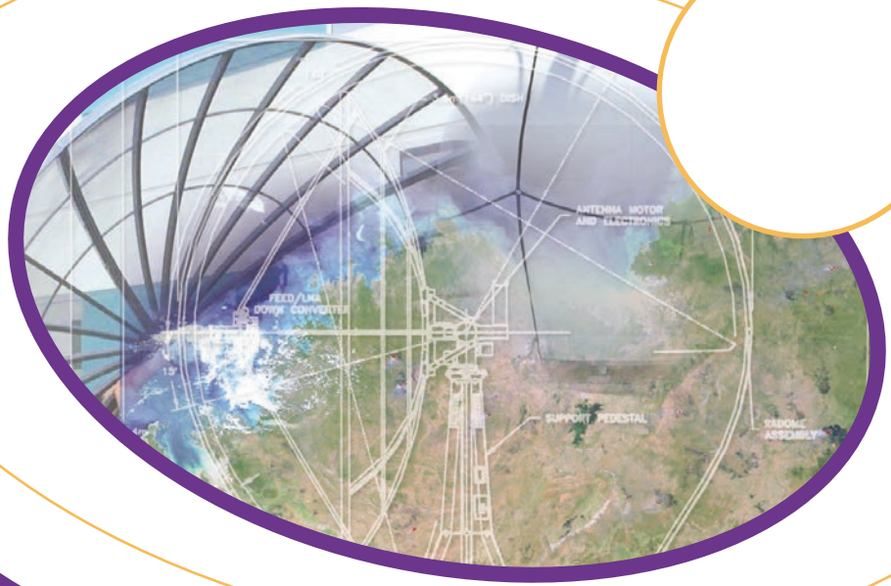
# WASTAC Annual Report 2000




Western Australian Satellite Technology and Applications Consortium

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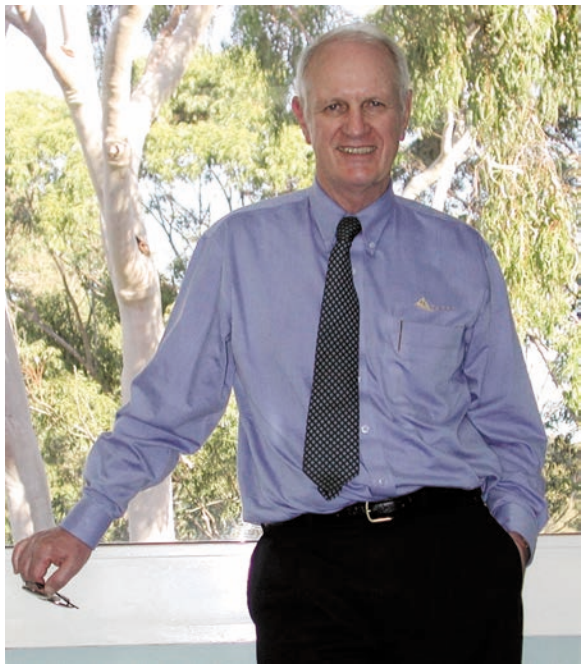
# WASTAC Chairman's Report 2000



WASTAC Strategic Plan anticipated that to capture direct broadcast data from the MODerate-resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite when launched and transmitting in X-band (8200MHz) would require an upgrade of WASTAC's reception capability. WASTAC recognised that MODIS, a super AVHRR/SeaWiFS instrument, would open up significant new opportunities in ocean and land monitoring with its 36 spectral bands and resolutions of 0.25km in the visible and near infrared. On the following satellite AQUA, due for launch in 2002, there will also be the Atmospheric InfraRed Sounder (AIRS) which will significantly increase the accuracy of weather forecasts from improved vertical sounding of the atmosphere over the Southern and Indian oceans.

With the successful launch of MODIS in late 1999, the Strategic Plan resulted in an immediate case for the $700,000 being presented to members and the State Government. The Consortium members and AUSLIG committed this amount, with Murdoch University offering its meteorological tower and high bandwidth link as an excellent site for the new receiver. Agreement was reached on the technical specifications at the end of 2000 and the Request for Tender followed in early 2001. The preferred tender SeaSpace Corporation of San Diego with its proposed TeraScan SX-EOS system with a 3.6m antenna was announced in June 2001. We expect the station to be delivered in September and commissioned in October 2001.

So begins the next exciting chapter in WASTAC's history and the start of negotiations with AUSLIG and Murdoch University which will enlarge the Consortium to six members.

While all this excitement was occurring, WASTAC collected over 4000 overpasses of NOAA and SeaWiFs during 2000 thanks to the diligence of Ron Craig, DOLA and Don Ward's technical staff at the Bureau of Meteorology. Richard Stovold as Secretary maintained the smooth running of the WASTAC Board and Standing Committee. Alan Pearce's input to the editorial board for the annual report has continued to provide significant improvements in content and presentation. Again Curtin University's Accounts Department has assisted us ably in WASTAC's auditing and sound financial management.

Richard Smith

## WASTAC Board for 2000

Dr Richard Smith (Chairman)
Department of Land Administration

Mr Richard Stovold (Secretary)
Department of Land Administration

Assoc. Prof. Merv Lynch
Curtin University of Technology

Dr Doug Myers
Curtin University of Technology

Dr Graeme Pearman
CSIRO, Atmospheric Research

Dr David Jupp
CSIRO, Earth Observation Centre

Dr David Griersmith
Bureau of Meteorology

Mr Len Broadbridge
Bureau of Meteorology

## WASTAC Standing Committee and Proxy to the Board

Dr Richard Smith (Chairman)
Department of Land Administration

Mr Richard Stovold (Secretary)
Department of Land Administration

Assoc. Prof. Merv Lynch
Curtin University of Technology

Dr Doug Myers
Curtin University of Technology

Mr Alan Scott
Bureau of Meteorology

Mr Don Ward
Bureau of Meteorology

Mr Alan Pearce
CSIRO, Marine Research

Dr Peter Hick
CSIRO, Exploration and Mining

## WASTAC Technical Committee

Mr Don Ward (Chairman)

Assoc. Prof. Merv Lynch

Dr Doug Myers

Mr Ronald Craig

# Our Vision

Improve the economy, society and environment through the acquisition of satellite observations of Western Australia and its oceans for research and near real-time applications.

# WASTAC Strategic Plan

## Mission

The mission of WASTAC is to:

- provide high-speed access to NOAA (TOVS and AVHRR) and SeaWiFS satellite data to members on a non-profit basis;
- contribute these data for national and international initiatives in remote sensing;
- adopt recognised data formats to ensure wide access to WASTAC data;
- maintain the integrity of archived data for research and operational applications;
- promote the development and calibration of value-added products; and,
- ensure maximum use of NOAA and Seawifs data in the management of renewable resources.

## Future Strategies

- To develop internet quicklook and promote archived data;
- update the communications, ingest and reception equipment by a process of planned asset replacement;
- review future satellite reception opportunities in both S- and X-band and plan new assets (e.g. antenna) to capture these opportunities;
- expand acquisition and distribution of satellite data through high speed communication links;
- investigate the cost/benefits of an X-band consortium with ACRES and TERSS to provide improved national coverage of X-band reception;
- identify new national and state opportunities in environmental monitoring for sustainable development using WASTAC satellite data; and,
- identify new requirements for improved exploitation of WASTAC data.

## Future Satellite Opportunities

- Fenyung – 1c (S-band)
- SPOT Vegetation Sensor (S-band)
- MODIS on Terra (X-band)
- MODIS on Aqua (2001) (X-band)
- METOP (Replaces NOAA in 2003) (X-band)

# Operational Status

**Don Ward , Regional Computing Manager**
**Bureau of Meteorology(BOM): Perth**

WASTAC facilities consist of 2.4m antenna and antenna controller at Curtin University of Technology, ingest and display computers with hard disk storage and tape archive facilities, located at the Bureau of Meteorology premises at 1100 Hay Street, West Perth. A low-speed uni-directional microwave link connects the antenna to the ingest computers. A high speed microwave communications system was installed in June 1996, allowing the transmission of raw and processed satellite data between the Leeuwin Centre, Curtin University, and the WA office of the BOM.

Colour and grey scale quicklook pictures are produced at Satellite Remote Sensing Services (SRSS) in near realtime for archive, indexing and distribution. The raw data archive is produced on 4GB DAT tape and a duplicate copy is currently produced for a national NOAA data archive program that is coordinated by CSIRO Office of Space Science and Applications(COSSA) in Canberra.

The AVHRR ingest and display system, developed and installed by the Bureau of Meteorology in September 1996 consists of two HP UNIX workstations, one provided by WASTAC and the other by BOM. Software systems were upgraded late in 1999.

The ingest program runs on both workstations providing display, processing and backup facilities. The TOVS data, a subset of AVHRR is automatically sent to the Bureau of Meteorology in Melbourne so that atmospheric temperature retrievals can be included in the global numerical weather prediction models. Sea surface temperatures (SST) are being produced by the BOM and DOLA. DOLA is able to produce vegetation maps and to monitor fire scars in near realtime. NOAA and SeaWiFS archive information are posted to DOLA's World Wide Web page.

Equipment failures during the year resulted in the loss of 7 days of data.

The dedicated efforts of DOLA and BOM staff, resulted in a total of 5197 passes being recorded for the year.

DOLA is currently holding the archive on 8mm and DAT tapes.

A 20GB DLT tape was introduced as archive media late in the year 2000.

Orders for digital data can be provided on 8mm data tape, DAT tape, DLT tape, CDRom or 6250/1600bpi magnetic tape in raw format.

# Future Directions

Further upgrades to the system this year will provide an Internet connected control computer at the Curtin Antenna site. WASTAC is also proposing to set up an Internet site – www.wastac.wa.gov.au as a promotional vehicle for current and future WASTAC activities.

A proposal is being prepared that will provide another antenna and reception system allowing access to X band and other data streams as well as providing a backup NOAA reception facility.

# WASTAC DATA ARCHIVE

The WASTAC archive of NOAA and SeaWiFS satellite passes, managed and maintained by the Department of Land Administration (DOLA) Satellite Remote Sensing Services (SRSS) group, is held at the Leeuwin Centre in Floreat,W.A.

DOLA actively manages the daily archive and management systems which have been installed to ensure rapid and reliable delivery of WASTAC satellite data for research and wider community use.

WASTAC is continuing to supply NOAA passes as part of the Australian contribution of data to the global one kilometre data set which is being administered for CSIRO by COSSA.

The WASTAC duplicate set of NOAA passes which commenced in March 1994, continues to be stored at the Earth Observation Centre at Gungahlin, Canberra, and is specifically for research use by CSIRO and collaborative partners. The global one kilometre data set dates back to April 1992.

A total of 4354 NOAA passes were recorded for 2000. Passes comprised data from the NOAA 12, NOAA 14, NOAA 15 and NOAA 16 satellites. Of these passes 1804 were stored on 44 4mm tapes with the remaining 2550 passes added to the new DLT tapes.

The archiving of SeaWiFS data onto 4mm data tapes commenced on 31 October 1997. During 2000, 843 SeaWiFS passes had been archived to seven data tapes.

We continue to maintain the near real time quick-look archive of NOAA-AVHRR data on the world wide web. The digital archive holds data from the present time back to 1983. A similar archive of SeaWiFS quick-look data is also held on the world wide web.

Web addresses:

**NOAA**:
http://www.rss.dola.wa.gov.au/noaaql/NOAAql.html

**SeaWiFS**:
http://www.rss.dola.wa.gov.au/seawifsql/seawifsql.html

Ron Craig (DOLA) accessing the WASTAC NOAA/AVHRR archived tapes at DOLA Leeuwin Centre, Floreat.

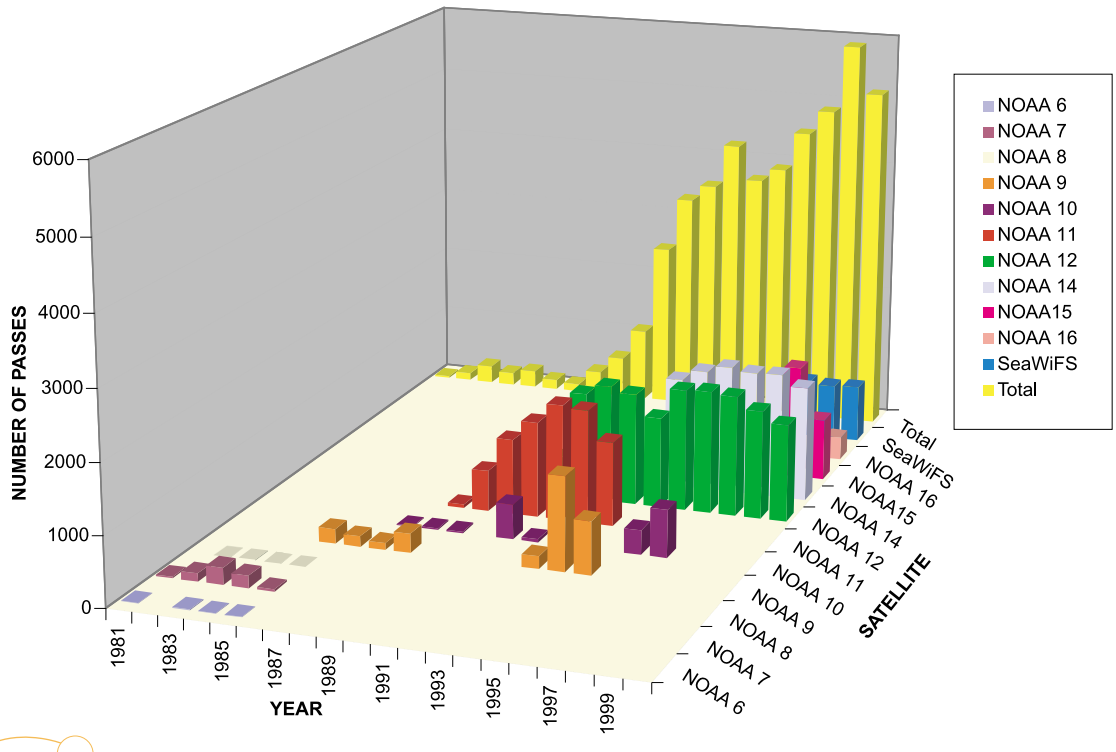
John Adams (DOLA) displaying his NOAA/AVHRR cloud composited vegetation curing index map.

