THE JABILUKA PROJECT

ENVIRONMENTAL ISSUES THAT THREATEN KAKADU NATIONAL PARK

SUBMISSION TO UNESCO WORLD HERITAGE COMMITTEE DELEGATION TO AUSTRALIA

FROM:
PROFESSOR R J WASSON

PROFESSOR I WHITE

DR B MACKEY
AUSTRALIAN NATIONAL UNIVERSITY

MR M FLEMING
CONSULTING ECOHYDROLOGIST

CONTENTS

1. PREAMBLE

In a letter (dated 22 June 1998) to the World Heritage Committee, we described issues that we claim are threats to the World Heritage status of Kakadu National Park. The issues we raised were:

1. The process of the EIS and Review was deeply flawed.

2. The proposal to mill at Jabiluka needs a new EIS.

3. The EIS ignores cultural heritage.

4. The proposed mine site water management plan is now obsolete and flawed.

5. There are many (other) flaws in the EIS.

The case for a new EIS for the on-site milling proposal stands as set out in our letter (attached), and cultural heritage is being addressed by a submission from the Australian Academy of the Humanities.

The document that follows is concerned mainly with water management.

2. SUMMARY OF CONCLUSIONS

a The environmental and landscape context of the EIS is too limited to provide a view of the significance of the Jabiluka area as part of the entire national park.

b The Jabiluka mine site is located at the point of juxtaposition of an escarpment, (like that of the main Arnhem Land Escarpment), a sandy footslope, and a major wetland. This juxtaposition is unique in Kakadu.

c The EIS provides inadequate landscape analysis to quantify and visualise fully the paths by which pollutants might impact on the surrounding areas; particularly, Magela Swamp and the East Alligator floodplain and river.

d Design of waste containment structures at the Jabiluka mine site is flawed by the use of a design method based upon the assumption of statistical stationarity in the rainfall and runoff series.

e Future climate change, driven by greenhouse gas warming, is likely to change the hydrology of the mine site, making it impossible, in the face of current analyses, to guarantee the safe containment of wastes.

f Design of surface retention ponds is flawed, even assuming stationarity, because the EIS consultants have not adopted either sound assumptions or calculations procedure. The recent 1998 extreme rainfall event at Katherine, 100km south of Jabiluka, probably exceeded the calculated extreme rainfall at Jabiluka; so the calculations of extreme runoff at Jabiluka are likely to be underestimated.

g Evaporation calculations appear to be seriously in error, again putting in doubt the proposed surface water management scheme.

h Again because of errors in calculation of evaporation of the mine air stream, storage requirements for water are underestimated. Redesign of the containment ponds is essential.

i Metals accidentally released from the mine site could be mobilised in highly acidic waters on the Magela Plain associated with acid sulfate soils.

j Pumping of water from Ja-Ja Billabong (and/or Mine Site Billabong) would oxidise the acid sulfate soils of the Magela Plain, mobilising metals and causing the water quality to deteriorate seriously.

3. QUANTITATIVE LANDSCAPE-WIDE ANALYSES

Inadequacies of the environmental context of the EIS

In order to adequately evaluate the potential impact of the Jabiluka development proposal it is essential that quantitative landscape-wide analyses are undertaken. These are necessary for a number of reasons including:

- To provide appropriate geographical and environmental context
- To model the potential flow of substances through the landscape, and
- To simulate potential impacts over time under different management and climate change scenarios.

These kinds of analyses were not undertaken by the Jabiluka environmental impact assessment. Rather, the assessment focussed on the vicinity of the mine site and related activities. Landscape-wide assessment techniques appear to have been limited to qualitative descriptions of Land Systems and generalised vegetation classes.

The Land Systems methodology was developed by the CSIRO in the 1940s and was intended for broad-scale reconnaissance survey only, (Christian and Stuart 1953). Therefore the Land Systems presented in the report represent too coarse a scale of analysis for current purposes. Similarly, mapping general vegetation units is on its own insufficient. Furthermore, the appropriate context for the impact study is the entire Kakadu National Park – not some arbitrarily defined area around the Jabiluka site as used by the impact assessment.

Indicative analyses

All that we are able to do here is provide some examples that illustrate the kinds of analyses that need to be undertaken in order to provide an adequate evaluation of the potential impact of the Jabiluka development on the Kakadu Ntional Heritage park.

Fig. 1 shows the catchment (watershed) boundary for Magela Creek. This flows into the Magela swamp, and constitutes the total contributing catchment area which contains the Jabiluka proposal. This is the minimum landscape context that should be used when evaluating the potential hydrological impact of the Jabiluka development on the Kakadu National Park. Fig 1a shows the same but for the N.E. corner near the Jabiluka proposal. Also mapped are the main areas of swamp.

Fig. 2 shows total annual precipitation for the Kakadu National Park. The Jabiluka proposal can be seen to be in the highest rainfall zone. These gridded estimates of precipitation were generated by coupling the digital elevation model to existing interpolated surfaces of long term mean monthly climate. It would be interesting and useful to generate similar spatial data sets for (a) an index of year-to-year precipitation variance (eg. precipitation percentiles) and (b) extreme/maximum rainfall events. It is also now possible to generate such landscape-scale models under projected climate change scenarios generated by the CSIRO Limited Area Model.

Fig. 3a shows a terrain classification based on classes of elevation and topographic position calculated from the digital elevation model. Fig 3b shows the same analysis for the N.E. corner where the Jabiluka proposal is located. This classification delineates the major landform units in Kakadu. The Jabiluka site can be seen to occupy a unique landscape positions – it is the only escarpment unit adjacent to the swamp ecosystem

Also mapped is the potential flow path of water from the mine site through the Kakadu National Park. This is based on calculation of potential catchment contributing area (ha) at each grid point (see Fig. 4). This analysis only approximates total potential flows, as sub-surface flows in this landscape are very complex and do not necessarily only mimic surface slope.

