The Auditor-General

Audit Report No.22 1999–2000
Performance Audit

Weather Services in the Bureau of Meteorology

Department of the Environment and Heritage

Australian National Audit Office

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Australian National
Audit Office

Canberra ACT
22 December 1999

Dear Madam President
Dear Mr Speaker

The Australian National Audit Office has undertaken a performance audit in the Bureau of Meteorology in accordance with the authority contained in the *Auditor-General Act 1997.* I present this report of this audit, and the accompanying brochure, to the Parliament. The report is titled *Weather Services in the Bureau of Meteorology.*

Following its tabling in Parliament, the report will be placed on the Australian National Audit Office's Homepage—http://www.anao.gov.au.

Yours sincerely

P. J. Barrett
Auditor-General

The Honourable the President of the Senate
The Honourable the Speaker of the House of Representatives
Parliament House
Canberra ACT

AUDITING FOR AUSTRALIA

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Abbreviations/Glossary

AIFS	Australian Integrated Forecast System
AMDISS	Australian Meteorological Data and Information Service System
AMDAR	Aircraft Meteorological Data Relay
ANAO	Australian National Audit Office
ASL	Average Staffing Level
AWS	Automatic Weather Station
Autosonde	Radiosonde system (see below) in which balloon preparation and release is carried out through automated systems rather than manually
Bureau	Commonwealth Bureau of Meteorology
Doppler	Radar that enables measurement of wind speed through the analysis of the nature of radiowaves reflected from raindrops
FAR	False Alarm Rate
FMIS	Financial Management Information System
FWW	Fire Weather Warning
GASP	Global Assimilation and Prediction System (for weather predictions to seven days)
Gigaflops	Measure of computer power (10^9 floating point instructions per second)
GNP	Gross National Product
GPS	Global Positioning System
JTWC	Joint Typhoon Warning Centre (in Hawaii)
LAPS	Limited Area Prediction System (for more detailed 1–2 day predictions over the Australian region)
MAB	Management Advisory Board
NEXRAD	Powerful Doppler radar units for the detection of severe weather events
NHC	National Hurricane Centre (of the USA)

NOAA	National Oceanic and Atmospheric Administration (of the USA)
POD	Probability of Detection (such as for severe thunderstorms)
Radiosondes	Small instrument packages carried aloft by a weather balloon that transmit back data on temperature, pressure and humidity via radio
RFC	Regional Forecasting Centre
SAMU	Sydney Airport Meteorology Unit
SWS	Special Weather Services (weather information tailored to the needs of particular clients)
SSU	Special Services Unit that provides commercial services
Supercell	Severe thunderstorm that can result in hail, very strong wind gusts or tornadoes
TAF	Terminal Area Forecast
TCWC	Tropical Cyclone Warning Centre
WMO	World Meteorological Organization
WSH	Weather Services Handbook

Summary and Recommendations

Summary

Background

1. The Commonwealth Bureau of Meteorology (the Bureau) is a statutory body and a self-contained agency within the Environment and Heritage Portfolio with responsibility for planned outcome 2—'*Australia benefits from meteorological and related science and services*'. The Bureau is formally established under the *Meteorology Act 1955*. The Act sets out the Bureau's functions which are, *inter alia*, the taking and recording of meteorological observations and other observations required for the purposes of meteorology; the forecasting of weather and of the state of the atmosphere; the issue of warnings of weather conditions likely to endanger life or property; the supply, publication and promotion of meteorological information; and cooperation with international meteorological agencies in relation to the functions just listed. The Act also states that these functions are to be performed in the public interest generally.

2. The Bureau's revenues are estimated to total some $193 million in 1999–2000, including appropriations of $180 million. Salary costs account for over half of total costs in the Bureau. Staff numbers have declined by 4.6 per cent since 1994–95 with a greater proportion of staff now funded from external revenue sources than prior to 1994–95.

Audit objective and criteria

3. The objectives of the audit were to:

(a) use national and international benchmarks to evaluate the Bureau's performance in terms of timeliness, cost and quality of weather services to meet the needs of clients; and

(b) assess how well the Bureau is placed in measuring its outputs/outcomes within the context of the Accrual Budgeting Framework.

4. Following a request from the Minister for the Environment and Heritage on 18 May 1999, the audit objectives were expanded to include benchmarking the Sydney Regional Forecasting Centre (RFC) against other RFCs in Australia in terms of:

(c) risk management planning and practice for Severe Weather Services;

(d) the adequacy, sufficiency and reliability of operating and management systems used for severe weather warnings; and

(e) the sufficiency and skill levels of staff involved in severe weather forecasting.