## TOTAL NUMBER OF SATELLITE PASSES HELD IN WASTAC ARCHIVE AT THE LEEUWIN CENTRE

| | NOAA 6 | NOAA 7 | NOAA 8 | NOAA 9 | NOAA 10 | NOAA 11 | NOAA 12 | NOAA 14 | NOAA15 | NOAA 16 | SeaWiFS | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 5 | 22 | | | | | | | | | | 27 |
| 1982 | | 115 | 1 | | | | | | | | | 116 |
| 1983 | 12 | 244 | 12 | | | | | | | | | 268 |
| 1984 | 7 | 179 | 4 | | | | | | | | | 190 |
| 1985 | 7 | 33 | 4 | 212 | | | | | | | | 256 |
| 1986 | | | | 151 | | | | | | | | 151 |
| 1987 | | | | 97 | 18 | | | | | | | 115 |
| 1988 | | | | 280 | 25 | 53 | | | | | | 358 |
| 1989 | | | | | 21 | 601 | | | | | | 622 |
| 1990 | | | | | | 1103 | | | | | | 1103 |
| 1991 | | | | | 506 | 1399 | 575 | | | | | 2480 |
| 1992 | | | | | 47 | 1693 | 1571 | | | | | 3311 |
| 1993 | | | | 183 | | 1656 | 1720 | | | | | 3559 |
| 1994 | | | | 1362 | | 1227 | 1641 | | | | | 4230 |
| 1995 | | | | 770 | | | 1326 | 1615 | | | | 3711 |
| 1996 | | | | | 354 | | 1780 | 1776 | | | | 3910 |
| 1997 | | | | | 694 | | 1797 | 1876 | | | 142 | 4509 |
| 1998 | | | | | | | 1763 | 1828 | 432 | | 859 | 4882 |
| 1999 | | | | | | | 1589 | 1839 | 1663 | | 822 | 5912 |
| 2000 | | | | | | | 1427 | 1681 | 905 | 341 | 843 | 5197 |

Held as: 57 Curtin archive 8mm tapes
1282 WASTAC archive 6250 bpi tapes (copied to 44 8mm tapes)
835 WASTAC archive 8mm tapes
421 WASTAC archive 4mm tapes
11 WASTAC archive DLT tapes

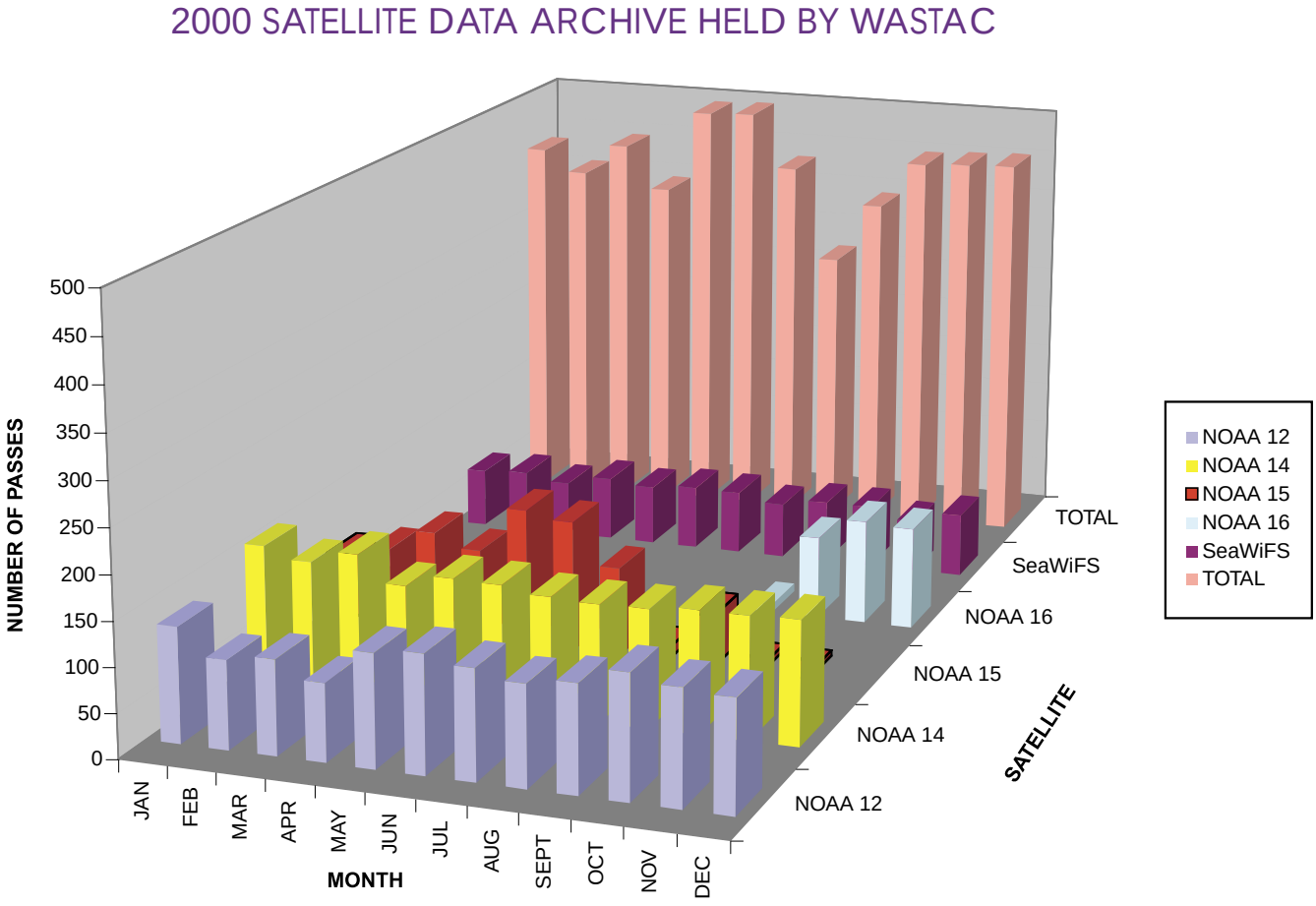
## WASTAC NOAA/AVHRR and SeaWiFS ARCHIVED DATA



## 2000 SATELLITE DATA ARCHIVE HELD BY WASTAC

| | NOAA 12 | NOAA 14 | NOAA 15 | NOAA 16 | SeaWiFS | TOTAL |
|---|---|---|---|---|---|---|
| JAN | 129 | 155 | 83 | | 69 | 436 |
| FEB | 99 | 143 | 96 | | 72 | 410 |
| MAR | 106 | 157 | 121 | | 64 | 448 |
| APR | 87 | 128 | 106 | | 75 | 396 |
| MAY | 126 | 142 | 159 | | 70 | 497 |
| JUN | 132 | 141 | 151 | | 75 | 499 |
| JUL | 123 | 134 | 103 | | 74 | 434 |
| AUG | 113 | 132 | 13 | | 65 | 323 |
| SEPT | 120 | 133 | 60 | 9 | 73 | 395 |
| OCT | 138 | 138 | 7 | 95 | 73 | 451 |
| NOV | 129 | 138 | 6 | 120 | 61 | 454 |
| DEC | 125 | 140 | | 117 | 74 | 456 |

| | **NOAA** | **SeaWiFS** |
|---|---|---|
| 4mm Tapes: | 1804 passes on 44 tapes | 843 passes on 7 tapes |
| DLT Tapes: | 2550 passes on 11 tapes | |
| Total data archived: | 259 gigabytes | 47 gigabytes |



# Research and Operational Applications

# Research and Operational Applications

## CSIRO

### Remote sensing of the Leeuwin Current

A F Pearce
CSIRO Marine Research

During 2000, Advanced Very High Resolution Radiometer (AVHRR) satellite images were used in a number of oceanic studies off Western Australia, covering the tropics (Dampier) to the south coast (Esperance). Locally-received imagery has also been used in longer-term modelling studies of the water properties and circulation in the south-eastern Indian Ocean by CSIRO Marine Research in Hobart.

#### *Hillarys Transects*

The set of Hillarys Transect papers are in the final stage of preparation, covering the physics, chemistry, chlorophyll, light and plankton across the continental shelf off Perth (see previous reports for Transect details). AVHRR-SST (Sea Surface Temperature) images are being extensively used to assist interpretation of the position and thermal structure of the Leeuwin Current and its relationship to the shelf waters covered by the Transect. The seasonally-reversing cross-shelf temperature gradient can be explained by air-sea heating/cooling processes near the coast and alongshore advection by the Leeuwin and Capes Currents (the former stronger in winter than in summer, and the latter only between about October and March), complemented by cross-shelf mixing processes.

A sample transect in February (**Figure 1a**, representing summer) shows the generally featureless thermal structure while the Leeuwin Current is weak; there was warming near the coast, and the cooler Capes Current was flowing mid-shelf. In winter by contrast (**Figure 1b**, for August), the Leeuwin Current was flowing strongly and was clearly defined in the SST transect, being over 2°C warmer than the offshore waters.

*South-eastern Indian Ocean* (acknowledgements David Griffin, CSIRO Marine Research, Hobart)

As part of a Fisheries Research and Development Corporation (FRDC) study of oceanic processes in the south-eastern Indian Ocean, WASTAC SST imagery is complementing TOPEX satellite data to verify surface currents derived from the altimeter and thus assist in modelling the trajectories of particles simulating rock lobster larvae. This project, in which Fisheries WA is collaborating, is attempting to simulate the year-to-year changes in settlement of the puerulus stage of the western rock lobster in our coastal reef system. The model is successfully reproducing the offshore dispersal of the early-stage larvae after hatching in summer, and tracks the open-ocean drifting phase. Many of the larvae are either lost way offshore or to the south, but a number of later-stage larvae are able to return to the coast to settle.

#### *Esperance*

At the request of Fisheries WA, an analysis has been undertaken of sea temperature variability in coastal waters off Esperance, on the Western Australian south coast. While some continuous temperature logger data were available from the Esperance harbour, AVHRR images and sea-surface temperature transects were analysed to show the larger-scale variability and in particular the thermal structure of the Leeuwin Current in that area.

There were clearly pronounced seasonal changes in the thermal structure of the water, largely associated with the seasonal strengthening of the Leeuwin Current in autumn. In February (**Figure 2a**) and April, the water temperature was almost constant across the shelf, decreasing only slowly southwards into the Southern Ocean; the Leeuwin Current was weak and poorly defined. By September (**Figure 2b**), the Leeuwin Current was flowing strongly eastwards along the outer shelf, with characteristic offshoots and eddies carrying pools of warm water well southwards into the Southern Ocean.

The SST transects (**Figure 3**) reveal the finer detail. In summer and autumn (represented by the February and April curves respectively), thermal gradients across the Leeuwin Current were weak. By July, the Current was flowing strongly; there was a band of cooler water near the coast (not resolved in the colour image) and a very strong frontal region of over 3°C at the shelf-break. In September, this was weakening, and it contracted further during spring (October) before returning to the summer situation in December.

*Dampier*

AVHRR images were also prepared to complement other oceanographic measurements as part of a review of oceanographic processes in the Dampier Archipelago. A team of Australian and international biologists participated in the Woodside Dampier Marine Biological Workshop held in the Dampier Archipelago between 25 July and August 2000, conducting field studies of the ecology of the coastal waters. The results of the Workshop will be published by the Australian Museum, complementing the Proceedings from previous workshops held in Albany, Rottnest Island and the Houtman Abrolhos Islands.

An oceanographic review paper of the Dampier region is being prepared by a team of oceanographers, and will include seasonal NOAA-AVHRR SST images (**Figure 4**) to illustrate the major thermal features of the North West Shelf during the year 2000, as well as two images during the period of the Workshop itself. The January image (**Figure 4a**) shows the cool Ningaloo Current (with possible upwelling) intruding north-eastwards past Barrow Island and towards Dampier, into the generally warm and otherwise featureless water mass, with warm water along the coast due to coastal warming.

In winter, heat loss to the atmosphere results in a band of cooler water in the shallower coastal waters with an appreciable temperature rise to the warmer waters at the edge of the continental shelf (**Figure 4b**); this is unlikely to be associated with upwelling which generally occurs (weakly) during the summer months. There is a much larger seasonal temperature change in the near-coastal waters around Dampier and in Exmouth Gulf than further offshore. A variety of eddy-like features are apparent along the outer shelf, probably associated with stronger alongshelf currents (including the Leeuwin Current) in winter.