Recommended *Best Practice*

It is possible and feasible to use the kinds of techniques illustrated here to develop landscape-wide, temporally dynamic models of the flux of water, and related substances, through space and time.

Hence rather than looking at coarse scale, qualitative patterns over arbitrarily delineated areas, quantitative measure of hydrological and related fluxes could be simulated. It is important to keep in mind that key processes in the water balance do not occur at uniform rates across the landscape. For example, actual evaporation is affected by, among other things: net surface radiation (which is a function of topography and albedo or land cover reflectance); leaf area index (vegetation type); and soil water (which in turn reflects surface and sub-surface flows, soil depth and soil texture).

Landscape-wide modelling - that utilises Geographical Information Systems, remotely sensed data, digital elevation models, and process simulation algorithms - is required to realistically integrate the suite of critical biophysical parameters. (Goodchild *et al.* 1996)

Once such a process-based, dynamic, landscape model is compiled, the potential downstream/off site impact could be simulated as a function of climate change scenarios. Such a model could therefore be calibrated to indicate the potential landscape response to the projected changes in precipitation, temperature, and radiation, and the flow-on effects for evaporation, vegetation cover, evaporation, and the water balance on a catchment-wide basis

Please note that the indicative analyses presented here are based on a 250m resolution digital elevation model. Definitive rather than indicative results would require far more substantive analyses based on a digital elevation model of 5-10m resolution. The data exist, or could be generated, to calculate such a model.

Because of the significance of the Kakadu National Park, it is essential that *World Best Practice* in environmental modelling be employed when assessing the potential impact of the Jabiluka proposal. Indeed, cutting-edge landscape modelling techniques should be used where ever possible. This is a feasible proposition given that Australia can lay claim to being an international leader in this area of applied environmental science.

We recommend that further analyses along the lines suggested here are required before an adequate risk assessment can be made of the potential impact of the Jabiluka development on the Kakadu National Park.

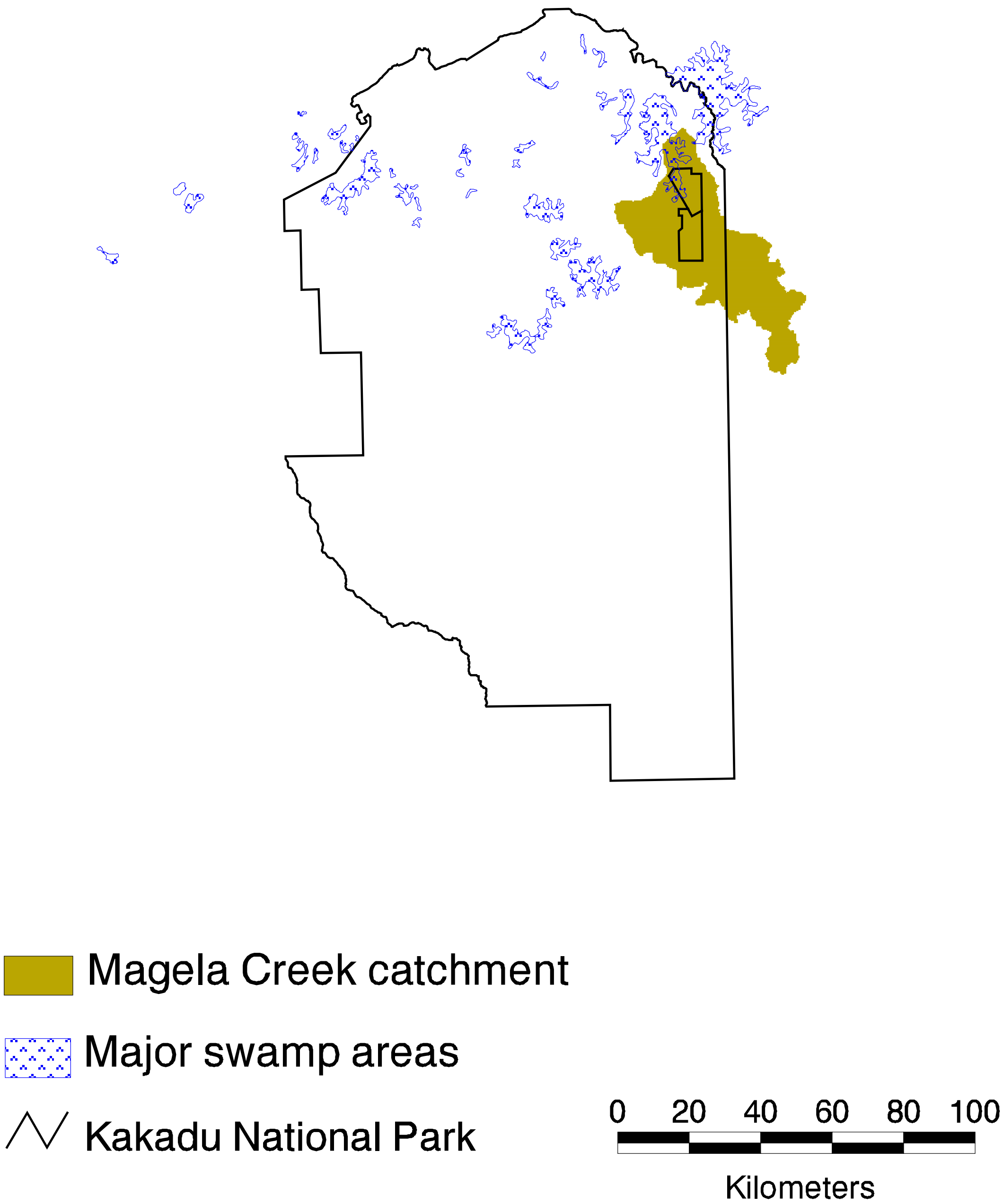

Figure 1 a. Catchment (watershed) boundary for Magela Creek.

