Geomorphology and hydrology of Gulungul Creek, NT

KS Crossing

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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 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 has found that there is limited data on the geomorphology of Gulungul creek.

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 PhD project was proposed to meet these aims and carry out a broader study of the creek system. This report describes the work carried out in the initial stages of this project.

2 Scope of report

The scope of this report is to:

- Outline the PhD project proposal
- Provide a catalogue of historical and recently acquired data
- Describe the results of an initial channel and landform mapping exercise

3 PhD project outline

The proposed project described below aimed to both contribute to the existing research and monitoring strategy at Ranger and to meet the requirements for a PhD. As well as the research and monitoring program at Gulungul creek, it was proposed to study the impact of mine site derived sediment on a number of backflow billabongs in the mine site area.

3.1 Background

Ranger uranium mine lies in the Magela Creek catchment, in the Alligator Rivers Region (ARR), Northern Territory. Gulungul creek is a left bank tributary of Magela creek, forming a billabong where it joins Magela about 7 km downstream of Ranger. Georgetown, Coonjimba and Djalkmarra Creeks, small creeks within the mineral lease, also form billabongs where they join Magela.

These mine site tributaries are affected to different degrees by the existing Ranger mine structures. Djalkmarra and Coonjimba creeks are impounded by embankments, limiting dispersal of mine site generated sediment (Erskine & Saynor 2000) while artificial wetlands have been created on Georgetown creek upstream of the billabong. The tailings dam lies partly within Gulungul creek catchment. In addition, any material eroded from the final rehabilitated landform at Ranger will be transported into the surrounding catchments.
Figure 1  Gulungul creek catchment showing the main creeks and tributaries, Ranger Mineral Lease and mine infrastructure, gauging stations and the Arnhem Land Plateau
Currently, *eriss* undertakes chemical and biological monitoring in the creeks around Ranger. A water quality baseline has been determined for Magela creek and the mine site tributaries. Trigger values derived from this baseline data are used to detect any significant change in water quality that may be caused by the mine. Toxicity tests on fish and other aquatic plants and animals are used to determine how much change can occur without harming these plants and animals. Regular monitoring of fish and other small aquatic animals both near Ranger and in undisturbed sites are used to check whether these animals are being affected by the mine.

Studies of soil erosion and sediment yield from natural and disturbed sites have been carried out at Ranger (Evans 1997, Evans et al 1998, Willgoose & Riley 1998) and elsewhere in the ARR (Riley 1995, Duggan 1988, Hancock et al 2002). Although previous geomorphic and hydrology studies have concentrated on Magela creek itself (Wasson 1992, Nanson et al 1993), a large proportion of this sediment will not reach Magela, but will be deposited in the mine site tributaries, including Gulungul creek and the mine site billabongs (Erskine & Saynor 2000).

A program of geomorphic research and monitoring in the catchments containing Ranger uranium mine is required both to assess any current mine impact on the stream systems and to determine a baseline and assessment strategy for future monitoring of the final rehabilitated landform (Pickup et al 1987, Erskine & Saynor 2000).

### 3.2 Project aims

The project will have three major outcomes:

1. Characterisation of sediment movement and channel stability in the channel and floodplain system, particularly in the central reaches of Gulungul catchment near Ranger mine.

2. Determination of the source and rate of pre-mining and current sediment deposition in three mine site billabongs (Georgetown, Coonjimba and Djalkmara) with different levels of disturbance.

3. Derivation of a model to predict the impact of sediment transport from the rehabilitated landform on Gulungul creek and the mine site billabongs, and a strategy for impact assessment and monitoring.

### 3.3 Description and methods

#### 3.3.1 Gulungul catchment

Two gauging stations will be installed on Gulungul creek, one upstream and one downstream of Ranger mine to monitor discharge and sediment transport. Historical gauging stations cannot be reactivated as their location is not suitable for this type of assessment, however their data will be retrieved. The location of both previous and proposed gauging stations around Ranger is shown on figure 1. Hydrology and sediment transport models for the central and upper reaches of Gulungul catchment will be established, based on both current and historical gauging data. The gauging stations will be installed, and data collected each wet season.