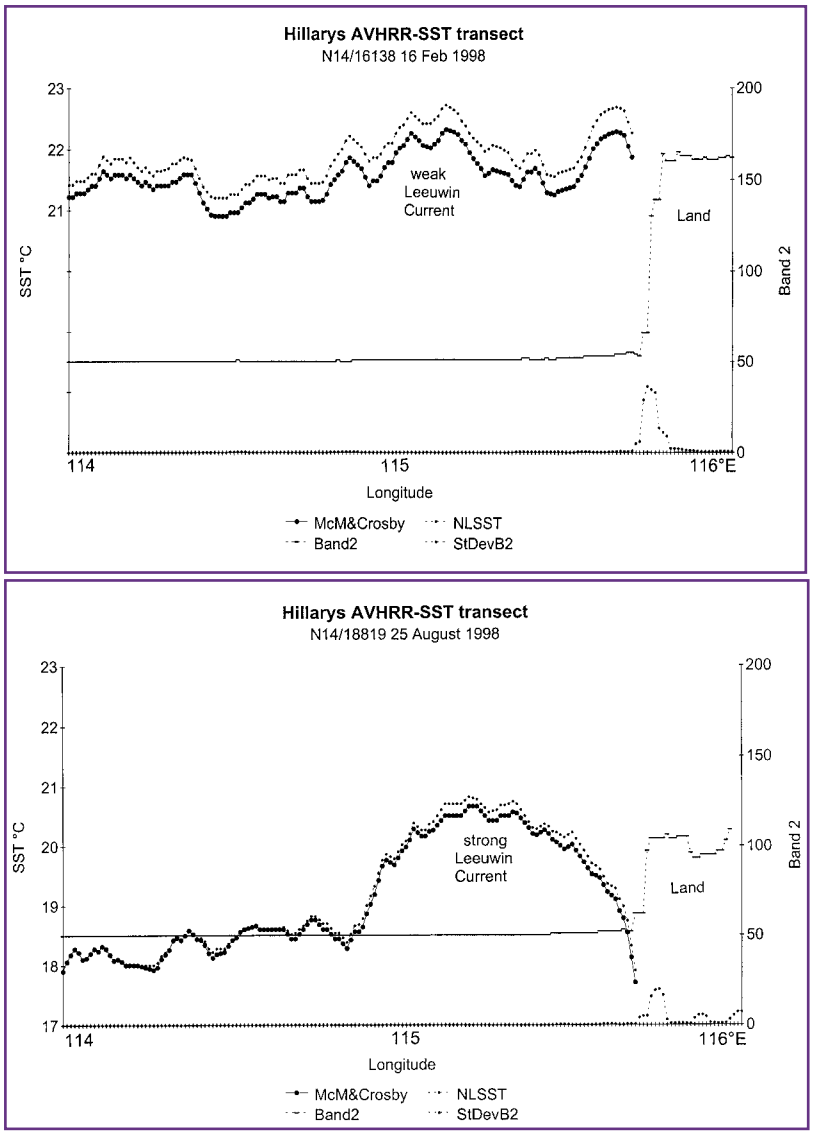



**Figure 1:** AVHRR-SST transects across the Leeuwin Current along (and westwards of) the Hillarys Transect in (a) February and (b) August 1998. The solid dots are the SST derived from the McMillin and Crosby algorithm, the small matching dots from the NOAA-14 NLSST. The horizontal dashes/line are raw counts in Band 2 and the small dots along the bottom axis are the standard deviation of 3-pixel moving segments in Band 2, both of these showing land (on the right of each transect) and the presence of clouds.

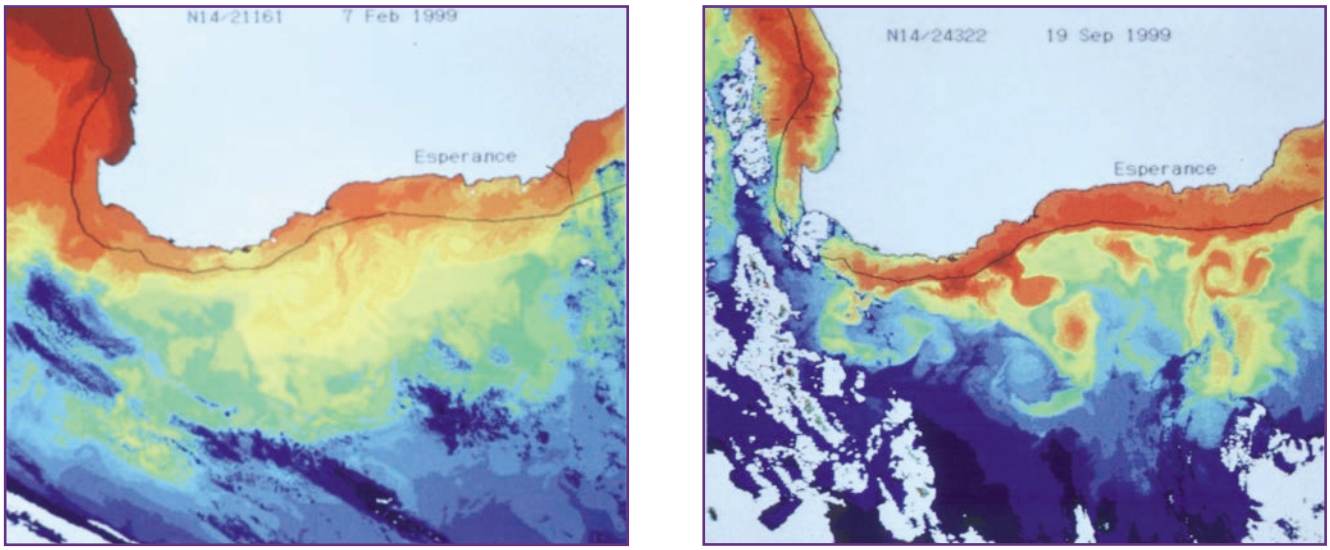



**Figure 2**: AVHRR images of the south coast in (a) February and (b) September 1999, showing the brightness temperature in AVHRR Band 4. Warmest water is shown in red, cooling through yellow and green to the coolest water in blue. The black line marks the approximate edge of the continental shelf. Satellite data by courtesy of WASTAC.

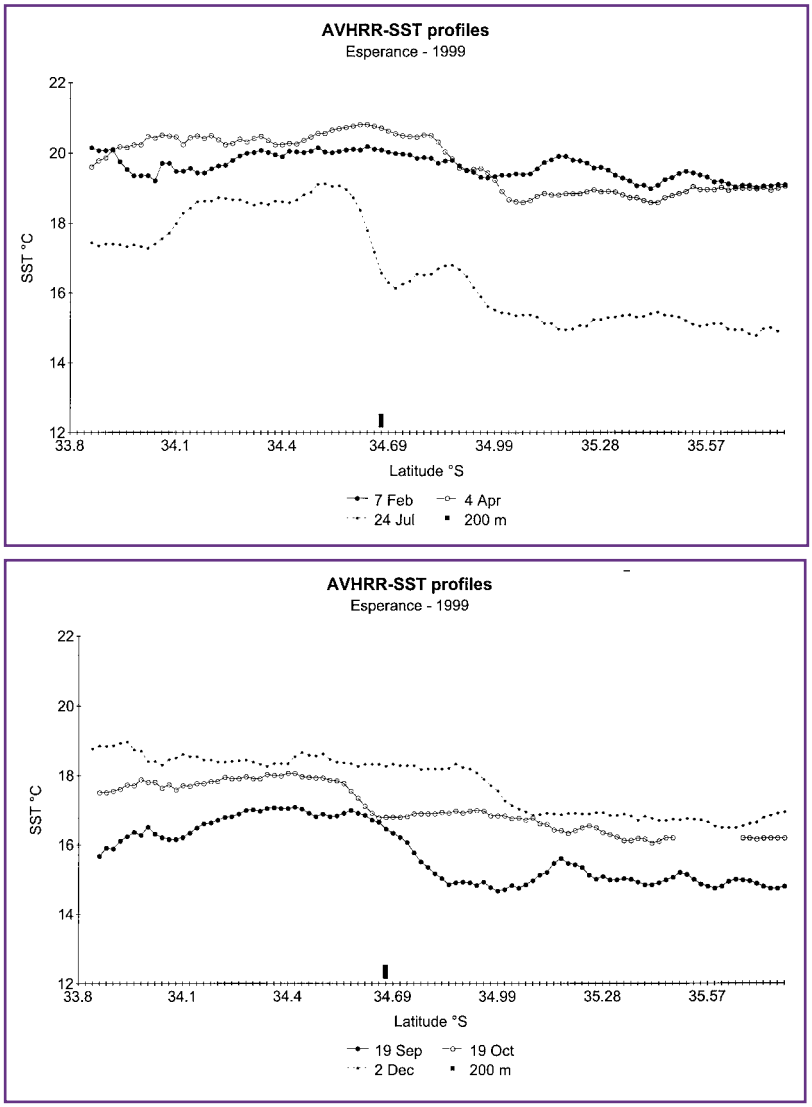



**Figure 3**: Sea-surface temperature profiles across the Leeuwin Current south of Esperance in 1999. The edge of the shelf is indicated by the black bar near 34.69°S.

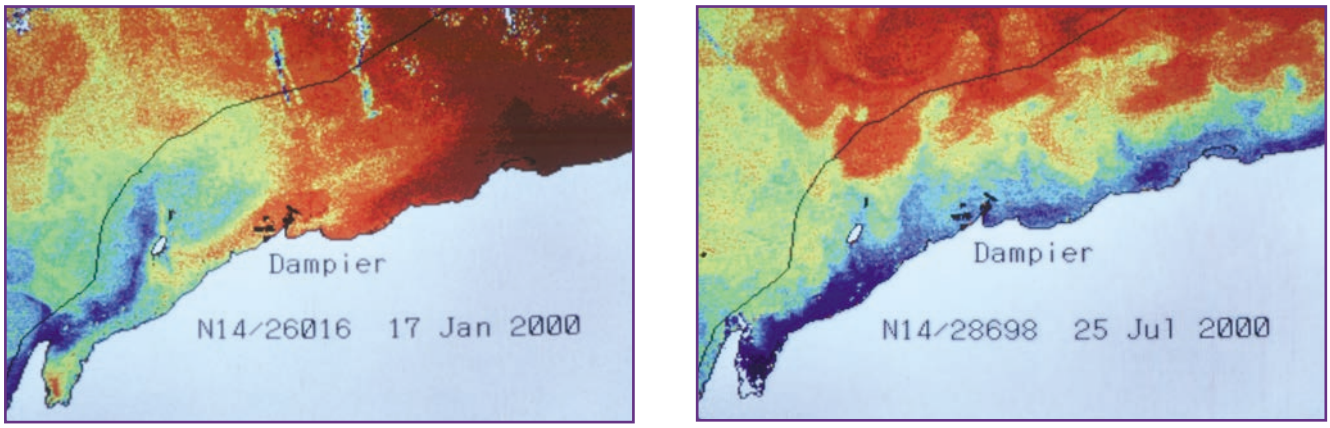



**Figure 4**: NOAA/AVHRR images showing the derived SST along the North West Shelf in (a) January and (b) July 2000. Details as in **Figure 2**.

# Department of Land Administration

## Vegetation Watch

R. Craig, J. Adams and R. Shaw

Delivery of vegetation information derived from the NOAA AVHRR data to clients of DOLA continued through 2000. The main product is the Normalised Difference Vegetation Index (NDVI) which is calculated from channels 1 and 2 of the AVHRR sensor. The individual passes are composited on either 14 day periods or half-monthly to minimise the loss of data due to cloud cover, smoke and sunglint **(Figure 1)**.

The data can only be produced from information received during daylight periods. NOAA 14 was the only satellite viewing the earth during daylight for most of 2000, although its orbital overpass time was drifting later in the day by about five minutes each month. This drift resulted in the loss of data over Tasmania and other southern Australian regions during the low sun elevation months of winter.

It became obvious that mid-latitude data would be unavailable for winter 2001 resulting in NOAA launching NOAA 16 in a near noon orbit in September 2000. As WASTAC began receiving this satellite very early in its life, DOLA has begun to process these early passes to NDVI composites. As the NOAA AVHRR sensor has no visible calibration available onboard, DOLA, with help from Environment Australia, is cross calibrating the data from NOAA 14 and NOAA 16 as a continuing time series of regional and continental NDVI stretching back over 10 years at one kilometre ground resolution.

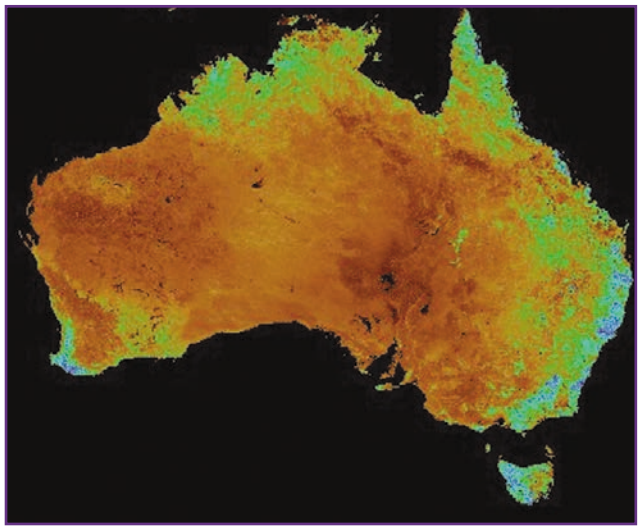


**Figure 1:** Australian continental Vegetation satellite map dated February 2, 2001

## FireWatch

R. Craig et al.

DOLA uses the fire channel, channel 3, of the NOAA AVHRR sensor to provide daily fire hot spot locations on the World Wide Web, www.rss.dola.wa.gov.au/newsite/apps/firedetect.html, for clients and the general public to view. The information is provided by fax to bush fire officers at the regional offices of W.A. Fire and Emergency Services Authority, and the Northern Territory Bushfire Council.

During 2000 a report was presented to the Commonwealth State of the Environment office providing information on all fires and fire affected areas mapped by DOLA, under contract with the Tropical Savannah Cooperative Research Centre, covering the two years 1998-2000. The raw data for this project was NOAA AVHRR data from the WASTAC archive.