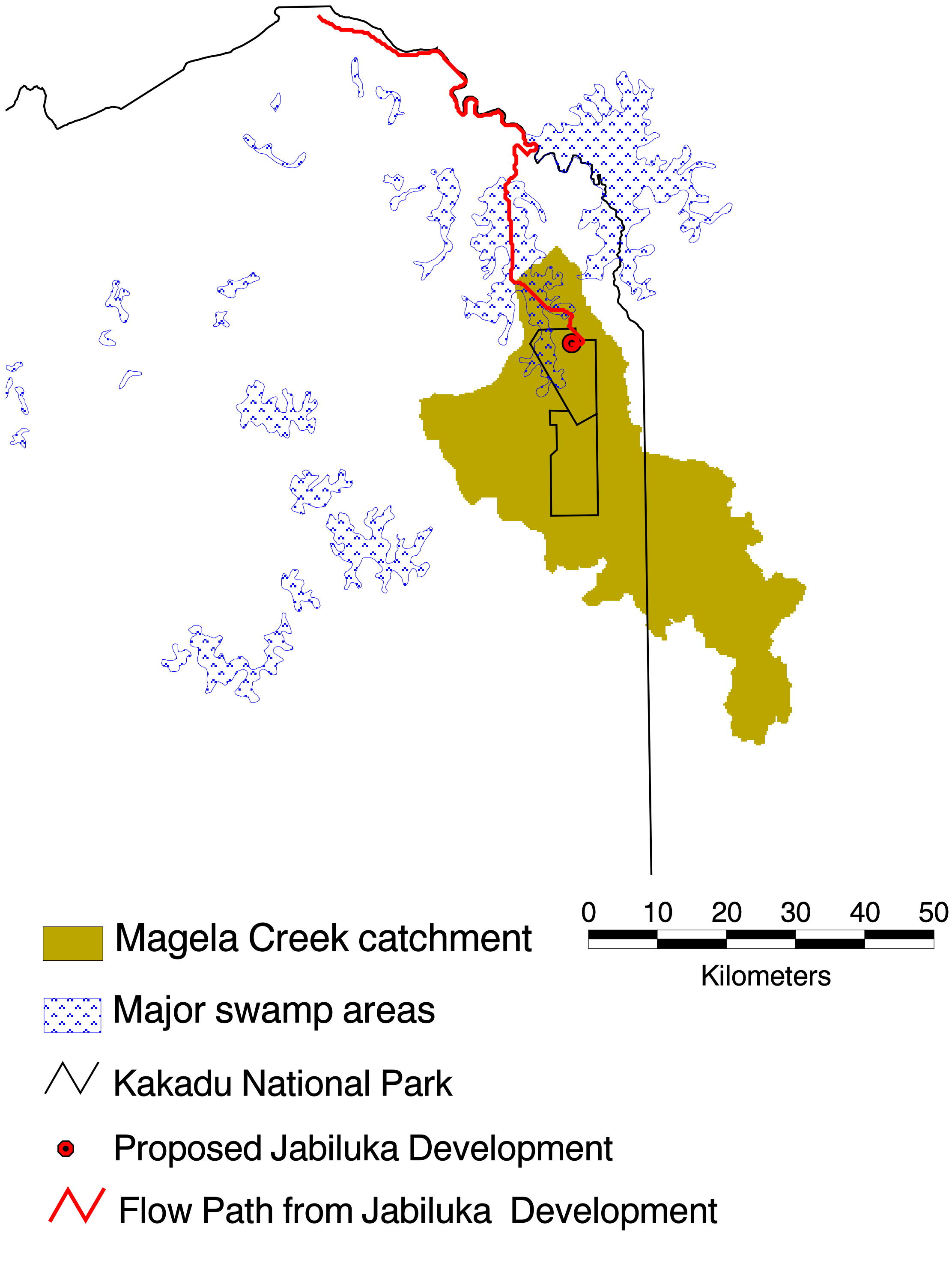

Figure 1 b. Catchment (watershed) boundary for Magela Creek . Detail is shown of the North-East corner of the Park, where the Jabiluka proposal is located.

