Appendix 1 Additional information

A1.1 Magela Creek floodplain: Summary of the data contained in ARRGIS

eriss has a number of data sets held in a Geographic Information System (GIS) of the lower Magela Creek. This GIS, named ARRGIS, has been developed as a joint project with NTU using ARC/Info software. The development work on ARRGIS was done by Chris Devonport while he was with the NTU.

The system is set up in a well organised directory structure on the SUN Sparcstation 2. This structure reflects the various elements that make up an ARC/Info GIS. This document summarises those elements.

Data

This directory serves to store raw data imported from various sources. These may be elevation data points in an ASCII file, scanned images (RGB or monochrome) of maps or aerial photographs, images acquired by scanners on satellites (eg MSS, TM, SPOT), or digital data from other GIS or mapping systems.

The following types of data are included, each in their own directory with their own 'about' files giving more detail at each level in the hierarchy:

elev:

A data file of topographic surface arranged as a set of x,y,z locations where x,y are AMG coordinates and z represents surface elevation (ie a DEM)

landu:

Black and white A0 scanned images of two landunit maps of the Magela Creek catchment area before processing and conversion to a polygon coverage

photo:

Colour scanned images of aerial photographs before processing (correcting for tilt and relief) and georeferencing. (Note: scanned images which are not intended to be processed or georeferenced are stored in the 'images/pics' directory).

soil:

Black and white A0 scanned images of three soils maps of the Ranger monitoring area before processing and conversion to a polygon coverage

tm:

Landsat thematic mapper (TM) image of the Magela Creek Catchment area

About ELEV Data

Digital elevation data of the Magela Creek catchment including, and downstream of, the Ranger Uranium Mine.

elevxyz is an ASCII file in the following format:

```
1,257000.03,8646844.33,3.02
2,257000.09,8646794.65,2.95
...
...
553490,276757.30,8605167.90,19.78
```

553491,276757.70,8605097.90,19.98
END

elevz is an ASCII file in the following format:

1,3.02
2,2.95
...
...
553490,19.78
553491,19.98
END

Documentation has not been sighted for this data but the following is believed to be correct:

- the x,y,z data were prepared from aerial photographs using conventional stereophotogrammetric techniques by AUSLIG around 1984
- eastings and northings are in AMG coordinates, elevation is in metres
- the are 553491 data points mostly in a grid pattern with a resolution of 30–35 metres. There is a higher concentration of points along drainage channels
- accuracy is thought to be 0.2 m vertical and 2.0 m horizontal (pers comm Mike Roberts at AUSLIG Darwin)

About LANDU Data

Land Units of the Magela Creek Catchment

Compiled by the Land Conservation Unit of the Territory Parks and Wildlife Commission, Darwin, NT, in 1978 from earlier land unit mapping (Mt Brockman, Cannon Hill, Munmarlary 1:50 000 sheets), and field survey data

Land Units Maps 1 and 2

Scale 1:50 000
Area 132 deg 43 min -> 133 deg 00 min E, 12 deg 15 min -> 12 deg 53 min S
Land units include: relief (slope), soils and vegetation information
Reference: Soil Studies in the Magela Creek Catchment 1978 Part 1
Wells, MR
Land Conservation Unit
Territory Parks and Wildlife Commission
Darwin NT
1979

The original maps were borrowed from CCNT for scanning (courtesy Director Matti Urvet and GIS staff member Peter Wilson) on the understanding that they would be returned together with the digital product.

These two land units maps were scanned in 1992 at the Australian Construction Services office in Darwin (courtesy of Brian Bates and Dan Pederson). The scanner was a Contex FSS 3012E full scale scanner (black and white - A0 format). The maps were scanned at 300 dpi, saved as run length compressed files (.rlc) and transferred to NTU on floppy disk. The original scanned images are landu1.rlc and landu2.rlc

The scanned images (.rlc files) were converted to TIFF format (.tif files) using the CONVERTIMAGE command. The TIFF images were opened in IslandPaint and all extraneous data (roads, lease boundaries, legends, etc.) were erased. The.tif files were then REGISTERed and RECTIFYed - see /arrgis/image/georef

About PHOTO Data

NT Government aerial photographs

filename: ntc977-122.bip
area: Ranger Mine
scale: 1:25 000
altitude: 3810 m AMSL
film: normal colour
date: 12 may 86
scanner: Sharp JX320
dpi: 300 (spatial resolution approx 2.0 m per pixel)

These photographs have not been corrected for tilt or relief, nor have they been georeferenced. They are saved in BIP (band interleaved by pixel) format together with a header file (.hdr) showing the number of rows, columns and bands and a statistics file (.stx) used for contrast stretching the image when displayed. This format is suitable for import into most image processing programs.

About SOIL Data

Soils of the Ranger Monitoring Area

Drawn by BRYCON Drafting for the Land Conservation Unit, Conservation Commission, Darwin, NT, from uncontrolled RC. aerial photography November 1981.

3 sheets
Scale 1:10 000
Area Ranger monitoring area
Description includes soil type and depth

The original maps were borrowed from CCNT for scanning (courtesy Director Matti Urvet and GIS staff member Peter Wilson) on the understanding that they would be returned together with the digital product.

These three soils maps were scanned in 1992 at the Australian Construction Services office in Darwin (courtesy of Brian Bates and Dan Pederson). The scanner was a Contex FSS 3012E full scale scanner (black and white - A0 format). The maps were scanned at 300 dpi, saved as run length compressed files (.rlc) and transferred to NTU on floppy disk. The original scanned images are soil1.rlc, soil2.rlc and soil3.rlc

These scanned maps have not yet been processed.

About TM Data

Thematic Mapper (TM) is a multi spectral scanner carried on Landsat satellites. It acquires data in seven bands (cf. 4 for MSS) at a spatial resolution of 30m (except the thermal band 6 which is 120m).

Reference: Image processing literature
ACRES data sheets and price lists
filename: mag0492.bil
source: ACRES Work Order Number 30015045
type: Landsat TM 1/4 scene

area:	Magela Creek Catchment
size:	approx 3000 x 3000 pixels at 30 m resolution
acquired:	27 apr 92
bands:	123457

This image is in BIL (band interleaved by line) format together with a header file (.hdr) showing the number of rows, columns and bands and a statistics file (.stx) used for contrast stretching the image when displayed. This format is suitable for import into most image processing programs.

This image was purchased by NTU from resources other than the OSS/NTU budget.

This image has not been georeferenced.

Coverages

A coverage is a digital analogue of a map forming the basic unit of vector data storage in ARC/INFO. In a coverage, map features are stored as primary features (such as arcs, nodes, polygons and label points) and secondary features (such as tics, map extent, links and annotation). Map features attributes are described and stored in associated feature attribute tables.

A specific coverage is a set of thematically associated data considered as a unit. A coverage usually represents a single theme or layer such as soils, streams, roads and land use.

A brief description of the coverages in this directory follows:

amg1000:

Australian Map Grid (amg) at 1000 metre resolution for overlay purposes. It covers most of the Magela Creek Catchment - see amg1000.about

amg5000:

Australian Map Grid (amg) at 5000 metre resolution for overlay purposes. It covers most of the Kakadu area - see amg5000.about

elevclip:

A coverage with a single polygon for clipping tins/grids/lattices built from the point elevation coverage elevpoint

elevpoint:

x,y,z elevation points for the Magela Creek Catchment area used to generate tins, lattices, etc.

landu:

Landunits of the Magela Creek Catchment. A polygon coverage with labels showing lucodes

About AMG1000 Coverage

Australian Map Grid (amg) at 1000 metre resolution for overlay purposes.

It covers most of the Magela Creek Catchment

About AMG5000 Coverage

Australian Map Grid (amg) at 5000 metre resolution for overlay purposes.

It covers most of the Kakadu area.

About ELEVCLIP Coverage

The elevation data are not bounded by a rectangular polygon and as a result TINs and LATTICEs generated from the coverage interpolate where there are no data points within the rectangle bounded by xmin, ymin, xmax, ymax. A clip cover is required to achieve this end. No algorithm could be found to draw a polygon around the perimeter of the points in the elevpoint coverage (ESRI support could not provide a solution either) so a polygon was manually drawn by editing a copy of the elevpoint coverage and deleting all the points except those forming the perimeter. The remaining points were joined and a coverage built with the clip polygon.

About ELEVPOIN Coverage

A point coverage of the Magela Creek Catchment elevation data.

About LANDU Coverage

Land Units of the Magela Creek Catchment

Compiled by the Land Conservation Unit of the Territory Parks and Wildlife Commission, Darwin, NT, in 1978 from earlier land unit mapping (Mt Brockman, Cannon Hill, Munmarlary 1:50 000 sheets), and field survey data

Land Units Maps 1 and 2

Scale 1:50 000
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Land units include: relief (slope), soils and vegetation information
Reference: Soil Studies in the Magela Creek Catchment 1978 Part 1
Wells, MR
Land Conservation Unit
Territory Parks and Wildlife Commission
Darwin NT
1979
Source: see $ARRGIS/data/landu/about

Grid

GRID is a raster- or cell-based geoprocessing tool that is integrated with ARC/INFO. GRID provides tools for both simple and complex grid-cell analyses. It represents space from a locational perspective (dividing space into discrete units called cells) and can accurately portray continuous surfaces.

GRID uses a georelational model for geographic data - the grid modelling structure is coupled with a relational database that manages all attributes associated with the cell values. A grid is similar to a coverage in that data belonging to different themes are stored as separate grids. Each categorical grid has an associated value attribute table (VAT) that is stored in the INFO relational database. The VAT of a grid is similar to the Polygon Attribute Table (PAT) of a coverage.

A grid is first divided into uniform square units called ‘tiles’. Each tile represents an actual portion of geographic space. A tile is divided into ‘blocks’. Because there are more blocks on the y-axis than on the x-axis, a block is always rectangular. A block is made up of cells arranged in a Cartesian matrix consisting of rows and columns. Cells are square.

A lattice is the point representation of a grid. The view is represented by a mesh of floating-point or surface values located at the cell centres. The GRID storage structure is used for lattices—ie grid = lattice in Rev 6.x of ARC/INFO despite some confusing historical manual references and the use of the word LATTICE in a number of the commands.

Note: GRID is not an image processing system or a document handling system.

Reference: ARC/INFO User's Guide: Cell-based Modelling with GRID

About ELEVFP Grid

Grid version of Magela Creek Catchment DEM with floating point values

The elev TIN is rather large for surface viewing since while both TINS and LATTICES can be loaded for viewing, the surface viewing system always works with a lattice structure. When a TIN is loaded for the purpose of surface viewing, it is dynamically resampled to a temporary viewing lattice. Processing time can be saved by building a permanent lattice from the tin with the TINLATTICE command.