5. The ANAO developed criteria against which to review the administrative effectiveness of Bureau operations in terms of the above objectives. The key criteria are discussed at the beginning of each chapter of the report. The audit focused on the most materially significant and visible elements of the Bureau's operations—namely the observation network and the forecasting elements of the services. While the ANAO recognises that the Bureau also has a wider role in maintaining the national climate record, based on the observation program, the audit was fundamentally about the client focus of the Bureau and those elements that directly influence the quality and cost of weather forecasts.[1]

Audit conclusion

Quality of services

6. Quality customer service is defined as the provision of service which meets client needs and expectations on the aspects of service which matter most to the clients within the framework of an agency's legislation, policy and budget. The Bureau provides commercial services to meet individual client needs and more generalised, basic services to serve the public interest. For the Bureau, the key attributes that comprise quality are factors such as the accuracy and timeliness of the forecasts and public access to data and information. These, in turn, are dependent upon the quality of the observation network; the capability of the numerical forecasting models; the support systems; and, most importantly, the relevance and accuracy of the meteorological information provided as well as the skill of the forecasters.

7. While clients are satisfied overall with Bureau services and the client focus of the Bureau has improved (particularly in regard to access to data), accuracy remains an ongoing issue for attention. Accuracy has improved since the Slatyer Reviews in 1996 and 1997 in some important areas, such as maximum temperature forecasts, but the level of accuracy of forecasts for rainfall and minimum temperature has shown little change over time. This is consistent with the experience in other leading meteorological agencies, such as those in the USA and Canada.

8. There are general World Meteorological Organization (WMO) standards for timeliness. The Bureau has applied these in some instances

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[1] The climate record is comprised of long term data on, *inter alia,* Australia's rainfall, temperature, and humidity whereas weather data is more immediate and localised information. Weather data is designed primarily to meet the present needs of the general public and of specialised users.

but performance monitoring against such standards is largely incomplete. The Bureau has indicated that warning lead times require further development to take more account of major variations in regional conditions. Sectoral forecasts such as for aviation, marine and some rural and severe weather services, are difficult for the Bureau or the ANAO to comment on with any confidence because of gaps in performance verification and reporting. This is an area that requires particular attention by the Bureau.

9. The quality of the Bureau's observation network has improved since the capital injection of funds from 1996–97 and is generally comparable with other meteorological agencies such as in Canada. A priority for the Bureau is improving the links between costs and outputs. This link is important to demonstrate that the mix of elements in the observation network contributing to the Bureau's outputs (such as the accuracy and cost effectiveness of forecasts) is optimum. Currently, the Bureau's financial systems are not sufficiently developed for accrual accounting and reporting purposes and are not closely linked to the performance information system, which make it difficult to calculate the cost effectiveness of outputs and outcomes.

Cost of services

10. The Bureau is a high cost service when considered on a per capita basis and/or as a percentage of Gross National Product (GNP). However, when considered on a cost to area basis, it is relatively low cost compared to most other national meteorological services. This is largely because of Australia's continent-wide investment in upper air stations used to measure upper air winds, temperature and humidity. Bureau services, such as for the aviation industry, are relatively modest cost centres.

11. Because of the importance of demonstrating cost effectiveness, the Bureau should be concerned that revenue from cost recovery services has not achieved the expectations outlined in the Slatyer Review in 1997. The significant cost pressures on the Bureau also indicate that every effort should be made to enhance revenue consistent with Government policy objectives.

12. The ANAO considers that there is ample scope for strengthening the marketing of 'value-added' Bureau services as part of a strategic, business planning process while maintaining access to cost recovery services and providing core public interest functions. This is illustrated by the experiences from meteorological agencies such as in the UK and in relation to the potential growth in electronic commerce and its application, which have been recognised by the Bureau.

Severe weather services

13. The Bureau has no formal risk management plan but resource allocations are generally made on an operational basis to areas and activities of highest significance to severe weather warning. The Bureau's performance in forecasting cyclones and fire weather has improved over time and, in the case of cyclones, is comparable with other leading agencies such as in the USA. Thunderstorm forecasting is more problematic as the current scientific capacity of the Bureau only enables fairly short lead times (15–20 minutes on average) and this requires higher quality observation systems. Achievement of performance improvement by the Bureau is not assisted by weaknesses in the consistency and quality of performance measurement in the Bureau. These weaknesses are also apparent in the measurement and reporting of performance in other areas of severe weather, such as sheep graziers' alerts and marine warnings.

