

A palaeochannel was also present there as well as low relief bars and low relief long wavelength bedforms. These landforms and deposits were produced by a flood flow up to 10 km wide that inundated the whole plain. The topographic setting of the Ross River floodout is similar to the East Alligator River at Cahills Crossing and Magela Creek downstream of Bowerbird Gauge. No assessment of the potential for, and causes of, channel avulsions and their significance for erosion of the rehabilitated mine site on the Koolpinyah Surface next to Magela Creek has been conducted. The work completed to date has been concerned with Quaternary landform evolution and the stability of these landforms for the long-term containment of mine waste (Nanson et al 1990, 1993, Roberts 1991, East et al 1993). The best site on Magela Creek for investigating the role of catastrophic floods in alluvial landform development is immediately downstream of the bedrock gorge, which terminates at the Bowerbird Gauge.

7 Long-term behaviour of Magela Creek and its tributaries

The late Quaternary history of Magela Creek and its tributaries have been investigated in detail by Nanson et al (1990, 1993), East et al (1989b, 1993), Roberts (1991) and Clark et al (1992a,b). This work has reconstructed environmental changes that may be relevant to the prediction of landform response to future climate and sea level changes. In this section, the late Quaternary history of the mine site tributaries, the anastomosing sand zone of Magela Creek and the lower floodplain of Magela Creek are outlined and used to predict channel response to future environmental changes.

7.1 Mine site tributaries

Nanson et al (1990, 1993) found that the mine site tributaries did not erode deeply into their bedrock basement during lower sea levels and joined Magela Creek at waterfalls (see Nanson et al 1993, fig 7). Pleistocene sediments are preserved at depth in both Georgetown and Gulungul Creeks. On Georgetown Creek, there is a complex sequence of stratified sands, mottled clays, sandy clays and basal gravels, filling a shallow bedrock valley. Age reversals were found and indicate that thermoluminescence may not be an appropriate dating technique in small catchments (Nanson et al 1993). On Gulungul Creek, thin gravel and extensive medium to coarse sand filled the bedrock trench to about 79 ka. Then a laterally migrating channel was active between 23 and 12 ka and deposited a sheet of fining upwards clean sand. Probable Holocene sediments form a thin cap on top of the late Pleistocene sand.

7.2 Magela Creek anastomosing sand zone

The generalised chronostratigraphic units of the Magela Creek anastomosing sand zone are shown in figure 15. The valley is slightly incised into the Tertiary Koolpinyah Surface but the bedrock basement is a deep trench cut into Lower Proterozoic metasediments. The alluvial cap on the Magela Ridge is probably of Tertiary age and the deep alluvial fill of the bedrock trench accreted between >300 ka and about 150 ka (Nanson et al 1993). Deposition is still occurring today. During lower sea levels, palaeochannels were incised into these Pleistocene deposits and subsequently backfilled. Palaeochannel 1 is the anastomosing sand-bed channel discussed in section 5.

