internal report **339**

Hydrology, sediment transport and sediment source in the Swift Creek catchment, Northern Territory

A PhD proposal

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September 2000

supervising scientist

HYDROLOGY, SEDIMENT TRANSPORT AND SEDIMENT SOURCES IN THE SWIFT CREEK CATCHMENT NORTHERN TERRITORY

A PHD PROPOSAL

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Table of Contents

1. FORWARD 2
2. PROPOSED STUDY 2
3. RESEARCH PLAN 2
    3.1 INTRODUCTION and BACKGROUND 2
    3.2 AIMS 3
    3.3 OUTLINE 5
4. METHODS 5
    4.1 INITIAL WORK 6
    4.2 DRY SEASON WORK 6
    4.3 WET SEASON WORK 7
5. OUTCOMES 11
6. TIMEFRAME 11
7. SCHOLARS 11
8. FACILITIES 12
9. ESTIMATED COSTS 12
10. CONFIDENTIALITY & INTELLECTUAL PROPERTY 12
11. APPROVALS 12
12 ACKNOWLEDGEMENTS 13
13. REFERENCES 14

1. FORWARD

This internal report contains the Ph.D. proposal submitted to the Department of Geography, University of Western Australia in November 1999 and accepted in January 2000. This proposal encapsulates many of the ideas and concepts that are presently part of a large project being undertaken at the ***Environmental Research Institute of the Supervising Scientist***. The project is studying the hydrology and sediment movement in the Swift Creek (Ngarradj) catchment, Northern Territory and this Ph.D. study will be an important part of the process. The Swift Creek catchment is of particular importance as the proposed Jabiluka mine is contained within its upper reaches.

The study was instigated in the later part of 1997 as it became evident that there was a strong chance that the Jabiluka uranium mine might become operational. Initial ideas were discussed during early 1998 and in September Dr Wayne Erskine (State Forests of NSW) was commissioned to help with the establishment of the project. The one recommendation that was made by Dr Erskine in addition to the those already arrived at by ***eriss*** staff, was the establishment of gauging stations at several locations within the Swift Creek catchment. Currumbene Hydrological was commissioned in November 1998 to install 3 gauging stations prior to the 1998/99 wet season, with the result that these 3 gauging stations were operational prior to any flow within the creeks. Also prior to the 1998/99 wet season various cross sections were established and monumented, erosion pins installed and various parts of the catchment mapped. Swift Creek was successfully monitored during the 1998/99 wet season. was monitored with no loss of data.

The author commenced a Ph.D. at the University of Western Australia on 14 May 1999.

2. PROPOSED STUDY

(i) The title of the proposed study is "Hydrology, sediment transport and sediment sources in the Swift Creek Catchment, N.T"

(ii) The study will make original and substantial contributions in the following areas

- The use of Differential GPS in geomorphic mapping. This will also be combined with aerial photograph interpretation to provide information about the recent evolution of the catchment.
- Investigate the hydrological response of creeks within the Swift Creek catchment, which has a pronounced wet and dry season, to seasonal events.
- Investigate if suspended sediment - turbidity relationships exist in the Swift Creek catchment,
- Investigate sediment storage and movement in the Swift Creek catchment,
- Determine from all the above, if the establishment of a mine site within the catchment is likely to have an adverse impact on the sediment transportation within the Swift Creek catchment

3. RESEARCH PLAN

3.1 INTRODUCTION and BACKGROUND

Swift Creek is located in Kakadu National Park, in tropical north Australia and experiences a pronounced wet and dry season. Swift Creek is a major downstream right-bank tributary of the Magela Creek that flows directly into the Magela Creek floodplain (Figure1). The Magela Creek and floodplain are listed as Wetlands of International Importance under the RAMSAR Convention and recognised under the World Heritage Convention. There are limited data on catchment geomorphology, channel stability, sediment movement and hydrology of the Swift Creek catchment, which contains the ERA Jabiluka Mine. This mine is in the early developmental phase with construction having commenced in June/July 1998. There is an urgent need to collect baseline channel, sediment and hydrological conditions so as to assess any changes within the creek system that might be caused by mining activities.

