5th MEETING OF THE

AUSTRALIA / NEW ZEALAND

GEOMORPHOLOGY RESEARCH GROUP

OUTLINE OF PROGRAM AND ABSTRACTS

PORT MACQUARIE, NSW

22nd - 26th APRIL

1992

AUSTRALIA/NEW ZEALAND GEOMORPHOLOGY RESEARCH GROUP: FIFTH CONFERENCE

Welcome to the fifth meeting of the Australia/New Zealand Geomorphology Research Group. The number of registrants at the conference seems to keep growing and growing - it reached 115 at last count. We are well beyond initial expectations, so we hope the venue doesn't become too crowded!

My apologies to those who haven't been placed in the session they wished, but I am sure that everyone understands that changes to the schedule were inevitable. The revised program is outlined on the following 8 pages. Abstracts are organized in order of presentation, not alphabetically. To include 68 talks with two field trips in only four and a half days required that presentations be restricted to fifteen minutes with five minutes for questions. It is imperative that we keep to the time schedule as rigorously as possible. People presenting talks should contact their session co-ordinator at the first opportunity.

I wish to take this opportunity to thank Judy Papps, a secretary in Bio and Geo at the ANU, for her enormous assistance in managing this conference and producing the abstracts booklet.

I hope that proceedings prove to be lively and stimulating, and that all participants enjoy their short stay in Port Macquarie.

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TUESDAY APRIL 21ST

16:00 - 19:00 Drinks and registration at Sea Acres Rainforest Centre

WEDNESDAY APRIL 22ND

8:00 Registration at Sea Acres

Morning Session : Long term controls on river evolution

Session Co-ordinator: Ian Rutherford

8:30 Opening remarks : Gary J. Brierley

8:40 Colin Pain and J.R. Wilford
Drainage evolution on Cape York Peninsula

9:00 Bob Bourman
River terrace chronology and formation in parts of southern South Australia

9:20 Jonathon Nott
Relict plunge-pool deposits in Australia's 'Top-end' - Are they indicative of past climates?

9:40 TEA BREAK

Session Co-ordinator: Colin Pain

10:00 Geoff Goldrick
Uplift, lithology and the oversteepening of long profiles - a case study of Bang Bang Creek, New South Wales

10:20 Jane Soons
The New River - Glacial and tectonic influences on a Westland catchment

10:40 Ian Rutherford
Caught in a rut: Subtle controls on the modern morphology of the middle reaches of the River Murray

11:00 Ken Woolfe
Complex sand sheets from non-avulsive meandering streams

11:20 TEA BREAK

Session Co-ordinator: Sandra Brizga

11:40 Gary Brierley, Keyu Liu and Keith Crook
Evolution of coarse-grained tropical alluvial fans, Markham Valley, Papua New Guinea

12:00 Bofu Yu
Gradient control on channel form and storage, Sepik-Ramu Rivers, Papua New Guinea

12:20 Trish Fanning
Long-term erosion rates in arid western New South Wales

12:40 Kit Brown

12:40 LUNCH BREAK

During lunch, at **13:15**, a video on "Computer modelling of long-term catchment evolution" will be presented by Garry Willgoose

Afternoon session : Coastal evolution in the Quaternary

Session Co-ordinator: James Shulmeister

14:00 Peter Cowell and Paul Bishop
Cainozoic inheritance in Holocene coastlines: NSW

14:20 Colin Murray-Wallace and Albert Goede
Quaternary coastal evolution, sea level change and neotectonism in Tasmania and Bass Strait islands

14:40 Jenny Hacker and Michael Gourlay
The question of late Holocene sea-level at Raine Island, northern Great Barrier Reef

15:00 TEA BREAK

Session Co-ordinator: Peter Cowell

15:20 Peter Roy, Ted Bryant, Wu Yi Zhuang and David Price
Implications for past sea levels from dating coastal sand barriers in central New South Wales

15:40 Monica Mulrennan and Colin Woodroffe
Holocene evolution of the plains of the lower Mary River, Northern Territory

16:00 James Shulmeister and Bob Kirk
Holocene evolution of a coastal plain, North Canterbury

16:20 Paul Augustinus and Eric Colhoun
Proglacial outwash gravel terraces and aeolian sand sheets, Macquarie Harbour, western Tasmania

16:40 TEA BREAK

Session Co-ordinator: Colin Murray-Wallace

17:00 Peter Roy, Marie A. Ferland and Peter Cowell
Headland-attached shelf sand bodies and drowned shelf barriers - their growth and decay

17:20 John Chappell
Late Quaternary evolution and human impact, Yangtse River delta, China

17:40 Colin Woodroffe
Holocene evolution of coral atolls

THURSDAY APRIL 23RD

Morning session : River Management issues

Session Co-ordinator: David Neil

8:30 Martin Thoms and K.F. Walker
Heavy metal accumulation in sediments of the River Murray, South Australia

8:50 Susan Curtis, R.J. Loughran and K.T. Roberts
The effects of urbanization on sediment dynamics in two small catchments that drain into Lake Macquarie, NSW

9:10 William Johnston
Community perceptions of catchment management issues in the Hastings River basin

9:30 Paula Douglas
NSW Rivers - deformation and revolution: A policy perspective

9:50 David Miller
Local rural organization: their increasing role in river management

10:10 TEA BREAK

10:30 Drive to Cassegrain winery

11:00 - 18:00 Field trip examining various aspects of river management along the Wilson and [illegible] Hastings Rivers.
Co-ordinated by David Outhet and Kevin Roberts.

18:00-? Winery tour, tasting and dinner at Cassegrain Winery

FRIDAY APRIL 24TH

Morning session I : Aspects of coastal geomorphology

Session Co-ordinator: Marie Ferland

8:40 Gerd Masselink, D. Mitchell and Ian Turner
Field monitoring of the beach groundwater table, nearshore processes and beach morphology in a macrotidal environment

9:00 Richard Davis
Morphodynamics of the Florida Gulf coast barrier system, USA

9:20 Patrick Hesp
Flow dynamics over transverse dunes

9:40 TEA BREAK

Morning session II : Further aspects of coastal geomorphology

Session Co-ordinator: Colin Woodroffe

10:00 Martin Bergs
Origins and evolution of inner shelf sand deposits seaward of a prograded and a receded barrier complex, southeast Australia

10:20 Scott Smithers, Colin Woodroffe, Roger McLean and Eugene Wallensky
Lagoonal sedimentation in the Cocos (Keeling Islands, Indian Ocean)

10:40 Errol McLean, Janine McBurnie, A. Buckland and P. Forsyth
Salt-wedge estuarine circulation under a mixed tidal regime - the Glenelg River estuary, Victoria

11:00 TEA BREAK

Morning session III : Non fluvial/coastal talks

Session Co-ordinator: John Magee

11:20 Gerald Nanson, David Price and Xiang-Yang Chen
The age and dynamics of desert dunes in central Australia

11:40 Xiang-Yang Chen
Development of a lunette dune and its lake basin : Some modern features of Lakes Cawndilla, Menindee and Victoria

12:00 Ken Page, Tony Dare-Edwards, Gerald Nanson and David Price
Late Quaternary evolution of Lake Urana, NSW

12:20 David Price
Comparison of TL characteristics of quartz grains of different origin

12:40 Bruce Gardiner
Problems associated with TL dating of Quaternary fluvial sediments in the seasonally wet tropics of Northern Territory

13:00 LUNCH

Afternoon session : Non-fluvial/coastal talks

Session Co-ordinator: Geoff Humphreys

14:00 Paul Williams
Speleothems, sunspots and Quaternary environmental change in New Zealand

14:20 Brad Pillans
Basalt and Bulldust: Soils and landscape evolution near Hughenden, semi-arid north Queensland

14:40 Mike Crozier
Changes to slope/regolith depth equilibrium conditions induced by deforestation

15:00 TEA BREAK

Session Co-ordinator: Susan Curtis

15:20 Cherith Moses and B.J. Smith
Limestone weathering in a coastal environment: A Mediterranean example

15:40 John Pickard
Small-scale karst features initiated in semi-arid gypsum deposits by rabbits

16:00 Derek Fabel, D. Henricksen, B.L. Finlayson and J. Webb
Nickpoint migration and landscape evolution at Buchan, Victoria

16:20 Cherith Moses and Andy Spate
A further use for the microerosion meter

16:40 TEA BREAK

Session Co-ordinator: Brad Pillans

17:00 Ben P. Wilson, Mike Melville and Ian White
Initial hydrological and chemical characteristics of a sugar cane site with potential acid sulphate soils

17:20 K. Hailes, Ian Prosser and Mike Melville
The control of aluminium toxicity by soil organic matter in a catchment suffering dryland salinization

17:40 Jesmond Sammut, Wayne Erskine and Robin Warner
Controls on lichen limits in bedrock channels

18:00 Susan Curtis
Assessing the amount of erosion on soils under cultivation and grazing using Caesium-137 technology

SATURDAY APRIL 25TH

Morning session : Human impact on river systems

Session Co-ordinator: Martin Thoms

8:20 Bob Loughran and Barbara Whitelock
Drainage basin sediment budgets : Two case studies from the Hunter region, NSW

8:40 Laurie Olive, W.A. Reiger, A.S. Murray, J. Olley, Peter J. Wallbrink, G.C. Caitcheon and R.J. Wasson
The Murrumbidgee River system - sediment transport and sediment sources

9:00 Sandra Brizga and Brian Finlayson
Objective definition of flood episodes in Gippsland

9:20 TEA BREAK

Session Co-ordinator: Geoff Pickup

9:40 Lesley Rogers and Gary Brierley
Gully form, process and evolution associations at Michelago,Southern Tablelands, NSW

10:00 Ian Prosser and Chris Slade
Some aspects of the initiation of gully erosion

10:20 David Williams and Steve Riley
Some geomorphic thresholds related to gullying in Tin Camp Creek, Arnhem Land, Northern Territory

10:40 TEA BREAK

Session Co-ordinator: Ian Prosser

11:00 Geoff Humphreys
Induced changes in a small mountainous catchment in New Guinea

11:20 Patrick Benn and Wayne Erskine
Downstream hydrogeomorphic effects of Windamere Dam on the Cudgegong River, NSW

11:40 Pamela Scott and Wayne Erskine
Hydrogeomorphic impacts of extraction on river system stability

12:00 Justin Sherrard, Wayne Erskine and Ian Rutherford
River response to hydraulic gold mining

12:20 Nicola Smith
Hydrological changes in the Avoca River catchment, northern Victoria

12:40 LUNCH

Afternoon Session : River styles: Form, Process and Evolution

Session Co-ordinator: Dave Edwards

14:00 Gerald Nanson and Jacky Croke
A genetic classification of floodplains

14:20	Ingrid Sedgwick Downstream variations in modes of floodplain formation on Webbs Creek, NSW
14:40	John Webb and Grant Eggleston Form and process on alluvial fans - examples from Antarctica and New Zealand
15:00	TEA BREAK
	Session Co-ordinator: Jonathon Nott
15:20	Michael Saynor and Wayne Erskine Slackwater deposits and palaeofloods on the Nepean River: Implications for the spillway capacity of Warragamba Dam
15:40	Ivars Reinfelds and Gerald Nanson Characteristics and formation of braided river floodplains, Waimakariri River, South Island, New Zealand
16:00	Jenny Hacker and Michael Gourlay The development of the Pioneer River, north Queensland
16:20	TEA BREAK
	Session Co-ordinator: Jacky Croke
16:40	Dave Edwards Late Quaternary floodplain evolution on the Macdonald River, NSW
17:00	~~Geoff Pickup~~ John Magee. ~~Patterns and processes in arid zone fluvial systems~~ The Warburton Groove: what is it?
17:20	Ejaz Huq and Gary Brierley Floodplain sedimentology of the Clarence River downstream of Grafton: Preliminary results
17:40	Wayne Erskine, Stan Schumm, John Willeard and Justin Sherrard Evolution of anastamosing channels on the riverine plain

SUNDAY APRIL 26TH

Trek-along coastal geomorphology field trip south of Port Macquarie. This will be a half-day trip, for which participants must co-ordinate their own transportation. Peter Roy has offered to lead proceedings. Participants and vehicles will meet outside Sea Acres Rainforest Centre at **8.30 a.m.**

POSTERS TO BE PRESENTED AT THE CONFERENCE

R.S. Abell
Darling River catchment : Drainage evolution

Derek Fabel
Denudation in Southeastern Australia

Damian Gore
Examples of ice-damming in the southeastern corner of the Vestfold Hills, East Antarctica

S.G. Hafer and Mike Melville
Assessing the acidity hazard potential of acid sulphate soils on NSW coastal floodplains

Ted Hickin
The dynamics of scour and fill at channel sections

C. Lin and Mike Melville
Acid sulphate soils relation to landscape characteristics in coastal NSW

David Neil
Suspended sediment concentrations in the Tully River and Rockingham Bay during the 1990 wet season

Mike Melville, R.B. Calinan and G.C. Fraser
The association between outbreaks of ulcerative fish disease and the existence of acid sulphate soils

Susan White
Karst Development in Tertiary Limestones Cape Range, Western Australia

Colin Pain / Mike Craig
BMR Regolith landform mapping - Kalgoorlie and Ebagoola.

WEDNESDAY 22ND APRIL

MORNING SESSION

LONG-TERM CONTROLS ON RIVER EVOLUTION

DRAINAGE EVOLUTION ON CAPE YORK PENINSULA

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Drainage patterns on Cape York Peninsula indicate early superimposition of rivers across much of the Coen Inlier. The Pascoe River rises immediately west of the Great Escarpment at about 250 m a.s.l. and flows 20 km westwards before plunging through a 200 m deep gorge cut through granites. Elsewhere rivers such as the Holroyd and the Coleman flow through gorges cut through N-S trending quartzite ridges.

On the western side of the peninsula, antecedent rivers cut through a slightly higher area (the so-called Weipa Plateau) before entering the Gulf of Carpentaria.

There have been a number of river captures, both along the Great Escarpment and lower erosional scarps to the west. A captured stream flowing down the Great Escarpment has not yet had time to form a bedrock channel, and only 40 m horizontally and 3 m vertically separates another channel from a retreating scarp edge.

Several rivers east of the Great Escarpment, such as tributaries of the Olive and Pascoe Rivers, have been reversed. Evidence for this reversal comes from both river alignment and the distribution of a species of freshwater fish.

There is abundant evidence for relief inversion, ranging from drainage lines that run along broad triangular-shaped or linear plateaus to narrow ridges with central linear depressions. Some still have active channels flowing at levels higher than the general landscape. Others are represented by ridges capped with alluvial gravels, while still other remnants have no remaining alluvium.

Following emergence at the end of the Cretaceous most rivers in the area flowed northwest from a divide east of the present coastline. These rivers were initiated on the upper surface of Cretaceous sediments that may well have covered much of the Coen Inlier. Superimposition of drainage occurred as these rivers were lowered onto rocks of the Inlier during erosion of the sediments.

Subsequent gentle down-warping of the eastern margin of the peninsula reversed the headwaters of rivers such as the Jardine. The development and retreat of the Great Escarpment led to river capture (e.g. the Pascoe and Stewart Rivers).

Antecedent drainage across the Weipa Plateau suggests gentle up warping of the eastern part of the peninsula.

Relief inversion appears to have been a continuing process throughout the Cenozoic. Induration of valley floors with both ferricrete and silcrete led to lateral migration of channels, some of which are now many kilometres from their original locations. Relief inversion may also have occurred when scarp retreat and general landscape lowering isolated former drainage lines at higher levels.

RIVER TERRACE CHRONOLOGY AND FORMATION IN PARTS OF SOUTHERN SOUTH AUSTRALIA

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Paradoxically, in the driest state in the driest continent, suites of river terraces flank streams within and on the margins of the Mount Lofty Ranges. They must surely attest to former greater stream discharges in the past.

The vast majority of terraces have developed on valley fill materials, forming both filltop and fillstrath terraces, but some hard rock strath terraces also exist. The lowest terraces, which often merge into floodplains, are underlain by grey-black sandy clays, variably named (Waldella Formation and Breckan Sand), and have been dated as mid-Holocene in age using the techniques of radiocarbon and amino-acid racemisation dating.

Fill-top and fill-strath terraces immediately above those formed on grey-black alluvium have developed on red to yellow coloured sandy clays containing calcareous pedogenic horizons. These sediments have been named the Adare Clay (Victor Harbor area), the Christies Beach Formation (Noarlunga and Willunga embayments), the Klemzig Sand (River Torrens area) and the Pooraka Formation (throughout South Australia). There is some conflict concerning the age of these sediments. Radiocarbon dating of calcareous horizons within the Pooraka Formation returned an age of about 30,000 years BP, but in other localities equivalent sediments are of probable last interglacial age (125,000 years BP), as they grade to a last interglacial shoreline (+6 m) and contain *Anadara* shells dated as last interglacial by various techniques.

In some places Pleistocene sediments older than the last interglacial stage (Taringa Formation and Ochre Cove Formation or the Hindmarsh Clay) form terraces at higher levels but these are most typically alluvial fan deposits located near to the mountain front.

The terraces, which have resulted from episodes of cutting and filling, are variably filltop or fillstrath and converge or diverge downstream depending on proximity to the shoreline and the influences of faulting and climatic change. Terrace sequences occur within the Mount Lofty Ranges graded to the same local base level and conseqently converge in a downstream direction. They are almost certainly a consequence of climatic change. Close to the coast, relative sea level changes have dominated over climatic changes and the thalassostatic terraces are separated in elevation at the coast. Streams with longer passages to the coast typically reduce in discharge across the plain and this is reflected in the terraces which converge, merge and overlap, with the younger grey-black sediments completely covering the older units instead of being restricted to valleys cut within the older sediments. Some of these crossover points are marked by the location of known faults, and may be useful indicators of fault traces in other areas. Downfaulting of the older sediments clearly encouraged the deposition of younger materials over them.

The terraces described here thus appear to reflect the influences of tectonism, climatic change and sea level migrations, with the relative importance of these factors varying temporally and spatially.

RELICT PLUNGE POOL DEPOSITS IN AUSTRALIA'S "TOP END" - ARE THEY INDICATIVE OF PAST CLIMATES?

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Two 1.5 m - 2.5 m high crescentic ridges surround the plunge pool at the base of Gunlom or Waterfall Creek Falls in Kakadu National Park. The outer ridge lies approximately 185 m away from its inner counterpart which in turn lies approximately 30-40 m from the dry season plunge pool. High discharges during very wet 'wet' seasons (such as the 1990-1991 'wet') raise the level of the plunge pool to within a metre of the crest of the inner ridge.

At first sight both ridges look very much like lunettes. Yet the outer one is composed of medium to coarse sands and numerous rounded quartz pebbles up to 1 cm diameter (A-axis). This suggests that the outer ridge is a water lain feature. The inner one, however, is composed entirely of fine sand and silt.

Using sedimentological data this talk outlines the origin of these features. The conclusion that they are plunge pool beach deposits leads to the suggestion that this plunge pool has contracted in size since formation of the outer ridge. This may well have occurred as a response to a decrease in precipitation.