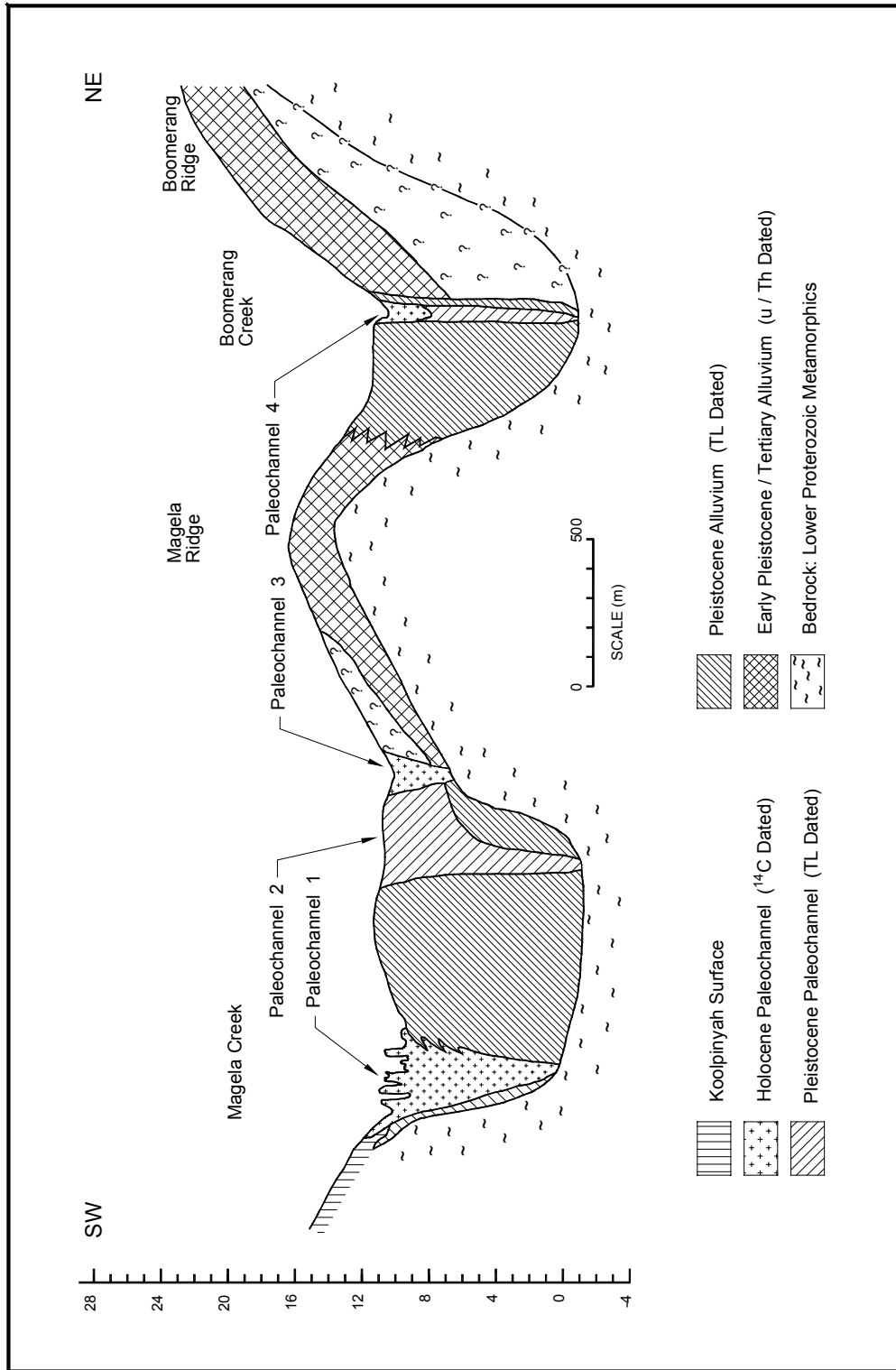


Figure 15 Generalised chronostratigraphic units of the Magela Creek valley-fill next to ERARM (East et al 1993)

7.3 Lower Magela Creek floodplain

Clark et al (1992a) identified five major stratigraphic units overlying bedrock on the lower Magela floodplain (fig 16). In vertical sequence, these were:

1. Basal fluviatile sands and gravels;
2. A complex body of freshwater interbedded sandy clay, clayey sand, sand and gravelly clayey sand capped by a discontinuous palaeosol;
3. Early- to mid-Holocene estuarine blue grey clay containing a number of clay, peat and sandier lithofacies, which are rich in mangrove pollen and sedimentary pyrite;
4. Late Holocene mottled, oxidised, estuarine grey clay; and
5. Late Holocene dark, organic-enriched, freshwater clays.