Swift Creek flows in a well-defined valley in a northwesterly direction from the Arnhem Land plateau to the Magela Creek backplain (Figure 1). Swift Creek debouches from the Arnhem Land plateau where there is an extensive area of monsoonal vine forest and then flows as a meandering tree lined sand bed channel through a wooded lowland before entering a sandy braided reach above the Oenpelli road and then a depositional fan below the Oenpelli road. Below this fan the creek flows into a billabong on the North East of Magela floodplain.

There is one major right bank tributary (herein called Tributary East) which is essentially a bedrock channel upstream of the escarpment and has a large plunge pool where it debouches from the sandstone onto the sand apron Figure 1. A meandering, tree lined, sand bed channel is present from the plunge pool to Swift Creek. There are several left bank tributaries which are smaller, usually discontinuous and more complex. Jabiluka mine is located near the apex of a large alluvial fan drained by three channels, called Tributaries South, Central and North. Tributary West is the largest of the left bank tributaries and drains the southern part of the catchment (Figure1).

The main objective of this study will be to investigate the movement of sediment within the Swift creek catchment. The hydrological response of the creeks to the seasonal wet and dry season events will also be investigated. The data and information obtained in the thesis will be incorporated in a Geographic Information System (GIS) which is being developed at the same time.

3.2 AIMS

The specific aims of the project are:

1. To obtain baseline data on the channel network, channel stability, channel boundary sediments, sediment storages, sediment transport and hydrology of the Swift Creek catchment;

2. To determine the change in channel stability, sediment storage, sediment transport and hydrology of the channels impacted by mining;