UPLIFT, LITHOLOGY AND THE OVERSTEEPENING OF LONG PROFILES - A CASE STUDY OF BANG BANG CREEK, NEW SOUTH WALES

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Long profiles compiled from 1:50,000 topographic maps (contour interval 20 m) were used to analyse Bang Bang Creek, and its two tributaries Rock Hole Creek and Blacketts Creek, in central western New South Wales. The catchment is situated upstream (east) of the Illunie Range mountain front which lies in a north-south trending zone in which there is a variety of geomorphological evidence for uplift of the order of 70 to 100 metres. A large alluvial fan at Bang Bang Creek's exit through the mountain front is local evidence of the uplift. All three streams exhibit graded (log linear) long profiles in their upper reaches and oversteepened long profiles in their lower reaches. Both tributaries join the trunk stream along its oversteepened reach.

In order to distinguish between lithologically-induced oversteepening and uplift-induced oversteepening, the graded long profiles of the upper portions of each creek were projected downstream to the stream junctions to estimate the height differences between the graded profile and the actual stream bed at these points. If the oversteepening is related to uplift, and records the upstream passage of one or more knickpoints, then the height difference between the projection of the graded profile and the actual stream bed is equal to the total height of knickpoints that have migrated past that point. This height difference must necessarily be the same for a trunk and its tributary at their junction. Lithological oversteepening is related to rock hardness and downstream distance (stream power), and the relationship between these properties would vary for different streams. Therefore, it is unlikely that the difference in height between the projection of the graded profile and the actual bed for a tributary would be the same as that for a trunk stream.

At the junction of Blacketts Creek and Bang Bang Creek, height difference between the projection of the tributary graded profile and the creek bed was 70 metres whilst the difference between the projection of the trunk graded profile and the creek bed was 80 metres. Further downstream, at the junction of Rock Hole Creek and Bang Bang Creek the height difference between the projection of graded profile and the creek bed was 90 m for both the trunk and the tributary. This congruence of estimates indicates that oversteepening is more likely the result of uplift than lithological variation.

Projection of the upstream (graded) long profile of Bang Bang Creek to the point where it crosses Illunie Range indicates that the total amount of uplift along the mountain front is approximately 100 metres, an estimate comparable with other geomorphological evidence in the uplift zone. Thus, the oversteepened reaches of Bang Bang Creek and its tributaries still preserve a record of the total amount of uplift that has taken place. Sedimentological evidence indicates that initiation of the phase of uplift recorded here dates back to at least the Pliocene and possibly the middle Miocene, suggesting that disequilibrium may be very persistent within the landscape. The results from this map survey will be compared with those from a more detailed field survey.

THE NEW RIVER - GLACIAL AND TECTONIC INFLUENCES ON A WESTLAND CATCHMENT

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North Westland, in the South Island of New Zealand, is a tectonically active area where uplift and warping have been continuous over a long period. This has affected Quaternary marine, glacial and glacifluvial deposits. This paper examines the effects of glaciation and tectonics on the New River drainage system, a relatively small catchment between the Grey and Taramakau Rivers. The area was marginal to the limits of late Quaternary ice occupying the Taramakau valley and the Lake Brunner depression, and a suite of terraces was formed by meltwater drainage during successive advances. Abandoned channels are present across the nose of the Paparoa or Brunner anticline, and other traces of former channels are visible in the Card Creek valley. Aggradation and overriding of tectonic influences in periods of ice advance appears to have alternated with incision and drainage diversion at other times.

CAUGHT IN A RUT: SUBTLE CONTROLS ON THE MODERN MORPHOLOGY OF THE MIDDLE REACHES OF THE RIVER MURRAY

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Much of the complex pattern of changes along the middle Murray are inherited from the late Quaternary. The effects of inheritance continue to influence processes in the modern river.

Reaches of the Murray can be defined as either confined or unconfined. Confined reaches have a narrow floodplain occupying the trench of large, Late Quaternary 'ancestral streams'. Unconfined reaches occupy three, low-angle alluvial fans produced by the rise of the Cadell Fault Block. Confined reaches are laterally accreting, whilst unconfined reaches are vertically accreting. Not surprisingly, the pattern of confined and unconfined reaches influences channel size. However, they also continue to influence several other dimensions of the channel morphology.

* Flood frequencies are lower in confined reaches because of higher overbank flood velocities, and because of gradual anabranch development in unconfined reaches. The higher velocities also increase the incidence of chute cutoffs.
* Where the channel is confined (underfit) within ancestral meanders the cross-section is narrower and deeper. Surprisingly, the river's pool-riffle sequence is also underfit within the ancestral pool-riffle sequence.

Further, the Murray and its tributaries are amongst the most laterally stable streams reported in the literature. Comparison with other streams suggests that this stability is predominantly caused by the abundant clay in the channel boundary, rather than by low stream-power. The abundant clay in the boundary is partly inherited from past channel systems, and partly deposited after saline-flocculation. The Murray's stability partially reflects the subtle balance between water and clay chemistry.

In conclusion, to explain the stability and the morphology of the Murray, one must consider the persistent influence of Quaternary stream systems, as well as the subtle influence of water and clay chemistry. Such influences are probably most pronounced in a low-energy, suspended-sediment stream system.

COMPLEX SAND SHEETS FROM NON-AVULSIVE MEANDERING STREAMS

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The Weller Coal Measures (Early Permian) at Allan Hills, Antarctica, consist of interbedded sandstone sheets and coal seams (up to 4 m thick) which can be walked out over 10 km^2 of continuous exposure. Well developed epsilon crossbedding, fining-upwards cycles and diverse paleocurrent directions within some of the sandstone sheets suggest deposition by meandering rivers. The absence of clearly defined channels, crevasse splay and over-bank deposits (other than coal and permineralised peat) is problematic and makes the sequence difficult to interpret using classical meandering river models. Detailed mapping and paleocurrent analysis has confirmed that the "multidirectional" sandstone sheets observed at Allan Hills were most likely deposited by non-avulsive meandering streams.

Field relationships enable two types of sandstone sheet to be identified within the sequence. Type 1 sheets consist of stacked sets of trough crossbeds with unidirectional paleocurrent directions which are consistent from sheet to sheet. These sheets are attributed to advancing distal lobes of sandy alluvial fans.

Type 2 sheets contain abundant complex, commonly truncated sedimentary structures and large (up to 5 m high) epsilon crossbeds. Within each sheet paleocurrent directions are very diverse and variation from sheet to sheet seems to be controlled by preferential preservation of left and right handed bars. From facies relationships between coal seams and type 2 sandstone sheets it is inferred that the meandering streams (which deposited type 2 sand sheets) did not contribute clastic sediment into the surrounding swamp environment. It is concluded that, although aggrading, the streams were incised into the surrounding swamp and were consequently non-avulsive.

A number of possible modern analogues have been investigated in South Westland, New Zealand. Here, steep alluvial fans draining the Southern Alps periodically advance across low lying coastal swamps depositing type 1 sand sheets directly on top of peat. At their distal reaches smaller fans become anastomosing during low flows, and during high flows they discharge directly into standing (or very slowly moving) surface water associated with the swamp proper. Further into the swamp small distributary channels from the fan combine with small riverlets on the swamp surface to form "swamp-draining" meandering channels.

These swamp-draining meandering channels transport sand and granules scavenged from the surrounding swamp deposits (and type 1 sand sheets). They are incised relative to the surrounding swamp, have no levees, and during floods surface water moves from the swamp into the channel. Consequently the channels do not generate clastic over-bank deposits.

It is concluded from studies of both the rock record and of modern swamps and estuaries that internally complex sand sheets may be deposited by non-avulsive meandering channels if "flood plain" aggradation exceeds the rate of channel floor aggradation. This condition requires that "floodplain" aggradation is dominated by a process which is largely independent of the channel, such as biological accumulation or, in the case of estuaries, by suspension settling at high tide.

EVOLUTION OF COARSE-GRAINED TROPICAL ALLUVIAL FANS, MARKHAM VALLEY, PAPUA NEW GUINEA

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Architectural-element analysis is applied to describe the sedimentology and geomorphic evolution of the modern Umi Fan and the upper (alluvial fan) part of the Pleistocene Leron Formation in the Markham Valley, Papua New Guinea. Detailed stratigraphic analysis of the lowest terrace of the Umi Fan, in exposures up to 25 m high and kilometres long, reveals that the fan is dominated by sheetflood deposits, with minimal preservation of either debris flow or hyperconcentrated flood flow sediments. Channel fill elements make up a larger proportion of exposures in the proximal-fan than elsewhere, while 95% of distal-fan exposures are composed of sheetflood sequences. These depositional features, described as first- to fourth-order lithosomes, likely result from massive sediment dispersal associated with abundant sediment availability and a flashy discharge regime. Channel fill units, along with slope-related deposits from debris and hyperconcentrated flood flows are only likely to be preserved following fan entrenchment and subsequent trench backfilling. These deposits are restricted to interpretation as fifth-order lithosomes constrained by trench geometry.

Proximal-distal relations are remarkably consistent in the Umi Fan and Leron Formation fan sequences. In neither instance are debris flow deposits observed in great abundance. Rather, reworking of deposits plays a dominant role in preservation of sheetflood deposits at the expense of slope-related deposits. From analysis of the Leron Formation in relation to its tectonic setting, sixth- to seventh-order lithosomes are interpreted, with an age span of the order of 100,000 years.

The Umi and Pleistocene Leron Formation fans exemplify fan development in a post-collisional molasse basin, under a tropical monsoonal climate. Carbonate concretions observed in distal-fan facies may provide a possible diagnostic feature of these seasonally humid/arid tropical fans.

GRADIENT CONTROL ON CHANNEL FORM AND STORAGE, SEPIK-RAMU RIVERS, PAPUA NEW GUINEA

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The Sepik-Ramu catchment lies on the northern side of New Guinea Island, and the two rivers collectively drain a total area of about 96,000 km^2. One of the distinctive features of these rivers is that they both originate from the central highlands and through steep descent they flow onto flat lowland with extensive backswamps and numerous lakes. The gradient of the lower Sepik River is exceedingly low (<0.047 m/km), partly because of the non-subsiding nature of the area around the river mouth. Rainfall in the catchment is quite high, especially in the highlands. Both inter-annual and intra-annual rainfall variability are low, and so is the streamflow variability. For example, the 20-year flood is no more than 30% greater than the 2-year flood for these rivers. Along most natural stream channels, river bed elevation is lowered during high flow because of the increased sediment transport capacity, while the bed level recovers to a higher elevation when the river stage falls. Along the main stem of the Sepik River, however, the river bed elevation in fact slightly increases during high flows. This apparent aggradation is in part due to the extremely low longitudinal gradient. During the high flow, high sediment input from its tributaries may temporarily exceed the transport capacity, as a result the main channel essentially acts as a temporary storage. Extensive backswamps and numerous lakes along the Sepik River also affect the streamflow variability by providing an active storage area during the wet season. Consequently, streamflow along the Sepik main stem is highly regulated for high flows, which is in direct contrast with the streamflow variability of its tributaries.

LONG TERM EROSION RATES IN ARID WESTERN NEW SOUTH WALES

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Surface lowering by sheetwash, rilling and deflation has been monitored over a ten year period in a small (19 km^2) catchment on Fowlers Gap Station in the Barrier Range, north of Broken Hill, NSW, using erosion pins and runoff plots. The calculated sediment loss rates exceed those reported elsewhere for this region (e.g. in Wasson and Galloway, 1986), and possible reasons for this will be discussed. The implications for rangeland management practices, and for long-term landform evolution in the study area, will be addressed.

COMPUTER MODELLING OF LONG-TERM CATCHMENT EVOLUTION

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The catchment geomorphology determines the flood and erosion response of a catchment and the flood and erosion response, over geologic time, strongly influences the catchment geomorphology, through the sculpting of the landscape. Despite this fundamental truism, research into fluvial geomorphology and hydrology has proceeded independently until recent years. The author has been actively involved in establishing a theoretical basis for the emerging research area of hydro-geomorphology; the study of the interactions between catchment hydrology and catchment geomorphology. The author will describe his work on the response of the catchment geomorphology to governing erosional and hydrologic physics. The discussion will centre on the modelling of the changes of catchment geomorphology (elevations, slopes and channel networks) over time in response to changing hydrology, climate, and geology. This work will be exemplified with a computer animation demonstrating the evolution of a catchment over geologic time, showing the development of the catchment geomorphology and drainage structure, the channel network and the contributing hillslopes. Some of the implications of this work will be discussed. In particular, it will be demonstrated that the geomorphology converges to an equilibrium state. These states can be simply described mathematically and are dependent on geology and climate. Some field evidence for this assertion will be presented.

ESPL 1991
Water Resour. Resear. 1991

WEDNESDAY 22ND APRIL

AFTERNOON SESSION

COASTAL EVOLUTION IN THE QUATERNARY

CAINOZOIC INHERITANCE IN HOLOCENE COASTLINES: N.S.W.

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The emergence of the non-linear dynamics of deterministic chaos has focussed attention again on questions of scale in geomorphology. The overwhelming importance of scale in the cumulative evolution of landscapes stems from the operation of inheritance, whereby landscape morphology is dependent on (some function of) preceding morphologies. This is illustrated by the interaction between the evolution of river valleys and coastal morphology over Cainozoic and Quaternary time scales. The Cainozoic denudation of the continental margin yields palaeochannel networks truncated by marine planation and cliffing at the coastline. The resulting bedrock substrate is inherited as one of the fundamental boundary conditions in the Quaternary evolution of coastal depositional morphologies. The other boundary conditions include glacio-eustatic sea-level fluctuations and regional oceanographic (especially wave) climate. Consideration of Quaternary inheritance calls for an understanding of the relationship between the configuration of marine-truncated palaeochannels and the disposition of sources and sinks for coastal sand bodies. This relationship produces a strong coastline equilibrium at regional-scales at any given sea-level stillstand. The manifestation of this has been described heuristically by Langford-Smith & Thom (1969, *J.Geol.Soc.Aust.* 16: 572-80) and Roy (*in* Chapman, 1982, *Coastal Evolution and Coastal Erosion in New South Wales*: 21-44) for N.S.W. under present conditions. Geometric characteristics of this equilibrium are represented by the dimensions of coastal embayments. The relationship of these dimensions to those of the drainage network in the hinterland then characterises the nature of Cainozoic inheritance. The relationship is of the form $L = f(N,D)$ where L is the embayment Length (a surrogate measure of embayment cross-sectional area), N is stream order at the point that the catchment is truncated (drowned) by the coastline, and D is the drainage density of the catchment, which is in part a function of catchment lithology and structural characteristics. The dimension L is the distance between palaeochannel interfluves at the coastline and N scales with the catchment area, A, inland of the coast. For a sample of embayments on the NSW coast, we find that $L = 0.80A^{0.39}$ with a 0.80 correlation. The exponent probably represents D.

This strong relationship derives from the scaling laws of catchment geometry. For individual embayments, dimensions reflect distance from the inland drainage divide to the embayment. This distance incorporates the extent to which the marine escarpment has receded into the catchment and the degree to which the coastal plain and barriers may have prograded within or seaward of this marine escarpment. Thus the coastline configuration is a product of the intersection of the catchment by the sea-level plain in the vertical, and barrier penetration into the drainage network in the horizontal. These elements are the results of geomorphic processes operating in concert but at Cainozoic and Quaternary time scales respectively. The latter depends, of course, on sediment abundance relative to palaeochannel volumes. Where sediment is not abundant, embayments are closed sediment compartments with respect to littoral transport. These have Davies' swash-aligned shorelines and are characteristic of southern N.S.W. Where sediment volume exceeds palaeochannel volume, embayments constitute only a segment of larger sediment compartments such that alongshore bypassing of sand occurs. These embayments have Davies' drift-aligned shorelines and typify northern NSW. Here the shoreline location for each embayment is generally fixed by a bedrock promontory at its downdrift end. This acts as a spillway for littoral transport beyond the embayment storage area. It is the former, however, the sea-level dependent intersection of the catchment by the coast in the vertical, that yields the geometric succession of smaller interfluve spacings as the escarpment recedes over the Cainozoic into the network of seaward-flowing streams of progressively lower order. The model breaks down, however, when the coastline captures the headwaters of landward-flowing streams. The occurrence of this in a coastal drainage basin depends upon antecedent basin shape and orientation, and the extent to which the coastal escarpment has already truncated the basin, advanced truncation resulting in fewer such captures. This capturing is rare on the N.S.W. coast indicating either substantial recession of the escarpment and/or low initial basin circularity; i.e., a rectilinear, seaward-flowing stream network.

QUATERNARY COASTAL EVOLUTION, SEA-LEVEL CHANGE AND NEOTECTONISM IN TASMANIA AND BASS STRAIT ISLANDS

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This research arose form the observation that numerous marginal marine sedimentary sequences and landforms in Tasmania, of last interglacial age occur at elevations significantly higher than attained by a glacio-eustatic sea surface during the Last Interglaciation (oxygen isotope substage 5e; ca. 125,000 yr BP). Amino acid racemisation, electron spin resonance, uranium-series disequilibrium and radiocarbon dating have provided a time-framework to evaluate aspects of Quaternary sea-level change and neotectonism in Tasmania and the Bass Strait Islands, King Island and Flinders Island.

Amino acid racemisation and electron spin resonance data confirm the widespread occurrence of last interglacial marginal marine sediments in Tasmania, King Island and Flinders Island. Radiocarbon dates on marine shell from these deposits represent minimum ages and highlight the difficulty of isolation contamination during sample pretreatment procedures. Minimum ages of 39,900 ± 800 BP (SAU-2925) and 31,100 ± 300 BP (SAU-3000) were obtained respectively on aragonitic molluscs from Mary Ann Bay, Tasmania and North East River Estuary, Flinders Island. In contrast, last interglacial ages are indicated for these sequences based on amino acid racemisation and electron spin resonance analyses of sub-samples of these molluscs. The amino acid data from the Tasmanian region are also in accord with latitude-temperature gradient models of diagenetic racemisation for southern Australia.

Coastal sediments of last interglacial age occur at elevations that range from + 12 to + 13 m AHD near Smithton on the NW coastline of Tasmania, + 24 m AHD at Mary Ann Bay near Hobart and up to + 32 m AHD at Stumpys Bay in NE Tasmania. These data indicate varying degrees of neotectonic uplift of Tasmania since oxygen isotope substage 5e. The mechanism for uplift remains enigmatic. In contracts to mainland Tasmania, the levels of coastal sediments of confirmed last interglacial age have not been found to exceed + 6 m AHD, a widely cited *de facto* datum for the height attained by the sea surface during the Last Interglaciation. Although emergent Holocene coastal sediments have not been identified in Tasmania, elevated shingle beach facies resting on planar laminated lower shoreface sands, have been identified on King Island. A calibrated radiocarbon age of 4560 +/- 120 cal BP (SUA-2926) was obtained for a mixed species assemblage from the shingle unit. However, the high energy 'storm'(?) conditions under which these sediments may have developed precludes a conclusive interpretation regarding Holocene sea-levels.

The extent of amino acid racemisation for a range of amino acids in specimens of the cockle *Katelysia scalarina* and *K. Rhytiphora* points to a Middle Pleistocene age (oxygen isotope stages 9 or 11) for a basal shell facies that is unconformably overlain by a 6 m thick sequence of peats at Egg Lagoon on King Island. Electron spin resonance data also point to a Middle Pleistocene age for this unit. By implication, Egg Lagoon preserves a lengthy palaeoclimatic record given the assumptions of the absence of major diastems and that the marine molluscs from the basal shell unit are not *remanie* fossils.