14. In relation to the Sydney hailstorm in April 1999, there is no evidence to suggest that the NSW RFC has inadequate equipment or staff resources compared to those in other regions. To the contrary, the NSW RFC has amongst the best and most reliable equipment, systems and skilled staff in Australia for severe weather forecasting. The main challenge evident from the Sydney hailstorm is the appropriate allocation of expert severe weather staff to forecasting duties outside of the severe weather seasonal roster. The current arrangements mean that in the 'shoulder' period of lower, but still significant severe thunderstorm risk (April–May), expert staff are not generally available for severe weather forecasting out of 'standard hours'.

15. While noting the positive steps already taken by the Bureau (such as the acceleration of the Bureau's training program in the use of radar for severe thunderstorms), variations in the duration of the severe thunderstorm season from year to year and the $1.5 billion in damage costs from the 'out-of-season' hailstorm, suggest that greater priority needs to be given to severe weather forecasting for improved effectiveness. This should include greater flexibility in the allocation of staff resources if the very significant costs from severe weather are to be mitigated.

Agency response

16. The Department of the Environment and Heritage welcomed the ANAO's constructive observations on the performance of the Bureau of Meteorology's weather services. The Bureau of Meteorology agreed, or agreed with qualification, to each of the 10 recommendations.

17. The Bureau of Meteorology indicated that it is committed to working closely with its key clients and the general public to continually evaluate requirements for services as well as their assessment of service quality and timeliness. The Bureau has in place a Service Charter. It indicated that it monitors performance in the context of that Charter. While stressing that weather and climate forecasting will not be completely accurate at all times because of the inherently chaotic nature of atmospheric and oceanic processes, the Bureau accepted the advice of the ANAO to continue to set its performance indicators at a challenging level through these broad consultative processes.

18. While the Bureau gives highest priority to warning the Australian community of severe weather in all its manifestations (for example, tropical cyclones, floods, severe thunderstorms and droughts), it is also continually working to improve services across-the-board. As part of these activities the Bureau routinely benchmarks its operations against, and draws extensively on the experience of, its counterparts in other countries.

19. The Bureau agreed with the ANAO that important lessons can be learned from experience in the United Kingdom and Canada on enhancing revenue streams from cost recoverable and commercial services. Furthermore, the Bureau noted that there are also lessons to be learned from other National Services in North America and Europe where commercial service provision has always been left to the private sector in a public-private partnership made or where, after experimenting with commercial service provision, the National Services have now reverted to a solely public good role.

20. The Bureau indicated that it is in the process of re-developing its management information and financial systems in response to the implementation of accrual accounting, the introduction of the GST and other recent changes in the APS management environment. These systems will enable the Bureau to more easily gather performance information and, in particular, assist with the costing of components of the Bureau's basic systems, including observation infrastructure.

Key Findings

Quality of services

Weather services

21. The Bureau has demonstrated a consistent improvement in forecast accuracy for maximum temperatures over time. Between 1985 and 1998 maximum temperature forecasts have improved by 13.6 percentage points. However, rainfall and minimum temperature forecasts have generally shown no significant improvement over time. This is consistent with trends for similar forecasts in the USA and Canada. Differences in performance are evident between capital cities but this is explained largely by differences in the difficulty of the forecasting task in the different locations. Inconsistent and incomplete verification of performance in other areas, such as in relation to aviation, marine, severe weather or specific services to primary industries, make it difficult for the Bureau to measure and report performance with a reasonable degree of confidence. The Bureau needs to give priority to ensuring consistency in performance measurement and reporting for management purposes as well as for accountability. The Australian Integrated Forecast System (AIFS) has a particularly important role to play in this regard, as has the recent review of verification procedures for weather services.

The observation network

22. While the Bureau's observation network serves a variety of purposes (such as providing data for the national climate record, climate change monitoring, state of the environment monitoring, and weather research), it is a critically important input into the accuracy of weather forecasts as it provides the basic data sets. The network involves a mix of sources, such as stations to measure upper air temperature, humidity and winds and radar for storm monitoring, as well as surface stations, aircraft, automatic weather stations, satellites and drifting buoys. These sources sometimes involve overlapping coverage. For example, a satellite may measure weather conditions for the same area as an automatic weather station (AWS). Generally, different sources fulfil different roles and have different costs and benefits. Upper air stations are an expensive component of the Australian data collection system but are very important for the maintenance of the climate record and for providing, *inter alia*, critical information on the potential for severe weather.