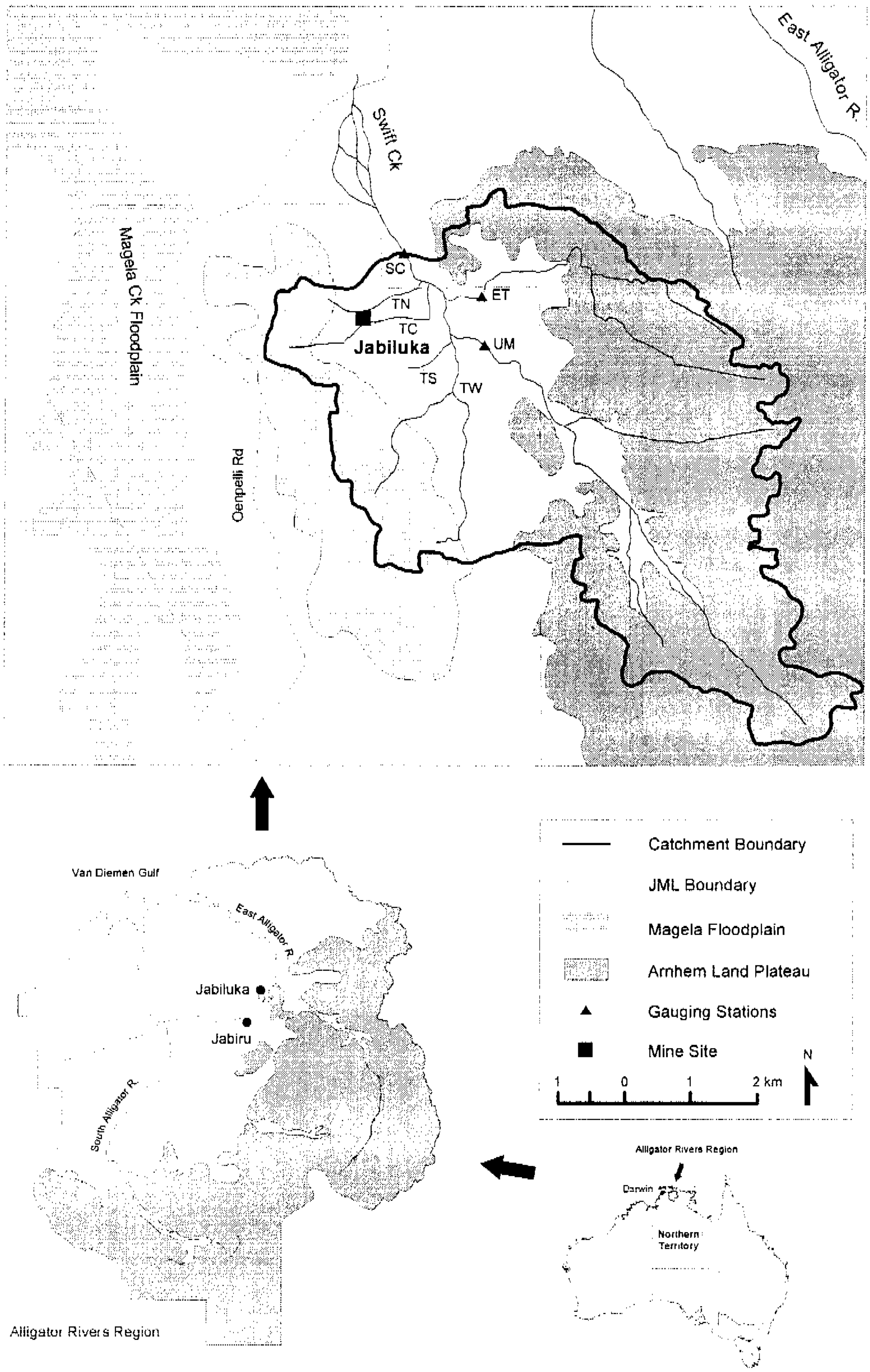

Figure 1: Location diagram for Swift Creek

3.3 OUTLINE

To achieve the aims the following 10 parts need to be completed;

1. Prepare a geomorphic map of the Swift Creek catchment and define morphologically homogeneous channel reaches throughout Swift Creek, thus providing a spatial framework for monitoring and impact assessment;
2. Assess historical stability of each channel reach from all available vertical air photographs to provide an understanding of pre-mining channel characteristics and to provide baseline conditions for the assessment of post-mining channel changes;
3. Selectively measure bank erosion rates and knickpoint migration rates to determine the significance of in-channel sediment sources in comparison to the sediment yields generated on the mine site;
4. Install permanently marked cross sections and survey annually to monitor bed sediment storage and/or large scale erosion throughout the channel network;
5. Install scour chains at each gauging station (see below) to determine the maximum depth of bed scour or deposition during each wet season;
6. Determine the grain size of channel boundary and floodplain sediments for each channel reach to provide baseline conditions for the assessment of post-mining impacts on sediment movement;
7. Install and operate at least 3 stream gauging stations and pluviographs to obtain hydrology and sediment transport data on Swift Creek immediately up and downstream of the mine site as well as on Tributary East (undisturbed) which joins Swift Creek between the two stations;
8. Undertake suspended sediment concentrations and turbidity measurements at each stream gauging station to calculate suspended sediment loads;
9. Undertake detailed bed load measurements at each river gauging station to calculate bed-material loads; and if time permits
10. Map and measure the volume of sediment in discrete sediment storages occurring downstream of the mine site;

Each of the activities required to establish characteristics of the above mentioned 10 points are described in detailed in the methods section below

4. METHODS

The 10 parts of the project mentioned above can be split into three categories depending on time frames and season. The initial geomorphic mapping and aerial photo interpretation (Parts 1 & 2) are ongoing throughout the duration of the thesis and can be done at any time. The remaining parts can be categorised as dry or wet season work. Parts 3 to 6 and 10, are work that will be completed during the dry season when there is no rain or flow in the creeks. The remaining parts 7 to 9 are work that requires flow within the creeks and will be completed during the wet season.