TINLATTICE interpolates mesh point z values from <in_tin> at the specified resolution or sampling interval to produce the <out_lattice>. The <out_lattice> mesh point z values are interpolated from the tin using the specified interpolation method.

The <out_lattice> covers a rectangular area. Those mesh points falling outside the <in_tin> hull or fall inside an ERASE region are set to the NODATA value.

Because interpolation of the <in_tin> surface occurs at regular intervals, some loss of information in <out_lattice> should be expected. How well the <out_lattice> represents the <in_tin> is dependent on the resolution of the <out_lattice>, and the degree and interval of the <in_tin> surface variation.

Generally, as the resolution is increased, <out_lattice> more closely represents the <in_tin> surface.

About ELEVINT Grid

Grid version of Magela Creek Catchment DEM with integer values ie to 1 m

Using an integer grid saves a significant amount of disk space. Therefore, whenever possible, convert the grid to integer.

About ELEVSHD Grid

Grid version of Magela Creek Catchment DEM with integer values ie to 1 m

HILLSHADE creates a shaded relief grid from a lattice surface by projecting an artificial light source onto the surface and determining reflectance values. The illumination source is considered to be at infinity.

The light source for creating hillshaded relief is usually from the northwest. It should never be from the south because this results in a pseudoscopic effect, or a reversal of the image: ridges appear as depressions and valleys will appear as ridges.

The easiest way to draw the shaded relief grid in ARCPLOT is with the GRIDPAINT command.

Arcplot: gridpaint <out_grid> value identity gray

This command line draws the shaded relief grid to the display stretching the actual grid cell values over a range of 256 shades of gray.

Arcplot: gridpaint <out_grid> value linear gray

The best hillshaded views are produced when the colormap has been set to allow the display of a large number of shades of gray. This is done with the COLORMAP option of the DISPLAY command.

About LANDU1 Grid

Land Units of the Magela Creek: grid created from georeferenced image landu1.tif as an intermediate stage in the raster to vector conversion.

About LANDU2 Grid

Land Units of the Magela Creek: grid created from georeferenced image landu2.tif as an intermediate stage in the raster to vector conversion.

Imagegeo

Georeferenced images

Images encountered in geographic applications can be broadly grouped into two categories: images that are associated with a geographic feature, such as a scanned document and images that reside in the geographic space of interest, such as a satellite image. Images in the first category do not need to be georeferenced. These images help to describe a geographic feature, but do not actually have a spatial extent. Images in the second category must be georeferenced if they are to be displayed concurrently with other spatially referenced data.

Georeferencing an image with the IMAGE INTEGRATOR is a two-step process. The first step is to establish the relationship between the image coordinate system (rows and columns) and a map coordinate system (x,y coordinates). This is done with the REGISTER program. REGISTER is an interactive program that allows you to enter a series of links, or displacement vectors, identifying locations in an image and their corresponding locations in map coordinates. Using the links as a series of control points, REGISTER applies an affine transformation to calculate the amount of scaling, rotating and translating required to align the image to map coordinates. The parameters for the affine transformation are stored in a file called a world file.

Once the image-to-map transformation is established, the second step is to apply the transformation to the image. This is done with RECTIFY. RECTIFY creates a new image by permanently transforming the input image using an affine transformation based upon the parameters stored in the world file. During the transformation process, the input image must be resampled in order to determine the output pixel values in the transformed image. See Chapter 2 in Image Integration for a complete discussion of the three different interpolation methods available.

The georeferenced scanned images in this directory are scanned maps which have been georeferenced but not processed further (ie converted from raster to vector, etc.)

About KNPMAP Image

Colour scan at 300 dpi of a portion of the Kakadu National Park and surrounds 1:250,000 map. The area covers the Magela Creek Catchment.

Accuracy of the original map is stated as:

horizontal 100m
vertical 25m

The scanned image was saved in BIP (.bip) format:

nrows 3240
ncols 1584

nbands 3
layout bip

This image has been registered to a specially prepared coverage which contained the lat/long positions on the map projected in UTM (AMG) (see below). The results of the registration show a high level of precision. The spatial resolution of the map is about 20m per pixel.

Scale (X,Y) = (21.181,21.203) Rotation = 0.033 degrees

RMS error (image,cover) = (0.663,14.044)

Rectification was not possible on the.bip image as an error occurred. A work around was found by converting the image to TIFF (.tif) format which was rectified and is named knpmap.tif

This image was scanned to provide some cultural details such as roads and also to provide a source for a base map to register the satellite image against. This work remains to be completed.

About LANDU1 Image

Land units of the Magela Creek Catchment - Map 1

Georeferenced cleaned.tif file ready for raster to vector conversion.

About LANDU2 Image

Land units of the Magela Creek Catchment - Map 2

Georeferenced cleaned.tif file ready for raster to vector conversion.

PRJ

A coverage or grid can contain an explicit definition of the coordinate system in which it is stored. This can be created using PROJECTDEFINE or added from another data set using PROJECTCOPY. If not defined, the projection will be listed as UNKNOWN.

Since flat maps are used to represent some part of the Earth's surface, projections are implemented to associate locations from the curved globe to an appropriate location on the map's flat surface. Any accurate base map must be based on projected data and the name of that projection and its parameters should be stated in the map's legend.

Conversion between geographic (lat/long) and Australian Grid values is reasonably straight forward using the ARC/INFO command PROJECT. The only requirement is a knowledge of the parameters that define the grid and those for the project command.

This project uses Australian Map Grid Coordinates (AMG):
Australian National spheroid parameters: 6378160 6356774.719
Zone 53 central meridian: 135 deg

latlong-amg53.prj:

input and output information for geographic to AMG projection in Zone 53

amg53.prj:

information for PROJECTDEFINE in zone 53

Reference: Tech note from ESRI (Bob Sutton) (GIS Lab)
The Australian Map Grid Technical Manual (NTU Library)
ARC/INFO User's Guide: Map Projections & Coordinate Management

TIN

A TIN is a representation of a surface derived from irregularly spaced sample points and breakline features. Each sample point has an x,y coordinate and a surface or z value. These points are connected by edges to form a set of non-overlapping triangles that can be used to model the surface.

Triangulated Irregular Networks (TINs) store the topological relationship between triangles and their adjacent neighbours; ie which points define each triangle and which triangles are adjacent to each other.

Reference: ARC/INFO User's Guide: Surface Modelling with TIN

About ELEV TIN

TIN of Magela Creek Catchment created from point coverage

NOTE: This TIN has not been fully explored and may not be clipped properly. It is possible that the boundary of the TIN (ie the hull) is rectangular which means some gross interpolation has taken place in substantial areas where there is no data. If this is the case a TIN should be GENERATED from the original data which might work out a better hull shape.

A1.2 List of satellite imagery held by Parks Australia

New #	Path-row	Date	Scale	Composite	Note 1	Other Cover
NRM 1	112-69B	10-Mar-1980	1:250 000	Colour	CLOUDY;LDO	
NRM 2	112-70B	10-Mar-1980	1:250 000	Colour	CLOUDY;LDO	
NRM 3	111-70	25-Jun-1980	1:250 000	Colour		
NRM 4	112-68	26-Jun-1980	1:500 000	Colour		Coburg
NRM 5	112-69	26-Jun-1980	1:500 000	Colour	MKD	
NRM 6	112-69B	26-Jun-1980	1:500 000	Colour	MKD	
NRM 7	112-70B	26-Jun-1980	1:250 000	Colour	MKD	
NRM 8	111-69	22-Jul-1980	1:500 000	Colour	LDO	
NRM 9	111-70	22-Jul-1980	1:500 000	Colour	LDO	
NRM 10	112-68	23-Jul-1980	1:500 000	Colour		Coburg
NRM 11	112-69	23-Jul-1980	1:500 000	Colour		
NRM 12	112-68	10-Aug-1980	1:500 000	Colour		Coburg
NRM 13	112-69	10-Aug-1980	1:500 000	Colour		
NRM 14	111-69	14-Sep-1980	1:500 000	Colour		
NRM 15	111-70	14-Sep-1980	1:500 000	Colour		
NRM 16	112-68	15-Sep-1980	1:500 000	Colour		Coburg
NRM 17	112-69	15-Sep-1980	1:500 000	Colour	MKD	
NRM 18	112-68	3-Oct-1980	1:500 000	Colour	CLOUDY	
NRM 19	112-69	3-Oct-1980	1:500 000	Colour	CLOUDY	
NRM 20	112-68	25-May-1981	1:500 000	Colour	LDO	
NRM 21	112-69	25-May-1981	1:500 000	Colour		
NRM 22	112-69	25-May-1981	1:500 000	BW	Band 4	
New #	Path-row	Date	Scale	Composite	Note 1	Other Cover
NRM 23	111-69	11-Jun-1981	1:500 000	Colour	CLOUDY;LDO	
NRM 24	111-70	11-Jun-1981	1:500 000	Colour		
NRM 25	111-70	17-Jul-1981	1:250 000	Colour	MKD	
NRM 26	112-69	18-Jul-1981	1:500 000	BW	Band 4	
NRM 27	112-69	18-Jul-1981	1:500 000	BW	Band 7	
NRM 28	112-69B	18-Jul-1981	1:250 000	Colour	MKD	
NRM 29	112-70B	18-Jul-1981	1:250 000	Colour	MKD	