The Gulungul main channel, anabranches, tributaries and floodplain will be mapped using a combination of aerial photography interpretation, ground truthing and representative cross-sections. Grab samples of surface sediments will be analysed to map the sediment size distribution across the landforms. Particular attention will be paid to the central reaches...
between the junction with Baralil creek and the un-named tributary upstream of the mine site, however the mapping will be extended downstream to Gulungul billabong and the junction with Magela creek and upstream to the catchment source area. Field-based work, including surveying of cross-sections and collection of grab samples will be started in the 2002 dry season, and continued in the 2003 dry season.

Channel stability and recent landform changes will be mapped using historical aerial photographs from 1950 on. Surface sediment size distribution will also indicate recent changes in flow paths and sediment loads. Variations in tributary and side channel flow, floodplain inundation and channel morphology will be described during wet seasons, and inter-annular changes in channel geometry will be surveyed at representative cross-sections each dry season.

All the above information will be used to build an understanding of the processes acting within the Gulungul creek system, and the functioning of the various elements of the system. Shallow coring and stratigraphic dating at selected cross-sections may be used to answer specific questions about the rate and variability of these processes.

3.3.2 Mine site billabongs

Sediment transport and deposition regimes will be determined for three of the four mine site billabongs. Gulungul lies about 7 km downstream of Ranger and is effectively in a natural state. Georgetown and Coonjimba have reduced flow and probably reduced sediment load from their natural catchments due to mine infrastructure: in Georgetown a series of bunds have created artificial wetlands upstream of the billabong, in Coonjimba retention pond 1 is fully impounded, truncating upstream flow. The fourth billabong, Djalkmara, has been physically cut by the Ranger access road and is not in a natural state suitable for study.

Combined bathymetry and sampling surveys will be undertaken for the three billabongs in the 2003 dry season, in order to determine the shape and capacity of the billabongs, and their current sedimentation regimes. Bottom sediments will be sampled, and the sediment size distribution and organic content measured. The water column will be sampled to determine the suspended sediment size distribution, organic content and various water quality parameters. Previous bathymetric surveys have been undertaken by eriss (A Johnston, pers comm 2002) and a search of the eriss databases is required to find the data from these surveys.

Geomorphic mapping of the surrounding landforms, using both aerial photograph interpretation and ground truthing will be undertaken to build a complete understanding of the sedimentary environment of the billabongs. Ground truthing may include the use of representative cross sections and grab samples, and will be started in the 2003 dry season. Sand plugs deposited by Magela creek dam these backflow billabongs and deflect the billabong outlet channels down the left bank of Magela creek (Nanson et al 1993). The sampling data and mapping will be used to determine whether sediments are sourced only from the upstream catchments or also from backwater flow from Magela creek.

Coring and sediment dating techniques (lead-isotope and/or thermoluminescence) could be used to help determine recent changes in sediment transport and deposition, in particular since the start of mining. Historical bathymetry data for Georgetown and Coonjimba billabongs will be used to determine the rate and volume of infill since the start of mining. Some wet season sampling of the inflow and outflow channels may also be considered to refine the sediment budget of the billabong systems.
3.3.3 Impact assessment and monitoring

An erosion model has been developed to assess proposed post-mining rehabilitated landforms (Evans et al 1998). New rehabilitated landform proposals can be input into this model for assessment. Hydrology and sediment transport models developed from the above studies of Gulungul catchment and the mine site billabong systems, together with the erosion models, will be used to infer the long term erosion, transport and deposition of mine site derived sediments within the catchments, and whether any material will be transported through to Magela.

Consideration will be given to purchasing a DEM of the complete Gulungul catchment, and extending the erosion model to this catchment. This will be useful to further quantify the effect of mine site sediments on Gulungul catchment. An understanding of current and recent past geomorphic processes, and climate change predictions, will be used to predict the effect climate change will have on natural and mine site derived sediment transport regimes.

Based on these results, a monitoring and assessment strategy will be developed to put in place before the end of mining at Ranger. This will ensure that short-term effects of the mine site rehabilitation are adequately monitored, and that differences between observed and predicted sediment transport can be assessed.

