially Installed 30 Oct 02

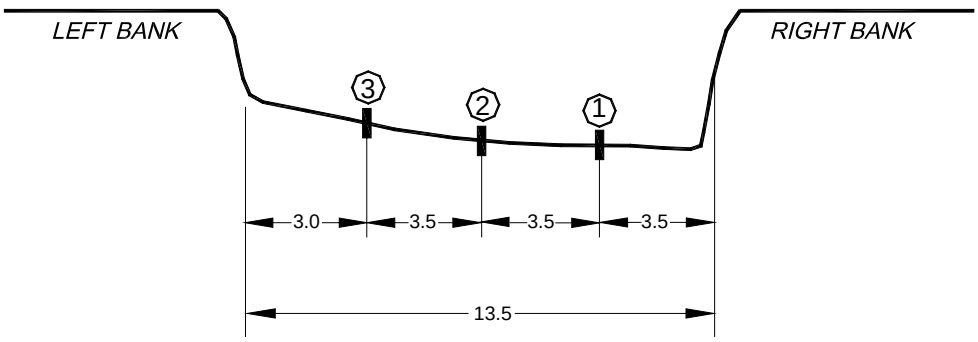


SCOUR CHAIN 1 1.0m All Links Vertical
SCOUR CHAIN 2 0.6m All Links Vertical
SCOUR CHAIN 3 1.0m All Links Vertical

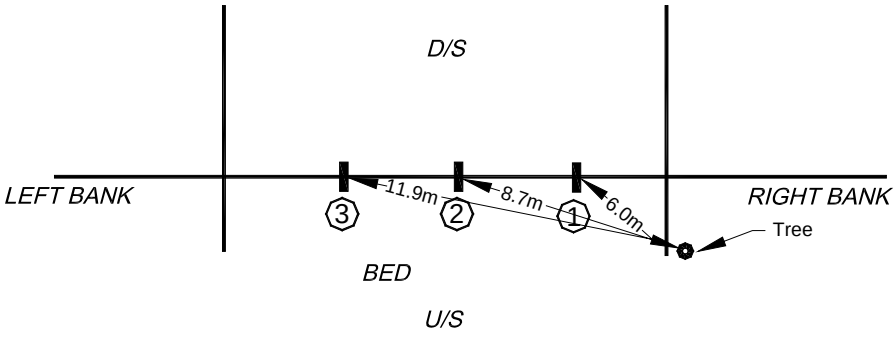


MG08

Chains Initially Installed 30 Oct 02

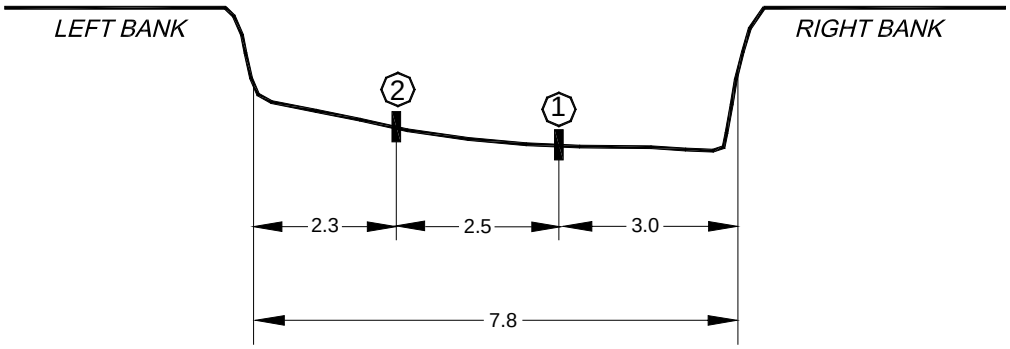


SCOUR CHAIN 1 1.0m All Links Vertical
SCOUR CHAIN 2 1.0m All Links Vertical
SCOUR CHAIN 3 1.0m All Links Vertical



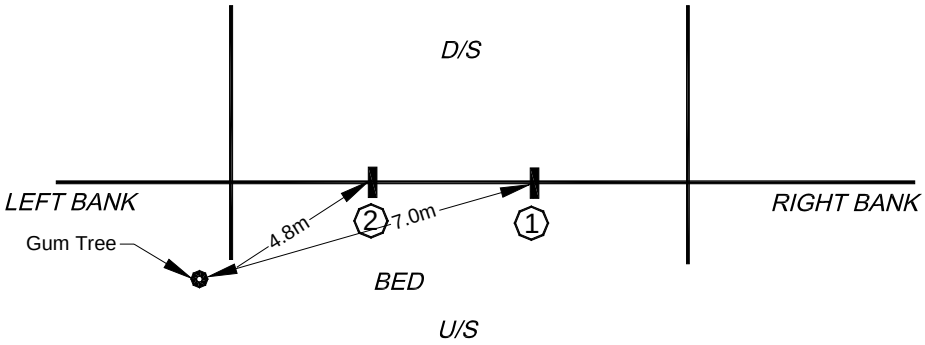
DG10

Chains Initially Installed 30 Oct 02



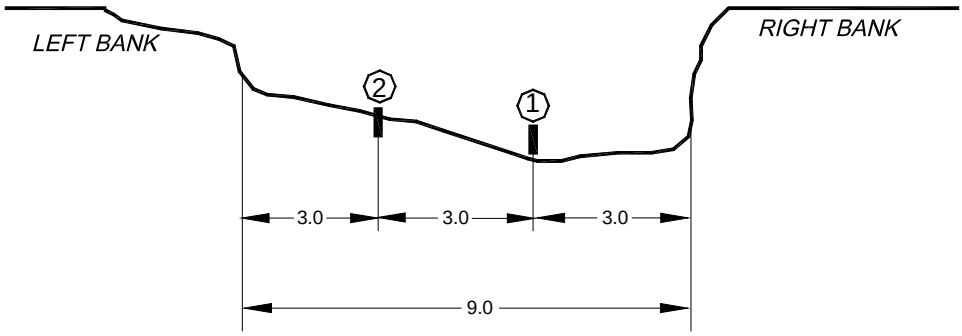
SCOUR CHAIN 1 0.8m All Links Vertical

SCOUR CHAIN 2 0.8m All Links Vertical



DG11

Chains Initially Installed 30 Oct 02



SCOUR CHAIN 1 1.0m All Links Vertical

SCOUR CHAIN 2 1.0m All Links Vertical