Marine molluscs from the Pliocene Cameron Inlet Formation and the Early Pleistocene Memana Formation from Flinders Island, have also been analysed using amino acid racemisation and electron spin resonance methods to assess the age range of these dating methods in southern Australia. The extent of racemisation of a range of amino acids in the molluscs *K. scalarina, Glycymeris (Tucetilla) striatularis, Dosinia coerulea*, and *Divalucina cumingi* from the Memana Formation are not consistent with an Early Pleistocene age and are likely to reflect problems with fossil preservation (eg., leaching of amino acids from a fossil).

An occurrence of the arcoid bivalves *Anadara trapezia* has been identified in estuarine sediments at Royal Park, Launceston. A numeric age of 2600 ± 400 yr BP is indicated based on the extent of leucine and valine racemisation. Electron spin resonance data are also in accord with this age assessment. Collectively, these data imply a late Holocene contraction of the geographic coverage of this species that may have been induced by climate change.

In summary, this work indicates that Tasmania and Bass Strait Islands preserves a more diverse Quaternary marginal marine record than previously recognised. Numerous stratigraphic problems have been identified and there is ample scope for future research.

THE QUESTION OF LATE HOLOCENE SEA-LEVEL AT RAINE ISLAND, NORTHERN GREAT BARRIER REEF

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Raine Island is a large stable vegetated sand cay which has developed on the leeward end of Raine Reef, latitude 11° 36'S, longitude 144° 2'E. Raine Reef is a small detached reef lying just outside the outer barrier and separated from it by water greater than 200 m deep. Raine Island is the world's most important green turtle rookery and Australia's most important nesting site for tropical seabirds. A stone tower on the eastern end of the island was built by convicts in 1844 to act as a beacon to mark safe passage through the reef.

Raine Island is comprised of an elevated, largely vegetated central portion bounded by a small cliff. Below this cliff the sand rises gently towards the berm which surrounds the island. Beyond the berm the steep beach drops down to the reef flat. The berm height varies between 3.7 and 4.4 m LAT (3.3 to 4.0 m above the reef flat). The lower berm levels are at the western end. The cliff surrounding the central portion is composed of phosphate rock, formed from the calcareous cay sands which have undergone phosphatic cementation. The phosphate rock extends across the island under the central depression and presumably under the higher areas on the southern side. The phosphate rock was mined in the 1890s but early records indicate that the central depression existed before the mining took place and that soil had developed over the phosphate rock. The phosphate rock cliff has an elevation of 4.3 m LAT at the eastern end rising to more than 5 m on the northwestern side. The levels of the phosphate rock, except at the eastern end, are substantially above those achieved by sediments being moved by observed beach processes at the present time. Wave height is limited by the depth of water over the reef flat. Heavy materials such as clam shells are found in the upper layers of the phosphate rock which suggests that they had been moved there by wave action. This, in turn, requires that sea-level was approximately 0.6 m higher than the present level. Clam shells from the phosphate rock provide ages of 1040 to 1640 BP (uncorrected) (Limpus 1987). Uncorrected dates are considered to be preferable in the dynamic reeftop environment of Raine Island. The dates of the clam shells indicate that the phosphate rock was formed within the last 1000 years. Reefal material underlying the island yielded an uncorrected radiocarbon date of 4780 BP (C. Rasmussen, pers. com. 1990). Therefore the island has formed since that time.

The question is, what agent was responsible for the apparent higher sea-level at Raine Island? The possibility of glacio-hydro isostatic rebound is discounted because of Raine Island's location right on the edge of the continental shelf. There is evidence that some tilting or slumping down the continental slope may have occurred, but this does not affect the question of the apparent raised sea-level. This leaves two further solutions. A eustatic rise in sea-level is possible and may have coincided with the warmer conditions encountered in the Northern Hemisphere c.900 AD. Alternatively, there may have been a temporary rise in sea-level caused by an extreme weather event or events, such as tropical cyclone(s) with a central pressure below 940 hPa. Coastal processes can occur very rapidly under storm conditions. The problem with invoking extreme weather events is that under current climatic conditions severe tropical cyclones do not usually occur as far north as Raine Island.

Reference:

Limpus, C.J. 1987. A Turtle Fossil on Raine Island, Great Barrier Reef. *Search* 18: 254-256.

IMPLICATIONS FOR PAST SEA LEVELS FROM DATING COASTAL SAND BARRIERS IN CENTRAL NEW SOUTH WALES

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Prograded sand barriers at Forster-Tuncurry in central NSW range in age from the Penultimate interglacial, c. 220 K yr, to the late Holocene. They include a number of interstadial drowned barriers on the continental shelf and their cross sectional width, including the onshore barriers, is in excess of 25 km (Fig. 1). Barrier morphology, internal structures and sediments have been studied in drill holes, vibrocores, high resolution marine seismic and ground penetrating radar; their age structure has been determined by radiocarbon and thermoluminiscence dating. Despite surface reworking and diagenesis, estimates of barrier geometries indicate approximate palaeo sea levels at the times the barriers formed (Table 1). Preliminary findings include:

1. Similar surface elevations for the Penultimate and Last Interglacial (LIG) barriers (+6 m) indicate that either sea levels at these times (Isotope Stages 7 and 5(e)) were the same or this part of the NSW coast has been slightly uplifted (c. 5 m in 100 K yr). The latter conclusion conflicts with evidence of tectonic stability from LIG deposits (+4 to 6 m) which do not appear to be uplifted.

2. The surface of the first interstadial barrier at +1 m indicates a maximum sea level of about -5 m, 95-80 K yr BP. Stratigraphically, this should correspond to Stage 5(c) but the thermoluminiscent ages are closer to Stage 5(b).

3. A drowned barrier corresponding to the early part of Stage 3 is well developed on the inner shelf, although about 5 m has probably been eroded from its surface during the PMT. A slowly falling sea level, 30-50 m below present is indicated at this time (c. 59-43 K yr). A younger barrier (the latter part of Stage 3) on the mid-shelf in water depths > 65 m was not sampled.

4. Palaeo sea levels indicated by the interglacial and interstadial barriers on the central NSW coast differ to some degree from recently published sea level curves for the late Pleistocene (Fig. 2).

TABLE 1

Ages, Elevations and Indicated Palaeo Sea Levels for Barriers in Central New South Wales

Barrier	Age Range Range (K yr BP)	Barrier Elevations (m relative to present)		Indicated Sea Level (m)	Isotope Stage
		SURFACE	BASE		
Penultimate	261-217 ±28	+6(d)	-7	+2 to 4	7
Last Interglacial	147-128 ± 31	+6(d)	-8	+2 to 4	5(e)
First Interstadial	96-87 ± 14	+l(d)	10 to -15	-3 to 5	5(c/d)
Second Interstadial	59-44	(e)	-45 to 70	-30 to 50	3(a)
Third Interstadial	-	(e)	-70 to 100	-60 to ?	3(b)
Holocene	7 5 - 1.5 (22^{C}14 dates)	+6	-18	+l to 0	

(d) = diagenetically modified
(c) = eroded

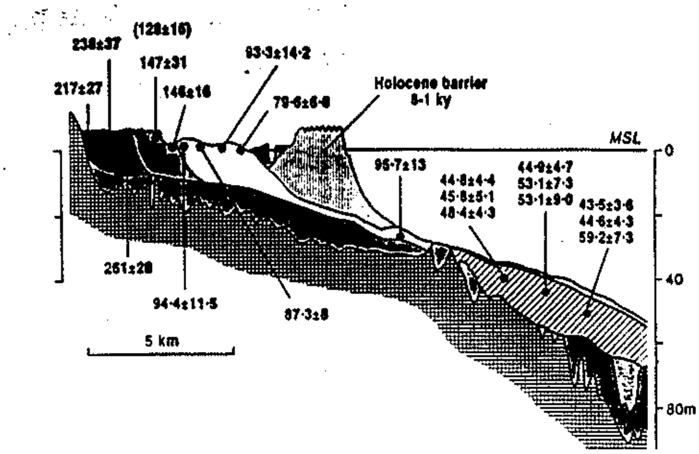

Figure 1:
West to east cross section through the Forster-Tuncurry barriers (32° 09'S) showing stratigraphic relationships and ages.

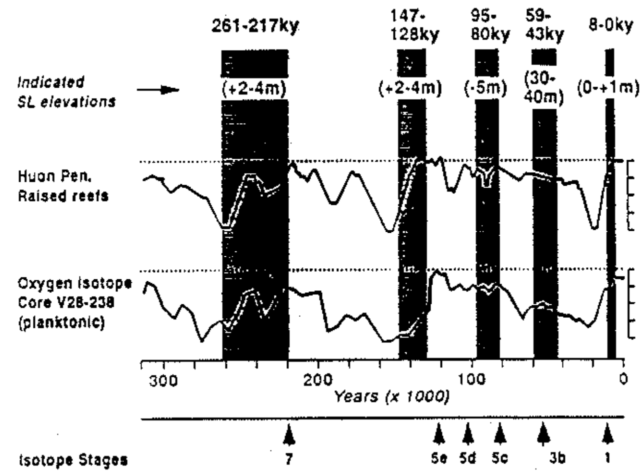

Figure 2:
Relationships between ages and indicated sea-levels of barriers on the central NSW coast and shelf and Late Pleistocene sea level curves based on dating of raised coral reefs (Chappell, 1983) and oxygen isotopes from planktonic foraminifera (Core V28-238, Shackelton and Opdyke, 1973).

HOLOCENE EVOLUTION OF THE PLAINS OF THE LOWER MARY RIVER, NORTHERN TERRITORY

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Extensive low-lying coastal plains characterise the southern shore of van Dieman Gulf, Northern Territory. These extend as estuarine plains along the lower reaches of rivers draining the undulating, lateritised hinterland into the gulf. The Mary River is unique amongst these rivers, in that despite a reasonably large catchment of >8000 km^2, it was not until recently that the river reached the coast as a discrete channel. Before the 1940s the main channel bifurcated into a series of multiple channels and much of the freshwater discharge evaporated off the plains. Extensive drilling of these plains has shown that they are underlain by organic muds laid down beneath mangrove forests. Much of the present area of the wetlands is a palaeo-estuarine plain which formed beneath widespread 'big swamp' mangrove forests 6500-5000 radiocarbon years ago. The broad coastal plain has prograded out from a chenier shoreline of about that period. Rapid progradation occurred during the period 5000-3000 years BP. The shoreline has prograded little over the past 3000 years, but has been modified by episodic chenier ridge deposition and palaeochannel abandonment, infill and reoccupation. The modern wetland environment is changing rapidly with tidal creek extension, salt-water intrusion and palaeochannel reoccupation.

HOLOCENE EVOLUTION OF A COASTAL PLAIN, NORTH CANTERBURY, NEW ZEALAND

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The coastal plain between the Ashley and Kowai Rivers, North Canterbury, New Zealand is being studied to produce a Holocene sea-level history for this region. The plain is up to 2 km wide and is backed by a cliff that is believed to have been marine cut and to relate to the maximum Holocene transgression, estimated to have occurred 6500 years go. The coastal plain is comprised of a series of sand and gravel beach ridges separated by estuarine deposits and overlain by at least four dune ridges.

The frequency of the sand/gravel ridges increases from south to north, with three ridges apparent near the Ashley River and up to nine near the Kowai. The Ashley is the main contributor of sand to the ridges while the Kowai dominantly contributes gravel. This is a function of the flow regimes in the rivers, where a substantial base flow exists in the Ashley, while the Kowai is dry for much of the year but has a high discharge during floods.

Based on the flow regimes and the observed tendency for the mouth of the Ashley to periodically migrate northward, a model of beach ridge formation is proposed, as follows;

1. Low flow. During low flow periods, dominant southerly swell conditions drive a northward trending longshore drift in Pegasus Bay that is able to deflect the mouth of the Ashley progressively further north. This results in sand from the Ashley being fed to beaches as far north as the Kowai and a sandy beach is formed between the two rivers.

2. Flood flow. During flood flows, the Ashley cuts a direct route to the sea through the barrier. This starves the northern (distal) beaches of their sand source. At the same time, the floods cause a slug of gravel to be discharged from the Kowai. This gravel is available to be worked onto the beaches by seasonal north-easterly swells. Although the volume of gravel is small, it is sufficient to convert the beaches to a gravel beach and if high flow is maintained, the gravel beach will migrate progressively south.

The southward migration terminates when either (a) the supply of gravel runs out or (b) the Ashley starts migrating north and the system is flooded by sand. Both conditions can be triggered by low flow.

Much further work remains, but the system appears to behave similarly to the true sand and gravel systems of South Canterbury (e.g. Kirk, 1991). The history of the beach ridges may give insights into palaeoclimatic conditions by identifying periods of high flow, as well as variations in sea-level.

Reference:

Kirk, R.M. 1991. River-beach interaction on mixed sand and gravel coasts: a geomorphic model for water resource planning. *Applied Geography* 11: 267-287.

PROGLACIAL OUTWASH GRAVEL TERRACES AND AEOLIAN SAND SHEETS, MACQUARIE HARBOUR, WESTERN TASMANIA.

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A series of terraces are well developed around Strahan at a range of levels from 80 to 10 m above present sea-level. The best developed terraces are at ~64, 41, 21 and 10 m asl, with discontinuous terrace remnants at intermediate levels. These terraces have been argued to have a marine origin, but recent field mapping has shown that they represent glacial outwash surfaces originating from the King River Valley and from a till mantled surface south of Teepookana on the western side of the West Coast Range. At Strahan an erosional unconformity separates outwash gravels of early Pleistocene age from Eocene (?) coarse gravels and sands. Within the outwash gravel sequences are interbedded sandsheets that are variously massive, plane laminated, or trough crossbedded. Particle size analysis of the sand sheets within the upper outwash surfaces (41-80 m) suggests that most originated as proglacial waterlain sands. SEM analysis of the modal fine sand fraction indicates angular, conchoidally fractured sand grains with v-shaped notches indicative of fluvial transport. The gravel capped terraces have been cut into a massive Eocene (?) sand sheet with field sedimentary structures, particle size characteristics and SEM textures suggestive of an aeolian origin. SEM textures on the quartz grains display evidence of glacial crushing and fluvial entrainment, as well as abrasion and grain/grain impact during aeolian transport. The basal sand sheet is interpreted as having developed from deflation of fine sands from the proglacial outwash surfaces sourced from southern eastern and southern Macquarie Harbour. The bedding structures in the sand vary from horizontal laminae to massive dune cross-bedding indicating transport and deposition from the SE.

HEADLAND-ATTACHED SHELF SAND BODIES AND DROWNED SHELF BARRIERS - THEIR GROWTH AND DECAY

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The continental shelf of NSW is characterized by moderate to high energy waves, tectonic stability and low sediment supply. As a result, late Quaternary sea level fluctuations have initiated cycles of erosion and re-deposition on the inner shelf. The dominant northward transport of littoral sand by southerly storms occurs within large, regional sediment compartments that vary in size depending on changing sea level positions.

Headland-attached shelf sand bodies (SSBs) are convex-up accumulations of marine sand that occur off prominent headlands where the shelf is relatively deep and the substrate gradient is steep. In northern and central NSW, SSBs occur in a depth range of 30-70 m on the inner shelf, and formed as shallow marine deposits during the post-glacial marine transgression (PMT) and stillstand. SSBs of Pleistocene age have not been found and it is likely that, because of their exposed setting off headlands, they are almost totally reworked by wave erosion during marine regressions.

Coastal barriers, on the other hand, occur in shallow gradient embayments, often in close proximity to SSBs. Barriers at the present coast are well known, but recently, relict barriers have been discovered on the inner shelf in water depths of 30-60+ meters. These drowned shelf barriers formed during late Pleistocene interstadials, when sea level was generally falling.

Both the transgressive SSBs and regressive barriers represent depocenters of quartzose marine sand, much of it supplied by littoral drift. The close proximity, overlapping range of water depths, and similar sediment composition of SSBs and drowned barriers suggest that their genesis is linked, although their times of formation are different. We hypothesize that during transgressions, SSBs grow and shelf barriers are partially eroded and reworked, but during regressions, the reverse occurs.

The occurrence of sand barriers on some parts of the NSW shelf is related to a combination of conditions initiated by falling sea level and an influx of sediment. Barrier growth coincided with marine erosion of existing SSBs that had formed as sea level rose during the previous transgression and interglacial highstand of the sea. The influx of SSB sediment to the littoral drift system created a positive sediment budget locally, which undoubtedly contributed to barrier building on the adjacent downdrift shelf. After the last glacial maximum, rising sea levels once again encountered the steep inner shelf substrates off headlands and SSBs began to re-form. The loss of littoral sand into these features created a negative littoral drift imbalance with the potential to cause downdrift erosion. Thus, shelf barriers that occur immediately to the north of SSBs on this shelf have undergone surficial erosion as they were transgressed by the sea.

The hypothesis linking SSBs and shelf barriers, in a cycle of growth and decay, has been tested using volumetric calculations based on several SSBs in the vicinity of Cape Hawke, and a nearby drowned barrier system on the Tuncurry shelf (32.0 to 32.5° S). Computer modelling indicates that the shelf barrier experienced about 5 m of surface erosion during the PMT as a direct result of SSB growth, which removed an average of 180,000m^3/year of sand from the littoral drift system.

LATE QUATERNARY EVOLUTION AND HUMAN IMPACT, YANGTSE RIVER DELTA, CHINA

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Have human environmental impacts reached such a size as to be visible to future geologists? Biologically, the answer is "yes", and the future palaeontologic record will testify to human-induced faunal extinctions, deforestation, and geographic rearrangements of plants and animals. It is not so clear whether there will be large-scale stratigraphic records of human impact, however. China, with its long history of high population levels, in an excellent context for examining this question, and this paper is based on the Holocene history of the Yangtse delta. Holocene sedimentation in the delta has been affected by sea level changes, and possibly by climatic change, however, and the effects of these must be identified before downstream effects of human impact in the Yangtse catchment can be assessed.

Delta sedimentation occurs in shifting compartments of channels, shorelines, islands, and offshore deposits. To establish the three-dimensional history of all compartments, facies keys utilising sedimentary and microfaunal indicators are being developed. Shoreline changes over the last 1800 years are recorded by historical data and ancient sea-walls of the Yangtse delta, and archaeologic deposits extend the record to about 5000 years. Vertical sedimentary history is based on over 40 stratigraphic drillholes. Radiocarbon dating is supplimented by ages estimated for subsurface intertidal deposits from a calibrated sea level curve.

Five stages of growth of the Yangtse delta, over the last 6000 years, were mapped. Using these plus drillcore data, the increase of delta area and sediment volume over the last 2000 years appear to have occurred at constant rates. This suggests that human impacts in the Yangtse catchment are not manifest in the delta, but these are preliminary results, however. The record of the last 600 years, when population growth in the Yangtse catchment accelerated rapidly, has not been dissected. A complication is that the fraction of Yangtse River sediment which is deposited in the delta may have changed as the delta grew seaward. These and other factors are being examined. If the project confirms that effects of population increase are difficult to detect, it will imply catchment sediment yield is dominated by the normal geologic factors of tectonic uplift and weathering.

It should be noted that the work is heavily dependent on collaboration with Professors Wang Pinxian and Li Congxian at the Department of Marine Geology, Tongji University, Shanghai. The author is responsible for interim conclusions in this paper.