East et al (1989b) and Clark et al (1992b) reconstructed the major sedimentary environments corresponding to these stratigraphic units (fig 17). After about 8 ka, sea level rose from about -13 m AHD to near present sea level between 5.5 and 7.0 ka (Woodroffe et al 1987, Clark et al 1992b). This resulted in both the sea flooding the lower Magela valley and the first appearance of mangroves at about 6.2 ka (Clark et al 1992b). Rapid estuarine sedimentation occurred in a *Rhizophora* forest, called the 'big swamp' phase on the neighbouring South Alligator River by Woodroffe et al (1986, 1989). The mangroves retreated downstream from the Mudginberri Corridor to the Central High between 4.4 ka and 2.3 ka. As the strength of tidal connection was progressively severed, transition sediments were deposited and the former tidal channels were dismembered (Clark et al 1992b), forming the channel and floodplain billabongs of Hart and McGregor (1980) and Walker and Tyler (1984). Between about 1.5 and 1.0 ka, freshwater wetlands formed and dark clay or black soil was deposited over the bulk of the lower floodplain (Clark & Guppy 1988, Clark et al 1992b).

7.4 Response to future environmental changes

McQuade et al (1996) pointed out that climate variability is likely to mask for decades any evidence of the climate change suggested by global climate models. Nevertheless, Wasson (1992), Mitchell et al (1994) and Suppiah et al (1998) have predicted future climate change projections in the Northern Territory due to the enhanced greenhouse effect. Bayliss et al (1997) and Eliot et al (1999) used the estimates of Mitchell et al (1994) for the year 2030 for their vulnerability assessment of predicted climate change and sea level rise in the Alligator Rivers Region and summarised the major local predicted climate change as comprising, among other things:

- 1–2°C increase in temperature
- 0–10% increase in total cloud cover
- more intense monsoon
- general increase in rainfall intensities
- possible marked increase in heavy rain events
- more floods and dry spells
- topographic effects (such as the Arnhem Land escarpment) could locally cause two to three times greater change in rainfall
- increase in potential evaporation of 5–15%
- stronger monsoon westerlies and stronger winds during severe weather
- rise in sea level by between 80 and 300 mm.