NRM 30	112-69	5-Aug-1981	1:500 000	BW	Band 4	
NRM 31	112-69	5-Aug-1981	1:500 000	BW	Band 7	
NRM 32	112-68	23-Aug-1981	1:500 000	BW	Band 7	Coburg
NRM 34	112-68	23-Aug-1981	1:500 000	BW	Band 4	
NRM 35	112-69	23-Aug-1981	1:500 000	BW	Band 7	
NRM 36	111-70	15-Oct-1981	1:250 000	Colour	MKD	
NRM 37	112-68	16-Oct-1981	1:250 000	BW	Band 7	Coburg
NRM 38	112-68	16-Oct-1981	1:500 000	Colour		Coburg
NRM 39	112-69	16-Oct-1981	1:250 000	BW	Band 7	
NRM 40	112-69	16-Oct-1981	1:500 000	Colour		
NRM 41	112-69	16-Oct-1981	1:500 000	Colour	MISSING	
NRM 42	112-69	16-Oct-1981	1:500 000	BW	Band 4	
NRM 43	112-69B	16-Oct-1981	1:250 000	Colour	MKD	
NRM 44	112-70B	16-Oct-1981	1:250 000	Colour	MKD	
NRM 45	112-69	27-Dec-1981	1:500 000	Colour	CLOUDY	
NRM 46	112-68	11-May-1982	1:250 000	Colour	LLS	
NRM 47	112-69	11-May-1982	1:500 000	Colour	LLS	
NRM 48	112-68	29-May-1982	1:500 000	BW	Band 7;LLS	Coburg
NRM 49	112-69	29-May-1982	1:500 000	BW	Band 7;LLS	
NRM 50	111-69	15-Jun-1982	1:500 000	Colour	LLS;LDO	
NRM 51	111-70	15-Jun-1982	1:500 000	Colour	LLS	
NRM 52	112-68	16-Jun-1982	1:500 000	Colour	LLS	Coburg
NRM 53	112-69	16-Jun-1982	1:500 000	Colour	LLS	
NRM 54	112-68	4-Jul-1982	1:500 000	BW	Band 7;LLS	Coburg
NRM 55	112-69	4-Jul-1982	1:500 000	BW	Band 7;LLS	
NRM 56	111-70	21-Jul-1982	1:500 000	Colour	LLS	
NRM 57	112-68	22-Jul-1982	1:500 000	Colour	LLS	Coburg
NRM 58	112-69	22-Jul-1982	1:500 000	Colour	LLS	
NRM 59	112-69	9-Aug-1982	1:500 000	BW	B4;LLS	
NRM 60	112-69	27-Aug-1982	1:500 000	Colour	LLS	
NRM 61	105-68F	24-Oct-1982	1:250 000	Colour	MKD	Coburg
NRM 62	105-69F	24-Oct-1982	1:250 000	Colour	MKD	
NRM 63	104-69C	2-Nov-1982	1:250 000	Colour	MKD	
NRM 64	104-70C	2-Nov-1982	1:250 000	Colour	MKD	
NRM 65	105-68	4-May-1983	1:500 000	Colour		Coburg
NRM 66	105-69	4-May-1983	1:500 000	Colour		
NRM 67	104-69	29-May-1983	1:500 000	Colour		
NRM 68	104-69C	29-May-1983	1:250 000	Colour	MKD	
NRM 69	104-70C	29-May-1983	1:250 000	Colour	MKD	
NRM 70	105-68	5-Jun-1983	1:500 000	Colour		Coburg
NRM 71	105-68F	5-Jun-1983	1:250 000	Colour		Coburg
New #	Path-row	Date	Scale	Composite	Note 1	Other Cover
NRM 72	105-69	5-Jun-1983	1:500 000	Colour		
NRM 73	105-69F	5-Jun-1983	1:250 000	Colour	MKD	
NRM 74	105-69	21-Jun-1983	1:500 000	Colour		
NRM 75	105-68	7-Jul-1983	1:500 000	BW	Band 7	Coburg
NRM 76	105-69	7-Jul-1983	1:500 000	BW	Band 7;CLOUDY	
NRM 77	104-69	16-Jul-1983	1:500 000	Colour		
NRM 78	104-70	16-Jul-1983	1:500 000	Colour		
NRM 79	104-69	1-Aug-1983	1:500 000	BW	Band 7	
NRM 80	105-68	8-Aug-1983	1:500 000	Colour		Coburg
NRM 81	105-69	8-Aug-1983	1:500 000	Colour		
NRM 82	105-69C	8-Aug-1983	1:500 000	Colour		
NRM 83	105-69C	24-Aug-1983	1:500 000	Colour	V.CLOUDY;Band7	
NRM 84	104-69	2-Sep-1983	1:500 000	Colour		
NRM 85	105-69C	9-Sep-1983	1:500 000	BW	Band 7; Cloudy	
NRM 86	104-69	18-Sep-1983	1:500 000	Colour	MKD	
NRM 87	104-70	18-Sep-1983	1:500 000	Colour		
NRM 88	105-68	25-Sep-1983	1:500 000	Colour	CLOUDY	Coburg
NRM 89	105-69	25-Sep-1983	1:500 000	Colour	CLOUDY	
NRM 90	105-69C	25-Sep-1983	1:500 000	Colour	CLOUDY	
NRM 91	104-69	4-Oct-1983	1:500 000	BW	Band 7; Cloudy	
NRM 92	105-69C	11-Oct-1983	1:500 000	Colour	V.CLOUDY	
NRM 93	104-69	20-Oct-1983	1:500 000	Colour	V.CLOUDY	

NRM 94	105-69B	14-May-1984	1:250 000	Colour		
NRM 97	105-69B	30-May-1984	1:500 000	BW	Band 7	
NRM 95	104-69B	23-May-1984	1:250 000	Colour		
NRM 96	105-68F	30-May-1984	1:250 000	Colour	MKD	Coburg
NRM 98	105-69F	30-May-1984	1:250 000	Colour	MKD	
NRM 99	104-69B	8-Jun-1984	1:500 000	BW	Band 7	
NRM 100	104-69C	8-Jun-1984	1:250 000	Colour	MKD	
NRM 101	104-70C	8-Jun-1984	1:250 000	Colour	MKD	
NRM 102	105-69B	1-Jul-1984	1:500 000	Colour	CLOUDY	
NRM 103	104-69B	10-Jul-1984	1:500 000	Colour		
NRM 104	104-69B	23-Jul-1984	1:250 000	Colour		
NRM 105	104-70	26-Jul-1984	1:250 000	Colour		
NRM 106	105-68	2-Aug-1984	1:250 000	Colour		Coburg
NRM 107	105-69	2-Aug-1984	1:250 000	Colour		
NRM 108	104-69B	11-Aug-1984	1:500 000	BW	Band 7	
NRM 109	105-69B	18-Aug-1984	1:500 000	Colour		
NRM 110	104-69B	27-Aug-1984	1:500 000	Colour		
NRM 111	105-69B	19-Sep-1984	1:500 000	Colour		
NRM 112	104-69B	28-Sep-1984	1:500 000	Colour	CLOUDY	
NRM 113	105-69B	5-Oct-1984	1:500 000	BW	Band 7	
NRM 114	104-69B	14-Oct-1984	1:500 000	BW	Band 7	
NRM 115	105-68F	21-Oct-1984	1:250 000	Colour	MKD	Coburg
NRM 116	105-69B	21-Oct-1984	1:250 000	Colour		
NRM 117	105-69F	21-Oct-1984	1:250 000	Colour	MKD	
NRM 118	104-69B	30-Oct-1984	1:250 000	Colour		
NRM 119	104-69C	30-Oct-1984	1:250 000	Colour	MKD	
New #	Path-row	Date	Scale	Composite	Note 1	Other Cover
NRM 120	104-70C	30-Oct-1984	1:250 000	Colour	MKD	
NRM 121	104-69B	24-Apr-1985	1:500 000	Colour		
NRM 122	105-69B	17-May-1985	1:500 000	Colour		
NRM 123	105-68	18-Jun-1985	1:250 000	Colour		Coburg
NRM 124	105-69B	18-Jun-1985	1:250 000	Colour		
NRM 125	104-69	27-Jun-1985	1:250 000	Colour	CLOUDY	
NRM 126	104-70	27-Jun-1985	1:250 000	Colour		
NRM 127	105-68F	4-Jul-1985	1:250 000	Colour	V.CLOUDY;MKD	Coburg
NRM 128	105-69F	4-Jul-1985	1:250 000	Colour	MKD	
NRM 129	104-69B	13-Jul-1985	1:250 000	Colour		
NRM 130	104-69C	13-Jul-1985	1:250 000	Colour	MKD	
NRM 131	104-70C	13-Jul-1985	1:250 000	Colour	MKD	
NRM 132	104-69	30-Jul-1985	1:250 000	Colour	MISSING	
NRM 133	105-69B	20-Jul-1985	1:500 000	Colour		
NRM 134	105-69B	5-Aug-1985	1:250 000	Colour		
NRM 135	104-69B	14-Aug-1985	1:250 000	Colour		
NRM 136	105-69B	6-Sep-1985	1:500 000	Colour		
NRM 137	104-69B	15-Sep-1985	1:250 000	Colour		
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NRM 141	104-69B	17-Oct-1985	1:250 000	Colour		
NRM 142	104-70	17-Oct-1985	1:250 000	Colour		
NRM 143	105-68	9-Nov-1985	1:250 000	Colour		Coburg
NRM 144	105-69	9-Nov-1985	1:250 000	Colour	CLOUDY	
NRM 145	104-69	4-Dec-1985	1:500 000	Colour		
NRM 146	105-69	11-Dec-1985	1:500 000	Colour	CLOUDY	
NRM 147	105-69B	18-Apr-1986	1:500 000	Colour		
NRM 148	104-69B	27-Apr-1986	1:500 000	Colour		
NRM 149	105-68	5-Jun-1986	1:500 000	Colour	CLOUDY	Coburg
NRM 150	105-69	5-Jun-1986	1:500 000	Colour		
NRM 151	104-69	14-Jun-1986	1:500 000	Colour		
NRM 152	104-70	14-Jun-1986	1:500 000	Colour		
NRM 153	104-69	16-Jul-1986	1:500 000	Colour		
NRM 154	104-70	16-Jul-1986	1:500 000	Colour	LDO	
NRM 155	105-68	8-Aug-1986	1:500 000	Colour		Coburg
NRM 156	105-69B	8-Aug-1986	1:500 000	Colour		