3.4 Changes due to withdrawal of PhD student

Much of the Gulungul catchment program described above is required as part of the eriss monitoring strategy at Ranger. Some of this work has already been carried out. This includes the selection of suitable locations for upstream and downstream gauging stations, the surveying of channel cross-sections and an initial geomorphic map and description. The installation of gauging stations and wet season monitoring program at Gulungul will be undertaken in 2003, mainly because of manpower limitations.

The mine site billabong studies and modelling of catchment erosion processes will be reassessed based on priorities at eriss.

4 Datasets

Various data have been collated or acquired relating to the hydrology or geomorphology of Gulungul catchment.

4.1 Aerial photography

Parks Australia North and ERA Ranger Mine have acquired aerial photography over all or part of the catchment in various years. eriss has copies of two sets of photos; the first from 1982 are black and white, and cover most of the catchment, and the second from 1997 are in colour and cover only the central section near Ranger mine. Further details are given in Table 1. The photographs are held in the eriss aerial photograph map cabinet in the GIS section. An Access database holds details of all the aerial photographs held by eriss. Other years where aerial photograph surveys were flown in the vicinity include 1950 (1:50 000 scale), 1964, 1984 and 1991. These surveys may cover all or part of Gulungul creek.
Table 1 Details of aerial photographs held by eriss over Gulungul catchment

<table>
<thead>
<tr>
<th>Date</th>
<th>Scale</th>
<th>Run Number</th>
<th>Photo Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>13/10/1982</td>
<td>1:10k</td>
<td>8</td>
<td>1321–1308</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>1363–1375</td>
</tr>
<tr>
<td>21/06/1997</td>
<td>1:12k</td>
<td>2</td>
<td>113–114</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>99–100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>91–92</td>
</tr>
</tbody>
</table>

4.2 Photographic database

An extensive collection exists of digital photographs related to Gulungul creek and its catchment. The majority of these were taken during recent investigations of the creek system and characterise some of the different geomorphic features of the creek. Other photographs were taken during visits to determine the best location for gauging stations and channel cross-section, and during a helicopter flight to map the extent of fire in the 2002 dry season. Older photographs are also included in the collection, which is catalogued in an Access database. The location of the photographs and database in SSD Explorer is \Landscape Characterisation and Monitoring\Sediment transport in Gulungul Creek catchment\Data\Photographs\.

4.3 Historical gauging station records

Two gauging stations have operated in Gulungul creek in the past (see figure 1 for locations). GS821012, located opposite the tailings dam (coordinates are S 12° 41.380’ E 132° 53.063’), operated for 22 years from 4/11/1971 to 13/08/1993. GS8210210, located just upstream of the Arnhem Highway, operated for 7 years from 20/04/1978 to 19/03/1985. Both stations were installed and run by the NT Power and Water Authority (now the Department of Infrastructure, Planning and Environment). The infrastructure at GS8210210 (near the road) has been completely removed except for a gauge board. The stilling well, inlet pipes, instrument shelter and gauge board are still present at GS821012, but it is not known how clear the pipes and stilling well are.

The records for GS821012 have been obtained from Simon Cruickshank at the Department of Infrastructure, Planning and Environment. The data were supplied in an earlier version of Hydysys (a hydrological data analysis package) than used by eriss, and it was only possible to import the stage height data, which shows fairly complete coverage for the 22 years. Ratings curves and calculated discharge data are also available, and it is recommended that an updated version of the data be requested from DIPE. The existing records are held in the eriss hydrology Hydysys database.

4.4 Channel cross-sections

Twelve cross sections have been surveyed across Gulungul creek at different sites between the upstream lease boundary and junction with Baralil creek. The location of the sections is shown on figure 2. These sections were surveyed in the 2002 dry season to provide a baseline for monitoring change in the channel banks and bed over time, with the aim of resurveying them each dry season.
Figure 2 Gulungul Creek showing location of cross sections
The majority of cross-sections were tied into two concrete plinths, one either side of the main Gulungul channel. These permanent markers should be accurately surveyed using differential GPS to allow the cross-sections to be compared to each other and to other datasets. 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 the survey set ups are given in Table 2.