Fire affected areas are mapped from daylight passes of NOAA AVHRR. Statewide coverage of both N.T. and W.A. are provided every nine days to the relevant state and territory fire groups. Towards the end of 2000, advantage was taken of the launch of NOAA 16 to provide maps of currently burning large remote fires to DOLA's clients. Images of these fires and uploadable GIS compatible data are available at http://www.rss.dola.wa.gov.au/newsite/apps/firescarmap.html

A recent addition to the Firewatch product range included integration of fire scar affected areas derived from NOAA-AVHRR data, validated and improved from Landsat TM data and imbedded into 1:250,000 topographic maps. A recent fire in the Mt Beaumont – East Esperance area **(figure 2)** indicates the resultant map products.

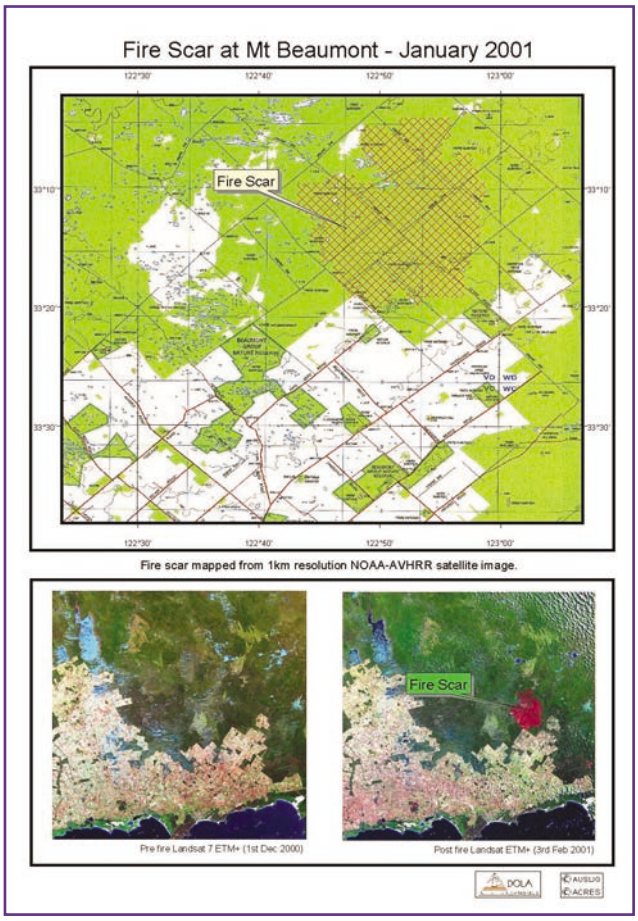



**Figure 2:** Fire scar map derived from NOAA/AVHRR (top). The bottom two LANDSAT TM scenes show the pre and post firescar.

## Flood Monitoring

WASTAC NOAA-AVHRR data was provided to Northern Territories Department of Primary Industry and Fisheries to monitor water movement in the "top-end"of the Northern Territory and keep pastoralists advised of possible trouble spots **(figure 3)**.

The images were provided in near real time to enable land managers to make both strategic and tactical decisions following unprecedented levels of rainfall from

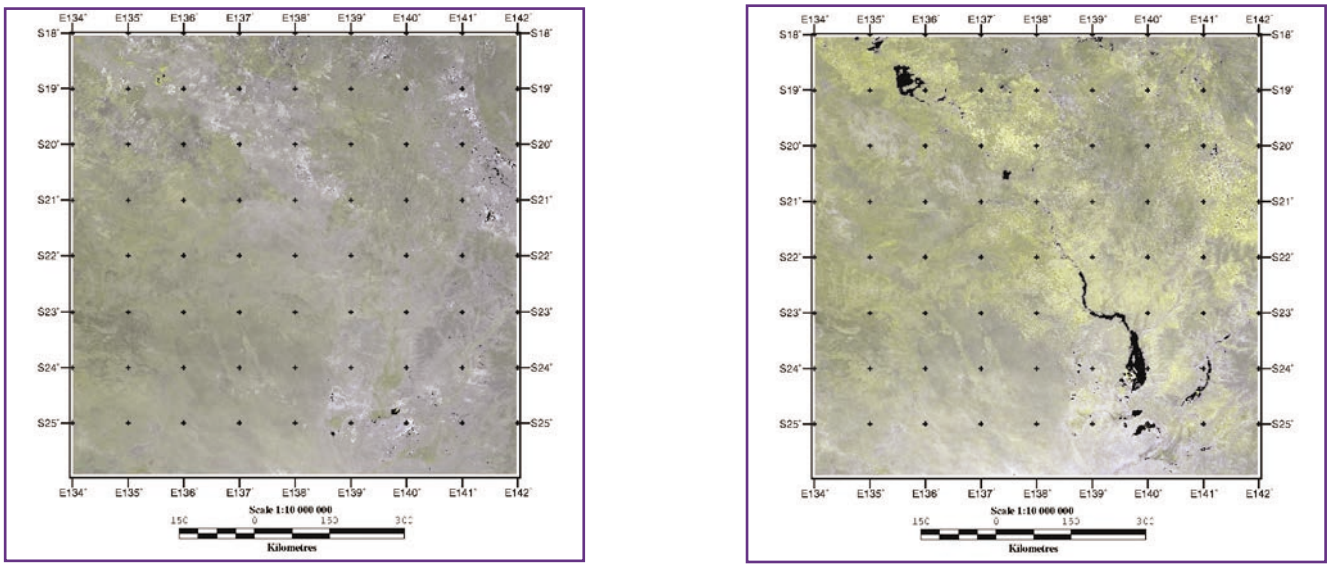



**Figure 3:** The pre-flood NOAA/AVHRR image on the left was taken in October 2000 contrasting with the flooded areas on the January 2001 image (right).

December 2000 to February 2001. A state of emergency was declared in parts of the Victoria River district and mass evacuations resulted.

## Sea Surface Temperature (SST)

M. Steber

SRSS and CSIRO Marine Research continued their collaborative project producing Sea Surface Temperature images **(Figure 4)** for the fishing industry. During the year 244 separate SST images were produced for clients. These clients included other government departments and commercial fisherman. In April 2000 DOLA launched its E-commerce web site Land Online. SST images (under the guise of "Fishing Hotspots") were the first product to appear on this site. Clients are now able to purchase images 24 hours a day using a credit card for $11 (including GST). To help clients determine which image is best (i.e. cloud free), thumbnail images, without the associated annotation and temperature information, are viewable for the seven different regions. The last seven days of Fishing Hotspots products can be purchased at www.landonline.com.au/hotspots.

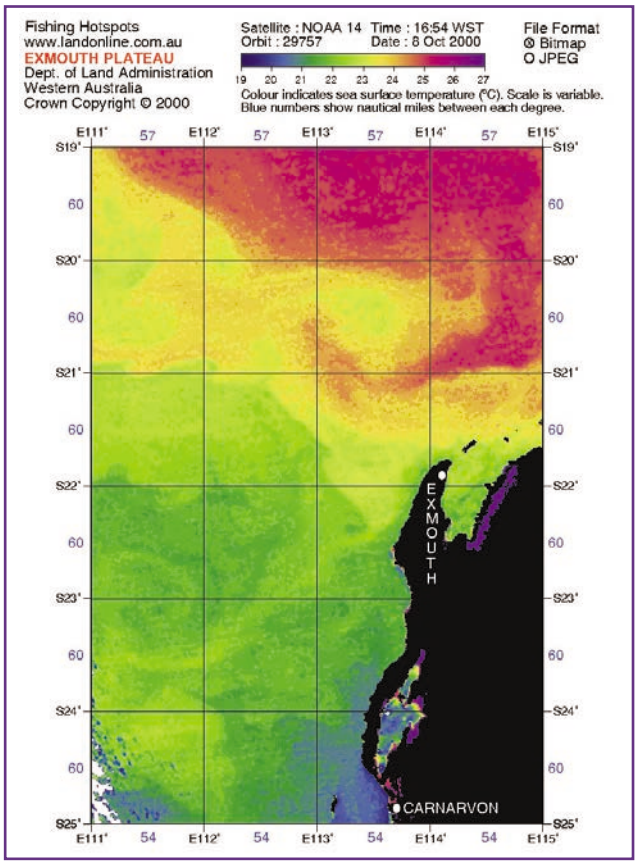



**Figure 4:** Fishing Hotspots product—Exmouth Plateau.

## Agricultural Drought and Frost Maps

R.Stovold, M.Tovar

During the year a number of maps were produced to assist Agriculture WA determine the extent of frost and drought affected areas in southern Western Australia to support applications for federal drought relief funding. By comparing the NDVI index for September1999 and the year 2000 integrated with shire boundary information **(Figure 5)** it was possible to illustrate the worst drought affected areas.

A further dimension to the loss of agricultural crop production is severe frost. Again using the thermal bands of the NOAA-AVHRR satellite, land surface temperature maps were produced **(Figure 6)**.

The damage to crops caused by the frost conditions could be assessed over individual shires.

A new regional biomass map derived from NDVI-AVHRR data has been developed for agribusiness managers on a monthly basis to support the monitoring of the development of cropping season on a regional basis. These maps have been incorporated with isohyet data.

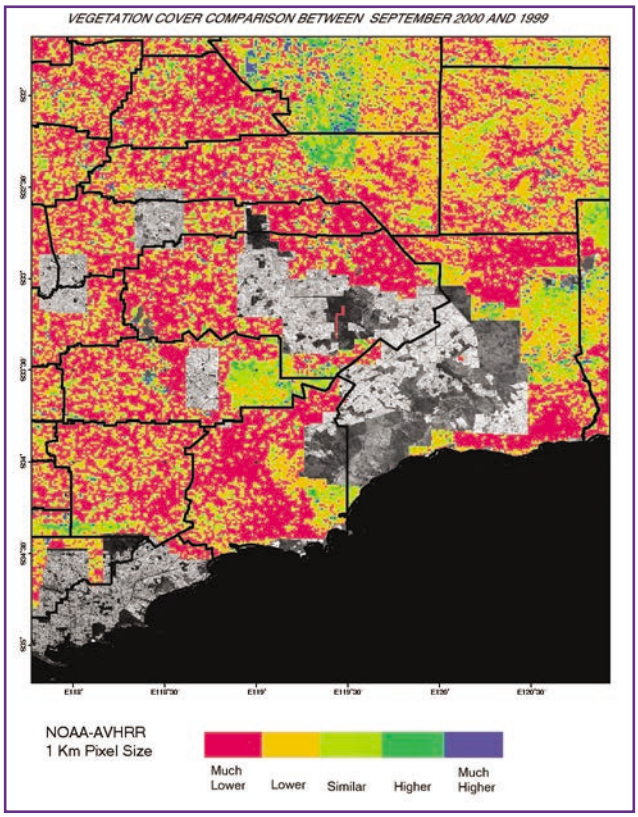



**Figure 5:** Vegetation cover comparison map of the south coast of W.A.

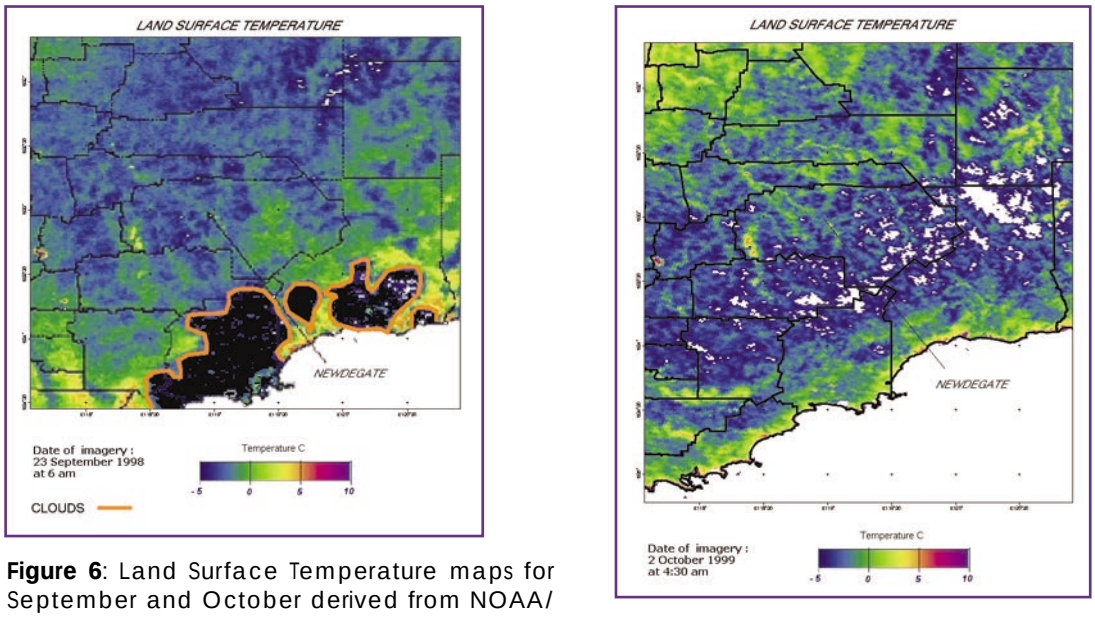



**Figure 6**: Land Surface Temperature maps for September and October derived from NOAA/ AVHRR.

## MODIS Data—A New era of Land and Water information

R. Stovold

With its sweeping 2,330-km-wide viewing swath, MODIS sees every point on our world every 1-2 days in 36 discrete spectral bands. Consequently, MODIS greatly improves upon the heritage of the NOAA Advanced Very High Resolution Radiometer (AVHRR) and tracks a wider array of the earth's vital signs than any other Terra sensor. For instance, the sensor measures the percent of the planet's surface that is covered by clouds almost every day. This wide spatial coverage will enable MODIS, together with MISR and CERES, to determine the impact of clouds and aerosols on the Earth's energy budget. The sensor has an unprecedented channel (centered at 1.375 microns) for detection of wispy cirrus clouds—believed to contribute to global warming by trapping heat emitted from the surface. Conversely, cumulus clouds and aerosols are thought to have a cooling effect on the Earth's surface by reflecting and absorbing incoming sunlight.