NRM 157	104-69B	2-Sep-1986	1:500 000	Colour		
NRM 158	105-69B	25-Sep-1986	1:250 000	Colour		
NRM 159	105-68F	27-Oct-1986	1:250 000	Colour	V.CLOUDY;MKD	Coburg
NRM 160	105-69F	27-Oct-1986	1:250 000	Colour	CLOUDY;MKD	
NRM 161	104-69B	5-Nov-1986	1:250 000	Colour	CLOUDY	
NRM 162	104-69C	5-Nov-1986	1:250 000	Colour	CLOUDY;MKD	
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NRM 166	104-69	23-Dec-1986	1:500 000	Colour	CLOUDY	
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NRM 169	105-69F	23-May-1987	1:250 000	Colour	MKD	
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NRM 171	104-69C	1-Jun-1987	1:250 000	Colour		
NRM 172	104-70C	1-Jun-1987	1:250 000	Colour	MKD	
NRM 173	104-69	4-Aug-1987	1:500 000	Colour	LDO	
NRM 174	104-70	4-Aug-1987	1:500 000	Colour		
NRM 175	105-68	11-Aug-1987	1:500 000	Colour	LDO	Coburg
NRM 176	105-69	11-Aug-1987	1:500 000	Colour		
NRM 177	104-69C	7-Oct-1987	1:250 000	Colour	MKD	
NRM 178	104-70C	7-Oct-1987	1:250 000	Colour	MKD	
NRM 179	105-68F	14-Oct-1987	1:250 000	Colour	MKD	Coburg
NRM 180	105-69F	14-Oct-1987	1:250 000	Colour	MKD	
NRM 181	104-69	23-Oct-1987	1:500 000	Colour		
NRM 182	104-70	23-Oct-1987	1:500 000	Colour		
NRM 183	105-68F	6-Mar-1988	1:250 000	Colour		Coburg
NRM 184	105-69F	6-Mar-1988	1:250 000	Colour	CLOUDY	
NRM 185	104-69C	15-Mar-1988	1:250 000	Colour	CLOUDY	
NRM 186	104-70C	15-Mar-1988	1:250 000	Colour	CLOUDY	
NRM 187	104-69C	19-Jun-1988	1:250 000	Colour	MKD	
NRM 188	104-70C	19-Jun-1988	1:250 000	Colour	MKD	
NRM 189	105-68F	26-Jun-1988	1:250 000	Colour	MKD	Coburg
NRM 190	105-69F	26-Jun-1988	1:250 000	Colour	MKD	
NRM 191	105-68	28-Jul-1988	1:500 000	Colour		Coburg
NRM 192	105-69	28-Jul-1988	1:500 000	Colour	LDO	
NRM 193	104-69	6-Aug-1988	1:500 000	Colour		
NRM 194	104-70	6-Aug-1988	1:500 000	Colour		
NRM 195	105-68F	16-Oct-1988	1:250 000	Colour	CLOUDY;MKD	Coburg
NRM 196	105-69F	16-Oct-1988	1:250 000	COLOUR	CLOUDY;MKD	
NRM 197	104-69C	25-Oct-1988	1:250 000	Colour	MKD	
NRM 198	104-70C	25-Oct-1988	1:250 000	Colour	MKD	
NRM 199	105-68F	13-Jun-1989	1:250 000	Colour		Coburg
NRM 200	105-69F	13-Jun-1989	1:250 000	Colour	MKD	
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NRM 202	104-70B	22-Jun-1989	1:250 000	Colour	MKD	
NRM 203	104-69	24-Jul-1989	1:500 000	Colour		
NRM 204	104-70	24-Jul-1989	1:500 000	Colour	CLOUDY	
NRM 206	105-68	16-Aug-1989	1:500 000	Colour		Coburg
NRM 207	105-69	16-Aug-1989	1:500 000	Colour		
NRM 208	105-68F	17-Sep-1989	1:250 000	Colour	MKD	Coburg
NRM 209	105-69F	17-Sep-1989	1:250 000	Colour	MKD	
NRM 210	104-69B	26-Sep-1989	1:250 000	Colour	MKD	
NRM 211	104-70B	26-Sep-1989	1:250 000	Colour	MKD	
NRM 212	105-68	15-May-1990	1:500 000	Colour		Coburg
NRM 213	105-69	15-May-1990	1:500 000	Colour		
NRM 214	104-69	9-Jun-1990	1:500 000	Colour		
NRM 215	104-70	9-Jun-1990	1:500 000	Colour		
NRM 216	MOSAIC	31-Jul-1990	1:250 000	Colour		
NRM 217	MOSAIC	31-Oct-1990	1:250 000	Colour		
NRM 33	112-69	23-Aug-1981	1:500 000	BW	Band 4	
NRM 218	105-69	3-Jun-1991	1:500 000	Colour		
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NRM 220	104-69	12-Jun-1991	1:500 000	Colour		
NRM 221	104-68	12-Jun-1991	1:500 000	Colour		
NRM 222	104-70	30-Jul-1991	1:500 000	Colour		
NRM 223	104-69	30-Jul-1991	1:500 000	Colour		
NRM 224	105-68	6-Aug-1991	1:500 000	Colour		Coburg
NRM 225	105-69	6-Aug-1991	1:500 000	Colour		
NRM 226	105-69	9-Oct-1991	1:500 000	Colour		
NRM 227	105-69	9-Oct-1991	1:500 000	Colour		Coburg
NRM 228	104-69	18-Oct-1991	1:500 000	Colour		
NRM 229	104-70	18-Oct-1991	1:500 000	Colour		
NRM 230	105-68	8-Jun-1993	1:500 000	Colour		Coburg
NRM 231	105-69	8-Jun-1993	1:500 000	Colour		
NRM 232	104-70	3-Jul-1993	1:500 000	Colour		
NRM 233	104-69	3-Jul-1993	1:500 000	Colour		
NRM 234	105-69	26-Jul-1993	1:500 000	Colour		
NRM 235	105-68	26-Jul-1993	1:500 000	Colour		Coburg
NRM 236	104-70	20-Aug-1993	1:500 000	Colour		
NRM 237	104-69	20-Aug-1993	1:500 000	Colour		
NRM 238	105-69	14-Oct-1993	1:500 000	Colour		
NRM 239	105-68	14-Oct-1993	1:500 000	Colour		Coburg
NRM 240	105-69	23-Oct-1993	1:500 000	Colour		
NRM 241	105-70	23-Oct-1993	1:500 000	Colour		
NRM 242	104-70	27-Apr-1992	DIGITAL	Colour		
NRM 243	104-69	27-Apr-1992	DIGITAL	Colour		
NRM 244	105-69	4-May-1992	DIGITAL	Colour		
NRM 245	105-68	4-May-1992	DIGITAL	Colour		Coburg
NRM 246	104-69	30-Jun-1992	DIGITAL	Colour		
NRM 247	104-70	30-Jun-1992	DIGITAL	Colour		
NRM 248	105-68	7-Jul-1992	DIGITAL	Colour		Coburg
NRM 249	105-69	7-Jul-1992	DIGITAL	Colour		
NRM 250	104-70	1-Aug-1992	DIGITAL	Colour		
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NRM 255	105-69	1-Dec-1993	1:250 000	Colour	For extra fire	
NRM 256	105-69	28-Nov-1992	1:500 000	Colour	For extra fire	
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NRM 260	105-068	11-Jun-1994	1:500 000	Colour		

A1.3 Kakadu National Park aerial photography index

Kakadu National Park – Nourlangie Study site	1950	Runs 12–15
Katherine – South Alligator	1964/5	Runs 12–79
Alligator Rivers (incl. Field & Barron Is.)	1975	Runs 1–26 (set 1+3)
Mary River East	1975	Runs 7–44
Alligator Rivers – Kapalga Project	1975	Runs 15–20
Mary River East – Kapalga Project	1975	Runs 25–33
Alligator Rivers	1975	Runs 1–26
Barron Island	1975	
Mary River East	1975	Runs 8–14
Alligator Rivers	1976	Runs 1–44
Alligator Rivers	1976	Run 20
Kakadu South	1978/9	Runs 1–16
Kakadu South	1978	Runs 1–16
Jim Jim Falls	1979	Run 1
Nourlangie Rock	1979	Runs 1–5
Obiri – Cannon Hill	1979	Runs 1–7
Jabiru Townsite	1979	Runs 1–9
Deaf Adder Creek	1979	Runs 1–5
Jim Jim Falls	1979	Runs 1–2
Coopers Creek – Murgenella	1979	Runs 20–23
Coopers Creek – high level	1979	Runs 4–5
Obiri – Cannon Hill	1979	Runs 1–8
Field Island	1979	Runs 1–3
Southern Plateau Sites	1981	Runs 1–29
Northern Outliers	1981	Runs 1–2
Jim Jim Falls Road	1981	Runs 1–7
Alligator Rivers	1981	Runs 1, 2, 20
Kakadu National Park	1983	Runs 1–10
Waterfall Creek	1984	Runs 1–2
El Sharana	1984	Runs 1–2
Christmas Creek	1984	Runs 1–4
Kakadu National Park	1984	Runs 1–53
Kakadu National Park	1984	Runs 48, 50–58
Gadjuduba	1989	Run 1
Jabiluka	1989	Run 1
Obiri	1989	Run 1
Baroalba	1989	Run 1
Jim Jim Falls	1990	Run 1
UDP Falls	1990	Runs 1–2
South Alligator Saltwater Project	1985	Runs 1–3
Munmarlary Experimental Fire Plots	1985	Runs 1–4

Appendix 2 Committees and meetings

A2.1 Membership of Joint Steering Committee for the Northern Territory vulnerability to climate change studies

Chris Uren	Northern Land Council
Max Finlayson	***eriss***
Dave Field	Department of Primary Industries & Fisheries
Jeremy Russell-Smith	Parks Australia
Helge Pedersen	Department of Lands, Planning & Environment
Herman Mouthaan	Department of Lands, Planning & Environment
Frank van der Sommen	Department of Lands, Planning & Environment, consultant
John Childs	Power and Water Authority
Peter Pender	Northern Land Council
Bob Richards	Department of Mines & Energy

A2.2 Summary of technical workshop on vulnerability to climate change projects for Darwin and the Alligator Rivers Region, Darwin 7/6/95

Purpose

To obtain comments from professional personnel from a wide range of government agencies on the approaches being taken by the two projects to assess vulnerability to climate change.

Procedure

The background to the DEST climate change programme was described by Peter Waterman. Frank van der Sommen described the methodology being used for the Darwin Project. The Alligator Rivers Region project was introduced by Max Finlayson and the approaches taken in relation to different major potential areas of impact were described by personnel working on them: coastal geomorphology by Ian Eliot; cultural impacts on aboriginal people by Ben Bayliss and Ray Hall and ecological aspects by Kym Brennan.

There was then a long discussion period guided by Peter Waterman and Max Finlayson in which the meeting was asked to address a number of specific issues and to offer any comments projects as outlined.

Summary of workshop

Objectives

Purposes of case studies

- splits in IPCC—environment/socio-economic factors
- European perspective
- Commonwealth definition—much broader, integrates human/environmental
- describe projects and identify adequacy of existing data and information for making assessments
- identify further data/information requirements
- explore the implications for management

Issues

- concern that we establish a national approach
- data collection standards
- evaluate risks
- include in planning—strategic—statutory
- impact mitigation
- health—disease vectors in coastal regimes

The critical issues identified were:

- knowledge—conditions and hazards
- sea level change implications
- hydrology and hydrodynamics of the coast
- biology
- social—cultural—economic issues
- type/funding of mitigation measures
- compensation and insurance

GOVERNMENT: Who pays and when do they pay?
There are mistakes being made.

Other variables relate to coastline insurance vs why should we pay.

Discussion

A description of each NT project was given by the relevant participants. Much debate about vulnerability particularly relating to the conservation issues, due to the intrinsic dynamism of natural systems.

Change is a human problem. 'balandagenic imposts'

Management process

→ control
↓
→ organisation
↓
→ planning ←
↓
→ implementation ←
↓
→ monitoring ←

A series of questions presented for discussion

1. What are the predicted climate induced changes ?
2. What affects could these changes have on components of the environment of the wet-dry tropics ?
3. What are the natural variabilities of these components ?