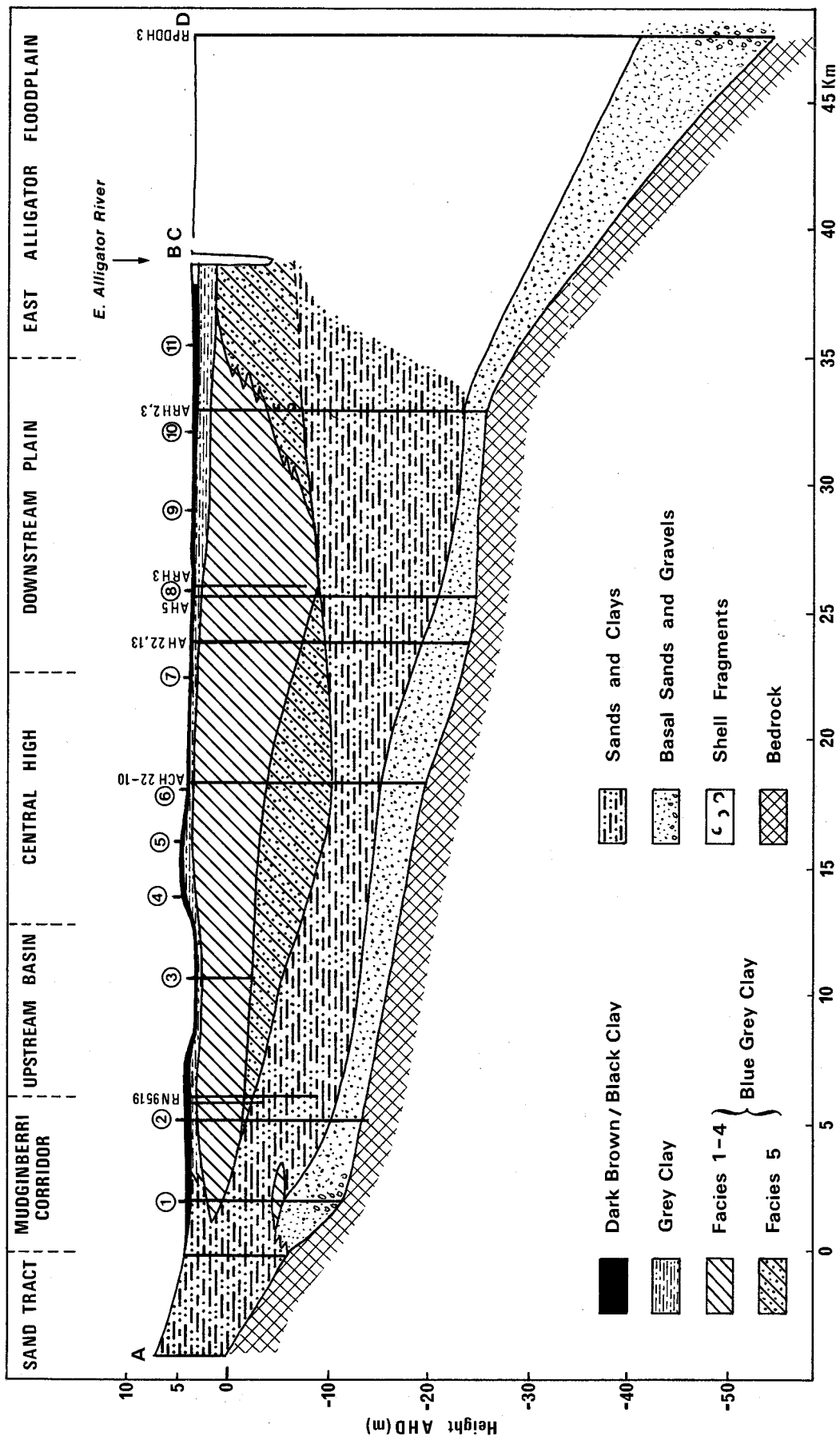


Figure 16 Longitudinal stratigraphy of the lower Magela floodplain, showing the five stratigraphic units of Clark et al (1992a)