MODIS is ideal for monitoring large-scale changes in the biosphere that will yield new insights into the workings of the global carbon cycle. While no current satellite sensor can directly measure carbon dioxide concentrations in the atmosphere, MODIS can measure the photosynthetic activity of land and marine plants (phytoplankton) to yield better estimates of how much of the greenhouse gas is being absorbed and used in plant productivity. Coupled with the sensor's surface temperature measurements, MODIS' measurements of the biosphere are helping scientists track the sources and sinks of carbon dioxide in response to climate changes.

Almost every day over the entire globe, the sensor monitors changes on the land surface, thereby building upon and extending the heritage begun by Landsat. MODIS maps the areal extent of snow and ice brought by winter storms and frigid temperatures. The sensor observes the "green wave" that sweeps across continents as winter gives way to spring and vegetation blooms in response. It sees where and when disasters strike—such as volcanic eruptions, floods, severe storms, droughts, and wildfires—and will hopefully help people get out of harm's way. MODIS' bands are particularly sensitive

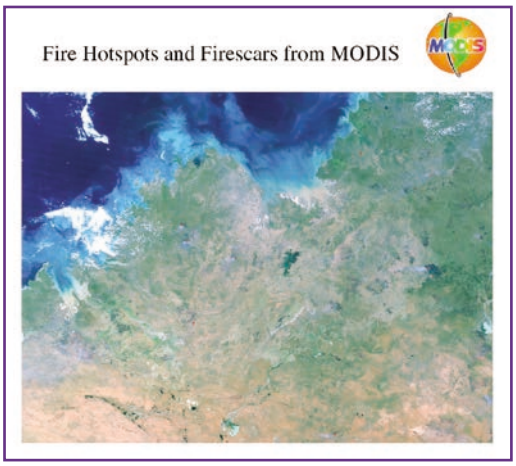



**Figure 7:** Northern Kimberley region depicting two fire hotspots and scars from MODIS.

to fires; they can distinguish flaming from smoldering burns and provide better estimates of the amounts of aerosols and gases that fires release into the atmosphere **(Figure 7)**.

MODIS sees changes in the phytoplankton populations that may signal the onset of the famous El Niño/La Niña climatic siblings well ahead of their arrival. In turn, by coupling its sea surface temperature and ocean colour measurements, MODIS will observe the impacts El Niño and La Niña have on the microscopic marine plants. While these measurements extend and build upon the heritage of the Coastal Zone Color Scanner, MODIS also has a unique new channel for measuring chlorophyll fluorescence. All plants bombarded with light begin to glow, or fluoresce, but in wavelengths that our eyes cannot see. The more plants fluoresce, the less energy they are using for photosynthesis. Thus, MODIS not only maps the distribution of phytoplankton, it also helps us gauge its health. (Article partly extracted from NASA Terra website http://terra.nasa.gov/ABOUT/MODIS/about_modis.html)

# CURTIN UNIVERSITY OF TECHNOLOGY

Compiled by MJ Lynch

## SeaWiFS Data Reception, Decryption and Archive

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Under the WASTAC Agreement with NASA/GSFC and OrbImage to downlink SeaWiFS data is the requirement to decrypt the data to Level 1a and hold it on archive for subsequent capture by the NASA SeaWiFS Science Team. The data downlink is achieved via the WASTAC S-band receiver. Delayed data decryption is achieved using the Seastar Ground Processor supplied by OrbImage. Decrypted data are held on active archive for capture by NASA and the raw level data are written to CD.

The project has operated from late 1997, when SeaWiFS was launched, and continues through year 2000 with 3 years of data collected, decrypted and archived. The data are used locally for research purposes under licensing agreement with NASA and OrbImage.

## SeaWiFS Application to Monitoring Marine Parks

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*CSIRO Marine Research

This is a 3-year research project supported under the NHT/ Coasts and Clean Seas programme. It primarily involves the development of a series of water quality indicators, their measurement from satellite and the validation of these products using in situ measurement. With respect to the latter, a series of cross shelf transects have been undertaken at regular intervals from Hillarys to some 40 km out to sea (also see p11). A number of bio-optical, thermal, physical and biological measurements are recorded at 9 predetermined measurement stations. Satellite data from SeaWiFS are used to produce chlorophyll a and light attenuation coefficient at 490 nm. Sea surface temperature data are extracted from NOAA/AVHRR and used to classify water type and identify dynamical processes.
A primary output from the project is the establishment of baseline data on the Perth Marine Parks that includes the spatial and seasonal variability as well as the interannual variability. Additionally, the factors that influence the water quality, such as coastal dynamics that transport water through the Parks, are also being studied. In particular, the influence of the poleward flowing Leeuwin Current and the equatorward flowing Capes Current are seen to be significant factors influencing regional water quality.

## Environmental Monitoring of Timor Sea Water Quality

P Hick*, M Lynch**, P R C Fearns**, H Chedzey** and J Wilson*
*CSIRO Exploration and Mining
Leeuwin Centre for Earth Sensing Technologies, Floreat WA
**Remote Sensing and Satellite Research Group
Curtin University of Technology

This is a combined project between Curtin Remote Sensing and Satellite Research Group and CSIRO Exploration and Mining to assess the Timor Sea region using products available from AVHRR, SeaWiFS and Landsat TM.

The purpose of this work was to investigate the effectiveness of remotely sensed data to ascertain the extent of spatial and temporal variations in sea surface temperature (SST), chlorophyll a concentration and light attenuation (K_490) in the Timor Sea.

A 12 month study (October 1999 through to September 2000) was undertaken to initiate a 'first glance' analysis of the area and provide a baseline archive for comparisons with future observations. This information then has the ability to be applied to better understand the physical characteristics and processes occurring in the region and add to the current knowledge of large-scale environmental processes in the area.

While valuable information resulted from this work, any definitive annual trend results were hindered by the persistent presence of cloud at tropical latitudes (9° to 15°S) and a technical malfunction occurring at the data reception facility during the study period. Extending the study periods would provide more environmental information from the area and allow the annual cycles to become better defined therefore improving confidence in trend analysis.

## Atmospheric Correction of SeaWiFS Ocean Colour Imagery

J E Davies and M J Lynch
Remote Sensing and Satellite Research Group
Curtin University of Technology

The SeaWiFS instrument was designed to gather information about ocean pigment concentration by measuring, from space, the sunlight reflected by the ocean (beneath the air/water interface). For this to be possible, at an accuracy useful for quantitative studies in ocean bio-productivity, the reflection and transmission properties of the atmosphere must be carefully modelled so that the atmospheric radiance component (which may be up to ten times the radiance ocean component in some spectral regions) may be removed from the satellite measurement.

Current generation over-ocean atmospheric correction algorithms use one or more channels at wavelengths that are long enough to be strongly absorbed by liquid water but short enough to be in the solar reflective region. Over the ocean these channels are therefore "atmosphere sensing" and may be used to characterise the optical properties of the atmosphere alone. An optical model can be used to extrapolate these properties to the shorter wavelength "ocean sensing" channels, channels which contain both the atmospheric radiance component to be removed and the ocean-leaving radiance that contains information on ocean pigment concentration. The principal difficulty is the presence of atmospheric aerosol since a number of defensible physical aerosol models can, at any given sample point (pixel), predict the radiometric observations in the "atmosphere sensing" channels but extrapolate differently into the "ocean sensing" channels with measurable consequences for ocean pigment retrievals.

We have modelled the maritime aerosol atmosphere using the three component (mode) Navy aerosol model since each mode has both spectral characteristics and a spatial correlation index. A satisfactory characterisation of the aerosol atmosphere in the "atmosphere sensing" channels now requires not only the closure of the radiance constraint equations on a pixel by pixel basis (to within instrument and modelisation noise levels) but also a minimisation of the aerosol mode's optical thickness spatial variances. To this end we have synthesised high resolution (1nm) bidirection reflectance distribution functions (BRDFs) for the ocean surface/atmosphere system using MODTRAN single scattered radiances and an in-house developed multiple scattering model. The BRDFs are decimated to match SeaWiFS spectral bandpasses and parameterised. BRDFs can then be generated for aerosol optical thickness as a continuous variable and adjusted for perturbations to ozone and water vapour concentrations and to surface barometric pressure. Construction of a combined spectral/spatial penalty function and a rapid forward prediction capacity (in an inherently non-linear system) permits characterisation of the aerosol atmosphere and its optical properties across all channels.

## Ocean Colour Modelling and Measurement

P R C Fearns and M J Lynch
Remote Sensing and Satellite Research Group
Curtin University of Technology

This work has focussed on the modelling of ocean optical processes. A Monte Carlo ocean optical model has been developed and used to investigate the relationship

between in-water inherent optical properties and the water-leaving radiance field. A relationship between the optical properties and the up-welling light field has been derived based on the results of this investigation.

Predictions of ocean reflectance and the structure of the upwelling radiance field based on this work have been compared to predictions based on HYDROLIGHT as well as modelling results of Andre Morel. A chlorophyll concentration retrieval scheme based on these predictions has been proposed and is being tested using data from the Hillarys cruises and the SeaWiFS satellite.

## Chlorophyll Seasonal and Interannual Variability in WA Coastal Waters

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Curtin University of Technology
*CSIRO Marine Research

The majority of work carried out in the year 2000 centred around the study of seasonal and interannual changes in phytoplankton (chlorophyll) concentration in the eastern Indian Ocean as measured by the Coastal Zone Colour Scanner (CZCS). Results suggest that the overall mean concentration is notably lower in the eastern Indian Ocean than for comparable regions in the eastern South Pacific and South Atlantic Oceans. Notable seasonal variation in relatively close coastal regions was observed along both the Western Australian coastline and Indonesian Islands. This is highlighted by the seasonal variation between the northern and western/southern Western Australian coastlines, where the highest concentrations are noted in summer and autumn/winter respectively. Interannual variation was also studied, with the years of 1981 to 1983 showing higher concentrations than occurred in the other years in which the CZCS was in operation (1979-1980 & 1984 to 1986).

Later work concentrated on the study of possible forcing terms which may have influenced the changes observed in phytoplankton productivity. These include nutrient levels, sea surface temperature (SST), wind speed data as well as the El-Niño (ENSO) of 1982/83. Furthermore, factors which may have influenced accuracy of data were studied such as the bathymetry in close coastal areas, especially along the northern section of the Western Australian coastline.

## The Productivity of Indonesian Waters Using SeaWiFS Data

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Remote Sensing and Satellite Research Group
Curtin University of Technology

The waters around Indonesia vary widely in their productivity because of factors such as upwelling, river outflows and pollution. In some regions water quality and productivity are very high, in other regions productivity is extremely low and other indicators of significant pollution problems are the presence of red tides or hazardous algal blooms. This project is using data from the SeaWiFS sensor to primarily assess the variability of Chl a in these waters over the annual cycle and interannually. The remote sensing work is coupled to field work and to date two cruises in the region have been undertaken as part of validating the satellite products. The data analysis is continuing.

*AusAID Scholar from University of Brawijaya, Malang, Indonesia.

## Monitoring the Oceanic Primary Production of the Western Australian Coast

L Majewski, M J Lynch, P R C Fearns
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Curtin University of Technology

The Western Australian commercial fishing industry has an annual turnover of approximately AUD $1billion. Factors that may affect the quality and quantity of the Western Australian fish stocks – such as the level of nutrients or the quality of the water – need to be observed. It is hoped that through the use and application of ocean colour data collected by the Sea-viewing Wide-Field-of-view Sensor (SeaWiFS), favourable or unfavourable conditions may be determined.

Ocean colour refers to the colour of an oceanic body of water. From the colour of the water an estimate of the abundance of phytoplankton may be obtained. Phytoplankton is a form of free-floating organism (algae, diatoms, coccolophores, and dinoflagellates) that can carry out photosynthesis. This phytoplankton forms the base of the marine food web.

Green waters indicate that a lot of phytoplankton is in the water, while blue waters indicate that there is very little phytoplankton present—phytoplankton

appear green because the chlorophyll within them (the substance that allows them to undergo photosynthesis) reflects green light. This photosynthetic process produces sugars from carbon dioxide and water from within the green plant cells—provided the cells are sufficiently illuminated.

The chemical energy contained within an ecosystem as a direct result of photosynthesis is commonly referred to as oceanic primary production (OPPn). As phytoplankton is the main contributor to this OPPn an estimate (of OPPn) may be obtained by combining the SeaWiFS estimates of chlorophyll concentration with estimates of daily photosynthetic available radiation (PAR) and the biological properties of the observed phytoplankton.

The SeaWiFS chlorophyll concentration data and the subsequently derived primary production product may be used to diagnose conditions that may affect the Western Australian coastal environment and any flow on effect this may have on the Western Australian commercial fisheries.