HOLOCENE EVOLUTION OF CORAL ATOLLS

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Mid-oceanic coral atolls are ring-shaped reefs surrounding a sheltered central lagoon, and are generally restricted to a mid-plate setting. Their overall structure appears to be explained by the Darwinian theory of coral reef development, involving gradual subsidence of the underlying volcanic basement and vertical reef growth. Drilling on a series of Pacific atolls has indicated that Holocene reef growth has occurred over a last interglacial reef marked by a solutional unconformity at around 8-17 m below sea level. Results from Indian Ocean atolls (particularly the Cocos (Keeling) islands and atolls in the Maldives) suggest a similar pattern of Holocene reef development to that in the Pacific, incorporating three phases:

i) rapid mid-Holocene vertical reef accretion as reefs catch up with sea level,
ii) mid-Holocene reef flat formation and emergence, and
iii) late Holocene island formation.

This general model of atoll development has important ramifications for the terrestrial ecology and human occupation of atolls. Individual atolls, however, show significant variation in patterns of reef growth and sediment accretion.

THURSDAY 23RD APRIL

MORNING SESSION

RIVER MANAGEMENT ISSUES

HEAVY METAL ACCUMULATION IN SEDIMENTS OF THE RIVER MURRAY, SOUTH AUSTRALIA

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The composition of river-bed sediments in the lower River Murray has been changed by agricultural and urban development and flow regulation through a series of 10 low-level weirs constructed in 1922-35. Sediment supplied to the 154 km reach between weirs 2 and 4 have become finer, as coarser material is trapped in upstream weir pools. Two-metre sediment cores extracted from the river-bed immediately upstream of the weirs indicate a progressive reduction with depth of up to 30% in median grain size and an increase in silt-clay content. Bed sediments downstream of each weir are well-sorted medium sands, grading to poorly-sorted fine sand behind the next downstream weir. Heavy metals associated with the bed sediment also display temporal and spatial patterns. Maximum concentrations of Cr, Cu, Ni, Pb and Zn occur in surficial sediments, with levels of Pb and Zn being >5 times greater in surface sediment that 2 m depth. These data may reflect increased urbanisation, although maximum loads occur upstream of the weirs rather than in the vicinity of urban areas. Heavy metal loads are amplified, however, by changes in sediment texture, and may therefore be an effect of changes in sediment transport, associated with flow regulation.

THE EFFECTS OF URBANISATION ON SEDIMENT DYNAMICS IN TWO SMALL CATCHMENTS THAT DRAIN INTO LAKE MACQUARIE, NSW

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The primary aim of this research was to determine the effects of urbanisation on sediment dynamics in a small catchment area. It is now becoming more widely acknowledged that human disturbance in a catchment can have a potentially significant and far reaching effect. Urbanisation is one of the more significant disturbances that has an impact on catchment area processes, thereby affecting the sediment supply and yield, and the hydrology. The catchment area of Lake Macquarie has become increasingly urbanised in recent years and this has led to a heightened awareness of the problem of urban sedimentation for the lake environment. this research centres on two catchments at the northern end of Lake Macquarie: South Creek and Carey Bay.

South Creek catchment has an area of 4.58 km^2, a relief range of 0-111 m and drains into Lake Macquarie at Warners Bay. The purpose of the South Creek study was, firstly, to determine which type of land use was the main sediment source area in the catchment, and secondly, to examine the pattern of recent (post-1954) sedimentation. The catchment was divided into seven sub-catchments, each dominated by a particular type of landuse, either open woodland, rural, established urban or developing urban. The main sediment source areas were determined by water sampling for suspended sediment within the sub-catchments, as this was used as an indicator of water quality. Sampling was carried out from March to July 1988. The ^{137}Cs technique was used on slopes under open woodland and rural landuse to determine the amount of soil erosion. ^{137}Cs and field observations were used to measure rates of sedimentation. Results revealed that the developing urban areas were the major source of poorest water quality, while developed urban areas were minor sources of sediment. Localised sedimentation during a flood runoff event produced deposits of up to 210 t on the flood plain. Sedimentation tended to be higher in the upstream portion of the flood plain, with average annual rates varying between 0.88 cm y^{-1} and 2.65 cm y^{-1}.

Carey Bay catchment has an area of 1.4 km^2 and a relieve range of 0-98 m. The purpose of the Carey Bay study was firstly, to determine runoff and suspended loads from three sub-catchments over the period 1 March - 1 August 1986, and secondly, to investigate the recent pattern and rate of sedimentation from the catchment into the lake and delta. Each sub-catchment was dominated by one of three different type of landuse; forest, older urban or recent urbanisation. The results reveal the influence of urbanisation in increasing both runoff and sediment transport compared with the forested part of the catchment. Runoff and sediment yield from the urban area was three times that of the forested area. The delta at the catchment outlet was recognised as an active depositional feature with an average rate of deposition on the delta being 2.308 g m^{-2} y^{-1}.

COMMUNITY PERCEPTIONS OF CATCHMENT MANAGEMENT ISSUES IN THE HASTINGS RIVER BASIN

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During 1991 a project, funded under the National Soil Conservation Program, was undertaken in the Hastings River Basin to determine the catchment management issues as perceived by members of the community.

The aims of the project were:

(i) to identify catchment management issues within the Hastings River Basin
(ii) to suggest possible actions to address these identified issues
(iii) to provide to the people of the Hastings River Basin, an introduction to the concept of Total Catchment Management.

The procedure for identifying the catchment management issues involved a comprehensive interview process amongst members of the community, together with the undertaking of a wide ranging literature review.

The interview process provided a representative list of community perceptions of catchment management issues within the river basin. Those interviewed included all relevant catchment managers and landusers, together with representatives from community groups as well as interested individuals.

The community identified a number of natural resource management issues within the Hastings River Basin which could be addressed through the Total Catchment Management process. Suggested actions to address these identified issues were also provided.

The issues of greatest concern to the community are as follows:

Urban development
Water quality
Streambank erosion
Soil erosion
Effluent disposal
Vegetation
Sedimentation
Land degradation

The findings of this project have now been documented and will be of invaluable assistance to the initial operations of the future Hastings Catchment Management Committee.

NSW RIVERS: DEFORMATION AND REVOLUTION: A POLICY PERSPECTIVE

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Rivers are important community assets with a wide range of benefits. In NSW many rivers have undergone accelerated deformation since European settlement and most especially in the last 40 to 50 years. The "deformation" has been due to both natural and human "processes". Planning for the reversal of these "processes" involves a revolution in policy perspective by management agencies and the community.

This presentation concerns itself with the relatively recent policy "revolution" in water resource management and river management in particular. Instead of seeing itself primarily as a water supply authority, the NSW Department of Water Resources (DWR) is increasingly accepting its role as a water resource manager. In this scenario, rivers are viewed less as conduits for water and more as integrated geomorphological units of wider ecological systems.

The revolution in policy perspective has been facilitated by a changing public attitude to the environment which is promulgating a sustainable development ethos. Like its counterparts in Canada and New Zealand, the NSW government is promoting a more integrated management perspective. This is evidenced in its adoption of the "Total Catchment Management" approach and the push for environmental protection.

Under the auspices of the NSW Water Resources Council and in conjunction with other state government agencies, DWR has developed the NSW State Rivers and Estuaries Policy. This policy aims to provide a framework to improve the condition of our rivers and estuaries over time. The mechanisms by which it will achieve its objectives are: component policies addressing specific river and estuarine uses or values; pilot studies to assess the adequacy and accessibility of existing data; state of the rivers and estuaries reports; and, inland and coastal advisory committees.

The first component policy to be completed is the NSW Sand and Gravel Extraction Policy for Non Tidal Rivers. This will be available at the conference. It recognises that sand and gravel is an integral part of the river system and removing too much of this resource will result in significant damage to the riverbed and banks as well as adversely affecting riparian and aquatic habitat. Other component policies are discussed as well as mechanisms to assess and report on the state of our rivers and estuaries over time.

The views expressed in this paper are the authors and do not necessarily reflect the views of the NSW Department of Water Resources or the NSW Government.

LOCAL RURAL ORGANISATION: THEIR INCREASING ROLE IN RIVER MANAGEMENT

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It has been observed that as local rural organisations such as Landcare groups become better established, more sophisticated and proactive, their role in stream management becomes increasingly important. It is asserted that with ongoing Government support, such groups will progressively instigate investigations and demonstrations of new and co-ordinated management regimes for the riverine corridor.

Case studies of four Landcare groups on the mid north coast of NSW are analysed. These groups are all addressing streambank erosion problems. Each group is developing its own approach to the erosion problems and these will be studied in detail. Further, the achievement of a co-ordinated approach to stream management, through a combination of whole farm and catchment planning, is described.

Finally, the advantages of farmers pooling their wealth of experience and ideas is examined. There is also a discussion on the role of government agency advisory and regulatory staff in this new scheme of operations.

It is concluded that energetic local rural organisations have an important role in stream management and it is the Government's role to facilitate this process as much as possible.

FRIDAY 24TH APRIL

MORNING SESSIONS I & II

ASPECTS OF COASTAL GEOMORPHOLOGY

FIELD MONITORING OF THE BEACH GROUNDWATER TABLE, NEARSHORE PROCESSES AND BEACH MORPHOLOGY IN A MACROTIDAL ENVIRONMENT

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An instrumentation system employing wave pressure sensors, bi-directional ducted flow meters and capacitance probe ground water wells has been developed for high resolution monitoring of nearshore dynamics and beach groundwater table in macrotidal environments. Two computers, two multiplexing systems and LabTech Notebook data acquisition software enables analogue signals from up to 32 sensors to be logged. Real time control is obtained via real time display of the signals on the computer monitors. The system has been used in a recent study of a macrotidal beach in central Queensland.

MORPHODYNAMICS OF THE FLORIDA GULF COAST BARRIER SYSTEM, U.S.A.

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The barrier system along the Gulf peninsula of Florida extends for 230 km and includes 30 barriers and 30 inlets. It is situated south of an open marsh coast and north of a mangrove coast. This microtidal coast experiences spring ranges of <1 m and a mean annual wave height of about 0.30 m. The adjacent inner continental shelf has a gradient that ranges from 1:700 to 1:1300 along the barrier coast. Dominant sediment transport is to the south overall with local reversals. Onshore passage of winter frontal systems dominate the wave-generated processes of this system with irregular hurricanes also being an important factor. Frequency of these events averages about one per five years.

Although this barrier-inlet system is located on a very low energy coast, it exhibits a diversity of morphologies that is unmatched throughout the world. This condition is due to the delicate balance between tide- and wave-dominated conditions. Another important variable is the wide range of tidal prisms. The consequence is a mixed energy barrier system that includes a spectrum of barriers from distinctly wave-dominated to classic examples of drumstick barriers. Likewise, the tidal inlets range from unstable, wave-dominated types to very stable tide-dominated ones. During the past century there have been several new inlets formed by intense storms and others have closed. Documentation of the development of numerous very young barrier islands indicates that they have formed as the result of upward shoaling of shallow sand bars formed by landward transport of reworked sediment.

The position of most of these barriers is influenced by the underlying Miocene limestones that may reach only -4 m MSL. Stratigraphic data and radiometric dating indicate that these barriers are no more than 3000 years old and that they formed as the result of a marked slowing of sea level rise beginning 3000 years ago. These data also indicate that the barriers formed at or near their present position. At present they are easily washed over during hurricanes due to their lack of significant elevation as the result of small or absent dunes.

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FLOW DYNAMICS OVER TRANSVERSE DUNES

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Transverse dunes are asymmetric sand ridges in which the long dimension is normal to the dominant wind direction. 'Transverse' dunes on the Eastern Australian coast are commonly around 15 m high, and reverse seasonally under the influence of winter obliquely offshore westerly winds and summer obliquely onshore sea-breezes and gradient winds. This pattern is underscored by southerly storm winds. The dunes do not advance in a net transverse direction but extend longitudinally.

Flow and sand transport data collected over several experimental periods indicate that relatively stationary roller vortices are formed within separation envelopes over the lee slipface of transverse dunes when winds approach within 70°-90° normal to the axis of the dunes. Transverse sand transport and deposition occurs in this flow regime.

Winds approaching between 15° and 70° act obliquely on windward faces and form sinuous, migrating, corkscrew roller vortices on the lee face which act to transport sand laterally along the slipface. The transverse dunes then act as oblique transverse (45°-70° range) dunes. Low angle to along-dune (0°-15°) approach winds result in straight flows along both dune faces and the dunes act as longitudinal dunes.

Models of dune dynamics developed from these experiments indicate that some traditional views of the movement and dynamics of certain dune types such as transverse and longitudinal dunes may be inaccurate, that 'transverse' dunes may maintain a typical transverse shape whilst predominantly acting as longitudinal dunes, and that estimates of potential sand transport and dune movement estimated from regional wind data may be considerably inaccurate.

ORIGIN AND EVOLUTION OF INNER SHELF SAND DEPOSITS SEAWARD OF A PROGRADED AND A RECEDED BARRIER COMPLEX, SOUTHEAST AUSTRALIA

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The aim of this study is to establish the depositional history of the inner continental shelf sand deposits seaward of two embayments in the Forster area of the NSW central coast, the Wallis Lake embayment and the Tuncurry embayment. These two embayments are characterised by distinctly different barrier morphologies. Previous work on barrier stratigraphy (Thom, 1974, 1978) has established that the two barrier complexes have different depositional histories, the Tuncurry barrier experiencing significant post stillstand deposition not evident in the Wallis Lake embayment. Since the sediment that comprises the two barriers has migrated onshore across the inner continental shelf (Roy and Thom, 1981) the development of inner shelf sand deposits is linked to shoreline displacement during the Post Glacial Marine Transgression.

The study has been designed to:

(i) test a series of hypotheses that explore both accretionary and erosional modes of formation of the inner shelf sand deposits and

(ii) assess the interdependence of the barrier/shoreface and inner shelf depositional environments.

Preliminary results of this study will be presented.

LAGOONAL SEDIMENTATION IN THE COCOS (KEELING) ISLANDS, INDIAN OCEAN

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The lagoon of the main atoll in the Cocos (Keeling) Islands is more than 15 m deep in the north, but shallows to the south, where it is dominated by an intricate pattern of blue holes, and much is exposed at low tide. Sediments in the lagoon range from muds to sandy gravel, and can be divided into three major types based on components:

i) coral sediments;

ii) molluscan muds and

iii) coralline algae/Halimeda sediments.

Radiocarbon dating of vibrocores, and historical accounts of the atoll, indicate rapid sedimentation and infill of blue holes by sand aprons composed of sediments carried into the lagoon through reef passages.

SALT-WEDGE ESTUARINE CIRCULATION UNDER A MIXED TIDAL REGIME - THE GLENELG RIVER ESTUARY, VICTORIA

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Time scales of measurement in S.E. Australian estuaries are usually related to the dominant semi-diurnal tidal forcing of circulation. Tide cycle stations are often selected for a period where any tidal inequalities produced by diurnal tidal components are at a minimum. The construction of mathematical models to simulate estuarine circulation is facilitated by the relatively simple semi-diurnal tidal model.

Where the diurnal tidal component becomes more significant to the tidal regime, the tide is referred to as being of Mixed type and varies over a period from dominance by semi-diurnal to diurnal components. This complicates input to simulation models.

This paper describes the results of a 32 hour station at Nelson on the lower Glenelg River Estuary under conditions where diurnal components dominated tidal circulation. Interactions with the salt-wedge pattern of this section of the estuary are presented and implications for modelling discussed.

FRIDAY 24TH APRIL

MORNING SESSIONS III

NON FLUVIAL/COASTAL TALKS

THE AGE AND DYNAMICS OF DESERT DUNES IN CENTRAL AUSTRALIA

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Dunes of the 'greater' Simpson Desert have been reworked from those deposited 270,000 years ago or more. While they provide important evidence of changing environmental conditions in central Australia over that time, care must be taken to separate inherited characteristics from those that reflect contemporary conditions. Despite their ancient Pleistocene heritage and longterm morphological stability, TL dating reveals that a large proportion of the sand within an individual dune has been reworked during the Holocene.

At Birdsville in the eastern Simpson Desert, the widespread asymmetry of roughly northward-trending longitudinal dunes, with steeper eastern faces and more gentle western faces, supports wind rose data showing sand-transporting winds from the southwest obliquely intersecting the dunes. While this is convincing evidence for a change in the prevailing wind direction since the dune field was initially oriented, it does not indicate that the dunes are necessarily shifting leeward (eastward) as a consequence. It is hypothesized that the direction of migration is controlled by the extent to which the dunes are vegetated. Relatively well vegetated dunes can accrete sand on their gentle stoss-slopes causing them to shift westward and hence obliquely into the wind, a condition that probably prevails in wetter regions and during episodes of relatively humid climate. In contrast, in very dry areas or during arid phases, sand can erode from a sparsely-vegetated stoss face and deposit as an avalanche or slip fact on the lee side, thereby causing the dunes to shift eastward. Despite evidence that longitudinal dune-crests can shift laterally to some extent, the dunes in the western part of the Simpson Desert have not migrated, either westward or eastward, more than 100m or so from their Pleistocene cores.

The stability and closed-system sediment budgets of longitudinal dunes are also clearly illustrated near Birdsville where dunes of contrasting colour stand adjacent. Despite the almost total reworking and TL bleaching of the sand within individual dunes over the last few thousand years, their colour indicates that there has been little or no sediment mixing between dunes. Relatively young source-bordering dunes formed from abundant sand blown off the bed of the Finke River are oriented 30° westward of the trend of the regional longitudinal dune-field nearby. The orientation of longitudinal dunes is largely self perpetuating, and the sediment within individual dunes is largely self contained, even if the prevailing wind shifts direction substantially. This is probably because, once formed, longitudinal dunes generate their own boundary conditions and associated near-surface flow field. Only where there is an abundant supply of fresh sand, such as from a river bed, will there be substantial sediment exchange between dunes and development a new orientation. In contrast to the mobility of sand on a windy day, the gross morphology of Australia's dune fields is remarkably stable and has probably been largely inherited from earlier Pleistocene conditions.

DEVELOPMENT OF LUNETTE DUNE AND ITS LAKE BASIN SOME MODERN FEATURES OF LAKES CAWNDILLA, MENINDEE AND VICTORIA

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Many lakes in southeastern Australia are characterised by a lunette dune along their eastern shoreline. Bowler's model suggests sand lunette formation by beach deflation during high water level and clay lunette accretion by lake floor deflation under an ephemeral saline lake condition. Lees recently proposed a new model as he found Bowler's explanation for the clay lunette formation depending on too specific climatic and hydrologic conditions. Lees' lake-segment model suggests that a sand lunette builds up initially on an emergent shoal and clay lunette develops when clay can deposit in a deepened basin and is deflated during low lake stages.

Recent field observations at Lakes Cawndilla, Menindee and Victoria provided more data to evaluate the above models. These lakes have been used for water storage. The longstanding high water levels created a condition suitable for sand lunette to form according to both, especially Bowler's model. A foredune, or a small modern lunette, is indeed forming along their eastern margins. At Lake Cawndilla, this dune, >20 m wide and 1-2 m high, developed during the last 200 years and probably mainly during the period of high water levels after water regulation since 1960. At Lake Victoria, the modern foredune developed even larger and a sheet of sand from this dune has been blown onto the higher lunette slope. A shoreline cliff at the lunette foot, cut by a previous too high artificial water level, can be seen on photos taken in early 80's but has been totally buried by the forming lunette. This fast sand accumulation along the eastern shore results from a process of west-to-east sediment transport, studied by Noble and Lees. Some shoaling process occurs and some kind of lake segment happens although at a much smaller scale compared to that suggested by Lees' model.