4.1 INITIAL WORK

4.1.1 CHANNEL REACH and GEOMPORPHIC MAPPING

All creeks within in the Swift Creek catchment will be classified into geomorphologically homogeneous reaches using an appropriate scheme. Kellerhals et al (1976) and Rosgen (1994), among others, have proposed such schemes. However, it must be stressed that there is no universally acceptable scheme and any classification will require modification to suit rivers and creeks different to those used to derive the scheme (Kondolf and Downs, 1996).

A geomorphic map of the Swift Creek catchment will be created using a combination of aerial photograph interpretation, field work and on the ground mapping using differential Global Positioning System (dGPS). Higgitt and Warburton (1999) investigated the potential of dGPS to map the upland fluvial geomorphology of 3 catchments in Northern England and found the technique to be successful.

This current study will further test the application of Differential GPS to geomorphological mapping.

4.1.2 RECENT CHANNEL STABILITY

The historical stability of the Swift Creek catchment needs to be determined from all available vertical air photographs to provide an understanding of pre-mining channel behavior and to provide baseline conditions for the assessment of post-mining channel changes. While many different data sources have been used to reconstruct historical channel changes on Australian rivers (for examples, see Erskine, 1986a; 1986b; 1992; 1993; 1999; Melville and Erskine, 1986; Erskine and White, 1996), most of these sources (except for vertical air photographs) do not exist for the Swift Creek catchment. Therefore, vertical air photographs must be used in combination with field evidence to determine channel changes over the last 50 years. In particular, the location and type of channel change, erosion, anabranch development and avulsions, and sediment storage zones need to be identified. This part of the work is similar to part 1 and will be undertaken at the same time.

4.2 DRY SEASON WORK

It is important to determine what the present rates of erosion are within the various reaches of the Swift Creek catchment. This will be done mainly through the use of erosion pins, the installation of permanent cross sections, scour chains and measurements conducted each dry season.

4.2.1 BANK EROSION RATES

Erosion pins will be installed at regular intervals in a vertical section of bank. The pins, 5-6 mm diameter metal rods approximately 300 mm long, are carefully driven into the bank and the amount of exposure after installation immediately measured. The pins are re-measured each dry season. Erskine et al (1995) recommend that the pins should be installed on a vertical section of bank at a spacing of 0.1 to 0.2 m, (depending on bank height), with about 10 mm left exposed so that they can be easily relocated. Pins that have been removed or have exposures greater that 50 mm should be replaced and reset and the exposure measured.

4.2.2 CHANNEL SEDIMENT STORAGE

To determine contemporary channel stability and whether sediment is deposited in, or eroded from, the channel bed, a series of permanently marked cross sections will be installed and repetitively surveyed each dry season. The cross sections will be located at reaches near each gauging station and on Tributaries North and Central. At selected sites longitudinal profiles should also be established and surveyed over short channel lengths.

4.2.3 BED SCOUR DEPTHS

Each wet season, the bed material of Swift Creek and its tributaries is reworked and transported downstream at various rates to various sediment storages. While the bed-material fluxes are to be measured during the wet season, it is also important to know the depth to which the bed is scoured and/or aggraded each wet season. The bed will be one of the first temporary stores to receive sediment generated on the mine site.

Scour chains (interlocked metal chains placed vertically into the bed sediment during the dry season) are the best means of measuring scour depths (Leopold et al 1966), and will be installed at various reaches of the Swift Creek catchment. The scour chains will be installed by digging a hole in the dry creek bed with a sand auger. The material that is excavated from the auger hole will described briefly in the field, in terms of sand texture and colour. More detailed laboratory description according to the methodologies recommended by M^c^Donald and Isbell (1990) will be conducted at a later date.