## Radiative Transfer Approaches to Determining Coastal Water Properties

W Klonowski, P R C Fearns and M J Lynch
Remote Sensing and Satellite Research Group
Curtin University of Technology

Shallow water regions pose additional complexities to the determination of water inherent optical properties since the bathymetry and the sea bottom reflectance impact the water leaving radiance. A simple approach might proceed by assuming that over the annual cycle the water depth and bottom reflectance are relatively constant and that this would enable a first order correction to be made for the bottom reflectance in extracting the inherent optical properties of the water column. A sample of 12 SeaWiFS images at a coastal site have been extracted for testing this scheme. However, a more rigorous approach is desirable if accurate correction is to be achieved. In principle, the in-water radiative transfer equation must be solved for the water inherent optical properties as well as water depth and bottom reflectance. The inversion of the radiative transfer equation may be attempted using one of the standard schemes, such as Levenburg-Marquardt. Simulated data, for example using a forward model, are required initially to test the retrieval scheme and possible used to refine it. Subsequently in situ data are required to validate the algorithm and assess the uncertainties.

## Remote Sensing of the Annual Chlorophyll Cycle of Geographe Bay

A Jutström[$], P R C Fearns[*] and M J Lynch[*]
Visiting Scientist Umeå University Kiruna, Sweden.
[*]Remote Sensing and Satellite Research Group
Curtin University of Technology

The Geographe Bay region is of interest because its level of in-water chlorophyll (Chl a) is impacted by two major currents, namely the Leeuwin Current that runs poleward and strongest during the winter months and has its origins in the Tropics. The Capes Current, in contrast, is an equatorward flow that initiates later in the year from waters to the south of the Australian continent when the Leeuwin Current weakens. Accordingly, the Leeuwin Current is a warm, low salinity and low nutrient flow whereas the Capes current is colder and higher in nutrients.

In this project data from the SeaWiFS sensor for the period November 1997 - November 1998 were processed into Chl a concentrations. Monthly median composite images were produced for a number of selected study areas along the coast to the north of and within Geographe Bay as well as along the Capes and further south so as to sample the Capes Current.

The interpretation of the temporal and spatial Chl a variability is undertaken with respect to the influence of these two coastal currents.

[$]Financial support for A Jutström from the Space Technology Program at Umeå University, Kiruna, Sweden is gratefully acknowledged..

## Remote Sensing of the Annual Chlorophyll Cycle in the Timor Sea

J Jutström[$], P R C Fearns[*] and M J Lynch[*]
Visiting Scientist Umeå University Kiruna, Sweden.
[*]Remote Sensing and Satellite Research Group
Curtin University of Technology

Data from the SeaWiFS sensor was used to conduct an initial investigation into the annual cycle of the production of chlorophyll (Chl a) in the Timor Sea off the north-western coast of Australia. The region is impacted by the Indonesian throughflow in winter and by monsoonal activity in the summer. These events will impact both the physical and biological properties of the Timor Sea. The monsoons, through direct precipitation over the ocean and from river outflow

onto the continental shelf from the Kimberley region river system, are processes that might lead to contrasting water masses in the region. In this preliminary study a grid of 61 regions was overlaid on the study area to permit comparisons to be made of Chl a concentrations to be made over the annual cycle. In particular, SeaWiFS data sets from the WASTAC archive were processed for the period November 1997 to November 1998. Median Chl a images were produced for each month in the annual cycle for each gridded region and the Chl a concentration produced for each region for the annual cycle. Generally background Chl a levels were low (0.2 - 0.3 $mg.m^{-3}$) and in the southern part of the study area evidence of an annual cycle with peak concentration in July of order 1 $mg.m^{-3}$ was observed. Some problems with data coverage were encountered arising from antenna problems (at low satellite elevation angles) and high levels of cloud cover due to monsoonal influences. The interpretation of the data would be enhanced if both sea surface temperature and altimetry data were available.

[$] Financial support for J Jutström from the Space Technology Program at Umeå University, Kiruna, Sweden is gratefully acknowledged.

## Investigation of Western Australian Tropical Cyclones Using NOAA/ MSU Data

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[*]Remote Sensing and Satellite Research Group
Curtin University of Technology

Microwave data from the Microwave Sounding Unit (MSU) has been applied to the estimation of the intensity of tropical cyclones off the NW coast of WA. In particular, the brightness temperature of MSU channel 3 has been used to estimate the system central pressure at the surface. A regression relationship, specific to these systems, has been derived, $P_{surf} = 22.4\ T_{msu} + 5.5$ (hPa), that has a regression coefficient of 0.68 and a standard error of 14 hPa.

Additionally, a horizontal structure scheme has been implemented using the MSU channel 3 temperature anomaly fields.

### *Some Interesting Web Links for Ocean Colour*

SeaWiFS Homepage
http://seawifs.gsfc.nasa.gov

NASA Ocean Colour Information
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/OB_main.html

NASA Ocean Primary Production Homepage
http://opp.gsfc.nasa.gov

IOCCG Homepage
http://www.ioccg.org

Earth Observatory Homepage
http://www.earthobservatory.nasa.gov

Fisheries WA Homepage
http://www.wa.gov.au/westfish/

# Bureau of Meteorology, Melbourne

Mike Willmott, David Griersmith, Agnes Apostolou, John Le Marshall

## Sea Surface Temperatures (derived from NOAA data)

The Bureau of Meteorology calculates satellite derived sea surface temperatures (SSTs) for the Australian region by combining data from the WASTAC Perth station with similar NOAA AVHRR data from its Casey, Melbourne and Darwin stations. The AVHRR data is navigated, calibrated, cloud cleared in real time and the processed orbit is available within an hour after the completion of the ingest. The resulting SSTs for a particular orbit are then sent to Melbourne for inclusion into the Bureau's national data set. The data is then quality controlled against SST data collected from ships and drifting buoys prior to being mosaiced into a national map. These data are mainly used in support of internal and defence operations (e.g. assimilation into Bureau numerical weather prediction models) but are also available to external users as metadata and browse images of daily mosaics (from November 1998) via the world wide web at **http://www.bom.gov.au/nmoc/archives/SST/.** A subscription service is also available for real time SST data and regional products via the Bureau's "Weather by Fax" service. The SST grid data are archived as part of Australia's National Climate Record.

The coverage from the four stations is shown in **Figure 1**, which shows the contribution from the WASTAC station and the Bureau's stations at Melbourne, Darwin and Casey.

SSTs are calculated using the Local Area Coverage data received at Melbourne, Perth and Darwin for each orbit of NOAA-15, -14 and -12. The maximum resolution of the pixels in each orbit is 1.1 km$^2$. The SSTs for any individual orbit will have gaps where the pixels have been tested and rejected from the calculations due to suspected cloud contamination or where the satellite zenith angle is greater than 53$^0$. Corrections are applied in the SST algorithms for intervening atmospheric absorption and to daytime algorithms for reflected solar radiation. **Figure 2** shows an example of a southbound NOAA-15 orbit over Western Australia, and **Figure 3** shows SSTs derived from that orbit.

A running 15 day composite SST mosaic in Mercator projection is used to provide complete coverage of the Australian region. The Mercator mosaic has a resolution of 2 x 2 km at the equator increasing to 1.4 x 1.4 km at 45°S. The latest available data pixels are used. However, where pixels are rejected on the basis of cloud contamination over a sequence of orbits, the data from previous days orbits are used. Areas of missing data in the composite mosaic indicate areas of cloud contamination persisting for more than 15 days. An associated age of data mosaic is also produced to complement interpretation of the SST mosaic. **Figure 4** shows the mosaic for the Australian Region and **Figure 5**, the age of data used in the mosaic.

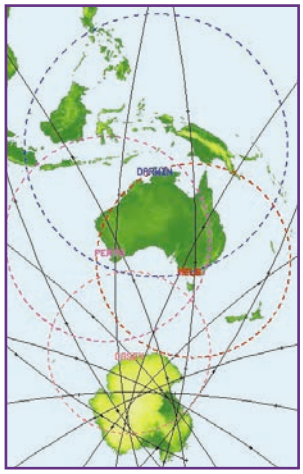

**Figure 1.** Map showing NOAA coverage from the Bureau's Casey, Melbourne, and Darwin reception stations and the Perth WASTAC reception station.

The Bureau has upgraded the processing of AVHRR data for SSTs to full resolution and future work will address better temporal resolution via use of geostationary satellites (hourly as compared to 6 hourly imagery) to reduce the impact of diurnal cloud contamination which can affect current SST mosaics.

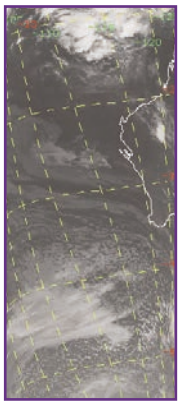

**Figure 2.** Southbound NOAA 15 Orbit for 00:31UTC 31 January 2000.

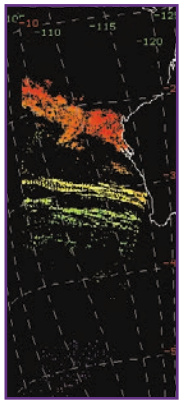

**Figure 3.** SSTs derived from orbit in Figure 2.

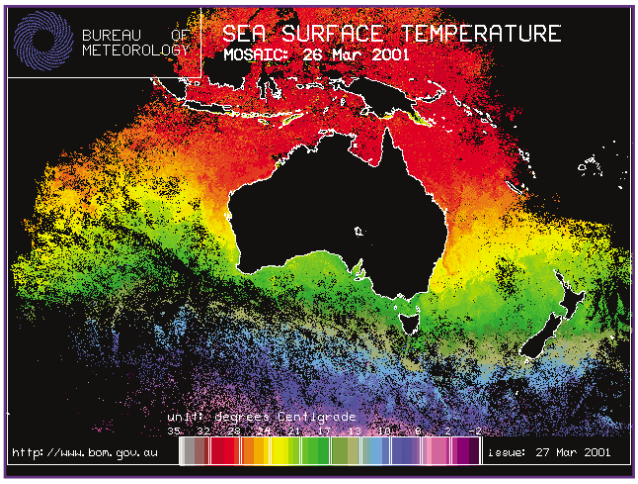


**Figure 4.** Map showing National coverage of Sea Surface Temperatures for 26 March 2001.

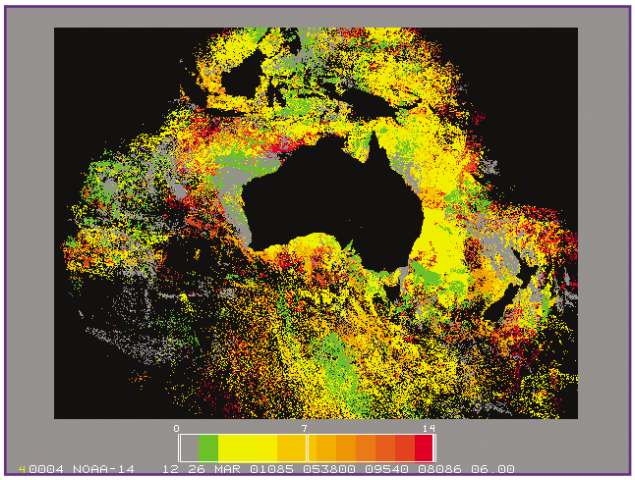


**Figure 5.** Map showing "age of pixels" for 26 March 2001. The black pixels are either "no data" or rejected pixels over 15 days old.

## Weather Modelling/Forecasting

The Bureau has produced locally derived Tiros Operational Vertical Sounder (TOVS) data for a number of years and more recently has been producing similar data from the Advanced TOVS system on NOAA-15. These data provide valuable information on vertical profiles of atmospheric temperature and moisture over the Australian region. With increased resolution of numerical weather prediction (NWP) models, data analysis and assimilation has become increasingly important. The standard observational network (ground and balloon based) has been supplemented by the inclusion of TOVS/ATOVS data into analysis and assimilation schemes. It has been shown (Kelly et al., 1999; Lesley and Le Marshall, 1999; Le Marshall et al., 1999) that assimilation of TOVS data into the Limited Area Prediction System (LAPS) NWP model improves the overall skill scores of the prognosis for +6, +12, +24 and +36 hours. The data received from the WASTAC system greatly improves the coverage of the data to the west of the continent and hence improves the overall skill of the models. **Figure 6** shows the coverage of ATOVS 500 hPa temperatures over southern Australia, whilst **Figure 7** shows an example of AMSU-A (an ATOVS instrument on board NOAA-15 and -16) data in the form of 250 hPa temperatures.

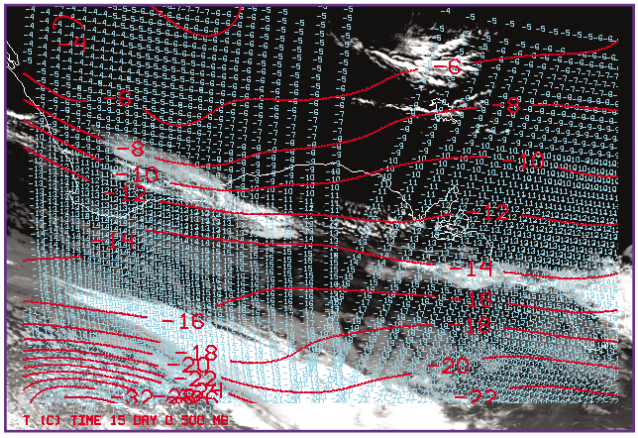

**Figure 6.** Coverage of ATOVS 500hPa temperatures over the southern portion of Australia (16 April 2001). Background image obtained from GMS-5.