Although so closely located, the lunette of Menindee shows some features significantly different from those of Cawndilla, one of which is the absence of the modern foredune. This may be explained by a 2 m depth-difference between the two lake basins. The sand transport process is much more active at Cawndilla.

A very young silty and clayey lunette unit at Lake Cawndilla indicates a non-saline environment. However, interbedded clayey silt and pure sand layers in the Lake Victoria lunette suggest relatively fast alternations between dominant high water levels and low lake, moderately saline conditions.

These observations show the so diverse processes of lunette and its lake basin development. The difference between the models of Bowler and Lees appears superficial. They are both correct if applied to right examples and could be both wrong if trying to expand their application too widely.

LATE QUATERNARY EVOLUTION OF LAKE URANA, NSW

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Lake Urana is located at the eastern margin of the Riverine Plain in southern NSW. In its oval to kidney shape, north-west to south-west orientation and shoreline geomorphology Lake Urana closely resembles other previously studied lakes of the Murray Basin including Mungo and Tyrrell, which are also relict features in the present semi-arid landscape. This paper reports the findings of a detailed stratigraphic survey at Lake Urana and is supported by a program of TL dating.

The eastern shoreline of Lake Urana is bordered by a dual lunette system which bifurcates to the north. In the north-east the inner lunette backs a superbly preserved beach and is characterised by sandy sediments and weak pedogenic characters. TL dates on this unit indicate that it was deposited between about 30K and 12K when lake levels were consistently high. The fining of a partial human skeleton, including a cranium, in an outlying southern part of the inner lunette points to human occupation of this area by about 25K. The skeletal remains are similar to those of the delicately boned gracile people known to have lived at Lake Mungo at this time (Bowler and Thorne, 1976).

The outer lunette ridge is topographically subdued but contains a pedogenically altered clay-rich surface unit overlying a sandy core. Dates on the upper pelletal clays are rather variable ranging from 60K to 36K but suggest that an early lake-full phase was replaced by oscillating lake levels and increased hydrologic stress in the period 40K to 30K. We expect that additional TL dates, now in the laboratory, will clarify the chronology of the older outer lunette.

Perhaps the most surprising finding at Lake Urana was that no evidence existed for a period of dessication in the period 18K to 16K. Although no regional significance need be attached to this finding from a lake with complex catchment hydrology, it is not without parallel elsewhere. At Lake Tandau, in the Menindee system, Hope, et al (1983) found evidence for persistent high freshwater conditions from 27K until at least 15K.

References:

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COMPARISON OF TL CHARACTERISTICS OF QUARTZ GRAINS OF DIFFERENT ORIGIN

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The notion that the characteristic thermoluminescence (TL) properties of certain crystalline minerals may be used to identify the source of the mineral is certainly not a new one. The majority of workers in the field, after extensive study, have concluded that the technique has "possibilities". The very sensitivity of the method itself somewhat defeats the object of the exercise stemming from physical processes which are poorly understood in naturally occurring crystalline materials and is best studied in controlled laboratory conditions using grown crystals.

The processes by which these characteristic TL signals are produced are outlined and the results of studies performed on quartz grains taken from coastal, fluvial and aeolian environments shown. Examples are given of the TL signatures exhibited by quartz taken from different units within various sedimentary sequences. These may differ in TL sensitivity as well as displaying differing TL energy characteristics. These differences are suggestive of the quartz having been formed under different conditions and therefore of the sediment having different origin.

This present study does not attempt to unravel the mysteries of the inner working of these natural processes but seeks merely to make use of the TL signature exhibited by certain crystalline materials collected from the same site to demonstrate the possibility of their having derived from a different source. Thus the study is entirely empirical and intended to add to the growing armoury of techniques available to the geomorphologist.

PROBLEMS ASSOCIATED WITH THERMOLUMINESCENCE DATING OF QUATERNARY FLUVIAL SEDIMENTS IN THE SEASONALLY WET TROPICS OF NORTHERN TERRITORY

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Thermoluminescence (TL) dating has been successfully applied to over 100 sediment samples during an investigation of the Late-Quaternary evolution of the Magela Creek, a major left-bank tributary of the East Alligator River. Dating was generally performed through the regenerative technique, although the additive-dose and partial bleach methods were also used, with the 90-115 micron quartz fraction. The ages obtained range from less than 500 yr to >318 kyr.

Samples were collected from four different depositional environments; channel infill, floodplain environment, colluvial/alluvial sand-sheets at the foot of the Arnhem Land escarpment, and within an ephemeral pond on the surface of the escarpment. Comparative radiocarbon (C^{14}) and TL dating of Holocene channel infill sediments proved inconclusive due to apparent high levels of residual TL found in near surface samples. This is a consequence of inadequate bleaching of the sediment by ultra-violet light due to sub-aqueous transport or oxide coatings on the grains. Hence confidence of accurately TL dating Holocene channel infill sediments in this region is low. Surface samples from the other depositional environments revealed low residual TL thus increasing the confidence in the calculated ages for samples from these areas. The low residual TL in these instances is attributed to bleaching by both ultra-violet light during transport and by the heating of samples through fire.

FRIDAY 24TH APRIL

AFTERNOON SESSION

NON-FLUVIAL/COASTAL TALKS

SPELEOTHEMS, SUNSPOTS AND QUATERNARY ENVIRONMENTAL CHANGE IN NEW ZEALAND

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Speleothems have been analysed for fluorescence, stable isotopes and uranium series. This yields a dated time series of proxy temperature and possible water balance information. Time series analysis indicates cyclicity in the fluorescence data, probably related to variations in receipts of solar energy at the earth's surface, although the paleo-environmental interpretation of fluorescence is equivocal. The relationship between fluorescence and other paleo-environmental indicators is explored. Existence of speleothems in a cave overrun by ice during Pleistocene glaciations of Fiordland provides the opportunity to identify and date non-glacierized intervals, because speleothems do not form beneath glaciers. Uranium series dating shows these relatively warm episodes to have occurred 0-14, 32, 41, 50-66, 124 and 183 ka ago.

BASALT AND BULLDUST: SOILS AND LANDSCAPE EVOLUTION NEAR HUGHENDEN, SEMI-ARID NORTH QUEENSLAND

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Soils chronosequences on unconsolidated parent materials such as late Quaternary alluvium and dunesand have been studied in a number of regions in Australia. In contrast, soil development rates on consolidated parent materials are essentially unknown, largely because soil age is more difficult to establish.

Basalt flows of Quaternary and late Tertiary ages have been dated by the K/Ar method in several volcanic provinces of North Queensland. Many of the dated flows have ages in the range 0 to 6 Ma, and are useful for quantifying long term erosion rates (Stephenson & Conventry 1986 *Search*, 17:220-223). They can also be used to quantify rates of soil development by studying soils on flows of different ages.

Basaltic soils in the Sturgeon Volcanic Province near Hughenden were studied on basalt flows ranging in age from 0.9 to 5.9 Ma. The study area lies at elevations of 250-800 m, in the headwaters of the Flinders River. Climate is semi-arid tropical, with summer-dominant rainfall of 450-600 mm/year. Vegetation is mainly an open savanna woodland dominated by *Eucalyptus* species (*E. crebra, E. papuana* and *E. dichromophloia*), with a ground cover of Mitchell grass (*Themeda australis*).

Black soils (black earths and grey clays) and red soils (euchrozems and kraznozems) occur on flows of all ages, with the change from one to the other typically occurring over a distance of a few metres. Black soils tend to be more clay rich (60-70%) than the red soils (20-60%). Smectite clays dominate the black soils, with kaolinite more common in the red soils. The red soils show a trend of increasing soil depth with age at a rate of about 25 cm/Ma. In contrast the black soils show no obvious change in depth with age, with soil depth apparently increasing to a steady state value of about 1.2 m within 1 Ma.

The two soil groups are clearly not the results of formation in differing climates because they occur together on flows of all ages, but they are certainly related to local soil drainage. Rates of soil development are spectacularly slow!

CHANGES TO SLOPE/REGOLITH DEPTH EQUILIBRIUM CONDITIONS INDUCED BY DEFORESTATION

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Infinite limiting equilibrium analysis has been applied to undisturbed regolith and mass movement colluvium in an eroding catchment. This allows theoretical equilibrium depths to be calculated for given slope angles. Comparison with measured slope/depth relationships in the field indicates that areas of undisturbed regolith exist in an unstable state while colluvium is in a stable condition. The original forest cover appears to have imparted sufficient strength to the slopes to have maintained stability.

LIMESTONE WEATHERING IN A COASTAL ENVIRONMENT: A MEDITERRANEAN EXAMPLE

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Limestone weathering and erosion in coastal environments represents complex interactions between rock properties, solution, biochemical action, salt weathering and abrasion. These interactions are reflected in morphological features which frequently vary with distance from the coast, as different weathering mechanisms become dominant and others cease to operate effectively. In this paper coastal weathering gradients are investigated through a study of the Miocene limestone platform on the southern coast of Mallorca. Numerous detailed variations occur but two broad divisions are identified. A spray zone, close to the edge of the platform in which salt weathering dominates to produce alveoli and fretted hollows; and a landward zone in which solution dominates to produce solution pits and pans. This apparent simplicity, compared to complex zonations identified in other areas, is largely a response to the micro-tidal regime of the area.

SMALL-SCALE KARST FEATURES INITIATED IN SEMI-ARID GYPSUM DEPOSITS BY RABBITS

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Extensive gypsum deposits are widespread across semi-arid southern Australia in winter rainfall areas. In western New South Wales, gypsum occurs in broad shallow depressions in very gently undulating plains. Small-scale karst features have developed on the fringes of the "Marlow" gypsum mine (32° 45'S, 144° 44'E) some 40 km east of Ivanhoe. Rabbits dig burrows and warrens in the relatively soft gypsiferous soils. Infrequent heavy rain caused localised flooding which drained by pouring down rabbit borrows into a warren and then flowed through warren tunnels into the abandoned mine. Burrows have expanded by collapse and erosion to form miniature dolines up to 3 m diameter and 1.8 m deep. These are linked by a network of expanded tunnels up to 0.5 m diameter. A large tunnel 1.5 x 1.0 m runs some 20 m into the mine. Fluvially deposited material on a ledge close to the roof of the tunnel demonstrates that the tunnel was full of water during exceptionally heavy rain in January 1984. These karst landforms were initiated by rabbits and enlarged by dissolution and erosion by flowing water. Measurements of doline dimensions from 1983 to 1991 show low rates of expansion (erosion/collapse): a few mm per year. A network of erosion pins shows that there has been no surface lowering on essentially flat surfaces, but a few mm per year on steep slopes. The karst is entirely localised to the edges of the mine and is an interesting geomorphological curiosity illustrating interactions between substrate, climate, animals and human activity.

NICKPOINT MIGRATION IN KARST TERRAINS : AN EXAMPLE FROM THE BUCHAN KARST , SOUTH-EAST AUSTRALIA.

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Correlations between epiphreatic cave levels and paired strath terraces in the Buchan Valley indicate at least three periods of stillstand in the Mid-Late Cainozoic evolutionary history of the Buchan area. Palaeomagnetic data from cave sediments suggests that the last still stand, represented by the lowest terrace and cave level, dates back to at least 730 Ka. Since this time total incision in the Buchan Valley has been less than 3 m. This, and the previous incisions are the result of the upstream migration of nickpoints through the karst terrain.

Recent work on the migration of some of these nickpoints has revealed several interesting aspects on their migration. Nickpoints in karst terrains may exhibit several unique characteristics. Underground capture of the drainage can leave surface nickpoints abandoned. Nickpoint migration can, as a result, be underground. This may occur in two ways, either by vadose incision or by the progressive capture of underlying phreatic cave passages which are enlarged by solution and collapse. Vadose incision is helped by mechanical erosion facilitated by coarse bedloads. It only occurs when small drops in baselevel take place at a connection between lower and upper cave systems. The rate of upstream transmission of underground nickpoints depends on the ratio between chemical and mechanical erosion.

A FURTHER USE FOR THE MICROEROSION METER

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The microerosion meter (MEM) has been widely used in a variety of natural and cultural environments to assess current weathering rates. Applications have included estimation of rates of limestone solution, coastal erosion processes, wind and chemical erosion in arctic regions and in cultural situations such as on buildings and Aboriginal rock art.

Heavily used tourist caves require cleaning to remove dust, lint and other organic debris from walls and floors. The debris itself has a variety of deleterious affects on the cave environment. Cleaning methods used at Jenolan and elsewhere in the world have included application of water at low pressure, high volume (with and without brushing), at high pressure, low volume and occasionally steam cleaning. All of these methods can be expected to have adverse impacts.

The MEM is currently being used to assess the impact, in terms of surface lowering, of cave cleaning activities in the Jenolan Cave system, New South Wales. The supplementary techniques of scanning electron microscopy and evaluation of the physical and chemical characteristics of wash water are also being used. Early results of this work will be presented.

INITIAL HYDROLOGICAL AND CHEMICAL CHARACTERISTICS OF A SUGAR CANE SITE WITH POTENTIAL ACID SULPHATE SOILS

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The geomorphic processes occurring during the post-glacial period of the Holocene have played a major role in the development of potential acid sulphate soils that have the potential to cause severe damage to aquatic life under certain conditions. These soils occur world-wide, but are particularly widespread in the coastal areas of South-east Asia. They have also developed around the lower reaches of the Tweed River on the far north coast of N.S.W. This estuary has a relatively small catchment area allowing tidal processes to dominate, so that with the rise in sea level between about 20000 and 6000 years B.P. the area was subject to marine sedimentation. It is under these brackish, waterlogged conditions that large amounts of pyrite developed in the estuarine muds and are now present in the soils underlying the main agricultural activity of this region, sugarcane production. These soils will remain in a stable condition if permanently waterlogged. However, when they are drained for agricultural production the watertable is kept at a level low enough to allow the pyritic material to oxidise. The main oxidation product is sulphuric acid and this decreases the pH of the soil sufficiently to increase greatly the solubility of aluminium. Following the next heavy rains, aluminium-rich, acidic water is flushed into the Tweed River that has at certain times caused spectacular fish kills. Although these effects have been reported to have occurred prior to European settlement of the area, the problem has been exacerbated by the system of pumps and drains installed by the sugar-growers to ensure as low a water table as possible. This is presumed to allow the best growing conditions to exist.

As the position of the water table appears to be the determining factor in the production of acidic oxidation products, this soil study focuses on the water balance of an area affected by these soils in the lower Tweed area. Results have so far shown that the occurrence of the acidic water in the Tweed River is related to the position of the water table and the preceding weather conditions, particularly following prolonged dry spells. However, other results during relatively wet periods have shown that perhaps the hydrology and related soil chemistry are not as simple as first believed. It appears that when the water-table is at a relatively high position, allowing waterlogged and reducing conditions to predominate, acid water is still being detected in the drains leading from the cane soils to the Tweed River. It appears that the simple rise and fall of the water-table may not be the only cause of acid output but rather a number of hydrological and chemical factors that combine to produce the potentially devastating conditions for the aquatic life and economic activity dependent on the Tweed River.

THE CONTROL OF ALUMINIUM TOXICITY BY SOIL ORGANIC MATTER IN A CATCHMENT SUFFERING DRYLAND SALINIZATION

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The Axe Creek catchment near Bendigo in central Victoria is experiencing dryland salinization following European deforestation and overgrazing. This catchment is now contributing a significant salt lode to the Murray-Darling system. Groundwater measurements in the catchment by P. Dyson show no clear relationship between rainfall and groundwater elevation beneath eucalypt forest but a markedly seasonal increase in groundwater elevation under cleared areas, corresponding to the winter rainfall, summer drought conditions.

This salinization could be controlled by reducing the accession of rainfall to the groundwater using revegetation with perennial plants. However, soils of the catchment are naturally very acidic leading to problems with revegetation due to aluminium toxicity. This is hindering management of the salinization problem. One issue that has been raised concerns the possible role of soil organic matter in altering the availability of phytotoxic aluminium.

Two comparable hillslope transects were surveyed across areas of contrasting landuse history and existing vegetation. The first transect is in a native eucalypt forest that was logged for mine timbers more than 50 years ago. The second transect is in the adjacent area which was cleared early this century and has a volunteer native pasture. The ridge, across which both hillslope transects run, is parallel to the bedding of steeply-dipping, metamorphosed sedimentary rocks so that resistant bands of rocks outcrop across the slope of each transect. Soils from comparable hillslope positions were described in the field and sampled for laboratory analyses. A range of extracts were made from topsoils and subsoils to determine the acidity, organic matter content, and concentrations of various aluminium fractions.

Some literature suggests a simple relationship between decreased pH and increased toxic aluminium. However, it is unclear whether this relationship holds generally. We are unsure whether the greater organic matter observed within the forest soils is causing the lower pH and therefore a possible increased toxic aluminium or whether the organic matter is able to immobilise aluminium and thereby decrease its toxic effects.

CONTROLS ON LICHEN LIMITS IN BEDROCK CHANNELS

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Gregory (1976; 1977) established that there are a series of lichen limits on the bedrock channels in the New England district of NSW. These lichen limits were related to periods of repeated floods which removed lower lichens from the rock surface through inundation and abrasion. We have investigated the effect of flow regulation on lichen limits along the Snowy River below Jindabyne Dam and along the Nepean River below the Upper Nepean Water Supply Scheme dams.

The Snowy Mountains Hydro-Electric Scheme was built between 1959 and 1974 and diverts nearly all of the runoff from the upper 1860 km2 of the Snowy River basin inland to either the Tumut or Swampy Plain Rivers. Since 1974, when Jindabyne Dam was closed, only 10 ML/d have been released for riparian purposes. Jindabyne Dam has only spilled in 7 of the last 288 months. There are two lichen limits based on Xanthoparmelia tasmanica at three sites below Jindabyne Dam. The upper limit is 1.65 to 2.0 m higher than the lower limit and is composed of lichens which have been dated to at least 1921. The lower lichen limit is composed of lichens which are not older than 1967 and correspond to a discharge of 40 ML/d. Clearly the upper lichen limit reflects the pre-scheme hydrologic regime whereas the lower lichen limit is adjusted to reduced post-scheme flows.

The Upper Nepean Water Supply Scheme constructed between 1888 and 1935, comprises four large and three smaller dams which regulate flow from 76% of the total upper Nepean Catchment. Since 1977 water has also been transferred from the Shoalhaven River to the Nepean River via Fitzroy Falls and Wingecaribee Reservoirs. Downstream flows are regulated by an additional eight weirs, five pumping stations and other assorted diversion structures. The Nepean River also has two well-defined lichen limits based on crustose species (currently being identified). The upper limit is 1.99 to 2.12 m higher than the lower limit and is composed of lichens which have been dated to before 1810. The lower lichen limit has been dated to 1950 and reflects colonisation of a scoured surface following the wettest year on record for the upper Nepean River in 1950. Lichen limits on the Nepean River are more sensitive to a cluster of closely spaced floods rather than flow regulation.