4. What ‘other changes’ can affect these components of the environment?
5. What information is available to enable a distinction to be made between:
   - climate induced change
   - natural variability
   - other changes?
6. What information is needed to develop management systems that can accommodate climatic and other changes?
   - the CHALLENGE—‘change management’
   - freeze-frame development planning
   - 5 year plans

The great dichotomy of Australia is represented in the 2 NT studies:

Darwin (city) Kakadu (bush)

Hopefully these consultancies will enable us to increase our capability and try to come to grips with the monitoring/understanding/assessment needs as well as spatial information management. The following table is an attempt to determine the current situation.

A2.3 Report on public workshop on climate change projects, Darwin 10/8/95

Meeting venue

Northern Territory University, 6.30 pm

Purpose

As part of the evaluation process, obtain the response of members of the public and representatives of different government authorities to the approach taken in the two case studies in the Top End and identify those values they perceive as threatened by natural and human induced processes of environmental change

Procedure

An outline of the background to the DEST climate change vulnerability assessment and the objectives of the 8 national case studies was presented by Peter Waterman. Frank van der Sommen then described the procedures developed for the Darwin Coastal Vulnerability project and some of the processes presently operating to cause change in coastal areas around the city.

The project on the Vulnerability of the Alligator Rivers Region to Climate Change was introduced by Ian Eliot. He also described the geomorphology of the coastline and floodplains of the region, the types of processes currently causing changes and the possible effects of climate change on these processes. The biological resources of the region and possible broad effects of climate change on these were then described by Max Finlayson.

Following these presentations, there was open forum discussion facilitated by Peter Waterman. This attempted to focus on (1) processes and effects of change, and (2) community coastal values and concerns.

Table A2.1 Vulnerability to climate change: Summary status of information requirements and management

	Changes occurring and problems	Data required	Availability of data	Accessibility to data	Source of data and contact
ATMOSPHERE	Monsoon intensity Cyclogenesis (no evidence of) Need to preserve continuity of observational record ENSO	Coastal station data (wind, pressure, rainfall, temp) Waves Surge	Limited in location and time series Darwin data is more extensive Darwin Airport has extensive and reliable record back to 1941	Hard copy Digital Reliability needs verification (some data may be unreliable due to site changes, data corruption etc	Bureau of Met, Ranger Uranium Mines, PAWA
MARINE HYDROLOGY AND HYDRO-DYNAMICS	Problems with data precision Dynamics	Tidal Sea level SST	Tides: from Port Keats to MacArthur River in the Gulf Storm surge study (Darwin)	Digital Public	PAWA, Flinders University (NTF)
TERRESTRIAL HYDROLOGY	Intergovernmental cooperation at regional levels needs strengthening User networks Discharge rates	Estuarine monitoring Sediment/salinity profiles Littoral transport Sediment accumulation in mangroves	Available data sets (short/broken series)	Public Messel/NARU reports	PAWA, LP+E (soil conservation)
GEOLOGY	No strictly 'coastal' investigations Subsidence Erosion Tectonics	Maps (various scales) Regolith mapping ongoing Figures	1:200 000/1:250 000 Geochemistry Petrology Soil Classification Geophysics Geological data sets	Hard copy Digital	LP+E, DME, AGSO
SOILS AND LANDFORMS	Susceptibility (erosion) Soil water-logging Erosivity Fresh-salt land interaction	Soil maps Sediment maps Digital terrain maps Land systems maps	Linked to (see) geology Also 1:1 000 000 Soil monitoring sites at Mary River	Hard copy (case by case) Digital (soils N.T.) Biogeographical regions (marine and terrestrial)	LP+E, DME, AUSLIG
PLANTS	Plants and biogeography Scale of information	Vegetation maps Species lists updated Biomass/productivity	NT vegetation map (1:25 000 for Darwin) Kakadu vegetation map	As above Herbarium records and atlas Mangroves (Darwin harbour) Remnant vegetation Darwin	*eriss* , TWP, LP+E, ANCA, NTU, Greening Australia, Clyde Dunlop

Table A2.1 Continued

ANIMALS, MICROBES ETC	Soil/water Plants Fish—patchy records No seasonal info Mangrove sensitivity/crabs Seagrass etc—not well mapped	Habitat mapping Time series Population data Dynamics information Mangrove dynamics/ phenology	Varied detail Turtle watch Fish catch records Kakadu—mangrove species list	Distribution of species maps Fauna studies-reports	As for plants, Also DPI+F, Museum, P. Wheelan—Health
PEOPLE/CULTURAL	Balandagenic imposts Hunting/foraging Commercial/ recreational fishing External pressure Increasing participation in management of coastal resources Other environmental concerns Disease potential	On all topics of change (see left) Effects of change on people and people on change and cultural values	Discussion with people. Some records on traditional hunting, fishing and sacred sites.	Through (see right)	NLC, ANCA, Resource centres, Community assoc., Land management offices, Federal and NT Health, CH + R analysis (Macquarie Uni)
SOCIAL	Population dynamics Health Immigration Tourism Comfort factors	Environmental factors linked to changes and problems Attitudinal data Demographic structure	Comfort index Energy use Health statistics	Literature and public domain Hard copy Digital	Tourist Commission, ANCA, Federal and NT Health, Chris Burchett, PAWA, Australian Bureau of Statistics
ECONOMIC	Infrastructure required Cyclone proofing standards Relaxation of standards Liability issues	Cyclone frequency/intensity State Emergency Service data Building codes/regulations Cyclone insurance	SES Building information Kakadu (needs establishment)	Files	Lands and Housing, Territory Insurance Office, SES, Transport and Works, Jabiru Town Development Auth., Jabiru Town Council

Discussion points

Summary points from the discussion session were compiled on a whiteboard to assist in the discussion process and focus ideas. These points are listed below.

- Suite of changes identified in the presentations but few can be quantified at this stage
- Some changes are difficult to manage because of the rate and extent of the change
- Cross boundary management—some conditions needing management are outside of the jurisdiction of single governmental organisation
- Need to look at the larger system and manage natural resources
- Inshore marine habitat—potential impacts need to be considered
- Need more extensive marine and ocean research at regional scales
- Biodiversity issues arising from pressures from existing uses
- Creating interest and raising awareness—set up feedback mechanisms
- Environmental health
- Quality of life sought by residents in urban areas of Darwin may require larger areas than at present to include areas of natural coastal habitats for recreation and aesthetics
- Society's wants and needs may be changing 'quicker' than sea level changes
- Planning extends to the 1:100 year event—buildings should be constructed above that level of safety standard
- Insurance is currently provided to all houses in storm surge zone in Darwin
- Rainfall increase would result in greatly increased flooding if rainfall pattern is evened out
- Although these case studies will contribute to management policy, the 'preservation culture' will prevail, even though natural changes can be shown to be inevitable and certain human practices are unsuitable in some places—'hazard-risk' insurance issues for the coastal zone
- Different values may be held for the built environment by different cultural groups. The cultural aspects and economic interest may vary with Aboriginal communities.
- Difficulty of assigning monetary value to environmental values for evaluation of threats
- Governments need priorities for environmental issues (limited resources)
- Aboriginal people have lived through generations of change and sea level rise (& fall?)
- Balanda (European) impost is more recent
- Involvement of Aboriginal people in management of coastal and other resources
- Other environmental issues/coastal issues—may take precedence over concerns for climate change
- Many Aboriginal people now living permanently on coastal edge (formerly more mobile)
- Food resources for Aboriginal people have a bush food focus. Planning for future development needs to see the natural environment as an economic resource

A2.4 Attendance at Meetings and Workshops

Attendees at Technical Workshop (NTU—Darwin 7/6/95)

Dave Walden	***eriss***
Ben Bayliss	***eriss***
Ray Hall	***eriss***
Kym Brennan	***eriss***
Bob Pidgeon	***eriss***
Max Finlayson	***eriss***
Peter Waterman	University of Western Australia (UWA)
Ian Eliot	UWA, consultant
Joanna Ellison	Australian Institute of Marine Science
Frank Van Der Sommen	Department of Lands, Planning and Environment (LPE)
Dave Howe	LPE
Meredith Lewis	LPE
Roly Griffin	Department of Primary Industry and Fisheries
Peter Pender	Northern Land Council
Greg Hill	Northern Territory University
Dave Williams	Power and Water Authority
Andrew Tupper	Bureau of Meteorology
Zia Bajwa	Department of Mines and Energy

Attendees at Public Workshop (NTU Darwin 10/8/95)

John Wileman	Auscript
Carol Pedersen	Auscript
Joanne Mouthaan	Auscript
Ron Billyard	Conservation Commission NT
Bernadette Mouthaan	Darwin resident
Barry Noller	Department of Mines and Energy
Peter Saunders	Institution of Engineers, Australia
Mick Reynolds	Law Faculty, NTU
Chris Uren	Northern Land Council
Paul Bates	Darwin resident
Ray Hall	***eriss***
Meredith Lewis	Department of Lands, Planning & Environment

Keith Martin	Dames and Moore Pty Ltd
Bob Pidgeon	***eriss***
Graeme Beech	Parks Australia
Graeme Marshall	Parks Australia
Ken McFarlane	Power and Water Authority, NT
Peter Pender	Northern Land Council
Frank van der Sommen	Consultant
Ian Eliot	Consultant
Peter Waterman	DEST Consultant
Herman Mouthaan	Department of Lands, Planning & Environment
Max Finlayson	***eriss***

Appendix 3 Maps showing zones of possible vulnerability within the study area (superimposed boundary lines approximately define low-lying areas most likely to be subject to inundation)

The topographic information in these maps was scanned from 1:250 000 maps: Darwin and Alligator Rivers Region and is copyright © Commonwealth of Australia, AUSLIG, Australia's national mapping agency, 1992 and 1989 respectively.