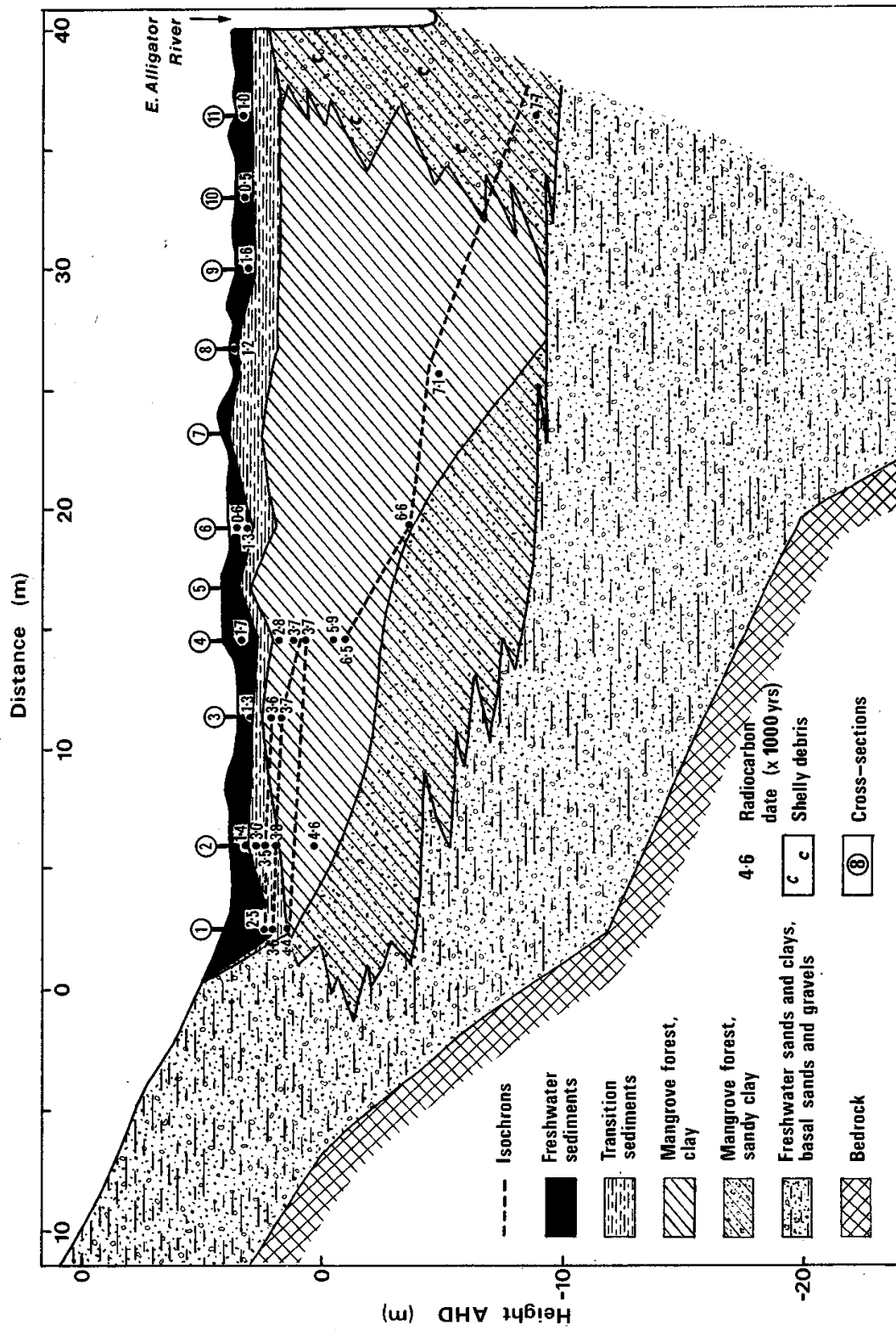


Figure 17 Longitudinal distribution of sedimentary environments of the lower Magela floodplain (Clark et al 1992b)

Jones et al (1999) used the latest general circulation and limited area models combined with a 4% historical increase in rainfall at Oenpelli to estimate the temperature and rainfall at Jabiluka for 2030. Local temperature will increase by only 0.85 to 1.0°C, Wet season rainfall will change by between -6 and +4% and Dry season rainfall will change by between -50 and +6%. Nevertheless, an increase in rainfall is still possible (Jones et al 1999). The regional climate model indicated that there would be little change in mean annual rainfall at Jabiluka by the year 2030 but that extreme rainfall and storm activity would increase substantially (Jones et al 1999). The current 1-in-10 year event becomes a 1-in-7 year event in 2030 (Jones et al 1999). Clearly, these changes are less than those cited above.

Environmental responses to the above greenhouse-induced climate and sea level changes are manifested through hydrological, hydrodynamic, geomorphological and ecological processes that interact with each other (Bayliss et al 1997). The following predictions are often based on a lack of local data and consequently are speculative. They are made in the hope of stimulating future work to address current deficiencies. An increase in storminess due to greater rainfall intensities, more heavy rain events and/or local topographic effects on rainfall will cause higher soil and channel erosion rates. These, in turn, will increase suspended load and bedload, and hence sediment yields. However, the establishment of a dense vegetative cover during the Wet season can significantly reduce soil erosion rates (Saynor & Evans 2000). Changes in Wet season rainfall reliability will interact with vegetative cover to influence soil erosion rates. Furthermore, the widespread use of fire during the Dry season also interacts with rainfall during the next Wet season to cause higher soil erosion rates (Evans et al 1999). Repetitive intense late Dry season burns of rehabilitated mine sites and Wet season runoff producing (ie saturated) zones should be discontinued in the future, to prevent further increases in soil erosion rates. Monsoon forests and riparian vegetation are important stabilising factors on sand bed streams in the Alligator Rivers Region (Nanson et al 1993). Such vegetation should not be burnt at any time so that it can continue to protect sand bed streams from the erosive forces of large floods. Similarly large woody debris in these river channels must be maintained to provide large scale roughness elements which serve to reduce in-channel flow velocities. The predicted higher soil erosion rates and sediment yields will also occur on the rehabilitated mine site. Downstream sediment storages will also be reworked. This will cause higher wetland (backflow and channel billabongs) sedimentation rates.