**Table 2** 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.

<table>
<thead>
<tr>
<th>Section</th>
<th>Instrument set up</th>
<th>Arbitrary coordinates (m)</th>
<th>Sighted to</th>
<th>Sighting angle (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>North</td>
<td>East</td>
<td>Height</td>
</tr>
<tr>
<td>UG01 - A</td>
<td>Plinth 1 (RB)</td>
<td>2000</td>
<td>5000</td>
<td>50</td>
</tr>
<tr>
<td>UG01 - B</td>
<td>Plinth 3</td>
<td>1864.60</td>
<td>5000</td>
<td>50.43</td>
</tr>
<tr>
<td>UG01 - C</td>
<td>Plinth 4</td>
<td>1747.45</td>
<td>5000</td>
<td>49.88</td>
</tr>
<tr>
<td>UG02</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>UG03</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>UG04</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>MG05</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>MG06</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>MG07</td>
<td>LB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>MG08</td>
<td>LB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
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<tr>
<td>MG09</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>DG10</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>DG11</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
<tr>
<td>DG13</td>
<td>RB plinth</td>
<td>3000</td>
<td>2000</td>
<td>50</td>
</tr>
</tbody>
</table>

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.

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.

Section UG01 is located where the proposed upstream gauging station will be installed, and it is proposed that the stage-discharge gauging measurements be carried out on the same section. The sections immediately upstream and downstream (UG02, 03 and 04) were chosen to ensure the channel reach around the gauging station is adequately characterised. Once the plinths have been surveyed, the gradient of the channel floor can be determined.

A downstream gauging station is proposed at the culverts on the Arnhem Highway. No cross section was done here, as the culverts are a permanent man-made structure rather than a natural stream channel. If 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.
**Figure 3** Section UG01: Upstream gauging station

**Figure 4** Section UG02

**Figure 5** Section UG03
Figure 6  Section UG04

Figure 7  Section MG05

Figure 8  Section MG06: Located near existing gauging station GS821012
Figure 12  Section DG10

Figure 13  Section DG11

Figure 14  Section DG13
4.5 Fire mapping

A helicopter survey of Gulungul catchment was undertaken on 12\textsuperscript{th} August 2002 to map the extent of burnt land in the catchment for the 2002 dry season. Extensive areas of the catchment were burnt this year, mostly on the Koolpinyah surface below the escarpment. Figure 15 shows the entire Gulungul creek catchment above Baralil creek and the extent of burnt areas for the 2002 dry season.

![Figure 15: The Gulungul Creek catchment showing the extent of fire in the 2002 dry season](image)

The approximate extent of burnt land was first drawn on a 1:50,000 topographic map, using photographs and observations from the flight. Along the central Gulungul creek reach near the mine site, field visits contributed to the mapping of fire affected areas. On the western side of the creek, fires extended all the way to the creek bank in many places. On the eastern side of the creek between the access track and the eastern bank of the creek unburnt, except near the Arnhem Highway, where fires occurred on both sides of the creek. The track along the Ranger mine site fence also blocked fires in many areas, protecting the mine infrastructure.
This fire mapping was transferred to digital format using Arcview 3.2. The Cahill 5472 1:100 000 topographic map was used as a base, supplemented by vector files showing up to date roads, tracks and mine infrastructure. The 1:50 000 topographic map is not available in digital format.

4.6 Water surface gradient
A detailed survey of the creek water surface gradient was undertaken between March and July 1989 (D Walden, pers comm 2002). Measurements were taken every 50 m along the stream from the Arnhem Highway to above the waterfall at Radon Springs. Additional measurements were taken in May 2001, from the Arnhem Highway downstream to the junction with Baralil creek. A graph of the cumulative water surface height is given in figure 16, and the data is given in Appendix 2.

![Figure 16 Gulungul creek water surface height, 1989. Distance is distance upstream from Arnhem Highway culvert and height is height above water surface at the Arnhem Highway culvert.](image)

5 Geomorphic map and description
A combination of aerial photograph interpretation and field visits was used to develop an understanding of the main geomorphic features of Gulungul creek and catchment for the reach between the upstream lease boundary and the Arnhem Highway. These observations are shown in the landform map in figure 17.