A length of metal chain will be cut and then carefully lowered down the hole, ensuring that all links remain in the vertical position. The hole will then be back filled to keep the scour chain links in the vertical position. The theory of the linked chain is that the vertical chain will lie down horizontally on the scoured bed surface as bed level deepens and will be buried as the bed aggrades.

4.2.4 BED, BANK and FLOODPLAIN GRAIN SIZE CHARACTERISITICS

For the initial baseline survey, auger holes will be dug, described and sampled at selected cross sections to provide stratigraphic details. In the creek bed this will be combined with the installation of the scour chains. The soil material will be described according to the methodologies recommended by M^c^Donald and Isbell (1990). All sediments sampled will be subjected to particle size analysis according to the methods of Gee and Bauder (1986). Other characteristics such as bulk density, soil moisture content, clay mineralogy and heavy mineral analysis of the sand fraction may be determined. Samples will also be obtained from the spoil areas and other areas of the catchment to help define sediment sources. These data will provide information on the sedimentary characteristics of the cross sections located throughout the catchment.

Bulk grab samples of the channel bed will be collected during the dry season at each cross section to see if the particle size distribution changes with time. Bulk samples of soil, sand, fine gravel and mixed sand and fine gravel should be collected by spade or hand trowel at multiple sites on each surveyed cross section. At least 5 equally spaced points on the river bed of each cross section should be combined for a single bed sample. Such samples will then be air dried and subjected to relevant laboratory analyses. Bulk sieve analysis will be used to determine grain size distributions as this has been recommended as the standard for use with river sediments (Kellerhals and Bray, 1971).

Floodplain sediment samples will be obtained using a combination of a Jarret bucket auger in suitable soils and a sand auger in the much sandier soils. As this is a time consuming process, samples will only be collected at selected representative cross sections from Swift Creek.

4.3 WET SEASON WORK

To determine the sediment flux characteristics of Swift Creek information must be collected during the wet season when the rivers are flowing and sediment transport is occurring. Stream stage height is necessary to determine discharges and total sediment loads.

4.3.1 STREAM GAUGING STATIONS

With the aims of this thesis to provide baseline data on the hydrology and sediment transport of the channels in the Swift Creek catchment as well as determining the impacts of mining, it is essential that continuous streamflow data be obtained at a number of sites. Sediment loads can only be calculated if there are corresponding discharge data, and this has not been collected to date, except for the 1997/98 wet season at one site on Swift Creek.

Preliminary field inspections of the Swift Creek catchment in September 1998 identified potential gauging and sediment transport measurement sites on Swift Creek. Three gauging stations were established during November 1998 at the following sites;

- The main channel of Swift creek upstream of all mine influences (herein called Upmain).
- The main channel of Swift Creek (herein called Swift Creek) downstream of all of the mine influence and the tributaries of both the right and left banks.
- The main right bank tributary (East Tributary) that flows into Swift Creek between upstream and downstream gauging stations. There is no mining activity this catchment.

The Swift Creek site is intended to measure any impact that the mine might have on sediment loads while the Tributary East and Upmain sites are intended to measure sediment loads in the undisturbed natural Swift Creek catchment. Tributary West, also undisturbed is the largest of the left bank tributaries, draining the southern part of the catchment and has a discontinuous channel with large swampy areas. Ideally this tributary should have been gauged however the nature of the channel made the installation of a gauging station an impossibility. There are three smaller right bank tributaries called Tributary North, Tributary Central and Tributary South. The Jabiluka mine is located in close proximity to these tributaries and the mining company has installed gauging stations and equipment on these streams. Figure 2 is a block diagram which shows the contributions and locations of Swift Creek and its tributaries.