ASSESSING THE AMOUNT OF EROSION ON SOILS UNDER CULTIVATION AND GRAZING USING CAESIUM-137 TECHNOLOGY

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This paper examines soil erosion at a grazing and a cultivated site on an agriculturally important krasnozem soil at Comboyne, NSW using the caesium-137 (^{137}Cs) technique. The radioactive environmental tracer ^{137}Cs is becoming a widely used tool in the assessment of erosion status of soils and the subsequent deposition of sediment in a number of landscapes. 137Cs is a fallout product of atmospheric nuclear weapons testing from the 1950s to the late 1970s. 137Cs was distributed globally in the stratosphere and deposited on the earth by precipitation, where it preferentially attaches to the finer soil particles. ^{137}Cs loss from a site can be used to determined soil loss using a proportional model for cultivated soils and a calibration curve for uncultivated sites.

The two sites studied were located at Comboyne, 50 km southwest of Port Macquarie in NSW. Both sites were located on a hillslope; the soil type was a krasnozem and the average yearly rainfall approximately 1800 mm.

Sampling at the grazing site was along a 170 m transect at approximately 10 m intervals. Samples were taken using a 10 cm diameter auger to a depth of approximately 30 cm. A total of 19 samples were collected. Soil loss was calculated using a calibration curve.

The cultivated site was under a potato/grazing rotation. Sampling was carried out over an area of approximately 40 m by 200 m on a grid layout. Samples were taken at approximately every 10 m across and down the slope to a depth of 30 cm using an 8 cm diameter core and a 10 cm diameter auger. A proportional model was used to calculate the amount of soil loss.

The following preliminary results were obtained:

Comboyne, NSW	Net Soil Loss ($t\ ha^{-1}\ y^{-1}$)
Uncultivated grazing slope (26% slope)	0.14
Cultivated slope (potato/grazing rotation; 20% slope)	*115.92

* net soil loss from slope/year for a 4 year period when slope was under cultivation. Allowance was made for net soil loss when the slope was under pasture.

Soil erosion, as a result of agricultural practices, is one of the main forms of land degradation in Australia. It is linked to decreased productivity, as well as decreases in water quality and increases in fluvial and coastal sedimentation. The results obtained from this study will be made available to landholders so that they can modify their management techniques to decrease soil erosion with a view to maintaining productivity, and thereby improving water quality and decreasing fluvial and coastal sedimentation rates.

SATURDAY 25TH APRIL

MORNING SESSION

HUMAN IMPACT ON RIVER SYSTEMS

DRAINAGE BASIN SEDIMENT BUDGETS: TWO CASE STUDIES FROM THE HUNTER REGION, NEW SOUTH WALES

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The drainage basin sediment budget concept is an accounting procedure of sediment entering (erosion), being stored (sedimentation) and leaving (sediment yield) a fluvial system. Because there are time-lags within this system, it is essential that a time-frame for the budget be established. One method which may be used is a tracer technique employing the fallout isotope caesium-137 (^{137}Cs), present in the environment since the mid-1950s. Soils and sediments exposed to fallout from atmospheric thermonuclear weapons tests will have been labelled with ^{137}Cs over the past 35 years, thus providing an initial date for sediment budgeting. This tracer can be used for assessing the erosion status of soils and the depth of sedimentation in sinks. In addition, sediment budgets have been used to examine the impact of human activity on sediment dynamics, where it may be assumed that sediment mobility was minimal, or at an assumed level, before the known onset of catchment disturbance.

The case studies reported in this paper attempt to construct sediment budgets for two small drainage basins which have undergone substantial human disturbance, using, amongst other techniques, the ^{137}Cs method.

Manula Creek

For this 1.7 km^2 catchment a sediment budget for the period 1971-1986 was constructed. Part of the basin was developed for vineyards, commencing in 1970, making up 10% of the basin area. The upper catchment was under native forest (60%), and the remainder was utilised for cattle grazing. Erosion-runoff plots and ^{137}Cs were used to measure soil erosion, ^{137}Cs profiles were used to estimate sediment storages, and measurements of sediment output from 1978 to 1981 were employed for extrapolating the longer-term sediment yield. It was estimated that the forest contributed 1.8% (310 t), the grazing land 1.6% (270 t) and the vineyards 96.6% (16 476 t) of the soil loss. Nearly 56% (9 460 t) of this sediment remained within the basin storages, with approximately 34% (5 840 t) being transported from the basin. The fate of approximately 10% of the eroded materials could not be accounted for.

Croudace Bay North

In March 1989 urban development began in this 14 ha catchment and, by mid 1991, had covered 34% of the area. The slopes above and below the residential area remained under open forest. Using the ^{137}Cs method and the USLE, a tentative sediment budget was constructed for the period 1954-1991. Soil losses within the open forest (36 years) were estimated as 0.48 t ha^{-1} y^{-1} (^{137}Cs) and 0.76 t ha^{-1} y^{-1} (USLE). The urbanising area had estimated soil losses (2 years) of 30.6 t ha^{-1} y^{-1} (^{137}Cs) and 47.4 t ha^{-1} y^{-1} (USLE), with a stream-channel sediment storage of 571 t (^{137}Cs). It was assumed that the bulk of the storage had occurred during the phase of urbanisation (2 years). The ^{137}Cs method suggested that there was no sediment output (to Lake Macquarie), whereas the USLE suggested that 262 t had been yielded.

THE MURRUMBIDGEE RIVER SYSTEM - SEDIMENT TRANSPORT AND SEDIMENT SOURCES

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Turbidity, related to suspended sediment, is a large problem in the Murrumbidgee system and a great deal of anecdotal evidence suggests a significant increase in turbidity over the past 20-30 years. A major project has been initiated to examine this problem and particularly to attempt to find the major sources of the sediment using a range of sediment tracers and techniques. The study has located some important new data sources which should enable the determination of more accurate sediment loads and a relatively simple, low cost monitoring program has been initiated. The project has two major thrusts. The first is to characterise sediment transport especially with respect to spatial and temporal variability. The second is to source the sediment using radionuclide and mineral magnetic tracers.

In most studies of sediment transport in Australia there are major restrictions due to data shortages and the difficulty of establishing remote monitoring stations. In this study a novel approach has been adopted utilising a data base which was previously not known. Most townships on the river derive their water supplies directly from the river and because of turbidity problems have to treat the raw water. To carry out this treatment they must determine the incoming river water turbidity and so monitor it on at least a daily basis. As a result, most plants have a relatively detailed turbidity record for variable lengths of time; commonly three to four years but in several cases much longer, for example Jugiong 16 years and Wagga Wagga 43. In some sections of the river there are no treatment works and the data is being supplemented by samples collected by operators of the irrigation weirs. This data base will enable an analysis of both spatial and temporal patterns. By establishing a relationship between turbidity and sediment concentrations a detailed sediment record can also be determined which will enable the calculation of sediment loads. In addition, flocculated sediment is stored in holding ponds and as the volume of water it is derived from is recorded these will also enable the determination of sediment loads based on relatively large samples of the stream flow. Both these methods should provide more accurate representations of sediment transport rates than those previously determined for large streams in the Murray-Darling system.

The origins of the suspended sediment are being investigated using two approaches. The first of these relies on surface soil being differentially labelled by both natural and artificial fallout radioactivity, compared with subsoil which is unlabelled. These fallout nuclides have been measured on both suspended sediments and modern deposited sediment to determine the contribution, if any, of sheet erosion to the suspended sediment load of the the river under various flow regimes. The natural mineral magnetic characteristics of the sediment and the concentrations of other naturally occurring radionuclides are being used to investigate the spatial sources of suspended sediment and hopefully distinguish between catchment and river channel sources. Stratigraphic records have also been sampled to investigate the time dependence of the various potential sediment sources.

OBJECTIVE DEFINITION OF FLOOD EPISODES IN GIPPSLAND

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Many New South Wales coastal rivers appear to be subject to flood-dominated (FDR) and drought-dominated regimes (DDR) extending over time periods several decades in length (Erskine and Warner, 1988). The extent to which this behaviour applies to other Australian rivers has not been adequately investigated. Erskine and Warner (1988) do not use an objective method for identifying FDR and DDR. In this paper we explore the usefulness of an objective method based on double-mass analysis (Chang and Lee, 1974) for defining FDR and DDR for three rivers in Gippsland, Victoria, and for the Hunter River in New South Wales. The implications of regime shifts for river channel morphology and behaviour are discussed for the Victorian rivers, together with an analysis of the patterns of expenditure on river management works.

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GULLY FORM, PROCESS AND EVOLUTION ASSOCIATIONS AT MICHELAGO, SOUTHERN TABLELANDS, NEW SOUTH WALES, AUSTRALIA

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Gully erosion is a serious environmental problem in Australia that has the potential to affect the sustainable use of both land and water resources. Gullying is especially prevalent in the Southern Tablelands of New South Wales. The present gully network in this region has changed very little since 1945 following the main phase of incision which occurred during the first four decades after European settlement (Eyles, 1977; Starr, 1989). The primary concern nowadays is to promote the stability of these gullies, and thereby improve associated water quality through a reduction in sediment production and delivery (Eyles, 1977; Prosser, 1991; Starr, 1989). Before these issues can be addressed, controls on form/process interactions in gullies must be understood. This information is essential if the character and rate of gully evolution is to be reliably interpreted. This study reports on the role played by the materials into which gullies have incised on consequent form/process associations and hence gully evolution. Gullies are examined in two adjacent catchments, within distinct lithologies, namely granite and metasedimentary sequences.

The role of materials on gully development is assessed at three spatial scales. First, implications for the gully network are assessed. Second, the role of materials on cross-sectional geometry and down-gully variations are evaluated. Finally, the consequences of materials for gully sidewall morphology are interpreted. To examine these scalar controls, two mapping schemes have been employed. The first is a gully sidewall classification scheme developed in Australia as a practical geomorphic tool for conservation management (Crouch & Blong, 1989). The scheme classifies the degree of sidewall activity, sidewall profiles, and the dominant erosion processes operating. The scheme has been devised to estimate sidewall erosion rates and to predict major sediment sources within a gully. In this study, the classification scheme has been used as a framework within which to characterise gully sidewall form and erosional processes. The second mapping scheme is a sediment inventory procedure which has been applied at both bedform-scale facies and elemental scales (sensu Brierley, 1991).

Broad-scale lithologic controls are self-evident at the network and cross-sectional scales. Gullies incised into granite have adopted a dendritic pattern and are shallower and broader than those incised into metasedimentary fan deposits, which have a sub-parallel configuration. Element-scale sedimentology determines down-gully variations in sidewall morphology, while at-a-site gully wall morphology is controlled by process/material interaction at the facies scale.

This study demonstrates the potential of combining standard geomorphological methods of mapping and process research in this type of gully investigation (Jungerius & van den Brink, 1991). This provided insights into the associations of sedimentary forms, the processes responsible for them, and their environment of deposition. Material properties and erosion processes differ in their control over gully morphology at differing scales. The framework used to evaluate gully erosion in this study has implications for conservation management on land degradation elsewhere.

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SOME ASPECTS OF THE INITIATION OF GULLY EROSION

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The initiation of gully erosion in a valley is frequently viewed as a threshold phenomenon, with incision starting when a critical power of flow is exceeded. There has been considerable examination of a range of environmental and geomorphic changes which may result in crossing of the threshold, but debate continues because there is much to be learnt about the processes of gully initiation.

Some aspects of gully initiation worthy of consideration include the influence of valley floor morphology, the stages of channel formation, and the critical shear stress for scour under a variety of conditions. Some preliminary evidence on these aspects of gully initiation has been gathered from examination of remnant unincised valleys, the stratigraphy of valley fills, and flume experiments on flow behaviour along vegetated valley floors.

The results suggest that gully initiation can be more complex than the simple exceedance of a critical shear stress. In many cases valley floors must first develop particular forms which concentrate flow and reduce the vegetation cover before erosion can begin. The dominant cover of tussock grass on the swampy meadows greatly retards flows and resists erosion but the tussocks to not grow in wetter sites of more constant flow which have a much less dense cover of sedges and are more susceptible to scour. Once scour commences, the development of a gully is not inevitable. Subsequent large events are needed as there is stratigraphic evidence of infilling of scour pools and incipient channels, preventing gully development.

The flume experiments demonstrate the role of vegetation in preventing gully initiation. The natural vegetation cover of many of the valley floors prevents scour but grazing of the sedge and grass greatly reduces retardance to flow and decreases the shear stress required to initiate erosion. Trampling by stock also reduces the resistance to scour. The data suggest that localised disturbances to valley floors may be at least as important as catchment wide increases in runoff as a cause for gully erosion.

SOME GEOMORPHIC THRESHOLDS RELATED TO GULLYING AT TIN CAMP CREEK, ARNHEM LAND, NORTHERN TERRITORY, AUSTRALIA

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The uranium mines in the top end of the Northern Territory are surrounded by national parks or reserved areas. When mining ceases these areas will have to be rehabilitated as the leases will be incorporated back into the surrounding landscape. Gully erosion is a potential hazard that may lead to the delivery of large quantities of sediment and may have detrimental effects on the surrounding streams and floodplains. The ability to predict gully erosion will be a critical aspect in the design of engineered landforms for the rehabilitation of minesites, especially the Ranger Uranium Mine. Analysis of gully development in terrains similar to that proposed for the rehabilitation structure provides a means for developing design rules. Several small catchments at Tin Camp Creek, approximately 300 km to the east of Darwin, Australia show well defined thresholds separating gullied and non-gullied catchments. A morphometric analysis of the catchments based on catchment area, slope gradient, and slope length suggests a viable approach to predicting gully erosion. The morphometric approach is a potential tool for land managers and engineers involved in rehabilitation works in the Alligator Rivers Region, particularly Ranger Uranium Mine, where 'mature' soils and landforms will probably be comparable to those at Tin Camp Creek.

INDUCED CHANGES IN A SMALL, MOUNTAINOUS CATCHMENT IN NEW GUINEA

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An experiment aimed at elucidating aspects of landform evolution is in progress in Harvey Creek, a small, mountainous catchment in the per-humid Ok Tedi region of New Guinea. Due to the daily addition of about 40,000 tonnes of mine waste to its headwaters, this formerly undisturbed, sediment-starved catchment has become relatively sediment-charged. The increase in sediment load has induced a number of pronounced changes including:

(i) Incision into the pre-existing, valley-fill deposits to expose the original bedrock channel (channel exhumation). This revealed a series of knickpoints (waterfalls) and, in the lowest reach, an 'inner channel' or slot within the bedrock.

(ii) In less resistant lithologies further incision has proceeded by knickpoint retreat, as a series of upstream migrating pulses, and by plunge pool action. Within the middle section of the catchment a band of competent monzodiorite has undergone very little change and acts as an effective base level control.

(iii) The bedrock channel has widened and the valley bottom has changed from a 'V' to a trough shape so that the channel has become more gorge like. Truncation of spurs is common but no unequivocal reduction in channel sinuosity has been demonstrated.

(iv) Incision has led also to destabilization of valley side slopes, especially on spurs; failure proceeds in an upslope direction to give the appearance of parallel retreat. However, at the zone of incision a steeper slope has resulted in convexity in the lower slope segment. With aggradation of the channel bed the lower slope, now protected, begins to stabilize and, in places, accumulated material at the base of these slopes provides a platform for footslope deposits and the development of slope concavity.

(v) Contrary to commonly held expectations, an increase in sediment load has not lead to aggradation in a down-valley sense. The reverse is true. At the confluence of the Ok Mani and its tributary Harvey Creek, accumulating fan deposits have raised base level and act as a type of barrier to enforce backfilling.

In a general sense many of the changes along the bedrock channel conform to known trends of channel metamorphosis in unconsolidated sediments. However, due allowance should be made for the influence of lithologies with different strengths, changing base level, and the role of the principle transporting mechanism - debris flows. This is an ongoing study, and the catchment is being closely monitored by a combination of fieldwork, still photography, whole catchment aerial photography and video recording.

DOWNSTREAM HYDROGEOMORPHIC EFFECTS OF WINDAMERE DAM ON THE CUDGEGONG RIVER, N.S.W.

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Windamere Dam is a 67 m high earth and rockfill dam on the Cudgegong River near Mudgee, with a storage capacity of 368,000 Ml and was closed in February 1984. The purpose of the dam is for town water supply to Mudgee and Gulgong and for irrigation in the Cudgegong valley. The response of the Cudgegong River to flow regulation was determined for 9 kilometres of river downstream of the dam where the channel is a laterally confined gravel bed stream. The dam has reduced downstream flood magnitudes for all recurrence intervals, by between 70 and 88%. Mean daily flows for durations less than 80% have been reduced by between 38 and 84% and those for durations greater than 90% have been increased by between 55 and 178%. The sediment trap efficiency is estimated to be 95 to 98% of the upstream sediment load. Channel changes induced by flow regulation were determined at eight sites. The dominant channel response was contraction of up to 30%, accompanied by degradation of up to 30%. No post-dam channel changes (accommodation adjustment) occurred at one site. Tributary mouth bars formed at five tributary junctions following dam closure because the regulated flows did not exceed threshold of motion conditions. Vegetation encroachment (Phragmites, Juncus, Casuarina) occurred at many sites for the same reason. Combined with research on other regulated streams a model showing the effects of flow regulation on laterally confined gravel-bed channels was proposed. The model predicts river response and channel recovery, allowing for differing degrees of flow regulation, following dam closure. The model is an effective tool for the prediction of river response and may be used for river management.

HYDROGEOMORPHIC IMPACTS OF EXTRACTION ON RIVER SYSTEM STABILITY

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Long term monitoring of river extraction is crucial for predicting the physical impacts on bedload transport, open channel flow and channel changes. Such a monitoring program has been carried out in the depositional zone of a large discontinuous gully on Double Swamp Creek, a tributary of the Clarence River at Grafton, NSW. Twenty permanently marked cross sections were installed before channel extraction commenced in 1987 and have been surveyed at least annually over the seven year monitoring period. Repeated surveys of cross sections, long profiles and channel planform have permitted sediment budgets to be constructed for various time periods and for channel reaches upstream and downstream of extraction holes as well as in the extracted sections.

The excavation of a large hole in the bed of a river induces three sediment transport discontinuities, namely upstream progressing degradation, progressive infilling of the excavated hole and downstream progressing degradation. Extraction on Double Swamp Creek commenced at one site in April 1987 and continued intermittently until November 1989. The removal of 2400m^3 of sand induced the three above sediment transport discontinuities, with floods eroding 278m^3 of sand from sixteen channel widths upstream of the extraction hole, 622m^3 from 29 channel widths downstream of the site and depositing 1345m^3 in the hole. Downstream of this degraded section the continuity of bed load transport was maintained. The flood in April 1988 supplied 1839m^3 of sediment to the channel. However, a subsequent larger flood in April 1989 deposited only 1210m^3. It appears that sand replenishment is dependent not only on the magnitude of the flood but also on the time interval between successive floods. After November 1989 extraction was extended to two new sites downstream. Between 1987 and January 1992 3911m^3 of sand have been extracted from the three holes. Consequently a total sediment deficit of 2824m^3 now exists over 81 channel widths. The interaction of upstream and downstream degradation from the three holes has now induced extensive degradation in the former stable section downstream of the original extraction hole. The flood in December 1991 was the largest for the last fourteen years but supplied only 812m^3 of sediment to the channel. It is apparent that the upstream sediment stores in the gully are greatly depleted and successive floods can no longer supply sediment to replenish extraction. Limits on extraction volumes are necessary to maintain the natural stability of the system.