23. Satellite information is inexpensive to Australia because most of the total cost is borne by other countries. For forecasting purposes, it is expected that the impact of satellites will continue to increase in significance in the future as part of the evolution towards fully integrated global observing systems. This could have significant cost implications for the Bureau. The challenge for the Bureau will be to manage these changes efficiently, within the discipline of its budget. Within this context, it is important for the Bureau to determine the optimal combination of observation sources that meets all the statutory requirements and adequately balances the capabilities of meteorological science with the costs to the taxpayer.

Progress since the 1996 and 1997 Slatyer Reviews of Meteorological Services

24. Since the capital injection provided by the Government in 1996–97 ($4.6 million for three years), the Bureau has improved the frequency of upper temperature and humidity observations in the short term. However, a longer term decline in the frequency of observations, relative to those conducted in 1991–92, is evident. Australia's network is still below WMO standards but is nevertheless comparable with other international meteorological countries, such as Canada, in terms of the number of upper air stations and computer modelling capacity (few countries actually achieve WMO standards). While management of the maintenance program to date has been good, risks are emerging in terms of increasing equipment outages. For example, average days out of service were 40 in 1990. These had dropped dramatically to 13 by 1992 but by 1998, outages had increased to approximately 23.5 days. The cost of replacing obsolete equipment is also an issue for attention with some $55 million required for the replacement of the entire weather watch radar network. These matters require careful consideration as part of the Bureau's outsourcing strategy and in terms of its priorities within the capital works program. They also highlight the need for the Bureau to consider offsetting revenue generation activity to assist in expediting the equipment replacement—particularly for the weather watch radar network that is so vital for severe weather forecasting.

Client focus

25. The client focus of the Bureau's services has improved since the Slatyer Reviews in 1996 and 1997. An ANAO survey of clients found that, overall, 94 per cent of clients surveyed were satisfied or very satisfied with Bureau services. Access problems to Bureau services have been addressed by the Bureau through the implementation of internet services and the Australian Meteorological Data and Information Service

(AMDISS), but further work is needed to fully integrate telephone services into AMDISS. While the overall client rating of the Bureau was good, accuracy in forecasts was one of the major areas of client concern. Almost one quarter of clients surveyed rated the Bureau's forecast accuracy as from average to very poor. Greater central coordination of marine services is also required if the Bureau is to fully meet the expectations of the Government following the 1996 Slatyer Review.

Cost of services

International comparisons

26. International comparisons indicate that the Bureau is a relatively high cost service compared to other leading meteorological agencies when considered on a per capita basis or as a percentage of GNP. However, it is low cost when assessed on the basis of cost to area of coverage. This is largely attributable to the considerable investment in stations that measure upper air temperature, humidity and winds. These stations are recognised as being particularly important for forecasting severe weather events. Weather services, such as for aviation, are relatively low cost compared to those provided by other international service providers.

Financial management

27. Since at least 1996, the Bureau has had ongoing difficulties with its financial management information system in that it does not readily provide a firm basis for allocating costs to outputs substantially beyond the four primary output classes that include Services and Monitoring and Prediction. The design of the financial management system produces accurate cost figures for accountability purposes, but does not provide the Bureau with effective cost or resource management information. The financial systems are not sufficiently developed for accrual purposes. As well, these systems are not closely linked to the performance information system that makes it difficult to calculate the cost effectiveness of outputs and outcomes. Particular problems were noted in relation to the lack of consistent attribution of costs across programs and regions. The Bureau has recognised the problem but clearer guidelines need to be given to regional and program managers, along with greater executive oversight, to ensure greater consistency in cost allocations.

Cost recovery and commercial services

28. Cost recovery and commercial services are given a lower priority than some comparable meteorological services, such as those provided in the UK and Canada. For Special Weather Services in particular, revenue is declining and has fallen below the estimates foreshadowed in the 1997 Slatyer Review. The ANAO considers that stronger strategic planning and more active management oversight are needed for Special Weather Services to ensure that the revenue stream is enhanced in the future. Important lessons can be learned from the experiences in the UK and North America in the planning and the marketing of weather services. The significant cost pressures on the Bureau suggest that efforts should be made to strengthen cost recovery and the provision of services on a commercial basis. This would complement Budget funding, so long as budget funding was not cut as a consequence, and enhance the capacity of the Bureau to provide an improved range of services to clients.