Each gauging station consisted of a stilling well with an aluminum shelter to house and protect the data logging equipment. Each site has the following sensors and equipment;

- A Unidata water level instrument with optical shaft encoder
- A Data Electronics DT 50, data logger
- A Hawk water level pressure sensor, as a backup stage indicator
- A Greenspan turbidity meter
- Gamet pump sampler – Automatic water sampler
- A Hydrological Services Pluviograph to measure rainfall
- Other miscellaneous items such as, solar panels, staff gauges, boat, wire cable across the channel and bench mark.

Pluviographs were installed at each site to measure rainfall amount and intensities. As part of the project it is intended to install additional pluviographs on the escarpment to pinpoint where in the catchment, rain falls and how long the water from these events take to reach the gauging stations (i.e. the lag time). Rain in the tropics usually occurs as individual thunderstorm events and widespread monsoonal activity.

These gauging stations were operational during the 1998/99 wet season and rainfall, stage height and sediment data were collected. The sites were visited weekly by helicopter to download the data loggers and collect the water samples from the Gamet sampler. In addition velocity-area gaugings were conducted and suspended sediment samples and bedload samples collected.

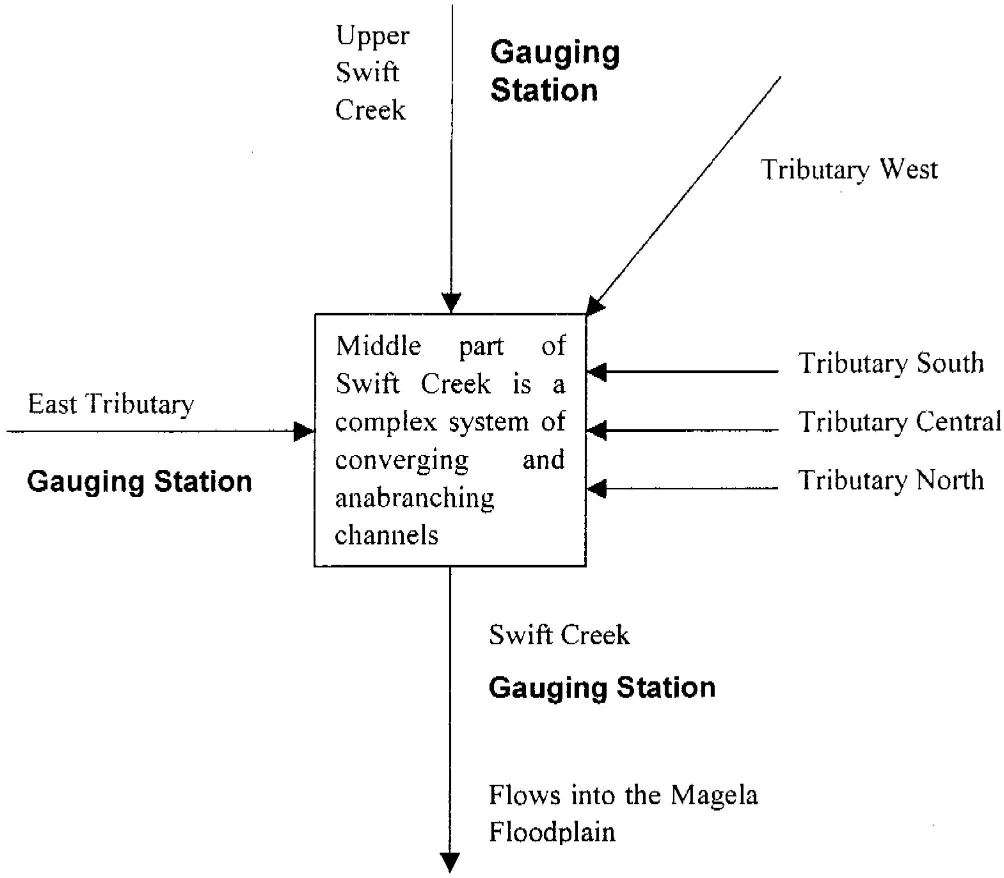

Figure 2: Block diagram showing the inputs and contributions into Swift Creek.