RIVER RESPONSE TO HYDRAULIC GOLD MINING

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Hydraulic gold mining took place between the 1850's and 1920's in several parts of eastern Victoria including Yackandandah Creek (Kiewa River basin), and the Tambo and Ovens river basins. Geomorphic impacts of alluvial tin mining in Tasmania have been investigated, but no other Australian examples of river response to hydraulic mining appear in the literature. The investigation of hydraulic gold mining impacts on Yackandandah Creek and the Tambo River drew partly from this Tasmanian work, but primarily form the hydraulic gold mining experience in the Californian Sierra Nevadas.

Neither Yackandandah Creek nor the Tambo River have fully recovered from high bed material loads induced during hydraulic sluicing and dredging for gold, and consequently present unusual problems to stream and catchment managers. On Yackandandah Creek the channel response has been complex. Hydraulic mining debris remains active in the source reaches where the channel is very wide and straight, and susceptible to bank erosion. Much bed material has been transported through the narrower downstream reaches, which have degraded by up to 2.7 m over the last 55 years, and may still be degrading. A number of short channel avulsions have taken place upstream of the Kiewa River confluence, resulting from the accumulation of hydraulic mining debris in this reach. The lower reaches of the Tambo River are characterised by slow migration of hydraulic mining debris as a sand slug or bed material wave. Bed aggradation following the passage of this sand slug caused a 12 km channel section to avulse during a large flood in 1893. The upstream sources of hydraulic mining debris are now exhausted and the bed has been degrading on the upstream tail of the sand slug for the past 30 years. In both systems, the stream and catchment management priorities focus on the need to control sediment movement through the basin.

HYDROLOGICAL CHANGES IN THE AVOCA RIVER CATCHMENT, NORTHERN VICTORIA.

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Abnormally high incidences of flooding and filling of terminal lake systems since the early 1970s, despite a 'normal' rainfall regime, led to the hypothesis that the Avoca River catchment and its neighbouring catchments in north western Victoria have experienced a change in their hydrological regime. This study is testing this hypothesis for the unregulated Avoca River catchment and establishing the cause of any identified change.

Detailed analysis of discharge and flood peak time series data reveal that since the early 1970's there has been a shift in the flow duration curve such that the frequency of all flows has increased. Results from similar detailed analysis of rainfall time series data show that this change in the hydrological regime is not paralleled by a change in the rainfall regime. This means that there must have been a change in the rainfall-runoff relationship in the Avoca River catchment and this has been confirmed using a simple catchment model.

Possible catchment changes which could result in this type of change in the rainfall runoff relationship include:

a) changes in landuse - deforestation, increase in agriculture, change in agriculture practices, and mining;
b) drainage network extension; and
c) rising groundwater tables.

Temporal changes in landuse, deforestation practices, and drainage network extension prior to the early 1970s have been analysed and no changes are sufficiently large to be a probable cause of a shift in the frequency of flows. This implies that the change in the rainfall-runoff relationship may be a result of rising groundwater tables; a detailed analysis of temporal changes in the depth to groundwater is in progress. Recent work on a small catchment in Western Australia has revealed that rising groundwater tables can result in a significant increase in river discharge through an increase in the quantity of direct runoff and baseflow (Ruprecht & Schofield, 1989. J. Hydrology,105:1-17). Parts of the upper Avoca River catchment exhibit groundwater tables close to, or at, the surface and, as with many of the other northern Victorian catchments, the area affected by rising groundwater tables is increasing. It is important to establish whether rising groundwater is resulting in increasing discharges in large catchments because such effects have major implications for catchment management.

SATURDAY 25TH APRIL

AFTERNOON SESSION

RIVER STYLES: FORM, PROCESS & EVOLUTION

A GENETIC CLASSIFICATION OF FLOODPLAINS

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Floodplains are formed by a complex interaction of fluvial processes but their character and evolution is essentially the product of stream power and sediment character. The relation between a stream's ability to entrain and transport sediment and the erosional resistance of floodplain alluvium that forms the channel boundary provides the basis for a genetic classification of floodplains. The purpose of this paper is two fold: firstly to review observations on the formation of floodplains and secondly, to develop a classification that highlights both the distinctiveness and interconnectedness of these complex landforms. The classification presented here is an energy-based systematic ordering of floodplains of varying morphological and sedimentary character. In theory, the sequence can occur in any single drainage basin from source to mouth but it is likely to be only partially represented along an individual river and not necessarily in an entirely predictable downstream pattern.

The classification recognises three floodplain classes (based on stream power and sediment characteristics) and a combination of thirteen floodplain orders and suborders (based on primary and secondary factors, largely geomorphic processes). The three classes are:

1) High Energy Non-Cohesive;
2) Medium Energy Non-Cohesive; and
3) Low Energy Cohesive Floodplains.

Thirteen derivative orders and suborders, ranging from confined, coarse-grained, non-cohesive floodplains in high energy environments to unconfined fine-grained cohesive floodplains in low energy environments, are defined on the basis of nine factors (mostly floodplain forming processes). These factors result in distinctive geomorphological features (such as scroll bars or extensive backswamps) that distinguish each floodplain type in terms of genesis and resulting morphology. It is proposed that, because floodplains are derivative of the parent stream system, substantial environmental change will result in the predictable transformation of one floodplain type to another over time.

Like all classifications, this one involves simplification and a resultant loss of information. However, the hierarchy of floodplain types forms a logical pattern that may help to focus research by drawing attention to poorly understood aspects, such as the formation of braided river floodplains and the variety of types of anastomosing floodplains and their causes. Research in this area is incomplete and further work will contribute to modification of this scheme.

DOWNSTREAM VARIATIONS IN MODES OF FLOODPLAIN FORMATION ON WEBBS CREEK, NSW.

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The aim of the project was to investigate the processes of floodplain formation on Webbs Creek a tributary of the Hawkesbury River in Central Eastern NSW. The channel flows through a highly dissected sandstone plateau.

Webbs Creek was found to be a laterally stable, sand bedded stream which formed its floodplains by vertical accretion processes. A downstream reduction in channel size was found to be caused by an increase in the percent of silt and clay in the channel boundary sediments and also a decrease in baseflow between link lengths.

It was found that the floodplains were in various stages of development downstream. The upstream reaches were well developed, vertically accreted floodplains with large channels, low flood frequencies and evidence of floodplain destruction. The middle reaches had actively forming floodplains, with small channels, high flood frequencies and little floodplain destruction. Here a floodplain of sandy deposits is forming over estuarine deposits of a drowned river valley, with rapid rates of levee development. The downstream reaches have estuarine floodplains and large tidal channels.

Therefore the downstream changes on the floodplain of Webbs Creek represents a continuum of floodplain development. The downstream development of the fluvial floodplain and the eventual process of floodplain destruction will have important implications for the future of agricultural land in the area.

FORM AND PROCESS ON ALLUVIAL FANS - EXAMPLES FROM ANTARCTICA AND NEW ZEALAND

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Alluvial fans are formed largely by catastrophic processes (debris flows or sudden floods), and are slightly modified by the day-to-day processes of alluvial channels, which serve merely to rework the sediments deposited by the catastrophic events. Alluvial fans dominated by debris flows tend to be smaller and steeper than those deposited largely by flooding events, and have smaller catchments. Nevertheless, debris flows often occur on fans deposited by flooding processes, where they are frequently responsible for diversion of the fan stream to a different portion of the fan. They may also be partially responsible for fan head trenching.

These characteristics of alluvial fans are common to fans deposited in arid freeze/thaw environments (Antarctica) as well as those forming in humid cool temperate conditions (New Zealand).

SLACKWATER DEPOSITS AND PALAEOFLOODS ON THE NEPEAN RIVER: IMPLICATIONS FOR THE SPILLWAY CAPACITY OF WARRAGAMBA DAM

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Investigations by the Sydney Water Board into the capability of Warragamba Dam to safely discharge large magnitude floods has revealed an inadequate spillway capacity. Recent increases in the estimated Probable Maximum Precipitation (PMP), indicate that a Probable Maximum Flood (PMF) with a peak discharge of 40,000 $m^3 s^{-1}$ could occur. This PMF is twice the safe discharge capacity of the original spillway which was designed to pass the then (1960) estimated PMF. Modifications to the dam are proceeding in two stages (with Stage 1 completed) to enable the safe discharge of the PMF.

The largest recorded flood on the Nepean River with a peak discharge of 16,600 $m^3 s^{-1}$ occurred in 1867 and has a return period of 100 years at the Warragamba River at Nepean Junction gauging station. Detailed field descriptions and particle size analyses of sediments at six sites in the Fairlight Gorge below Warragamba Dam identified high level flood deposits. Slackwater deposits (SWD's) are typically fine grained sand and silts, which accumulate rapidly from suspension during large floods in areas where flow velocities are reduced. However, the higher level SWD's were too thin and bioturbated to be clearly differentiated from locally derived colluvium. Heavy mineral analysis of the fine sand fraction of these high level SWD's found minerals (epidote and pyroxene) that were not present in the surrounding bedrock. Epidote and pyroxene were derived from distance sources and were emplaced by at least one palaeoflood. A radiocarbon date of 3756 +/- 72 yrs BP was obtained by tandem accelerator mass spectrometry on small fragments of charcoal contained in the high level SWD's. Therefore at least one palaeoflood larger than any historic flood occurred during the late Holocene. SWD,s indicated that the largest palaeoflood has a discharge of at least 30,500 $m^3 s^{-1}$ and a return period of about 1,000 years. If such a flood had occurred before the completion of stage 1 modifications the dam would have sustained substantial damage and may have failed. Stage 2 modifications are still being discussed but we recommend that they should be completed as soon as possible to allow Warragamba Dam to discharge safely, floods with magnitudes similar to the largest palaeoflood, indicated by SWD's.

CHARACTERISTICS AND FORMATION OF BRAIDED RIVER FLOODPLAINS, WAIMAKARIRI RIVER, SOUTH ISLAND NEW ZEALAND.

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The existence of floodplains along braided rivers has been questioned for decades as few details are available of their morphological characteristics and mechanisms of formation. Floodplains along the gravel, braided Waimakariri River, are discontinuous although generally extensive landforms composed predominantly of basal gravel bars capped with vertically accreted fines. Infilled secondary braid channels are common in some floodplains.

Three mechanisms initiate floodplain development along the Waimakariri River.

1) Riverbed abandonment by lateral migration of the braid-train initiates the formation of the largest and most common floodplains. These usually occur downstream from tributary fans and bedrock spurs.
2) Localised riverbed aggradation, often resulting from high magnitude floods, also initiates floodplain development. These are the second most common floodplains and usually occur in the headwaters of the Waimakariri River.
3) Localised channel incision is the least important mechanism and usually occurs in association with riverbed aggradation, riverbed abandonment, or both.

A six stage model, based on dendrochronology, vegetation associations and time lapsed aerial photography, is proposed for the sequential development of floodplains from:

i) active riverbed;
ii) stabilising bar;
iii) incipient floodplain;
iv) floodplain;
v) mature floodplain and
vi) terrace.

Three mechanisms, in order of importance, are responsible for the reworking and hence relatively young age (<350 years) of Waimakariri River floodplains:

a) lateral migration by the braid train
(a three phase model illustrates the formation and erosion of floodplains and terraces by this process);
b) reactivation of abandoned channels within floodplains; and
c) catastrophic stripping.

These three mechanisms may operate in combination, but frequently one will dominate at an individual site. Clearly, braided rivers can produce substantial areas of well developed floodplain even in high energy alpine environments.

THE DEVELOPMENT OF THE PIONEER RIVER, NORTH QUEENSLAND

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The Pioneer River is a comparatively short coastal stream which flows into the sea at Mackay, North Queensland. The river rises in the largely granitic coastal highlands with elevations of 1000 to 1200 m AHD some 80 km from the coast. The total catchment is only 1375 km^2 yet flood flows of up to 9800 $m^3 s^{-1}$ have been recorded since 1917. The catchment can be divided conveniently into three parts; the Upper Pioneer, Cattle Creek (the river's principal tributary) and the Lower Pioneer below the confluence of the Upper Pioneer and Cattle Creek (Fig. 1).

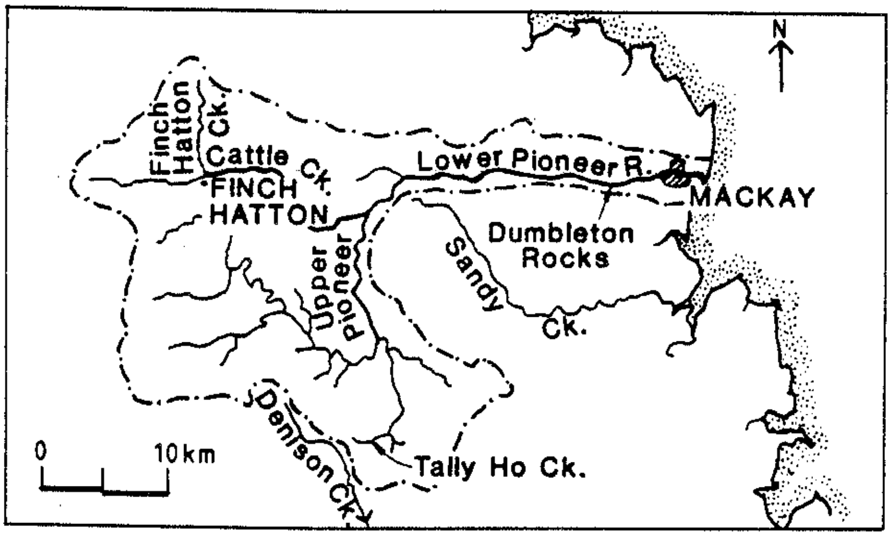

Figure 1: The Pioneer River Catchment

Most streams flowing into the Upper Pioneer follow the general northwest - southeast structural trend of the region. The profiles of these streams and the Upper Pioneer are markedly stepped and it is proposed that these streams used to flow into the Fitzroy system via Funnel Creek. Some river capture has since taken place and further capture will probably occur eventually between Tally Ho Creek and Denison Creek. By contrast, Cattle Creek and its tributary, Finch Hatton Creek, follow much simpler courses. Their profiles are not stepped and their drainage pattern is dendritic. The Lower Pioneer valley is notable for the fact that the catchment boundary follows the southern river bank for over half its length and there are no tributaries flowing into the river from the south. Furthermore, a substantial portion of the river bed in this reach is formed of bed-rock. The river then reaches its estuary immediately below Dumbleton Rocks, a series of rocky cascades, which form the tidal limit to the estuary.

It is suggested that Cattle Creek has developed along the Pioneer lineament, a line of geological weakness in the region, probably during late Tertiary and early Pleistocene times. This development would have followed the last stages of uplift of the coastal ranges and been assisted by weather conditions associated with periods of intense rainfall. In recent times, 530 mm has fallen in five hours at Finch Hatton on Cattle Creek. Heavy rainfall events in the Pioneer catchment are associated with tropical cyclones or southerly excursions of the monsoon trough. Such conditions were unlikely to prevail during periods of low sea-level or when this part of the Australian continent was situated further south. Subsequently and progressively, maybe during the Pleistocene, river capture of the Upper Pioneer system from the Fitzroy system occurred. At this time the pre-cursor of the Pioneer River probably flowed to the sea via Sandy Creek. Much more recently and quite possibly within Holocene time, and perhaps during a particularly large flood event, the Lower Pioneer River adopted its present, almost straight, course to the sea. The deposits in the Pioneer estuary are also indicative of the fact that the river has only occupied this location for a comparatively short time.

LATE QUATERNARY FLOODPLAIN EVOLUTION ON THE MACDONALD RIVER, NSW.

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Floodplain form and process has attracted less research interest by fluvial geomorphologists than aspects of channel form and process. Large scale and simplified facies models of floodplain development such as the meandering stream/point bar model have been well developed but these are not applicable to all streams or do not adequately explain the transition from one stage to another within the evolution of a floodplain as a result of

i) external adjustments to the fluvial system such as the Holocene marine transgression or
ii) responses to the exceedance of critical internal thresholds such as changes in channel and floodplain slopes.

Many coastal streams in south-eastern Australia have relatively young floodplain sediments (< 10,000 ka) overlying older estuarine units or previous valley fill deposits. Many of these streams are sand bedded and laterally confined and appear relatively stable in the historical past. The floodplains show extensive features of vertical accretion deposits and therefore these streams do not conform to the standard meandering stream/point bar model of floodplain development.

The Macdonald River floodplain exhibits some large features of vertical accretion on a very confined floodplain with some natural levees showing relief of up to 10 metres. A series of floods in the 1950's has had a dramatic impact on the channel of the Macdonald River but little is known about the impact of such floods on the floodplain.

Initial research has been undertaken to investigate the Late Quaternary history of the Macdonald River floodplain and to identify the relationships that may exist between the channel and floodplain elements based upon stratigraphic and sedimentological evidence. This information will assist in developing a model that explains the mode and timescales of formation of the floodplain and also help assist in determining the relative importance of external and internal adjustments to the fluvial system in floodplain evolution.

PATTERNS AND PROCESSES IN ARID ZONE FLUVIAL SYSTEMS

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Central Australian floodplains contain features suggesting activity at three scales. At the largest scale, there is a set of landforms whose appearance suggests a fluvial origin but which are much larger or more widespread than those associated with currently active river systems. These large scale landforms set the basic configuration of the floodplain and have not changed significantly since air photographs became available in about 1950. They are believed to result from a small number of huge floods. Set within the very large fluvial landforms, and at a smaller scale, are the active floodplain systems of the modern creeks and rivers. These landforms show considerable change over the period 1950-1989 which contains some of the largest floods of the last 900 years. Superimposed on both the active floodplain systems and the large-scale fluvial landforms is a third set of erosional and depositional features: the erosion cell mosaic. The mosaic consists of small overlaid and interlocking erosion cells, each consisting of a scour zone, a transport zone, and a deposition zone or sink. The erosion cell mosaic develops in response to localised runoff and associated redistribution of sediment. It may also be activated in areas close to rivers when floodwater spills out of the main channels.

Equilibrium-based floodplain forms do not develop because the events that shape the large-scale morphology of floodplain systems are so big that only a few of them have occurred in the most recent period of floodplain evolution. Each event produces drastic changes, so present-day morphology is more closely related to the last flood than to a whole sequence of floods.

Below the regional scale and set within the large flood-related landforms, the floodplain can be divided into the channel-levee complex associated with the modern river and the areas beyond it, where little or no sediment is delivered. Areas beyond the channel-levee complex remain largely unchanged between the great floods or develop erosion cell mosaics. Channel-levee complexes may be scoured extensively or even destroyed during great floods only to build up again in the intervening period. Therefore, they may be regarded as constructional landforms whose rate of development depends on the amount of sediment delivered from upstream and the number of smaller flood events experienced.

Away from the channel-levee complexes, in areas dominated by erosion cell mosaic structures, existing models of floodplain behaviour have little relevance. Virtually no sediment is delivered except during the huge floods and for most of the time, the landscape operates as a closed system with respect to sediment. Sediment redistribution within that system is probably rapid immediately after the huge floods, but once vegetation begins to colonise newly deposited sediment, the erosion cell mosaic develops more slowly. Once in place, the development of a mosaic is probably not reversible in the short term because sediment always moves downslope and there is no resupply from primary sources in the ranges until the next great flood.