Value for money

29. The ANAO survey of clients found that 63 per cent considered that the Bureau provided good or very good value for money. This is a positive result for the Bureau and supports studies that suggest the attainment of high benefit-cost ratios. However, a significant proportion (28 per cent) of clients surveyed could not comment. This reflects the difficulty clients have in determining value for money for largely free or cost recovered services. However, overall, there is evidence that the Bureau is providing value for money and that the majority of clients do not consider that the costs are excessive when charges are applied.

Severe weather services

Overview

30. Severe weather events have a major impact, sometimes involving loss of life. They have involved some $6.9 billion in insurance payouts alone in Australia over the last 32 years. A 1994 Department of Environment, Sport and Territories Portfolio Evaluation noted that a totally effective warning system could save about 40 per cent of lives and 20 per cent or more of the damage bill resulting from severe weather. Severe weather events are recognised globally as being particularly difficult to forecast because they are extreme events that can be unstable, of short duration and erratic in motion. Prior to 1987, Australia's Severe Weather Service was part of the public weather forecasting service. Prior to 1987, the Bureau had limited capacity to respond to bushfires or severe thunderstorms. Following an upgrade of the Bureau's capital assets and human resources in 1987, the Bureau's capacity was enhanced to the point where severe weather warnings for thunderstorms and fire weather are now part of a specialised Severe Weather Service.

Planning, analysis and priority setting

31. The Bureau does not have a formal risk management plan, although some qualitative risk assessment is undertaken and resources are allocated on an on-going operational basis to areas of highest vulnerability to severe weather (that is, the major urban centres of Australia). Staff skills and resources, and equipment are focused on the specific weather characteristics for each region. The Bureau has documented major risks to Australia from severe weather. Severe weather databases are kept in all regions that provide the basis for the Bureau's analysis and performance reporting.

Treating risks and allocating resources

32. Bureau financial data indicate a roughly proportional allocation of resources to the different regions, based on population. However, cost attribution problems make comparisons difficult to confirm. Equipment, such as the national weather watch radar network, is critical to the Bureau's severe weather warning capability. While coverage of that network is good, except for gaps along the north west coast of Australia and in north-east Victoria, the Bureau's radar lacks the extensive Doppler capability now being implemented in Canada and already in place in countries such as Japan and the USA. Sydney and Darwin currently have Doppler units but these are not yet fully operational. Equipment obsolescence and reliability are important issues in terms of the capacity of the Bureau to respond effectively to severe weather events. Allowing for planned radar re-equipment, about one-third of the units in the national radar weather watch network operate with 1950s technology.

33. The ANAO considers that incidents of radar equipment or software malfunctions prior to severe storms are an important quality issue requiring attention as part of a more detailed review of maintenance schedules. Attention to this issue would strengthen the Bureau's capacity to manage its risks. Nevertheless, NSW has the best equipment and the best record in terms of equipment inspection in Australia. NSW also has amongst the best trained severe weather forecasters in Australia. These experts are crucial to the accuracy of severe weather forecasts. However, the severe weather roster in NSW has the disadvantage of not having experts routinely on duty 'out-of-season' in circumstances when there are no early indications of severe weather, such as in the evening of April 1999 when the Sydney hailstorm occurred. The Sydney hailstorm has illustrated the lack of experience by non-expert forecasters during the off-season—despite the training emphasis provided by the Bureau to non-expert staff. Fluctuations in the duration of the thunderstorm season from year to year also suggest that a more flexible approach is warranted, along with greater priority to the management of severe weather events. The ANAO suggests that, because of the prevalent risks from severe thunderstorms and the very significant costs from storm damage, the NSW RFC should extend the forecasting role of its expert severe weather staff to cover the period from at least April to May. This would enable the Bureau to better manage the identified risks.

Performance monitoring and review

34. Performance information for severe weather indicates steady improvement in cyclone tracking and for fire weather warnings but patchy performance in relation to severe thunderstorms. Compared with the USA, a world leader in severe weather forecasting, the Bureau's severe thunderstorm performance has been less accurate. The USA's better performance can be explained by a number of factors, including the higher density of the observation network; the much more frequent and detailed satellite coverage; the much larger supporting research effort; the greater number of storm-spotters; and the greater sophistication of their radar systems.