4.3.2 SUSPENDED SEDIMENT LOADS

Suspended sediment samples were obtained during each weekly visit to the gauging station. These samples were collected at the cable section at each stream gauging station with a USDH depth integrated sampler (Guy and Norman, 1970). This sampler collects the water-sediment mixture at a rate proportional to the flow velocity at various levels in the vertical and the resultant concentration represents a discharge-weighted mean concentration for that vertical (Gregory and Walling, 1973). A USDH 48 sampler is designed so that it will not collect bed material when it reaches the bed. There is an unsampled zone of about 0.1 m immediately above the bed. Nevertheless, all field work needs to be conducted carefully.

Depth integrated suspended sediment samples were collected according to the Equal Transit Rate method (Guy and Norman, 1970). The *Equal Transit Rate* method involves moving the sampler at a constant rate between the water surface and the bed at each of a series of verticals equally spaced across the channel. No prior knowledge of the velocity pattern is required at the sampling site to obtain a mean suspended sediment concentration for the whole section.

Due to limited access during the wet season, a stage activated pump sampler, (Gamet Waste watcher) was installed to obtain detailed time series variations in sediment concentrations required for accurate load determinations (Rieger and Olive, 1988). The sampler intake was located 0.3 m above the bed level (pre 1998 bed levels) so that it samples suspended sediment.

Duggan (1988) found that there was no significant relationship between suspended sediment concentration and turbidity on Georgetown and Gulungul Creeks during the 1984-85 wet season. This was explained by the different turbidity readings for coarse and fine sediments of the same concentration. As the mix of grain sizes varies so does turbidity, even if concentration remains constant. Riley (1996; 1998) analysed the same relation for runoff samples on the ERARM waste rock dump. He found that although some of the relationships were statistically significant they were associated with relatively large errors. This suggests that there are real problems in using turbidity for continuous monitoring of suspended sediment transport in the Alligator Rivers Region. This suggested that further work was required along the lines of Gippel (1989a; 1989b; 1994). For this reason Greenspan continuous recording turbidity meters were installed at each gauging station to collect a detailed turbidity time series. The relationship between turbidity and suspended sediment concentration will be investigated further to determine whether turbidity can replace suspended sediment monitoring. The following investigations will be undertaken with the various turbidity measurements that are collected each wet season;

- correlation of laboratory determined turbidities with the insitu probe turbidities,
- correlation of laboratory determined turbidities with suspended sediment concentration
- correlation of probe turbidity with suspended sediment concentration.

After collection the suspended sediment samples are stored in a coolroom (max temperature 4 degree C) to restrict algal growth. Laboratory analysis comprises determination of the sand, silt and clay and solute concentrations.

4.3.3 BED-MATERIAL LOADS

The Helley Smith pressure difference bedload sampler (Helley and Smith, 1971) was designed to be compatible with depth integrated suspended sediment samplers and is one of the most accurate bedload samplers yet designed (Emmett, 1979). The orifice diameter of the Helley Smith sampler closely approximates the unsampled zone between the intake nozzle and the bed of a depth integrated suspended sediment sampler (Helley and Smith, 1971). The Helley Smith sampler has been used in Magela Creek studies (Roberts, 1991) and will be used in this study.

Field methods followed those used by the U.S. Geological Survey and have been outlined by Carey (1984; 1985), among others. At least 6 point measurements of bedload transport were taken at each gauging station cross section. Measurement times were determined on a trial and error basis and were generally 3-5 minutes for large flows and 10 minutes for smaller flows. Each bedload gauging consisted of a double pass across each section (i.e. 12 point measurements). Although instantaneous bedload fluxes are highly variable, it is possible to define a mean flux for a given discharge, provided thorough field measurements are made (Carey, 1985).

The samples from the 1998/99 wet season are presently being analysed in the laboratory, and the 1999/00 wet season sampling program is presently being prepared for.