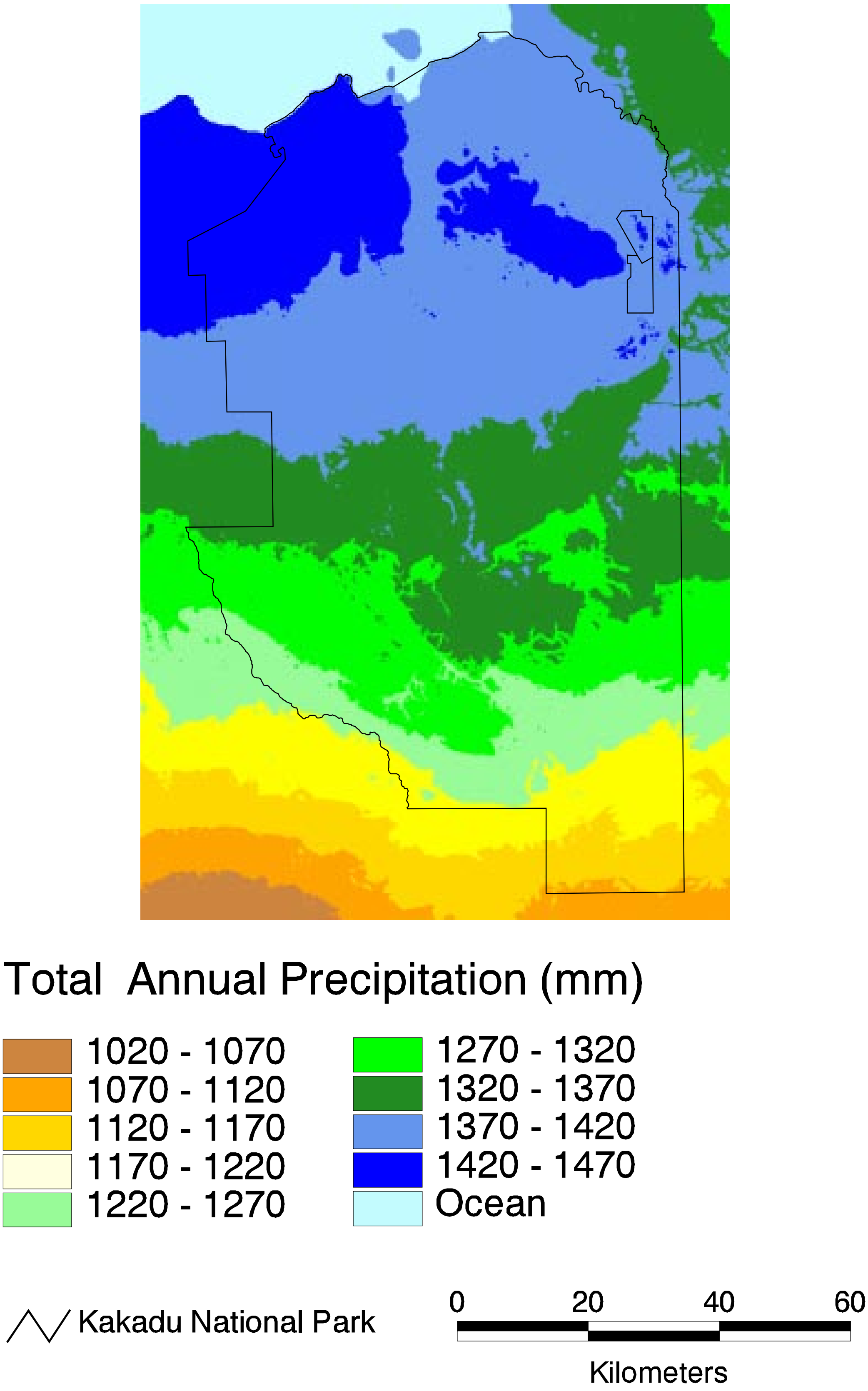

Figure 2. Total annual precipitation for Kakadu National Park.

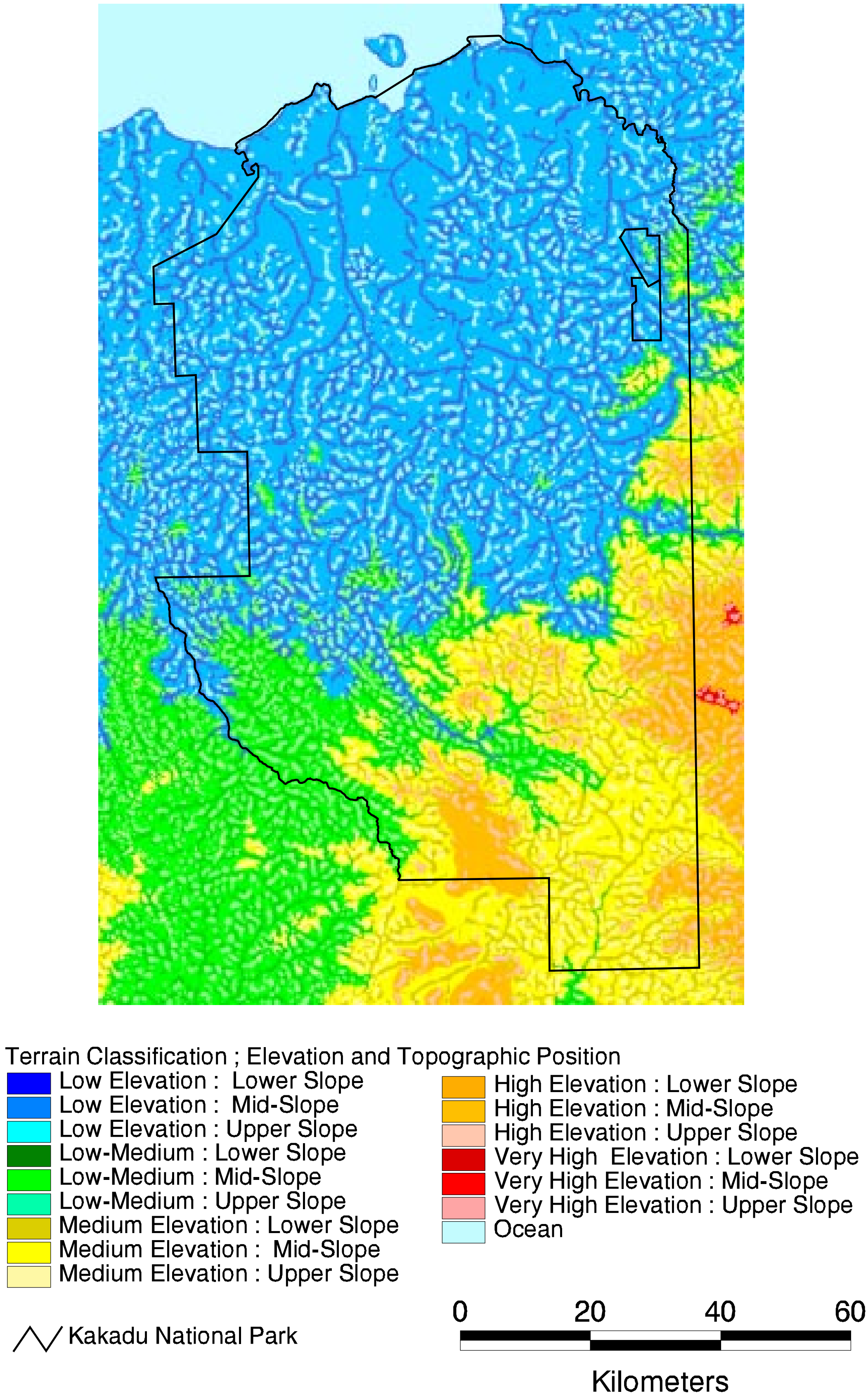

Figure 3 a. Terrain classification for Kakadu National Park based on Elevation and Topographic Position calculated from a Digital Elevation Model