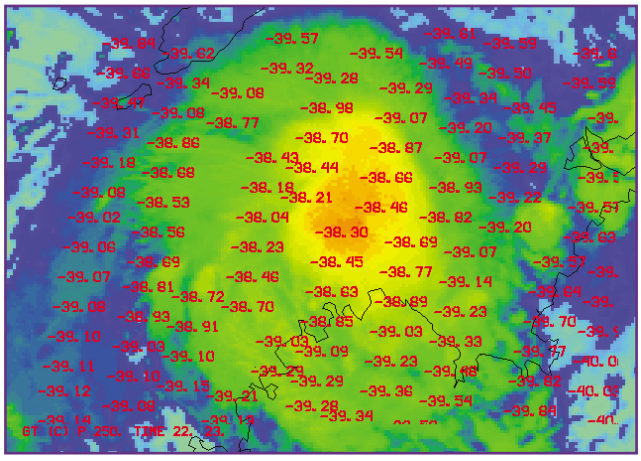

**Figure 7.** Example of AMSU-A 250 hPa temperatures over Tropical Cyclone Alistair, off the north coast of Western Australia (17 April 2001). Background image obtained from GMS-5.

## Fire Hot Spots and Smoke

The Bureau has developed algorithms for fire detection and although focused on the southern States will, in the future, use WASTAC AVHRR data operationally in support of its statutory obligations to supply fire weather forecasting and warning services for Western Australia.

## NDVI and relative greenness index

The Bureau currently produces NDVI products using AVHRR data received in Melbourne and Perth, which collectively give more comprehensive coverage in support of Bureau services, climate studies and research. The data is mosaiced using a maximum value composite approach and the WASTAC data enables a more complete coverage. The current product is available at http://www2.ho.bom.gov.au/nmoc/NDVI/ (an example of output is given in **Figure 8**).

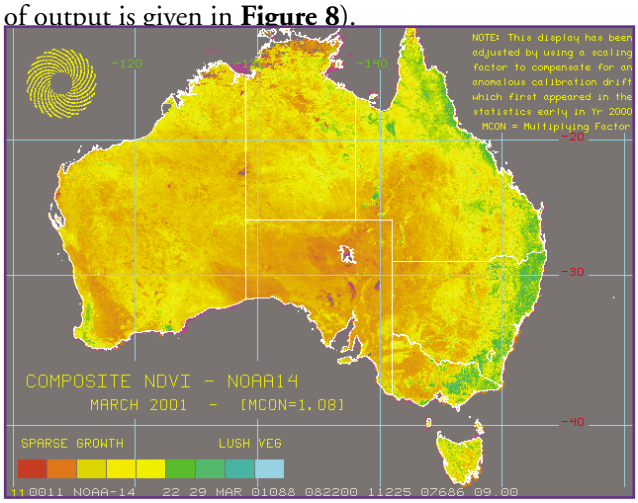


**Figure 8.** An example of the Bureau's Maximum Value Composite NDVI product.

## Flood Monitoring

The Bureau uses AVHRR data for flood monitoring in an operational and case study environment using various techniques. The systems, although under development,

have produced many useful images for the Bureau's hydrological services. The Bureau currently produces ad hoc NDVI images to assist in the national monitoring of flooded areas as well as special enhancements using multi channel techniques. An example of flood monitoring using NOAA-16 AVHRR data from northern WA is shown in **Figure 9** (multi channel technique).

## Volcanic Ash

The Bureau uses AVHRR (and GMS-5) data to monitor volcanic ash plumes from active volcanoes which are extremely hazardous to aviation. The most active volcanic region in the world lies just to the north of Australia where international air traffic to and from Australia is concentrated. Even though the Volcanic Ash Advisory Centre is located in Darwin, the AVHRR data from Perth is reviewed for a full coverage of Darwin's area of responsibility. By way of example, in 1996/97 Darwin issued a total of 267 advices covering the area south of $10^0$N between longitudes $100^0$ E to $160^0$ E.

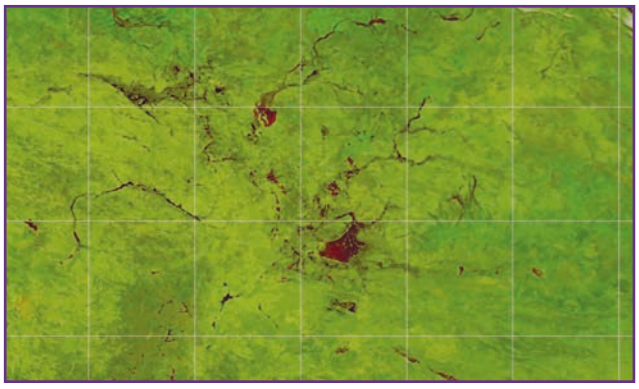

**Figure 9.** Example of multi channel false-colour composite image from NOAA-16 showing flooding along the Fitzroy River and in Lake Mackay (WA), on the 28 March 2001.

## Cyclone Monitoring

The Bureau's Western Australian Regional Forecasting Centre in Perth provides warnings of tropical cyclones whenever the need arises from their Tropical Cyclone Warning Centre (TCWC). The AVHRR data is used to assist in the monitoring of fine detail of tropical cyclones and supplements the positioning of these large systems by radar, GMS-5 imagery and NWP analysis. It is also a critical back-up to GMS-5 imagery noting that GMS-5 is now beyond its design life. As an example, **Figure 10** shows a tropical cyclone affecting Western Australia.

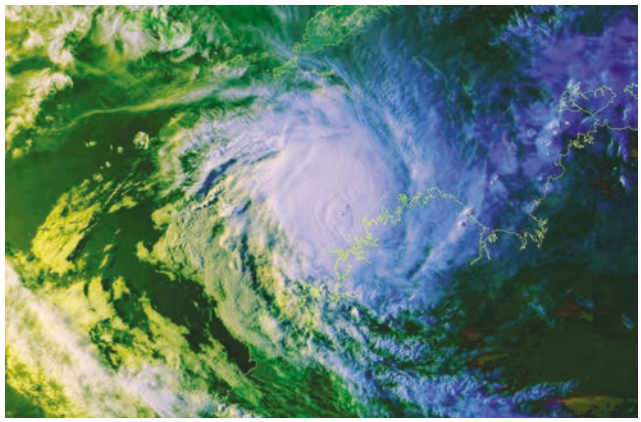

**Figure 10.** A NOAA-12 image (RGB Channels 1,2,4) of Tropical Cyclone Alistair off the north coast of Western Australia (18 April 2001).

## Fog and Low Cloud

The Bureau has commenced a research program to enhance its fog and low cloud forecasting services (including accuracy) especially for the aviation industry. This involves use of many observational and NWP techniques and the WASTAC AVHRR data will be of major importance in this. Various algorithms are being refined which use several channels in the AVHRR data to delineate low cloud and fog. Perth airport can be particularly susceptible to dangerous fog incidents. An example of NOAA AVHRR data for fog and low cloud determination is shown in **Figure 11**.

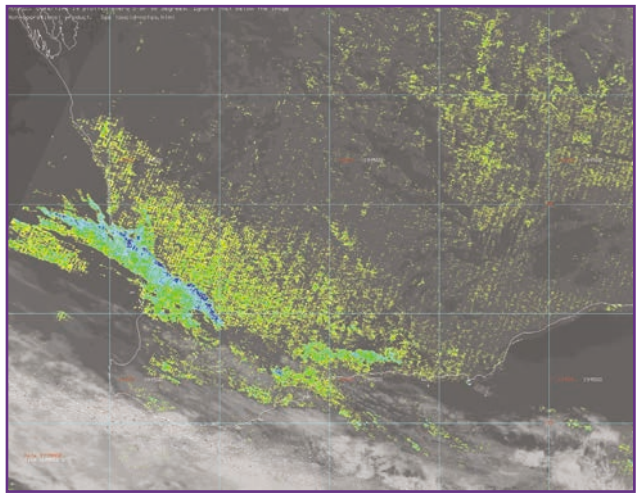

**Figure 11.** An example of the application of NOAA-16 channels 3 and 4 for the determination of areas of fog and low cloud (shown in green, cyan and blue) over the southern portion of Western Australia (15 April 2001).

## DCPs

As part of an international commitment, the Bureau provides Tiros Information Processor (TIP) data to Argos (Collecte Localisation Satellites) for input into its tracking system. The TIP data stream has embedded data from the Argos instrument carried on board NOAA satellites. The instrument allows the collection of data from remote platforms or transmitters on board ships, yachts, ocean buoys, animals, birds, cargo, etc. The Perth data gives Argos enhanced capabilities of receiving and using the data real-time (within 15 minutes of the end of the orbit) rather than having to wait 1 to 3 hours for the recorded data. In addition, the Bureau extracts and processes DCP data from the WASTAC TIP data to provide observations of meteorological variables such as pressure and temperature over data sparse ocean areas.

## AVHRR Access Service

The Bureau provides a realtime ftp subscription service to AVHRR data.

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# Financial Information

# WASTAC Budget 2001

**Estimated expenditure for the year**
**January 2001 – December 2001**

| | | PER ANNUM | |
|---|---|---|---|
| | | **2001** | **2000** |
| | | **$** | **$** |
| 1. | Telstra Rental | 4,980 | 4,980 |
| 2. | Data Tapes | 4,800 | 4,800 |
| 3. | System maintenance/repairs | 6,000 | 6,000 |
| 4. | Telecommunications licence of facility | 1,500 | 1,500 |
| 5. | Consultants (X Band proposal) | 3,000 | 12,000 |
| 6. | Sundry consumables | 1,500 | 1,500 |
| 7. | Travelling – Airfares | 3,000 | 4,000 |
| 8. | Provision for major equipment | 12,000 | 17,500 |
| 9. | Annual Report | 4,000 | 4,000 |
| TOTAL: | | $40,780 | $56,280 |

**Estimated income/revenue for the year**
**January 2001 – December 2001**

| | | | |
|---|---|---|---|
| 1. | Contributions received ($10,000 each member) | 40,000 | 40,000 |
| 2. | Sundry income (data replication) | 1,000 | 5,000 |
| 3. | Interest | 5,500 | 1,500 |
| **TOTAL INCOME:** | | **$46,500** | **$46,500** |

**Extra-ordinary expenditure January**
**2001 – December 2001**

| | | |
|---|---|---|
| 1. | Capital Reserve: | |
| | 1.1 Antenna replacement and componentry | $110,000 |

## Independent Auditor's Report

I have audited the attached financial statements for the year ended 31 December 2000 and in my opinion they fairly represent the transactions of the Consortium for the year then ended, the financial status as at 31 December 2000, and associated cash flows. The statements are based on proper accounts and records.

**P J Periam CPA**
Director Internal Audit
Curtin University of Technology
23 March 2001

## Balance Sheet as at 31 December 2000

| | NOTE | 2000 $ | 1999 $ |
|---|---|---|---|
| **CURRENT ASSETS** | | | |
| Cash at Bank | | 164,577 | 152,867 |
| Prepayments | | - | - |
| **TOTAL CURRENT ASSETS** | | 164,577 | 152,867 |
| **NON - CURRENT ASSETS** | | | |
| Computer Equipment | 2a | 17,426 | 23,235 |
| Other Equipment | 2b | 39,309 | 44,897 |
| **TOTAL NON - CURRENT ASSETS** | | 56,735 | 68,132 |
| **TOTAL ASSETS** | | **221,312** | **220,999** |
| **CURRENT LIABILITIES** | | | |
| Creditors & Borrowings | | - | - |
| Accrued Expense | | - | - |
| **TOTAL CURRENT LIABILITIES** | | - | - |
| **NON - CURRENT LIABILITIES** | | | |
| Creditors & Borrowings | | - | - |
| **TOTAL NON - CURRENT LIABILITIES** | | - | - |
| **TOTAL LIABILITIES** | | **-** | **-** |
| **NET ASSETS** | | **221,312** | **220,999** |
| **SHAREHOLDERS EQUITY** | | | |
| Asset Revaluation Reserve | 3 | 129,997 | 129,997 |
| Retained Profits/(Losses) | 4 | 91,315 | 91,002 |
| **TOTAL SHAREHOLDERS EQUITY** | | **221,312** | **220,999** |

# Income and Expenditure Statement for the Period 1 January 2000 to 31 December 2000

| | NOTE | 2000 $ | 1999 $ |
|---|---|---|---|
| **INCOME** | | | |
| Contributions Received | 5 | 40,000 | 40,000 |
| Sundry Income | | - | - |
| Interest Received | | 7,612 | 5,366 |
| **TOTAL INCOME** | | **47,612** | **45,366** |
| **EXPENDITURE** | | | |
| Annual Report | | 3,729 | - |
| Outsourced Work | | 5,885 | 4,800 |
| Conference Attendance | | 1,115 | - |
| Telephone | | 5,600 | 3,850 |
| Data Tapes and Disks | | 6,954 | - |
| Consumables | | - | 4,454 |
| Printing, Stationery & Photocopying | | 4,100 | 3,990 |
| Depreciation | | 11,397 | 14,246 |
| Maintenance of Equipment | | 6,500 | 790 |
| Equipment < $1,000 | | 832 | - |
| Computer Equipment Purchases | | - | 1,295 |
| Telecommunications License of Facility | | 1,187 | 1,193 |
| Loss on Disposal of Asset | | - | 612 |
| **TOTAL EXPENDITURE** | | **47,299** | **35,230** |
| Net surplus (deficit) | | 313 | 10,136 |
| Extraordinary items net surplus (deficit) and | | nil | nil |
| Extraordinary items | | 313 | 10,136 |
| Transfers to asset revaluation reserve | | nil | nil |
| Net surplus (deficit) transferred to retained profits/(losses) | | 313 | 10,136 |

# CASH FLOW STATEMENT
# FOR THE YEAR ENDED 31 DECEMBER 2000

| | $ | |
|---|---|---|
| **BALANCE OF CASH AS AT 1 JANUARY 2000** | **152,867** | **CREDIT** |
| RECEIPTS | | |
| Contributions Received | | |
| CSIRO | 10,000 | |
| Bureau of Meteorology | 10,000 | |
| Department of Land Administration | 10,000 | |
| Curtin University of Technology | 10,000 | |
| Total Contributions Received | 40,000 | |
| SUNDRY INCOME | | |
| Interest Received | 7,612 | |
| Total Sundry Income | 7,612 | |
| **TOTAL RECEIPTS FOR 2000** | **47,612** | |
| PAYMENTS | | |
| Data Tapes and Disks | 6,954 | |
| Printing, Stationery & Photocopying | 4,100 | |
| Telephone | 5,600 | |
| Conference Attendance | 1,115 | |
| Equipment < $1000 | 832 | |
| Mechanical & Equipment Maintenance | 6,500 | |
| Annual Report | 3,729 | |
| Telecommunications License of Facility | 1,187 | |
| Consultants | 5,885 | |
| **TOTAL PAYMENTS FOR 2000** | **35,902** | |
| **EXCESS OF RECEIPTS OVER PAYMENTS FOR 2000** | **11,710** | |
| **BALANCE OF CASH AS AT 31 DECEMBER 2000** | **164,577** | **CREDIT** |

# Notes to and forming part of the Financial Statement for the period 1 January 2000 to 31 December 2000

1. STATEMENT OF ACCOUNTING POLICIES

The following accounting policies have been adopted in the preparation of financial statements

1a. General Methodology

The financial statements, prepared in accordance with the provisions of approved Australian Accounting Standards Reporting are on the accrual basis of accounting and the accounts have been prepared under the historical cost convention.