4.3.4 SEDIMENT STORAGES

If time and resources permit the sediment storages of Swift Creek will be determined. The depth of sand in the channel bed will be determined by probe or sand auger, and will be used to determine volumes of stored sand. There are specific sediment stores downstream of the mine site that can be mapped individually. These sites, along with the channel bed, are likely to be the first areas to receive sediment eroded from the mine site.

5. OUTCOMES

Anticipated outcomes of the study are to gain a thorough understating of the sediment movement and associated hydrological parameters of the Swift creek Catchment. At present there are limited data on sediment movement and hydrology in the Swift Creek catchment, however this work in progress will attempt to address the issues outlined above and provide a much enhanced knowledge base. Reports and publications will be produced through the ***Environmental Research Institute of the Supervising Scientist.*** These will take the form of Internal reports, Supervising Scientist reports (refereed publications) and journal papers.

6. TIMEFRAME

The project has been set up for 3 years, to monitor 3 cycles of wet and dry seasons and will comprise the basis of this study. At the conclusion of this three years the results of the study will be assessed and recommendations made with regard to future work.

7. SCHOLARS

The following is a list of leading scholars in the fields relevant to this study.

Dr Wayne Erskine, Fluvial Geomorphology and Sediment movement
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8. FACILITIES

The project is being supported by the ***Environmental Research Institute of the Supervising Scientist (eriss)*** which is located at Jabiru in the Northern Territory. I am employed by this organistaion who support the research being undertaken, with the project included in the Institute's research plan. ***eriss*** is providing equipment, full laboratory and field support for the duration of the project. Their contribution is worth over $45000 per year and exceeds $90000 per year in kind support.

Supervision is being supplied by

Dr Ian Eliot and Professor J. Dodson, Department of Geography, University of Western Australia,
Dr Wayne Erskine, State Forests of NSW, and
Dr Ken Evans at ***eriss.***

(i) Special Equipment such as the gauging stations have been organised and paid for by ***eriss***.
(ii) At this stage no Special Techniques are envisaged as being necessary.
(iii) Literature is being obtained through interlibrary loans organised by the library at ***eriss***
(iv) Statistical Advice will be provided by the supervisors and their colleagues.

9. ESTIMATED COSTS

The estimated costs to the Department of Geography, will be minimal as the ***Environmental Research Institute of the Supervising Scientist*** is providing the funds necessary for the project which are in excess of $45000 in real costs. The annual costs to the Department will be approximately $3000 to cover an annual visit to the University by the Student as well as a visit to the Institute by the Supervisor.

10. CONFIDENTIALITY & INTELLECTUAL PROPERTY

As the project is being funded by the ***Environmental Research Institute of the Supervising Scientist*** approval will have to be obtained from the Commonwealth prior to publishing any papers and the submitting of the thesis. There should not be problem obtaining approval as the institute publishes many scientific documents.

11. APPROVALS

No university approvals are required. Annual approvals to work on Aboriginal lands in the Northern Territory are obtained from the Northern Land Council and the Northern Territory Government. These permits are obtained by ***eriss***.

12 ACKNOWLEDGEMENTS

I am grateful to the ***Environmental Research Institute of the Supervising Scientist*** for providing the means by which a Ph.D. can be undertaken, in particular to Dr Ken Evans (***eriss***). Thank you also to Dr Wayne Erskine (State Forests of NSW) for his valuable input into the establishment of the gauging stations and for agreeing to be a co-supervisor on the Ph.D. Thanks also to Dr Ian Eliot (School of Geography, University of Western Australia) for being the main supervisor and also to Professor John Dodson (School of Geography, University of Western Australia) for suggesting that I enroll in his department. Mark Daniell & Renee Lyons (ERA) are thanked for providing information as well as access onto the Jabiluka Mineral Lease. Andrew Wellings, and other staff of Parks Australia North provided information and gave guidance where possible with respect to the Swift Creek catchment and access.

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