FLOODPLAIN SEDIMENTOLOGY OF THE CLARENCE RIVER DOWNSTREAM OF GRAFTON: PRELIMINARY RESULTS

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The Clarence river valley, with a catchment of about 22, 000 km^2, is the largest eastward-draining river in NSW. Floodplain development is minimal upstream of Grafton, constrained primarily by valley width. Beyond Grafton is a broad flood basin. Channel configuration in this lowland basin has been controlled by events in the past, especially the incised nature of the channel during lower sea level intervals at times of glacial maximum. This study examines the character of floodplain response to these antecedent controls.

The study reach, between Grafton and Maclean, is made up of a wide range of channel, levee, ridge, alluvial flat and swamp units. These occur over a range of scales, with differing spatial associations in different zones of the floodplain. By focussing on three contrasting floodplain zones it is hoped to unravel controls on the character and distribution of differing floodplain styles, such that a realistic perspective on the complexity of floodplain sedimentology can be attained. This will be achieved by linking one-dimensional core/auger log data with two-dimensional section and subsurface data (using Ground Penetrating Radar) to gain a three-dimensional "model" of floodplain character. Principles of architectural-element analysis, based on lithosome geometry and bounding surface hierarchies, will be applied.

The active floodplain of the Clarence River in the study reach can be divided into two types: i) zones in which distributary/flood-out channels are parallel to the main channel, and ii) zones where these channels are perpendicular to the main channel. The Grafton and Woodford areas are characterized by parallel flood-out channels, while a NW-SE cross-section from Cowper to Tucabia across the Ulmarra floodplain clearly demonstrates flood-out channels both parallel and perpendicular to the main channel. Six different varieties of channel and levee unit have been identified, based on their scale and probable origin. Bedform-scale facies types within these units vary as differing facies associations of clay, grey fine sand, deep brown fine sand and medium sand.

Given the complexities of these geomorphic units and their facies association, it is evident that reliable interpretations of past-environmental reconstruction can only by assessed by detailed three-dimensional knowledge of sedimentary facies at a range of spatial scales.

EVOLUTION OF ANASTOMOSING CHANNELS ON THE RIVERINE PLAIN, AUSTRALIA

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Anastomosing channels are the characteristic stream pattern of the Riverine Plain and exhibit well defined multiple channels separated by floodplain. Investigations of the Ovens and King Rivers in north-eastern Victoria have shown that the individual channels vary markedly in channel morphology and age. Developing (i.e. young) channels have large capacities, large wavelengths, low sinuosities and are very unstable. They have the appearance of incised channels and have rapidly eroding bed and banks. Older channels, on the other hand, have small capacities, small wavelengths, high sinuosities and exhibit systematic lateral migration with cutbank erosion and concomitant point bar deposition. The multiple channels develop by avulsions. As the individual channels become older and more sinuous, they also become hydraulically inefficient. Thus increasing proportions of flood peak discharge are displaced overbank. This overbank flow concentrates in relatively straight floodplain depressions and erodes a new channel which develops by both upstream and downstream progressing degradation. Downstream progressing degradation is initiated at outflow points and upstream progressing degration is initiated where the overbank flow rejoins the main channel. Over time, both upstream and downstream developing channels coalesce to form an avulsion. Up to two avulsions have occurred over the last 150 year and are caused by internal adjustments. External causes have been invoked too often in the past to explain channel avulsions in the absence of a detailed understanding of the evolution of anastomosing channels. The Riverine Plain channels contrast to those in Canada and South America.

Floodplains are characterised by multiple, coarse-grained lateral accretion deposits encased in fine-grained vertical accretion deposits. Although splay deposits are present they are not as common as in other types of anastomosing channels.

Avulsions and lateral migration are major river management problems. An understanding of the evolution of anastomosing channels has enabled river managers to work with rather than against nature.

ABSTRACTS OF POSTERS PRESENTED AT THE CONFERENCE

DARLING RIVER CATCHMENT DRAINAGE EVOLUTION

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The Darling River Catchment occupies an area of about 640,000 sq km in southeast Australia. Topography ranges from an elevation of approximately 50 metres in the southwest to more than 1000 metres along the Eastern Highlands crest. Geologically, the catchment is best described as an intracratonic Cainozoic basin consisting mainly of continentally derived sediments. Bedrock areas (metamorphic rocks, granite, sandstone and shale) range in age from Ordovician to Cretaceous and form an elevated and dissected landscape around the margin of the catchment.

A drainage map at a scale of 1:1 million shows erosional areas of the catchment typified by various patterns of dendritic drainage. 'Normal dendritic' occurs on Mesozoic sediments in the north and west of the catchment which display a uniform lithology, shallow dip and open structures; 'radian dendritic' forms across Tertiary volcanic centres such as the Warrumbungles, Nandewars and Canobolas and 'modified dendritic' responds to bedrock structures along the eastern margin of the catchment and modifications resulting from Tertiary volcanic activity. Drainage in the central depositional area comprises braided channels and distributory systems typifying a "riverine plain".

Drainage origins are Mesozoic and associated with a "Gondwanaland landscape". Upwarping along the east of Gondwanaland in the Late Cretaceous - Early Tertiary reversed in part an ancient north-northwest directed drainage towards the Tasman Sea. The remains of this ancient drainage in the Darling catchment, now skewed to the southwest, developed through the Cainozoic primarily in response to basement reactivation associated with continental breakup eg, Darling lineament, and the need for this younger southwest drainage to find a new base level and outlet to the sea via the Murray River. The antiquity of the north-northwest drainage is evidenced in part by its coincidence with the structural grain in the Palaeozoic basement.

DENUDATION IN SOUTHEASTERN AUSTRALIA - A LONG -TERM MACROSCALE APPROACH

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Apatite Fission Track Analysis (AFTA) and palaeotopographical reconstructions suggest that coarse denudation rates, predominantly for mainland southeastern Australia east and south of the continental drainage divide, have varied considerably since the early Cretaceous.

The usefulness and limitations of the methodology applied to obtain the rates are discussed, and some of the implications with respect to the long-term evolution of the southeast Australian margin are outlined.

EXAMPLES OF ICE DAMMING IN THE SOUTH EAST CORNER OF THE VESTFOLD HILLS, EAST ANTARCTICA

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An ice dam with a former impoundment volume of $1.1 \times 10^6 m^3$ is reported from the Vestfold Hills, East Antarctica. The ice of the dam was derived from wind-drifted snow subsequently changed into ice by normal summer melt and freeze processes. The reformation (after 1979 and 1987) and failure of this ice dam (during 1987 and 1990) indicates the potential for the release of geomorphologically significant flows in a polar climate.

The origin of a nearby fluvially eroded channel is attributed to the release of an ice-dammed impoundment. The potential of such flows for reworking glacial debris may be important when considering the sedimentology of former proglacial areas.

ASSESSING THE ACIDITY HAZARD POTENTIAL OF ACID SULPHATE SOILS ON NSW COASTAL FLOODPLAINS

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Acid sulphate and potential acid sulphate soils are widely distributed in the coastal floodplain sediments of NSW. Pedogenesis in these coastal floodplains has been dominated by the oxidation products of the pyritic estuarine substratum, by periodic water table movements, and the properties and thickness of the overlying fluviatile sediments. These conditions have resulted in the development of highly complex soil profiles, often with acid sulphate and potential acid sulphate soils at depth. When these previously reduced soils are drained due to either natural or artificial lowering of the water table, pyrite is oxidised to sulphuric acid.

With assessment of agricultural suitability of land and the ecological impact of development it is important to determine the maximal possible potential acidity after reclamation and drainage of the soil. A method based on the rapid soil-base titration of samples oxidised using hydrogen peroxide has been used to estimate the total potential acidity (TPA) hazard on a number of soils from the floodplain sediments of Webbs Creek, a tributary of the Hawkesbury River, NSW.

The TPA and total actual acidity (TAA) values provided a good indication of the acidity hazard potential of acid sulphate soils at Webbs Creek. Also, the determination of TPA provided the means by which a calculation of the quantity of lime needed to neutralise a particular soil could be made.

The distribution of acid and potential acid sulphate soils at Webbs Creek were determined to be causally related to topographic variations from the levee to backswamp. The acidity hazard was determined to be minimal for current agricultural land practices which do not include deep floodplain drainage. Due to the downstream movement of fluviatile sands, the pyritic sediments are progressively being buried by greater quantities of alluvium, further decreasing the acidity hazard. However, the excavation or reclamation of these sediments have been shown to cause detrimental effects on a local scale, including the death of vegetation and increased acid-rich waters. Unfortunately Australian soil classifications do not account for acid and potential acid sulphate horizons. This may be seen as the result of the very limited research and recognition of acid sulphate soils in Australia.

SEASONAL SCOUR AND FILL REGIME ON FRASER RIVER, BRITISH COLUMBIA, CANADA.

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Water Survey of Canada gauging data for Fraser River at Marguerite in British Columbia reveal a strong annual periodicity in bed elevation conditioned by the seasonal snowmelt regime. As discharge increases in spring the bed level remains stable for flows below about 1500 m^3s^{-1} but scouring occurs above this threshold discharge. Maximum scour occurs in synchrony with the annual peak discharge in June when average bed level typically falls rapidly to about 1.0 lower than the level in winter. During the lower flows of the fall and winter months bed levels slowly recover to their approximate pre-scour levels.

Annual turnover in bed material in this reach of the river therefore amounts to about 200,000 m^3/km of channel length. Channel scour releases local interstitial fines from the bed which augment the suspended-sediment load and produces a discontinuity in the suspended-sediment rating curve at the threshold discharge. Related discontinuities in mean flow characteristics and the at-a-station hydraulic geometry signal the abrupt transition from rigid to alluvial boundary conditions at the threshold discharge. These effects also are apparent at other gauging stations (Hope, Agassiz, and Mission) along the lower Fraser River.

This distinction between rigid and alluvial at-a-station hydraulic geometry provides a basis for estimating the corresponding threshold discharge for the onset of channel scour (a local negative sediment budget). The relationship between the onset of scour and the initiation of bedload transport remains unspecified, however, and suggests a potentially fruitful line of enquiry.

ACID SULPHATE SOIL IN RELATION TO LANDSCAPE CHARACTERISTICS IN COASTAL N.S.W.

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Coastal reclamation has increased the acid sulphate soil problem in N.S.W. coastal lowlands. This involves the release of toxic substances from acid sulphate soils into estuarine ecosystems. Recent studies at several sites allow a preliminary examination of the relationship between the occurrence of acid sulphate soil and coastal landscape evolution.

Acid sulphate soils are characterized by the oxidation of accumulated iron pyrite which is commonly generated within the intertidal zone. The existing status of pyritic sediment in terms of its extent, pyrite content, thickness, occurrence depth and intensity or sulphurification are closely associated with a variety of factors such as sea level change, coastal embayment type, tide and wave characteristics, fluvial sediment supply, vegetational evolution and land use. The present study suggests that the pyritic sediments in coastal N.S.W. are basically confined to sheltered sites because relatively high wave energy of the nearshore area of the N.S.W. coast creates an unfavourable environment for pyrite formation. This, together with low sediment supply due to small river catchments, often limits pyritic sediment distribution. However, exceptions occur in some northern estuaries where larger rivers with greater sediment loads debouch. In such situations, pyritic sediments may have relatively widespread distribution within the larger floodplains. Although the extent of pyritic sediment is relatively limited, the potential sulphuric acidity is great owing to longterm maintenance of the pyrite layer at a given location.

The results also show significant differences in occurrence depths of pyritic layers among differing estuary types and varying geomorphic positions within an estuary. There is a tendency for increasing depth of the pyritic layer with increase of estuary size and fluvial sediment supply. Within a floodplain, the pyritic layer may occur at a much greater depth in the levee than in the backswamp. This has implications for estuary degradation following artificial drainage when there is no recognition of pyrite existence when planning drain elevations.

Although most acid sulphate soil problems occur where iron pyrite is associated with clayey sediments, several major problem areas have recently been found to occur with pyrite accumulations in sandy sediment. The lack of buffering capacity from clays in these areas may cause more severe acidity problems if improperly drained.

Sulphurification of pyrite following land reclamation and associated drainage in N.S.W. coastal lowlands is generally not as severe as most acid sulphate soil areas in the world. However, overdrainage in some coastal backswamps has led to production of a variety of pH-dependent elements to a toxic level which have actually contaminated estuarine ecosystems. Massive fishkills following heavy rain after dry seasons in northern N.S.W. coastal areas is attributable to such acid-associated pollution and it now appears that the fish disease EUS is also involved.

SUSPENDED SEDIMENT CONCENTRATIONS IN THE TULLY RIVER AND ROCKINGHAM BAY DURING THE 1990 WET SEASON

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Cyclonic activity in north Queensland in late March, 1990 resulted in a peak discharge in the Tully River (c.1 475 km^2, floodplain cleared for sugar cane and banana growing and improved pasture) of 1,000 cumecs (3rd in magnitude this century) in an event with a duration of five days. During this and subsequent runoff events, turbidity in the Tully River, in adjacent Rockingham Bay and at sites on fringing reefs on offshore continental islands was monitored (when sea state permitted). Suspended sediment concentration (SSC) was calculated from turbidity using a regression relationship. Two overflights of Rockingham Bay were undertaken (Fig. 1). The results of these observations are reported.

SSC and Q prior to commencement of rainfall (19.3.1990) were 5.5 $mg.l^{-1}$) occurred 11 hours before the flood peak, this being the average time by which Q lags SSC for the 6 peaks monitored. The maximum lag (25 hrs) is associated with the first Q peak (also the first significant rainfall of the season) and may be attributable to greater sediment availability. However, there is no evidence in the overall dataset of sediment depletion.

The maximum SSC recorded in Rockingham Bay was 12 $mg.l^{-1}$, the maximum at fringing reef sites was 10 $mg.l^{-1}$ and the highest mean for the three fringing reef sites nearest the river mouth was 8 $mg.l^{-1}$. Sediment plume movement was northeastward, toward fringing reefs in the vicinity of Bedarra and Dunk Islands.

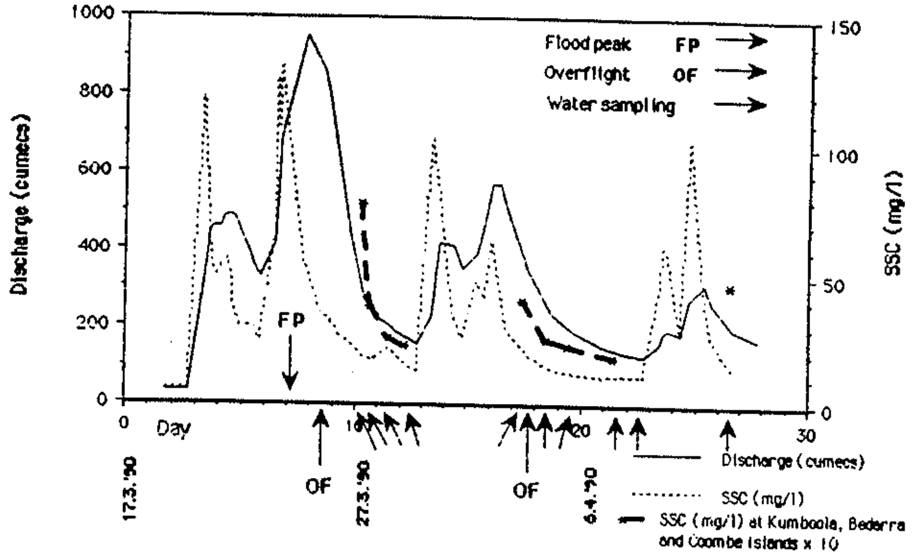

Fig.1: Times of overflights and water sampling in Rockingham Bay in relation to river discharge and sediment concentration (March-April, 1990). Also shown are the mean sediment concentrations at Kumboola, Bedarra and Coombe Islands for each sampling. Note that these concentrations are exaggerated by a factor of 10.

THE ASSOCIATION BETWEEN OUTBREAKS OF ULCERATIVE FISH DISEASE AND EXISTENCE OF ACID SULPHATE SOILS

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Incidents of ulcerative fish diseases have increased in native estuary fish stocks in Australia and South-East Asia since about 1970. As well, outbreaks of these diseases are increasing in cultivated freshwater fisheries in the region. This threatens both major existing protein resources for human consumption and also a key potential export industry in a region where population growth pressure and need for economic development are great. The cost, in terms of fish losses and control measures, now exceeds $10 m per annum and this figure is accelerating rapidly.

Recent work by Calinan and Fraser has established the aquatic oomycete fungus Aphanomyces sp. as the causative agent of Epizootic Ulcerative Syndrome, EUS (sometimes inaccurately termed "red spot"). Increasingly this specific disease is being recognised as the main ulcerative fish disease condition of the region. The fungus causes massive tissue destruction but is unable to invade the intact skin of healthy fish. Early indications from this research suggest that water quality characteristic of low pH and high dissolved aluminium concentrations causes the non-specific skin damage seen in early stages of outbreaks and that this allows invasion by Aphanomyces. Although EUS was only first reported in Australia from the Burnett River in 1972, it now shows a seasonal recurrence from many coastal areas of northern and eastern Australia. Typically, outbreaks occur in lower river catchments after periods of prolonged rain.

Waters with these acidic characteristics are also associated with run-off or drainage from areas with acid sulphate soils and there is now a clear geographic correlation between the disease outbreaks and the known or expected existence of this soil type. Nevertheless, reasons for the apparent onset and spread, or of the timing of outbreaks in relation to river hydrology/water chemistry, are not well understood. It seems likely that Aphanomyces was first introduced to Australia before 1972 but that there may have been subsequent other introductions. Ballast/bilge water from overseas ships could be involved in this introduction but much of the spread is likely to have been by fish migration. Our understanding of the relationships between river hydrology/water chemistry and disease outbreaks is hampered. Firstly, by insufficient information on the biology of Aphanomyces and the exact disease process, particularly with respect to water quality. Secondly, by uncertainties about the chemical oxidation processes in acid sulphate soils arid of their hydrological behaviour in relation to flows in drains or rivers where disease outbreaks occur. The simple equating of EUA-affected fish to a place of capture and existing water quality is inappropriate because the actual insult to the fish that predisposed it to pathogen invasion occurred at some unknown earlier time and place. Water quality and flow changes at a site in the estuary, and of most fish species movements, are maximal during the flood events with which EUS outbreaks are associated.

Our on-going research program intends to answer many of the questions concerning this disease and to develop management options to minimise EUS outbreaks. One first step is to develop a model of estuary genesis that predicts the distribution of palaeo-salinily that limits the accumulation of iron pyrite and therefore, development of acid sulphate soils.

KARST DEVELOPMENT IN TERTIARY LIMESTONES CAPE RANGE, WESTERN AUSTRALIA

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Evidence of two major periods of cave formation can be seen in the Miocene limestones of Cape Range, WA. Some evidence of previous wetter conditions exist but the present conditions are that of a semi-arid climate with occasional episodes of intense cyclonic rainfall which is very effectively drained into the cares. The area is very cavernilerous for such a semi-arid area.