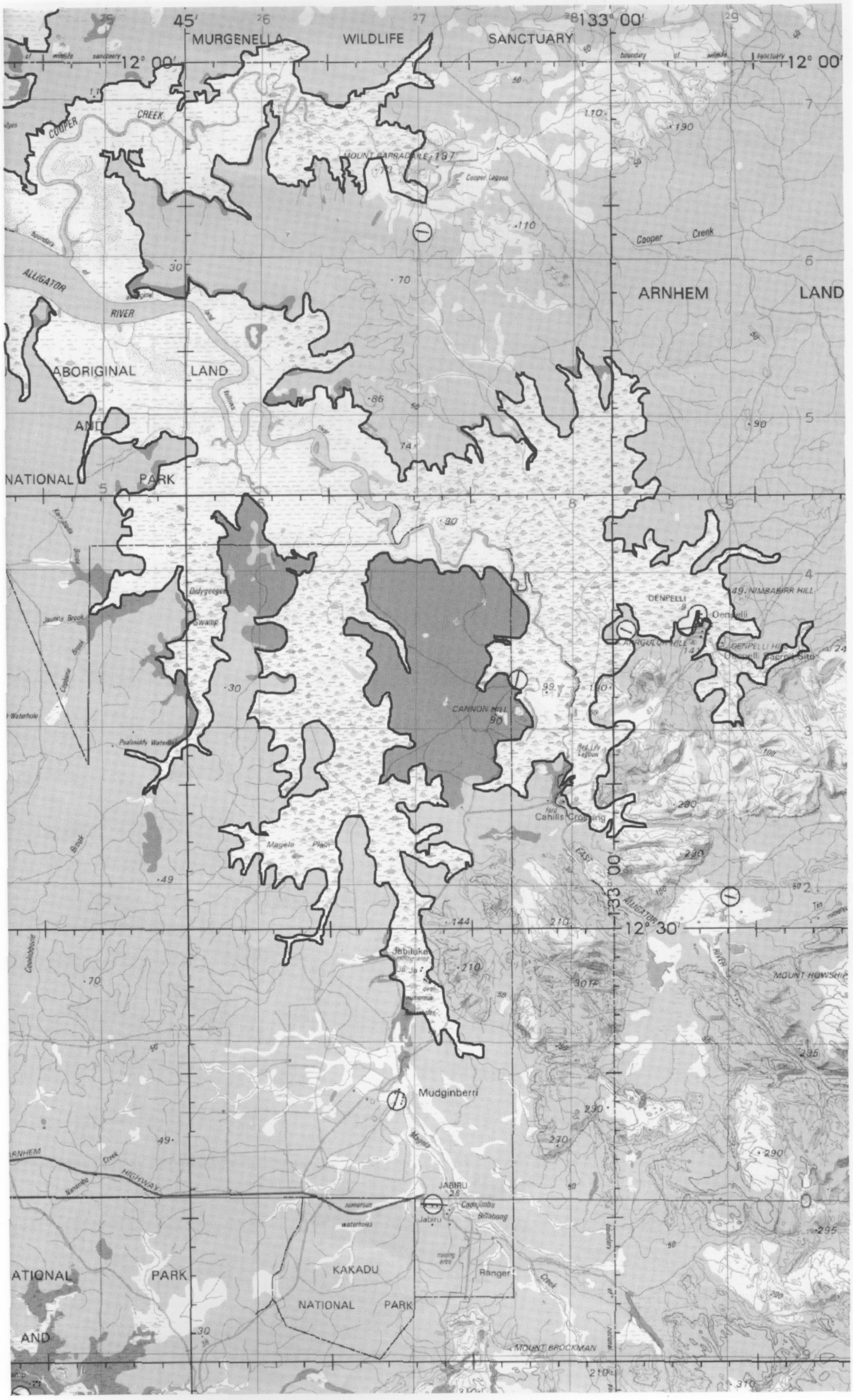

Figure A3.1 East Alligator River

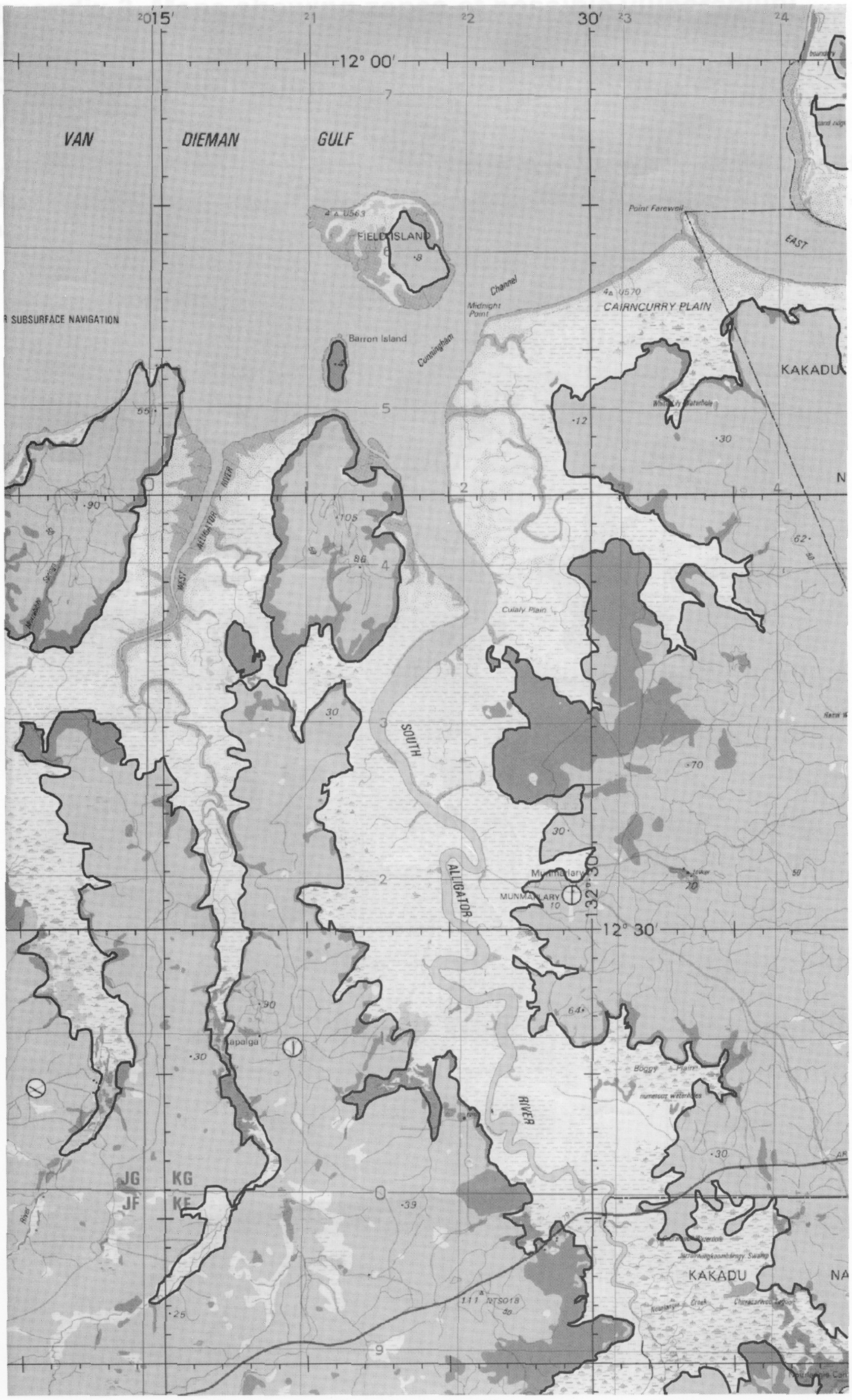

Figure A3.2 South and West Alligator Rivers

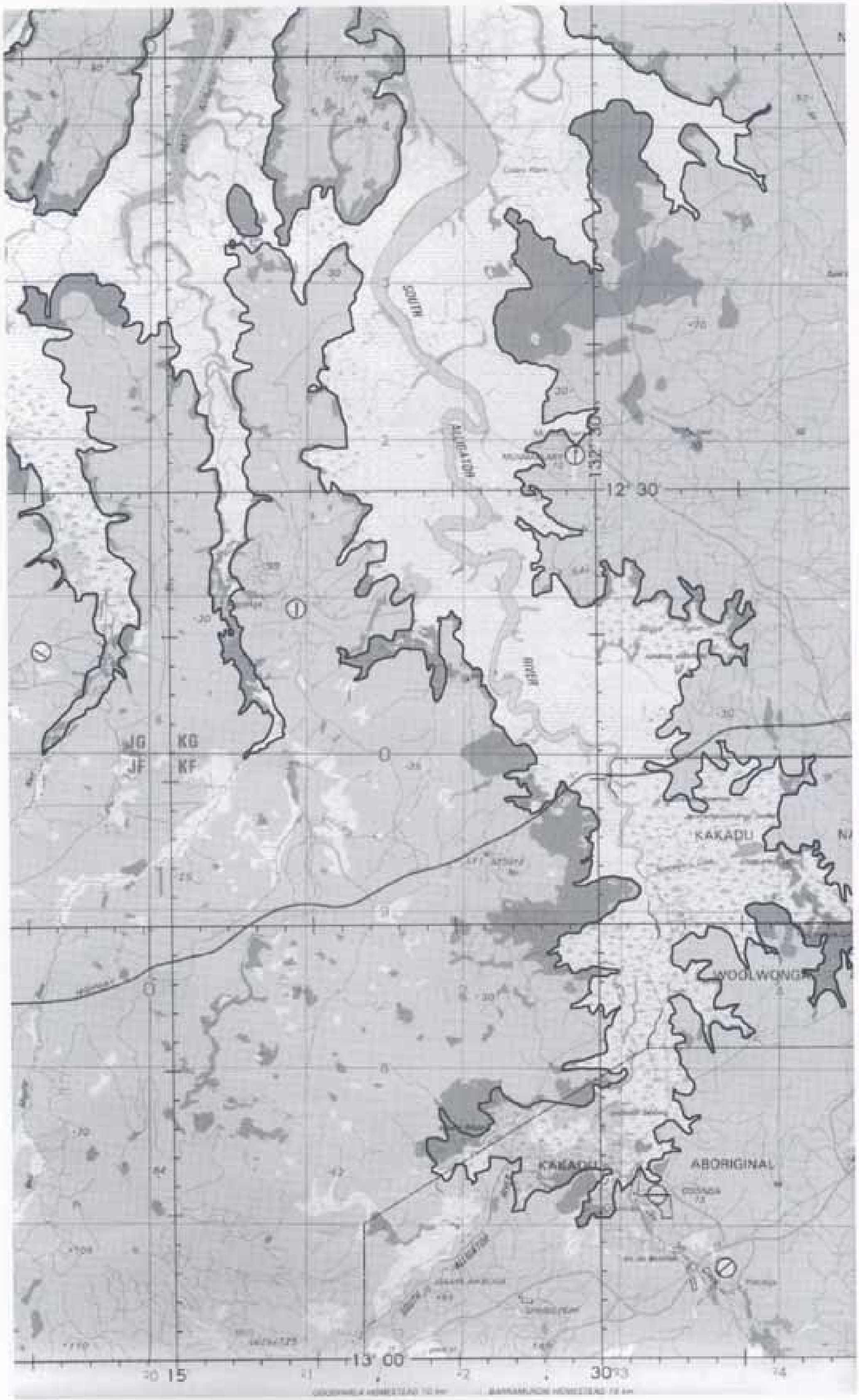

Figure A3.3 South and West Alligator Rivers continued

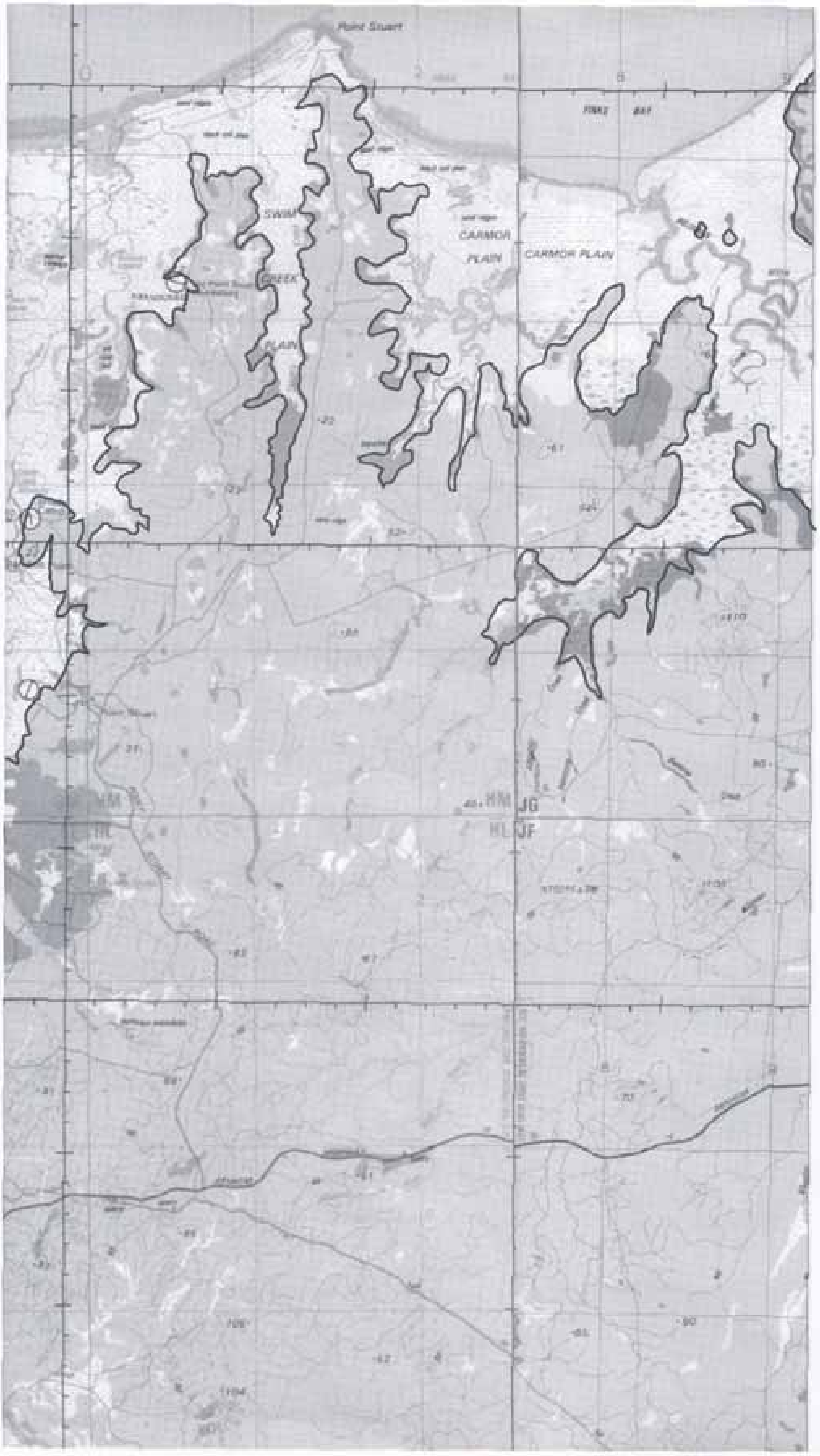

Figure A3.4 Wildman River to Sampan Creek

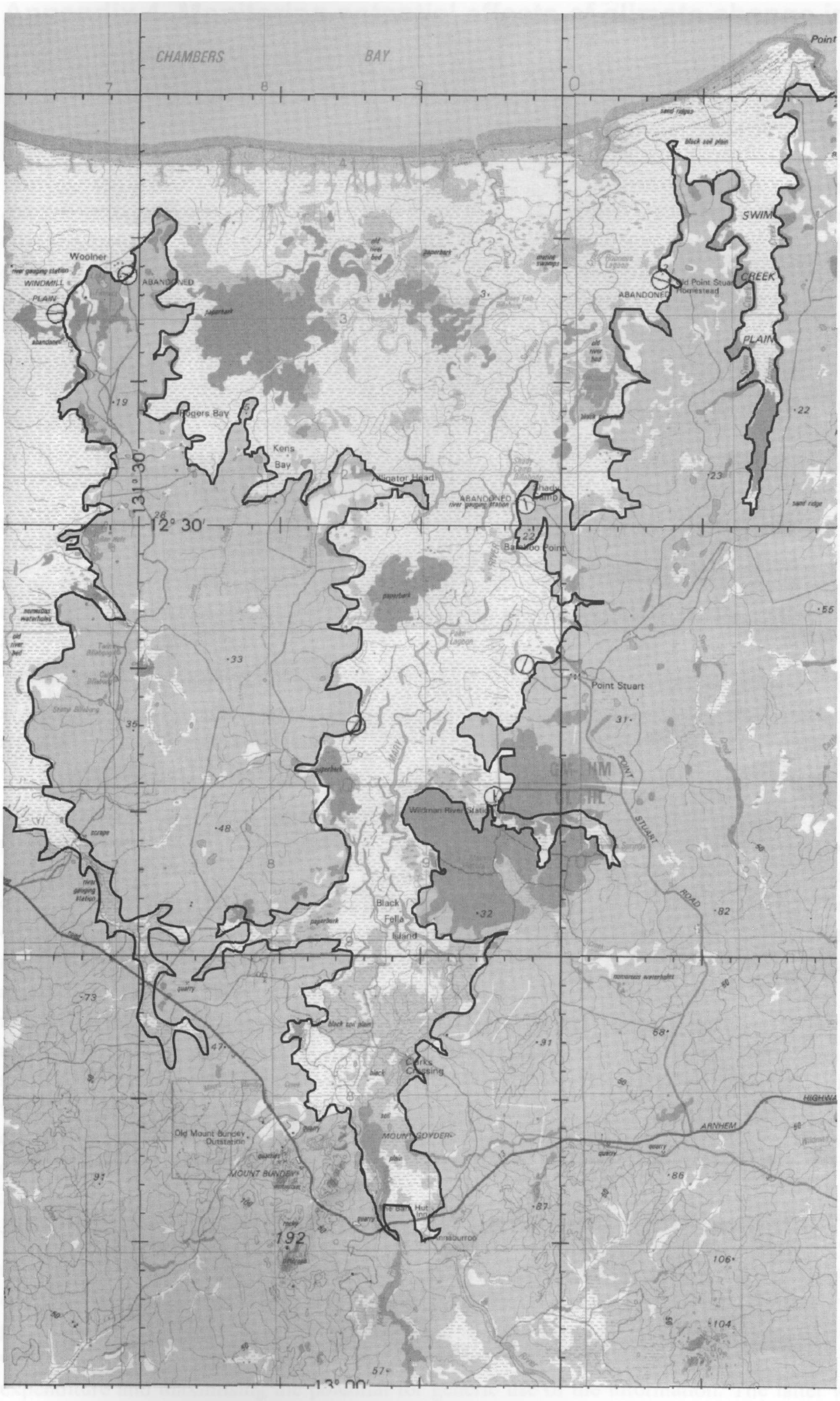

Figure A3.5 Mary River

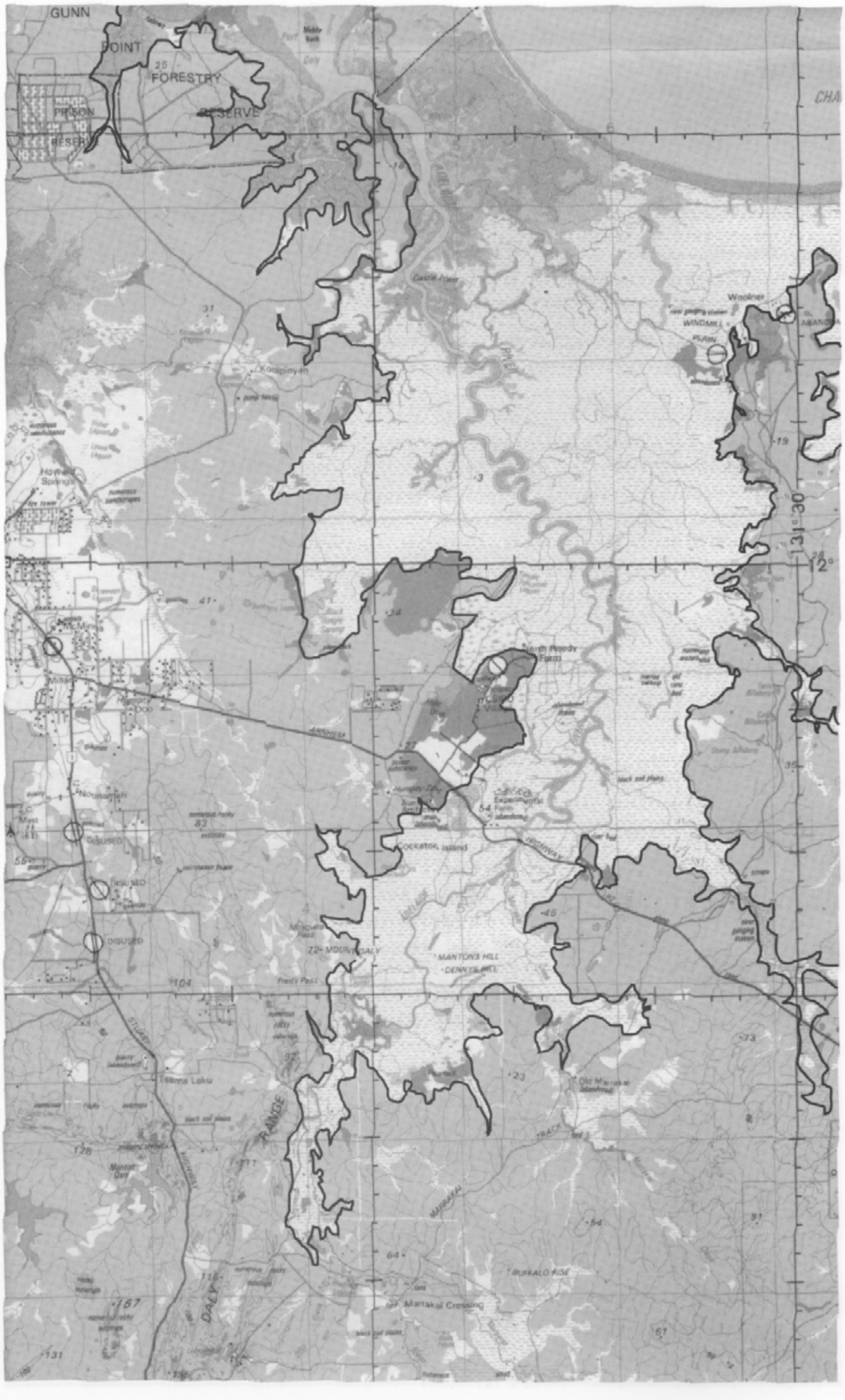

Figure A3.6 Adelaide River

Appendix 4 Monitoring potential effects of climate change in the Alligator Rivers Region

The wetlands of the ARR (or Kakadu National Park) cannot be managed in isolation of those in the adjacent areas (pastoral leases under NT regulation and Aboriginal lands represented by local associations and the NLC). Environmental information from across the larger region is required in order to implement ICZM. The wetlands are already undergoing major ecological changes and can be expected to change even further, especially in consideration of the predictions for climate change and sea level rise. Long-term monitoring of key biophysical parameters in the wetlands and their catchments and adjacent seas are required for change to be assessed and appropriate management to be implemented through an adequate spatial and temporal database that itself must be contained within an effective information management system.