1b. Valuation of Fixed Assets

In the years preceding 1990, the University operated on a cash accounting basis and consequently all fixed asset purchases were expensed in the year of acquisition. During 1990, all fixed assets were introduced into the financial statements at cost or valuation as an extraordinary item. This value was subsequently transferred to an Assets Revaluation Reserve.

In accordance with relevant Treasurer's Instructions, items costing less than $1,000 which were purchased during 1990 have been expensed in 1990. Items of plant purchased prior to 1 January 1990 which cost less than $1000 have been excluded from the group of assets introduced during 1990.

1c. Depreciation

Plant and equipment presented in these financial statement is depreciated in accordance with the following methodology.

Desktop computer equipment 100%
Other Computer equipment 25% reducing balance method
Other Equipment 12.5 % reducing balance method

| | | 2000 $ | 1999 $ |
|---|---|---|---|
| 2 | NON CURRENT ASSETS | | |
| 2a. | Computing Equipment (at cost) | 191,553 | 243,849 |
| | Cost of Disposal (Computing Equipment) | - | (52,296) |
| | Accumulated Depreciation | (174,127) | (168,318) |
| | **TOTAL COMPUTING EQUIPMENT** | **17,426** | **23,235** |
| 2b. | Other Equipment (at cost) | 192,920 | 194,820 |
| | Cost of Disposal (Other Equipment) | - | (1,900) |
| | Accumulated Depreciation | (153,611) | (148,023) |
| | **TOTAL OTHER EQUIPMENT** | **39,309** | **44,897** |
| | **TOTAL NON - CURRENT ASSETS** | **56,735** | **68,132** |
| 3. | ASSET REVALUATION RESERVE | | |
| | Opening Balance | 129,997 | 129,997 |
| | Movement During the Year | Nil | Nil |
| | **CLOSING BALANCE** | **129,997** | **129,997** |
| 4. | RETAINED PROFITS/(LOSSES) | | |
| | Opening Balance | 91,002 | 80,866 |
| | Net Surplus (Deficit) for the year | 313 | 10,136 |
| | **CLOSING BALANCE** | **91,315** | **91,002** |
| 5. | CONTRIBUTIONS RECEIVED | | |
| | Department of Land Administration | 10,000 | 10,000 |
| | Curtin University of Technology | 10,000 | 10,000 |
| | Bureau of Meteorology | 10,000 | 10,000 |
| | CSIRO - Earth Observation Centre | 10,000 | 10,000 |
| | | **40,000** | **40,000** |

# WASTAC Income & Expenditure Worksheet for the 12 Months Ending 31 December 2000

| DESCRIPTION | REF. | NOTE | 2000 [A] | ACCRUAL 1999 [B] | ADJUSTED TOTAL [C] = A + B | ACCRUAL / ADJ [D] | TOTAL PER P & L [E] = [C] + [D] |
|---|---|---|---|---|---|---|---|
| **Expenditure** | | | | | | | |
| Salary - General | | | 0.00 | | 0.00 | | 0.00 |
| On Costs | | | 0.00 | | 0.00 | | 0.00 |
| **Salary Total (A)** | | | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |
| Fee For Service Charge | | | 0.00 | | 0.00 | | 0.00 |
| Outsourced Work | | 2 | 8,885.00 | -3,000.00 | 5,885.00 | | 5,885.00 |
| Conference Attendance | | | 1,115.09 | | 1,115.09 | | 1,115.09 |
| Data Tapes and Disks | | | 6,955.00 | | 6,955.00 | | 6,955.00 |
| Annual Report | | | 0.00 | | 0.00 | 3729.00 | 3,729.00 |
| Telephone | | | 5,599.57 | | 5,599.57 | | 5,599.57 |
| Consumables | | 3 | 0.00 | | 0.00 | | 0.00 |
| Printing, Stationery & Photocopying | | | 4,100.00 | | 4,100.00 | | 4,100.00 |
| Mechanical & Equipment Maintenance | | | 6,500.00 | | 6,500.00 | | 6,500.00 |
| Equipment < $1000 | | | 831.82 | | 831.82 | | 831.82 |
| Computer Equipment Purchases | | | 0.00 | | 0.00 | | 0.00 |
| Furniture | | | 0.00 | | 0.00 | | 0.00 |
| Telecommunications License of Facility | | | 1,187.00 | | 1,187.00 | | 1,187.00 |
| **Total Other Expenditure (B)** | | | 35,173.48 | -3,000.00 | 32,173.48 | 3,729.00 | 35,902.48 |
| Prior Year Adjustment | | | 1,817.02 | | 1,817.02 | -1817.02 | 0.00 |
| Depreciation - Comp. Equip. | | | 5,808.74 | | 5,808.74 | | 5,808.74 |
| Depreciation - Other Equip. | | | 5,587.84 | | 5,587.84 | | 5,587.84 |
| **Total Non Cash Expenditure (C)** | | | 13,213.60 | 0.00 | 13,213.60 | -1,817.02 | 11,396.58 |
| **TOTAL EXPENDITURE (D) = (A) + (B) + (C)** | | | 48,387.08 | -3,000.00 | 45,387.08 | 1,911.98 | 47,299.06 |
| **Income** | | | | | | | |
| Interest | | | 7,612.43 | | 7,612.43 | | 7,612.43 |
| Contributions | | 1 | 20,000.00 | -10,000.00 | 10,000.00 | | 10,000.00 |
| Commonwealth Grant | | | 30,000.00 | | 30,000.00 | | 30,000.00 |
| **TOTAL INCOME (E)** | | | 57,612.43 | -10,000.00 | 47,612.43 | 0.00 | 47,612.4 |
| **TRANSFER OUT (F)** | | | | | 0.00 | | 0.00 |
| **TRANSFER IN (G)** | | | | | 0.00 | | 0.00 |
| **EXTRAORDINARY ITEMS** | | | | | | | |
| **NET TOTAL (H) = (E) - (D) - (F) + (G)** | | | 9,225 | (13,000) | 2,225 | (1,912) | 313 |

**Notional Cash Reconciliation**

| | |
|---|---|
| Notional Cash as per GL | $168,306.00 |
| Notional Cash as per Stm | $164,577.00 |
| **Variance** | **$3,729.00** |

Being:

| | |
|---|---|
| Expense - Accrual for Annual Report charges | $3,729.00 |
| Rounding difference | $ - |
| | **$3,729.00** |

## Curtin University of Technology WA Satellite Technology Centre
## Equipment as at 31 December 2000

| ASSET NUMBER | DESCRIPTION | ORIGINAL COST | ACCUMULATED DEPRECIATION | CLOSING W/DOWN VALUE |
|---|---|---|---|---|
| **COMPUTING EQUIPMENT** | | | | |
| 1358800 | SYSTEM SATELITE TRACKING STATION | 110,000.00 | 110,000.00 | - |
| 2478800 | 2.3GB 8MM EXABYTE | 6,272.00 | 6,272.00 | - |
| 2552700 | TAPE DRIVE 2 GBYTE X801A | 6,840.00 | 6,840.00 | - |
| 2553701 | ACQNR | 3,800.00 | 3,800.00 | - |
| 2585200 | PAINTJET XL C1602A | 2,425.00 | 2,425.00 | - |
| 2629700 | CARTRIDGE SYSTEM 2.5 G BYTE 8M | 4,950.00 | 4,950.00 | - |
| 3914000 | MICROWAVE COMMUNICATION SYSTEM | 57,266.00 | 39,839.77 | 17,426.23 |
| **TOTAL COMPUTER EQUIPMENT** | | **191,553.00** | **174,126.77** | **17,426.23** |
| **OTHER EQUIPMENT** | | | | |
| 1358700 | SATELLITE STATION TRACKING | 140,000.00 | 116,881.16 | 23,118.84 |
| 1948500 | POWER CONDITIONER | 2,000.00 | 1,573.36 | 426.64 |
| 2009000 | MA 23 CC | 20,365.00 | 15,922.79 | 4,442.21 |
| 2553700 | RECEIVER NOAA I/F FORMAT | 19,500.00 | 14,251.57 | 5,248.43 |
| 3852500 | CX-FS1P4 CISCO 4 PORT S/INTER | 7,440.00 | 3,352.88 | 4,087.12 |
| 3852501 | PA-7KF-E1/75 CISCO DUAL E1 G70 | 3,400.00 | 1,532.23 | 1,867.77 |
| 3852502 | CAB E1 BNC FSIP MIP-CE1 BNC 75 | 215.00 | 96.89 | 118.11 |
| **TOTAL OTHER EQUIPMENT** | | **192,920.00** | **153,610.88** | **39,309.12** |
| **DESKTOP EQUIPMENT (expensed)** | | | | |
| 3904000 | HEWLETT PACKARD 715/64 WORKSTATION | 25,208.00 | 25,208.00 | - |
| 4085100 | 9GB DIS DRIVE | 2,435.00 | 2,435.00 | - |
| 3923700 | LYNXPACK 6000E DDS2 4/8GB TAPE | 2,098.00 | 2,098.00 | - |
| 3923800 | LYNXPACK 6000E DDS2 4/8GB TAPE | 2,098.00 | 2,098.00 | - |
| 4522800 | WIDE DISK DRIVE | 2,164.00 | 2,164.00 | - |
| 4536800 | AMSU CARD FOR INST P/C | 6,765.77 | 6,765.77 | |
| **TOTAL DESKTOP EQUIPMENT** | | **40,768.77** | **40,768.77** | **0.00** |
| **TOTAL EQUIPMENT** | | **425,241.77** | **368,506.42** | **56,735.35** |

## WASTAC Adjustment notes to the worksheet for the 12 months ending 31 December 2000

Note 1 The following is a correction for 2001 depreciation charge that was entered as a prior year adjustment against fixed asset cost -$1,817.00”

Note 2 The following are charges for WASTAC 2000 Annual Report paid in February 2001
Ref: D0009928 Batch V6I1421 $3,729.00

# WASTAC Glossary

ACRES
Australian Centre for Remote Sensing
AOT
Aerosol Optical Thickness
AOCWG
Australian Ocean Colour Working Group
AMSU
Advanced Microwave Sounding Unit
AIMS
Australian Institute of Marine Science
AVHRR
Advanced Very High Resolution Radiometer
AIRS
Atmospheric Infrared Sounder
BOM
Bureau Of Meteorology, Australia
CAPS
Common AVHRR Processing Software
CALM
WA Dept. Conservation And Land Management
CGBAPS
Cape Grim Baseline Air Pollution Station
CD-ROM
Compact Disk-Read Only Memory optical storage media
COSSA
CSIRO Office of Space Science and Applications
CSIRO
Commonwealth Scientific and Industrial Research Organisation
DAT
Digital Audio Tape - 4/8 gigabyte
DOLA
WA Department Of Land Adminstration
DVD
Digital Versatile Disk
EEZ
Extended Economic Zone
EOC
Earth Observation Centre (CSIRO)
EOS
Earth Observation System
FAA
Fire Affected Area
FRDC
Fisheries Research and Development Corporation
HP-UX
Hewlett Packard UNIX Operating System
HRPT
High Resolution Picture Transmission
LAPS
Limited Area Prediction System NWP Model
L-Band
Low frequency spectrum, about 900 MHz to about 1.5 GHz
LST
Land Surface Temperature
MODIS
MODerate resolution Imaging Spectrometer
NOAA
US National Oceanographic and Atmospheric Adminstration
NDVI
Normalised Difference Vegetation Index
NWP
Numerical Weather Prediction
OS
Computer Operating System
SeaWiFS
Sea viewing Wide Field-of-view Sensor - allows ocean colour measurement
SeaDAS
NASA SeaWiFS processing software
SST
Sea Surface Temperature
SPOT
Vegetation satellite sensor
SRSS
WA Satellite Remote Sensing Services
TCWC
BOM WA Tropical Cyclone Warning Centre
TERSS
Tasmanian Earth Resources Satellite Station
TOVS
TIROS Operational Vertical Sounder
WWW
World Wide Web an international information service supported on the Internet.
WASTAC
Western Australian Satellite Technology and Applications Consortium
X-Band
High frequency spectrum, 7.5 GHz to about 11.5 GHZ - requires large reception antenna

Compiled by—Don Ward