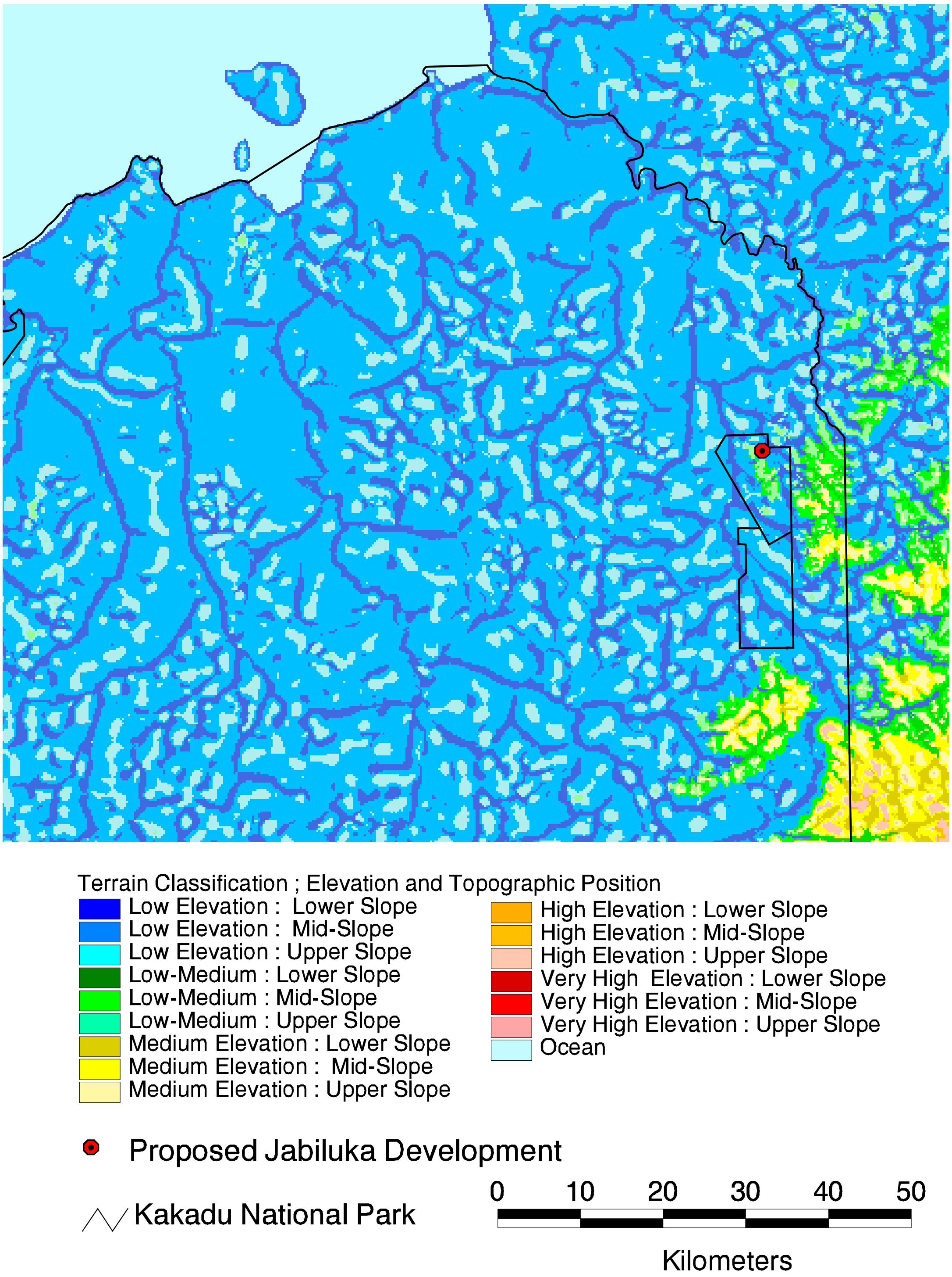

Figure 3 b. Terrain classification for Kakadu National Park . Detail is shown of the North-East corner of the Park, where the Jabiluka proposal is located.