For the long-term application of vulnerability assessment more precise information on areas likely to be impacted is required. Delineation at a more detailed scale would be useful, but only if complemented with more accurate meteorological and hydrological information, including tidal records and water movements in the adjacent seas. Ecological information is mainly confined to studies limited in space and time and generally do not address the processes that impose fragility or resilience in the face of impacts. The absence of a time series of reference data hinders the vulnerability assessment. The ecological character of the region is partially described, but data upon which changes to this character can be identified are at the best cursory.

There is a strong case for a national environment reference station concentrating on time series biophysical monitoring of coastal change in the wet-dry tropics. With the information already collected and compiled a reference monitoring station could be established immediately in Van Diemen Gulf and the Alligator Rivers Region.

Based on the analysis contained within this report the basis of a long-term monitoring program is described. Details of specific sites will need to be assessed and discussed with other agencies who have previously conducted similar monitoring or who would have a collaborative role in future monitoring. The monitoring will in many instances be done on a continuous basis with automatic recording equipment and will have utility for general management purposes. The data will be stored in databases linked to a GIS and made available to national data-holding agencies where applicable. All sampling locations will be mapped by differential GPS and can link into any national or regional reference monitoring network if these are established at some later date. In addition to a temporal distribution of sites across the major rivers a time series is essential for determining not only the natural variation but also the occurrence of anthropogenic change. Monitoring of changes in the coastal wetlands can not be done without also considering changes and events along the coastline itself and in the nearby seas.

The monitoring is divided into general monitoring of physical characteristics in the rivers and Van Diemen Gulf, the distribution of the wetland habitats and biological and physico-chemical parameters as specific indicators of change. Given the spatial and temporal nature of the monitoring, automatic recording and sampling equipment will be used where ever practicable and the data contained within a GIS. Agencies with existing skills and equipment will be encouraged to collaborate in the monitoring thereby potentially minimising the expenditure and maximising the potential for generic use of the information. The latter will be particularly important for developing future oceanographic studies in Van Diemen Gulf; this is seen as an extension of the monitoring and is not developed here.

Physical characteristics

The general physical features of the coastal wetlands and rivers require monitoring to detect natural variability, broadscale change, and to determine the rate of change. The dynamics of any change will require assessment and comparison to natural dynamics and processes. All sites will require positioning by marker pegs and GPS and could feasibly be undertaken using total survey station technology or by high resolution GPS. Monitoring the physical characteristics of the coastal habitats will provide generic information for management of other impacts and environmental problems within the ARR. The generic nature of the monitoring can not be under stressed, especially when considering that assessing the influence of extreme events will feature in the program with specifically targeted analyses.

Climate

Meteorological stations are needed in the catchments of the South Alligator and East Alligator Rivers. The density of this network will require specific assessment by meteorologists and hydrologists familiar with the region and climate. An initial assessment suggests three stations are required in each catchment These will be established with advice from the Meteorological Bureau and positioned in relation to existing facilities such as that at Jabiru East in the catchment of the East Alligator River.

Tides

The tidal regime on both rivers will be monitored in three locations (mouth, major stream channel and upper limit of tidal extension) using automatic gauges. These will be linked to the recording system for the National Tidal Facility and will make use of an existing station on each river in order to take advantage of existing temporal data sets. Advice from NT hydrologists will be obtained.

Hydrology

The flow in the rivers will be measured in conjunction with tidal measurements using initially, the existing gauging stations in the rivers. Major tributaries along each river will need to be gauged if not already part of the existing hydrological recording network. River flows will be used to produce rating curves for further assessments. The extent of flooding during the Wet season will be monitored using radar satellite imagery. The utility of the gauging network previously maintained by the NT Government on the floodplains will be assessed and where possible reactivated as part of the current proposal.

Hydrography

The sediment loads of the rivers will be monitored at the tidal recording stations. The frequency of sampling will be based on weather patterns over the year and the occurrence of specific storm/flood events, noting the problems of access at such times. Sampling will be done automatically and analyses conducted in the laboratory at ***eriss***. Changes in the shape of the channel of the rivers will be determined from boat mounted sonar and related to flow and sediment recordings during both the Wet and Dry seasons. Similar recordings will be required in Van Diemen Gulf with hydrographic mapping from aboard ships (eg such as those operated by AIMS) complemented by using satellite imagery.

Physico-chemical

The movement and upstream extension of the estuarine salt wedge will be monitored both seasonally and in relation to specific events. This sampling will be related to the tidal monitoring and done in relation to rainfall events. Salinity recordings along the length of the rivers will be required using both automatic gauges and specific targeted sampling from boats.

Coastal morphology

Photogrammetric surveys of the coast line will be undertaken once a year and maps of the coastal morphology, vegetation communities and the topography produced. Sampling times will be influenced by cloud cover for currently used imagery although radar imagery will reduce this problem. Elevational changes will be recorded using laser equipment on an annual basis at a network of sites across the coastal plain. This will be undertaken to determine if settlement and compaction of the plain or tidal erosion is responsible for local topographical changes. Several points may require surveying seasonally. The position and extent of the chenier ridges along the coast will also be mapped.

Wetland communities

Monitoring changes in wetland communities along the coast of the ARR will be primarily based on the fringing mangroves and adjacent saltflats. The mangroves are seen as integrators of environmental factors that shape the coast and themselves absorb various physical impacts. This monitoring will take into account monitoring for climate change being conducted by the Australian Institute of Marine Science along the north-eastern and north-western coasts of Australia, the monitoring being undertaken by the NT Museum in Darwin Harbour, and the only previous mangrove monitoring done in the ARR by the Australian Littoral Society (now the Australian Marine Conservation Society) more than a decade ago. The boundary between the saline mangrove habitats and the freshwater seasonally inundated plains along the rivers and streams will also be monitored.

All mangrove sampling will be undertaken along transects across the intertidal slope at five sites on each of the East Alligator and South Alligator Rivers. The site locations will be determined after field surveillance. Logistical aspects will include accessibility during the Wet season and under extreme tidal events.

Vegetation structure

Determined at each site by measuring tree size (diameter, height), density, species richness once a year and after specific major events such as cyclones. This will require approximately one day at each site.

Vegetation production

The organic production and phenology of the mangroves will be determined by monthly measurements of leaf area index, litterfall and decomposition at each site. This will require 2–3 days per month.

Macrofauna diversity/density

The macro-fauna will be determined quarterly from traps placed at each site every three months. Taxonomic identifications will be required and time saving sampling techniques are being devised. This will take approximately one week every three months.

Microtopography

Measurements will be done annually at each site and related to Australian Height Datum and the frequency of inundation. This will done in conjunction with the vegetation structure recording. Further recordings after major events will also be necessary and done opportunistically.

Sedimentation

The rate of sedimentation, particle size, total particulate matter, organic matter and redox potential will be recorded monthly with field equipment where ever practicable. This will be done in conjunction with the litterfall collections.

Habitat extent

The extent of major wetland habitats along the rivers and coast of Van Diemen Gulf will be determined by aerial photography each year. The boundaries between the habitats will be determined and the presence and extent of saline intrusion into the freshwater wetlands assessed. Satellite imagery could replace the photography. The extent of the storm surge debris line will be done in conjunction with the habitat mapping to determine if this is being forced in a landward direction and/or along the more recent chenier ridges.

The sampling will be established using a logistical framework for designing a monitoring program. This will include the steps given in the table below (CM Finlayson unpublished). All data will be collected after careful analysis of statistical requirements and field assessments of practical aspects of sample collection. The purpose is to implement a sampling program that is logically designed, has statistical rigour and generic utility for environmental monitoring at both the local and national scales.

Table A4.1 Tabular description of the framework for designing a wetland monitoring program

The problem/issue	State clearly and unambiguously State the known extent and most likely cause Identify the baseline or reference situation
The objective	Provides the basis for collecting the information Must be attainable and achievable within a reasonable time period
The hypothesis	Supports the objective and can be tested
Methods & variables	Specific for the problem and provides the information to test the hypothesis Able to detect the presence of and assess the significance of any change Identifies or clarifies the cause of the change
Feasibility/cost effectiveness	Determine whether or not it can be done regularly and continually Assess factors that influence the sampling programme: availability of trained staff; access to sampling sites; availability and reliability of specialist equipment; means of analysing and interpreting the data; usefulness of the data and information; means of reporting in a timely manner Determine if the costs of data acquisition and analysis are within the budget
Pilot study	Time to test and fine-tune the method and specialist equipment Assess the training needs for staff involved Confirm the means of analysing and interpreting the data
Sampling	Staff should be trained in all sampling methods All samples should be documented: date and location; names of staff; sampling methods; equipment used; means of storage or transport; all changes to the methods Samples should be processed within a timely period and all data documented: date and location; names of staff; processing methods; equipment used ; and all changes to the protocols
Sample analysis	Sample and data analysis should be done by rigorous and tested methods The analyses should be documented: date and location; names of analytical staff; methods used; equipment used; data storage methods
Reporting	Interpret and report all results in a timely and cost effective manner The report should be succinct and concise and indicate whether or not the hypothesis has been supported and contain recommendations for management action, including further monitoring