Two types of features are described: channels and catchment landforms. The channels are divided into three categories: main channel path, tributaries and side channels. Three categories of catchment landform are also described: dry ground (Koolpinyah surface and equivalents), irregularly inundated land (possibly equivalent to the high plain of Warner & Wasson [1992]) and regularly inundated land. The latter category includes possible palaeochannels, levee bank swales and swamps at the end of side channels or tributaries.

It should be noted that these observations are preliminary, and based only on dry season aerial photographs and field visits during the 2002 dry season.
Figure 17 Gulungul catchment between Arnhem Highway and the upstream Ranger lease boundary, showing major landforms and channel types. Mapping was carried out using a combination of aerial photograph interpretation and field visits.
5.1 Channel descriptions

5.1.1 Main channel
The main Gulungul channel in this reach has a sandy bed, often with one higher, steep bank and one shallower bank. The mature trees and dense root matter on the banks indicate however, that the channel banks are relatively stable. The channel has low sinuosity, but there are some sharp (almost 90°) bends. Also some sections are strongly braided, generally in the vicinity of a major anabranch.

There is generally a levee formed on the top of both banks. In some places a swale occurs behind the levee. Debris in trees and sand deposits indicate regular overbank flooding along much of this reach. The photograph in figure 18 below shows a typical straight section of the main Gulungul creek channel. In this section of channel, the right bank is nearly vertical, with exposed root matter, and the left bank has a shallow slope.

![Figure 18 Gulungul main channel near Section UG01, looking downstream](image)

5.1.2 Side channels
There are numerous small channels entering or leaving the main Gulungul channel along the reach being studied. These side channels form a complex patchwork of flow, which will require wet season observations to fully delineate. They include anabranches, avulsions ending in sand splays and short tributaries.

The channels have a range of forms from distinct incised, sand-bed channels to wide, shallow, black soil-bed flow paths. The former probably carry a significant amount of flow, while the latter may carry flow only during larger flood events. Figure 19 shows a typical sand-bed side channel with distinct banks. Figure 20 shows a black soil-bed side channel. The soil on the channel bed contains a high proportion of fine, dark organic matter, compared with the surrounding ground.
As shown on the map in figure 17, many side channels change from sand-bed to black soil-bed. Some even grade into or out of unchannelled swampy areas. In places, a sand-bed channel terminates in broad sand splays onto higher ground. A shallow black-soil bed channel may occur immediately downstream of the high ground. Side channels also terminate in swampy depressions with no well-defined exit. It appears that local, small-scale variations in
topography play a major part in the changes in form of these side channels. Debris in and around trees often indicate the height and direction of water flow, both within the channels and on surrounding floodplains and swampy ground.

There are also short linking channels between the main and side channels. These run almost perpendicular to the main channels, and the direction of flow is difficult to determine. It is possible that the flow may be in different directions at different times.

5.1.3 Tributaries
In the reach between the upstream lease boundary and the Arnhem Highway, there are five tributaries on the right bank of Gulungul and three on the left bank. Of those on the right bank, three flow from the area affected by the Ranger mine site, and one flows from the airport area. The other right bank tributaries, and the three left bank tributaries flow from undisturbed areas. On reaching the low ground near Gulungul, the tributary channels become less distinct. Rather than a single junction with the main channel, the tributaries generally open into a wide swampland which may intersect broad flow paths or side channels of Gulungul, with the major flow path being diverted downstream some distance before entering the main channel. This downstream diversion is illustrated in the landform map in figure 17.

5.2 Landform descriptions
The three broad landform categories defined in this geomorphic mapping process are described below. A more comprehensive survey of vegetation types is required to adequately define the typical vegetation assemblage for each category.