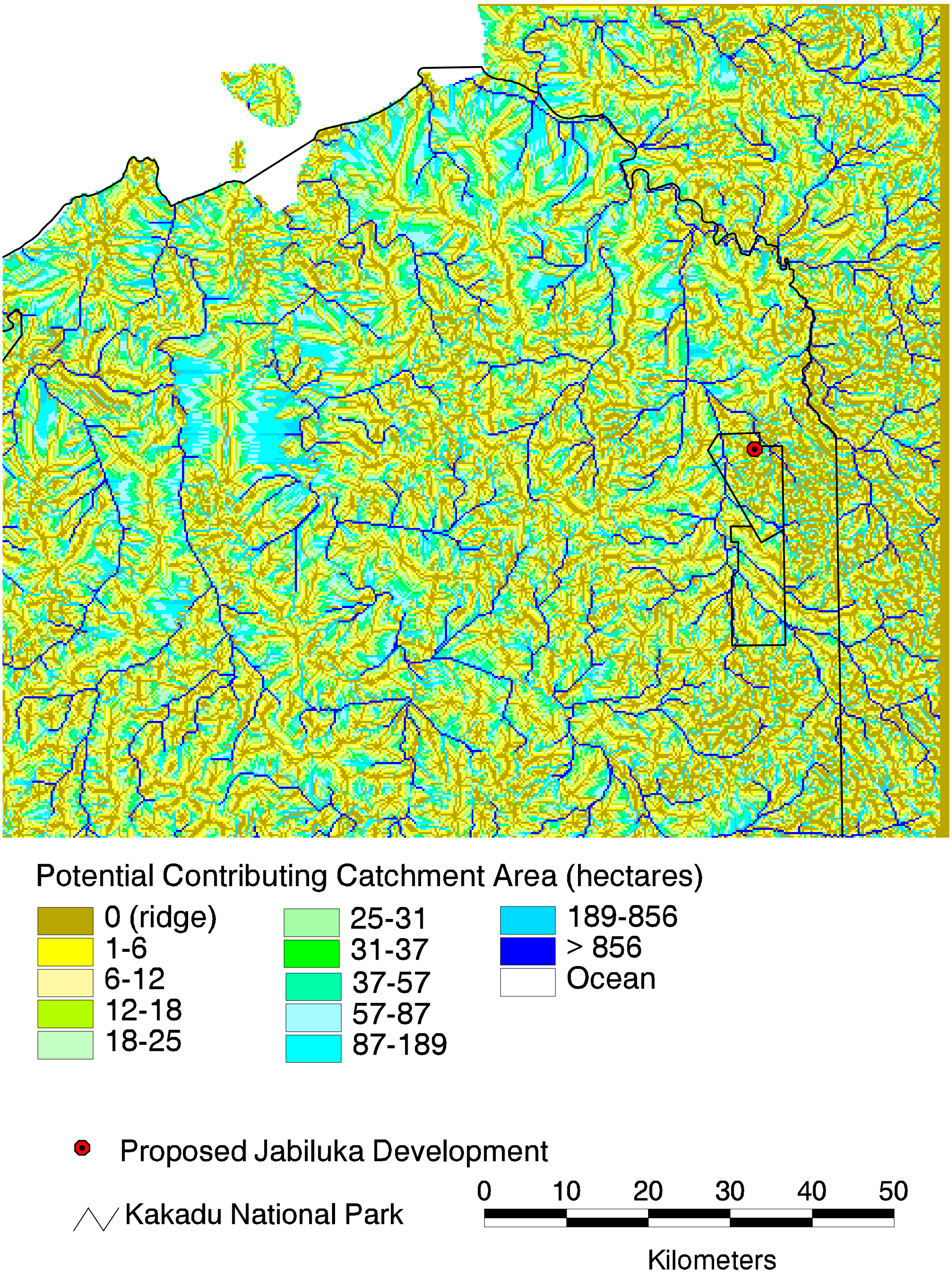

Figure 4. Potential contributing catchment area for Kakadu National Park calculated from a Digitial Elevation Model. Detail is shown of the North-East corner of the Park, where the Jabiluka proposal is located .

4. LONG-TERM STABILITY OF MINE WASTES

In both the EIS and in EA's advice to Minister Hill, the long-term stability of containment structures for mine wastes is highlighted. No leakage to the environment of tailings for 10,000 years is apparently required, a target which stretches anything humankind has thus far achieved. To assess the likely rainfall events, over such a time period, that might jeopardise the stability of tailings dams or water retention ponds, is highly problematic. If the water retention ponds become seriously contaminated, then they too will need to be stable for 10,000 years.

The design of the TCZ at Jabiluka is on the basis of the Rational Method for Urban Drainage (Public Environment Report, Tech. Appendices, June 1998), which depends upon an estimation of a runoff coefficient and a design rainfall intensity. The intensities are provided for 1 in 10 years events and the probable maximum precipitation (PMP), for 6 minute duration events.

This is standard engineering practice in Australia, and follows Australian Rainfall and Runoff (1987) guidelines. But it is simply inadequate in the face of the requirement for structural stability for thousands of years. The estimation of 1 in 10 year event, and the PMP, is based on recorded rainfalls, and their statistical manipulation. At root is the assumption of statistical stationarity, that is, the mean and variance of the instrumentally recorded rainfall will be constant for the next 10,000 years. This is patently absurd, given the climate changes of the last 10,000 years and the likelihood of enhanced greenhouse conditions.

Wasson *et al.* (1992) showed from data collected from the Magela Floodplain that between 1,900±200 and 1400±300 years before present, a drier than present climate came to an end. This was a period when the wet season inundation was shorter than present. After 1400±300 years ago, the current average climate was established, with evidence from many parts of Australia that this was a regional climate change.

Within the last 1400 years, the length of the wet season inundation has changed quasi-cyclically, with a wet period centred on 1200 AD. This was a time of warm climate in many parts of the world.

Prior to this most recent period, Nott (1996) has shown from Waterfall Creek Falls in Kakadu NT, that river discharges were about five times larger than now between 8,000 and 4,000 years before present. This was a time when the planet was about 1°C warmer than present, and provides an approximate analogue for the future when CO_2 concentrations have doubled.

That climate has not been stable in the past, almost certainly with variations of both rainfall intensities and vegetation cover, and so runoff coefficients, is demonstrated. Modelling of climate under a warmer Earth indicates that within the next century northern Australia may experience dramatic increases in flood magnitude and more frequent recurrence intervals. That is, the 1 in 10 year rainfall may in the future become the 1 in 5 year event. The PMP will probably be larger, approaching the events recorded at Waterfall Creek Falls, which may be close to the theoretical maximum flood.

The design of bunds, and all other structures to contain tailings, water and other wastes, at both Jabiluka and Ranger is based upon principles that are grossly inadequate. We simply to not know if the designed structures can withstand the major rainfall events of the future, so the integrity of Kakadu NP cannot be guaranteed with any probability.

5. **HYDROLOGICAL ISSUES**

Introduction

The principal design criteria for this project with respect to hydrological aspects has been to catch all surface and excess process waters with any possibility of contamination in ponds lined with low permeability material. These ponds are then expected to, in the long term, evaporate to dryness, using the notional excess of evaporation over precipitation at this location.

During the mining operation there are expected to be two additional sources of water: groundwater inflow to the mine which is below the regional groundwater level; and process water which may be taken to include potable waters for domestic and office use.

The major amount will be groundwater inflow, and its volume is the most uncertain. An upper limit has been set, on the operational premise that active means will be discovered to intercept or divert any flows above the set limit because this would endanger the whole mining operation.

Following decommissioning of the mine site, it is assumed that groundwater will no longer have to be removed and areas of contaminated runoff will be reduced very significantly, so that most retention ponds and contaminated water storage sites will only have to evaporate actual rainfall volumes. Maximum pond surcharge in the decommissioned state will be based on a single wet season's rainfall except for the cases where significant catchment runoff is accepted and it is possible that there will be a carry-over in very wet years.