A sufficiently large rise in sea level due to global warming will re-establish tidal connection with the former tidal channels of the Downstream Plain and possibly the Central High on lower Magela Creek (Wasson 1992). The simple reversal of the late Holocene environmental changes (ie freshwater to transition to mangrove forest) is not the inevitable trend (Wasson 1992) because the rate of rise is predicted to be much slower than for the Holocene marine transgression. Transition conditions are more likely and salinisation of extensive areas of freshwater wetlands can be expected (Bayliss et al 1997, Eliot et al 1999), as documented recently on the nearby Mary River (Mulrennan & Woodroffe 1998). However, hydrodynamic effects on tidal behaviour due to sea level rise are likely to vary across rivers because of differences in tidal channel geometry. Furthermore, variations in tidal range (ie low and high tide levels) will be just as important as changes in mean tide levels. Sea level rise is unlikely to impact on Magela Creek next to ERARM. However, the associated increased rainfall (Wasson 1992) or increased storminess (Jones et al 1999) will increase discharge and sand transport. This should cause bed aggradation, accelerated sand deposition on the floodplain and further damming of the mine site tributaries at their junction with Magela Creek (ie enlarged backflow billabongs with higher sediment trap efficiencies). Greater sand storage of sediment generated on the mine site would also occur in the anastomosed sand zone. However, current estimates of

sea level rise by 2030 (see above) are at the lower end of the values discussed by Wasson (1992). Therefore, the immediate effects of sea level rise are likely to be small in magnitude.

A fall in sea level is predicted within the next 5 ka as the next glacial starts (Wasson 1992). It will cause incision of the freshwater, transition and estuarine sediments of the lower Magela floodplain and the sand fill of the current anastomosing sand-bed channel on the western side of the valley near ERARM. This will, in turn, rejuvenate the mine site tributaries and erode the backflow billabongs. The tributaries will become fully integrated with the main stream and supply more sediment than is currently the case. Clearly, any mine-site generated sediment would be extensively reworked out of the mine site tributaries as a result of a substantial fall in sea level. Oxidation of the lower Magela estuarine sediments will generate acid and high iron contents by the oxidation of pyrite and organic matter. If tailings were stored with these sediments, heavy metals would also be mobilised.

8 Conclusions

As outlined in section 1, the purpose of this report was threefold:

1. To collate and review all of the existing data relevant to the discharge of solutes and particulate material from the rehabilitated mine site and from nearby tributaries of Magela Creek;
2. To determine the fate of particulates in the off-site system; and
3. To collate and review all of the existing material relevant to an understanding of the long-term behaviour of Magela Creek and its tributaries.

Although natural solute and sediment yields in the Alligator Rivers Region are low by world standards, mine sites can produce significantly higher yields. Disturbed sites generate sediment yields that are an order of magnitude higher than those from natural catchments. Large storms dominate soil erosion and sediment transport in the Alligator Rivers Region. Up to 7 m of erosion and 20.4×10^6 t of sediment will be eroded from the rehabilitated mine site over the 1000 years structural life. Assuming sediment delivery ratios of between 0.24 and 0.50, up to 15.5×10^6 t will be stored on site and up to 10.2×10^6 t will be transported off the mine site (table 5). Vegetation, the installation of convexo-concave slope profiles and the use of surficial gravel lags will all reduce the soil erosion rate on the rehabilitated mine site and should be incorporated in the final rehabilitated mine design.

The mine site tributaries and the backflow billabongs will be the most significant sediment storage sites downstream of the mine site. The backflow billabongs will be completely infilled with mine-derived sediment over the 1000 years structural life of ERARM rehabilitated mine site. Relatively little sediment storage will occur in the anastomosing sand zone of Magela Creek but the lower floodplain will trap and store essentially all of the mine-derived sediment supplied to it, if sufficient sediment is generated from the rehabilitated mine site.

Sea level rise will re-establish tidal connection with the old tidal channels and cause extensive salinisation of the most downstream wetlands on Magela Creek. This will cause the remobilisation of stored sediments but a large proportion should be redeposited elsewhere on the floodplain.

A substantial fall in sea level will result in incision of Magela Creek downstream of ERARM and the remobilisation of massive amounts of stored sediments and the oxidation of the remaining sediments. Mine site tributaries will be rejuvenated and any mine site generated sediment will be flushed into Magela Creek.