5.2.1 Koolpinyah surface
Higher ground away from the creek appears to be typical Koolpinyah surface, as described by East & Wasson (1992), with sandy soil and areas of laterite cover. The vegetation cover is tall open eucalyptus forest with thick annual grasses. Pockets of high ground within the creek system have also been included in this landform class. They appear to have similar vegetation and characteristics to the Koolpinyah surface, but the soils may be more recent alluvium. Figure 21 shows a typical area of this landform near cross-section UG01.
5.2.2 Irregularly inundated land
This landform class includes slopes and higher plains which show evidence of inundation at high water levels, but not of regular flow. Soils are generally sandy. Vegetation includes eucalyptus forest as well as Pandanus spp and other plants not found on the Koolpinyah surface. Some high levee banks are included, and the vegetation along these banks sometimes includes trees typical of tropical monsoon forest.

5.2.3 Regularly inundated land
This category includes the creek channels as well as any land showing evidence of regular inundation during the wet season. The channel types have been described earlier, and the inundated land can be divided into swamps, possible palaeochannels, levee bank swales and other flow paths.

5.2.3.1 Swamps
The swamps have little or no flow under normal conditions, although they may flow during very high water level events. Vegetation cover is generally sparse grass or Melaleuca spp. Swamps often occur near tributary junctions as described above. They also occur in the small right bank tributaries near the tailings dam, as shown in figure 22.

![Figure 22](image)

Figure 22 Shallow open swamp on the right bank tributary west of the tailing dam

5.2.3.2 Palaeochannels
A few wide, shallow flow paths between the Koolpinyah surface and the main channel have been identified from aerial photography as being possible palaeochannels. These flow paths appear to get most of their water directly from the slopes above, rather than from channelled flow from upstream. The flow path is typically a wide, shallow, black soil depression with young Melaleuca spp trees and no dry season grass cover, as shown in figure 23. Debris in the trees indicates that there is some flow along these channels.
5.2.3.3 Levee bank swales

In many sections of the main Gulungul channel, the levee bank swale shows evidence of regular flow. In some cases the side channels described earlier flow through these swales. In other cases, the flow path through the swale is less defined. It is generally narrow, heavily vegetated and discontinuous, intersecting other side channels and grading between channelled and unchannelled flow. Figure 24 shows both a levee bank and levee bank swale with grass cover.
5.2.3.4 Other flow paths
Other unchannelled flow paths grade into or out of the side channels or tributaries described earlier. These flow paths vary in character, but are generally wide and shallow. Vegetation may either be a concentration of floodplain vegetation such as *Pandanus* spp or *Lophostemon* spp or an open grassy area. They are slightly lower than the surrounding landforms. Figure 25 shows a fairly typical flow path and vegetation.

![Figure 25 Wide, shallow flow path with floodplain vegetation](image)

5.3 Discussion
A preliminary analysis of the main geomorphological characteristics of Gulungul creek has been presented in this report. These characteristics are shown in the landform map in figure 17. The main channel is a fairly stable, sand-bed channel with low sinuosity. It has an extensive network of smaller side channels which vary in character from distinct sandy channels to wide, shallow flow paths. Where the right and left bank tributaries join the main channel, flow is generally diverted downstream into side channels or swamps before entering the main channel.

It is evident from the discontinuous nature of these side channels, and the numerous swamps, that a large proportion of sediment eroded from upstream (either from the tributaries or the main Gulungul catchment) must be at least temporarily stored within this reach of Gulungul creek, and not transported further downstream into Magela creek. Hence, further study of the Gulungul creek system is required to ensure the effect of mine site derived sediment is fully understood.

6 Acknowledgements
Sincere thanks to my supervisors, Dr Peta Sanderson and Ken Evans for their support and guidance in developing this project. Mike Saynor, Wayne Erskine and Dene Moliere provided
invaluable advice on many aspects of geomorphology and hydrology, for which I am very grateful. The assistance of Bryan Smith and Gary Fox in field work was also greatly appreciated. I would also like to thank the Environmental Research Institute of the Supervising Scientist and the University of Notre Dame Australia for their support in providing a scholarship and other assistance for this work.

7 References


Hancock GR, Willgoose GR & Evans KG 2002. Testing of the SIBERIA landscape evolution model using the Tin Camp Creek, Northern Territory, Australia, field catchment. Earth Surface Processes and Landforms 27, 125-143.


Appendices
## Appendix 1 Cross Section Data

All values are in metres, based on arbitrary local datums defined in the main text.

**Section UG01**

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