Full details of actual daily or weekly water balance calculations are not provided even in graphical form. The only details are on an annual summary basis for years 1 through 7 and then years 10 and 15, and for three type scenarios. The annual evaporation rates for every scenario are the same and the average year rainfall sequence is for 15 successive average rainfall years. The extreme wet scenario is for a 1 in 10 000 AEP rainfall event in year 1 followed by a sequence of actual years. In both these cases there is an annual carry-over in the early years until maximum use is made of evaporation into the exit ventilation stream. There are reasons set out below to suggest that this is a major design fault.

Runoff is calculated by the Rational Method using simple fixed runoff coefficients for both volumetric and peak design flows. The Consultants obviously believe that they have adopted conservative values, but appear to have little understanding of runoff generation under extreme tropical rainfall conditions.

The various topics of concern will be discussed below, in particular rainfall at monthly and annual scales, evaporation estimation from open water bodies and by surcharging outgoing ventilation air, and alternative methodologies based on synthetic climate sequences.

Rainfall sequences

It appears that the Jabiru rainfall record has been selected as the one on which to base the design. The AEP concept has been adopted but the various statements about its use, particularly on pp 4.67and 4.68, do not provide great confidence that the Consultants know what they are talking about.

The Jabiru record of 24 years is set out in Table 6.2 on p 6.18. The mean value is 1446 mm and this is the adopted mean value for the report, however the maximum value is 2225mm which represents an increment of about 2.5 times the standard deviation and must represent an AEP of less than 1 in 50. The minimum value is 945 mm or - 1.65 s.d.. This indicates a fairly skewed distribution and the adopted extreme design value, for a nominal 1 in 10 000 AEP, is 2450mm or + 3.2 s.d.. The comment is made on p 4.68 that this value is asymptotic to something but does not indicate what. We do not believe that 225mm increment over the largest observed value in 24 years of record is a realistic design value. **The method of analysis used is not indicated, but should be investigated.**

There are well-regarded methods of generation of synthetic sequences of daily, weekly, monthly and so annual rainfall. Such synthetic records should be investigated and applied to the water balance model to give a better appreciation of the probability levels of pond surcharge. These could then also be applied to the estimation of the probabilities of generation of runoff volumes, for comparison with the fairly arbitrary assumptions currently adopted.

It is now common to seek advice from the Australian Bureau of Meteorology, for critical analysis of rainfall and runoff probabilities in cases of threat to human life and/or significant ecosystems. These analyses usually involve storm generation in a LCM, (Local Climatic Model), and if necessary transposition of storm generating mechanisms. The recent 1998 extreme rainfall event over the upper Katherine River Catchment was centered less than 100 km. due south of Jabiluka and would be an ideal event for maximisation and transposition. It has been spoken of in the press as generating an event with a 1 in 500 AEP.

It may be correctly pointed out that such limited duration storm events are difficult to tie into a total wet season of rainfall, which is what matters for surcharge estimation. However they would offer supporting evidence to support daily and weekly extremes in a stochastically generated 10 000 year sequence.

It is interesting that a recently released EIS for the Maud Creek Gold Mine near Katherine actually investigated the 1997-98 rainfall event and found it had been exceeded in the period 1893 to 1899,which was adopted as the design 6 year wet period. This report was prepared by Dames and Moore for Killkenny Gold NL. One of the authors was afforded an opportunity to examine the EIS by the Executive Director, Mr. Robert Reo, in the company offices in Perth.

The consultants did not in this case carry out any more complicated statistical analysis than looking in the longest local record. The maximum 6 year moving average was 1290mm with a long term average of 970mm, but no statistics were available for comparison with Jabiru.

Evaporation from open water

The Consultants have taken the US Class A records at Jabiru as the key estimate and the mean monthly values were converted to open water or pond evaporation by two simple seasonal coefficients, 0.60 in the dry season and 0.75 in the wet season. These coefficients are said to be based on Ranger experience and are in the right direction, and depend on the local exposure of the Pan. It is suspected that the meteorological enclosure at Jabiru is probably a bare soil one, in which case these values are reasonable. If there are any solar radiation data available then a check calculation by the Combination Equation would be useful.

A major study of evaporation from Manton Dam between Darwin and Katherine was conducted in the 1970’s although the results should be treated with some caution due to unreliable radiation balance estimation methods. (see Fleming, Aitken and Brown, 1992).

The principal source of evaporation error in the water balance calculations is the adoption of long term mean values in all calculations. There is a well known inverse relationship between monthly rainfall and monthly evaporation. Thus very wet months are usually associated with low evaporation, which is reasonable since such months have high cloudiness and so low solar radiation.

However it should be noted that Pan evaporation records show this tendency less securely than radiation based evaporation estimates. This is because it is very difficult to match rainfall measured in a rain gauge with actual Pan accumulated rainfall, especially if a bird-guard is installed. Frequent occasions with negative evaporation occur which are sometimes set to zero but more commonly to the long term daily average. The tendency can however be seen in a casual comparison of Tables 6.2 and 6.3.

Unfortunately the ignorance of the inverse relationship biases the design results from wet periods to produce a lower surcharge, and this error could exceed 10% over the wet season months in wet years. **Again we have a design methodology which favours lower maximum surcharges.**

Evaporation into the exit stream of mine ventilation

As foreshadowed, there is a major error in the calculation of the capacity of the exit air stream to receive water evaporated from misting nozzles. This forced draft evaporation provides about 30% of the total annual evaporation required and is absolutely essential for the project to meet objectives.

The engineering details of the evaporation installation are not given and the nominal calculations given in Appendix J show little understanding of the evaporation process into an air stream. This does not give great confidence with regard to this key element in the design process.

The latent energy for evaporation has to be taken from the air stream. The limiting factor is the amount of energy which can be supplied by cooling the water droplets as they evaporate and a ventilated wet bulb is the proper design analogy. Therefore we believe that the asymptotic saturation temperature of the exiting air is the ambient wet bulb temperature of the entering air stream.

The entering air stream is specified as being at 30 C and 60% RH which has a wet bulb temperature of about 23.4 C which would be the minimum possible exit temperature after complete energy exchange. Higher exit temperatures would indicate even lower evaporation had taken place. This reduces the maximum probable vapour uptake to less than 30% of the design value assumed in Appendix (J).

We therefore do not believe that the design pond behaviour can be achieved on these grounds alone. The over estimation of pond evaporation in wet years must be added to this shortfall which gives a total under-design of probably approaching 30%.

This will require a total redesign of the containment ponds and a probable proposal to dispose of excess water by irrigation as is the current practice at Ranger. **This will significantly increase the impact footprint and may induce some radioactive contamination in the soils and probably the ground water of the disposal area.**

Runoff calculations

The design method used on all locations is the Rational Method and peak flows in the vicinity of the Total Containment Zone use a runoff coefficient of 1.0 and a 6 minute PMP. This is very conservative design and in the case of exclusion bunds the minimum height of 0.5 m set by earth-moving practice exceeds these design values. The exclusion bunds are unlikely to be over topped.

Within the TCZ runoff coefficients are again 1.0 but this is realistic rather than conservative and so inflow volumes depend on design rainfalls only. The problems with these values have been raised separately. We are satisfied that this design aspect is satisfactory but the rainfalls are not.

Conclusions

(1) A serious design flaw has been found in the enhanced evaporation expected to be achieved by misting water into exit ventilation air stream. The design estimate is at least 3 times the probable maximum achievable and using the existing estimates of open water evaporation and rainfall sequences would require a significant redesign.

(2) It is believed that the design rainfalls, and in particular the 1 in 10 000 year AEP annual value may be significantly under estimated. Suggestions are made for investigating other more modern methodologies to provide greater confidence that the real probabilities of this critical matter.

(3) The use of standard evaporation estimates for each month based on the Pan Evaporation at Jabiru in **all** water balance calculations is considered unsafe. It is noted that other estimates could be used and in particular the invocation of an inverse relationship between rainfall and evaporation would be more realistic. It is estimated this could reduce evaporation rates by 10% during high overcast and rainfall periods and thus significantly increase pond surcharges.

6. ACID SULFATE SOILS

About 34,000 km^2 of recent, sulfidic sediments were deposited in coastal embayments and floodplains over the last 10,000 years during and following the last sea level rise. These sediments are known generically as acid sulfate soils. These soils occur throughout the floodplains of the Alligator River and Magela Creek (Willett et al., 1992), downstream of the proposed Jabiluka Project area. When oxidised these soils produce sulfuric acid which mobiles metal ions, including heavy metals from the sediments. The acidified groundwaters can be exported during rains at the end of the dry season (Hart et al., 1987) and are toxic to fish, other gilled organisms and plants (Brown et al., 1983, Sammut et al., 1996).

There are two concerns that relate to acid sulfate soils in the vicinity of the Jabiluka project. The first is that any heavy metals accidentally released from the site could be mobilised into downstream ecosystems by acid from acid sulfate soils. The second is that developments associated with the mine could lead to increased acidification of surface waters. As an example of the latter, it is proposed in the EIS to withdraw 10,000 L/d from Ja-Ja Billabong to service the recommissioned Ja-Ja mining camp. Table N9 in the EIS Appendices clearly demonstrates that Ja-Ja Billabong is subject to low pH during dry times, a clear indication that it is located in acid sulfate soils, as previously demonstrated by Wasson (1992). Pumping may lower water levels in the Creek promoting more acid production. At this pH, and with the expected aluminium levels, the water will not meet WHO consumption guidelines.

7. REFERENCES

Brown, T.E., Morley, A.W., Sanderson, N.T., and Tait, R.D. (1983). Report on a large fish kill resulting from natural acid water condition sin Australia. Journal of Fish Biology 22, 333-350.

Christian, C.S and Stewart, G.A. (1953). General Report on Survey of Katherine-Darwin Region, 1946. CSIRO Aust. Land. Res. Ser. No. 1, 164 pp.

Fleming, P.M., Brown, J.A.H., and Aitken, A.P. 1989. Evaporation in Botswana and Australia, the Transference of Equations and Techniques between Continents. Proc. Hydrology and Water Resources Symposium Christchurch N.Z. Pub. Inst. of Engineers,Australia. pp58-65.

Goodchild, M F and others (eds), (1996). GIS and Environmental Modelling: Progress and Research Issues. GIS World Books, 486 pp..

Hart, B.T., Ottoway, E.M., and Noller, B.N. (1987). Magela Creek System, Northern Australia. I. 1982-83 wet season water quality. Australian Journal of Marine and Freshwater Research 38, 261-288.

Institution of Engineers (1987) Australian Rainfall and Runoff – 2 Vols

Kinhill (1998). The Jabiluka Mill Alternative. Public Environment Report, Technical Appendices.

Nott, J (1996). Future Climate Change. Can we expect larger floods? Search 27(5): 154-157

Sammut, J., White, I., and Melville, M.D. (1996). Acidification of an estuarine tributary in eastern Australia due to drainage of acid sulfate soils. Marine and Freshwater Research, 47, 669-684.

Willett, I.R., Crockford, R.H., and Milnes, A.R. (1992). Transformations of iron, manganese and aluminium during oxidation of sulphidic material from an acid sulfate soil. In 'Biomineralisation: Processes of Iron and Manganese – Modern and Ancient Environments'. (Eds H. Skinner and R. Fitzpatrick.) Catena (Supplement) 21, 287-302.

Wasson, R J (ed) (1992). Modern Sedimentation and Late Quaternary Evolution of the Magela Creek Plain. Supervising Scientist for the Alligator Rivers Region, Aust Govt Publ Service, Canberra, Research Report, No. 6, 322 pp.