35. The Bureau's performance information needs to be viewed with some caution as seasonal conditions and methodological issues relating to factors such as the area covered and the probability of verification impact on the utility of the data for inter-regional and international comparisons. Greater attention is required in the central coordination of performance information and reporting in terms of consistency and completeness. This is important for both management purposes as well as for public accountability. While the AIFS aims to address this problem, it may take up to two years before all severe weather categories are included in the system.

Recommendations

Set out below are the ANAO's recommendations with the Report paragraph reference and abbreviated agency response. The ANAO considers that priority should be given to recommendations 1, 3, 4, 5, 7, 9, 10.

Recommendation No.1
Para. 2.16

The ANAO *recommends* that the Bureau of Meteorology in its development of appropriate service quality targets:

(a) build on its 1999–2000 set of performance indicators to focus on reporting against a core set of challenging but attainable results areas in consultation with key stakeholders and client groups;

(b) ensure that performance information and reporting, as far as appropriate, is consistent across regions for the core result areas;

(c) include all major weather services in the Australian Integrated Forecast System verification system as soon as practicable; and

(d) consider the scope for regular reporting on suitable international benchmarking of performance against leading international meteorological agencies.

Agency Response:

(a) Agreed.

(b) Agreed.

(c) Agreed.

(d) Agreed.

Recommendation No.2
Para. 2.24

The ANAO *recommends* that the Bureau of Meteorology examine ways to expedite nationally coordinated meteorological services to marine users.

Agency Response: Agreed.

Recommendation No.3
Para. 2.39

The ANAO *recommends* the Bureau of Meteorology ensure that proposed changes to financial management systems are directly linked to performance information to enable:

(a) the identification and monitoring of optimum costs and benefits within the mix of data sources required for the operation of an integrated observation network for both weather and climate;

(b) redundant or obsolete elements to be more easily identified over time; and

(c) future technologies to be better assessed for their cost effectiveness within an integrated observation network.

Agency Response:

(a) Agreed with qualification.

(b) Agreed.

(c) Agreed.

Recommendation No.4
Para. 2.53

The ANAO *recommends* that the Bureau of Meteorology:

(a) ensure that priority is given to resourcing the maintenance and capital replacement program to achieve optimal performance standards consistently over time and across regions;

(b) consider options to move closer to World Meteorological Organization standards for the observation network including redeploying resources; and

(c) consider the scope for at least market testing and possibly outsourcing all, or part, of the network maintenance and inspection where cost effective.

Agency response:

(a) Agreed.

(b) Agreed.

(c) Agreed.

Recommendation No.5
Para. 3.12

The ANAO *recommends* that the Bureau of Meteorology, in implementing their financial management system:

(a) provide clear guidelines to regional and program managers to ensure greater consistency in the attribution of costs to outputs; and

(b) establish clear linkages to performance information so that cost effectiveness can be appropriately assessed and demonstrated.

Agency Response:

(a) Agreed.

(b) Agreed.

Recommendation No.6
Para. 3.19

The ANAO *recommends* that the Bureau of Meteorology:

(a) phase out anomalies in service definitions and clarify the services to be included in the basic, cost recovery and commercial service categories as part of the regular review of the Basic Product Set; and

(b) expedite the review of Aviation Weather Services to enable consideration of the options for more open competition with private service providers.

Agency Response:

(a) Agreed with qualification.

(b) Agreed.

Recommendation No.7
Para. 3.27

The ANAO *recommends* that the Bureau of Meteorology give greater priority to implementing revenue generation to complement budget funding in the provision of a full range of services. This should involve:

(a) implementing, as soon as practicable, the electronic commerce system for web-based cost recovery and commercial services;

(b) consideration of market opportunities for expanding commercial services, including web-based services, through the Special Services Unit as part of a more strategic business planning approach to the provision of commercial weather services; and

(c) setting challenging, but attainable, financial targets for cost recovery and the provision of commercial services.

Agency Response:

(a) Agreed with qualification.

(b) Agreed with qualification.

(c) Agreed with qualification.

Recommendation No.8
Para. 4.14

The ANAO *recommends* that the Bureau of Meteorology continuously review the reliability of 'mission critical' equipment and systems used in severe weather forecasting and introduce maintenance schedules to improve the reliability of such equipment.

Agency Response: Agreed.

Recommendation No.9
Para. 4.20

The ANAO *recommends* that the Bureau of Meteorology:

(a) consider increasing the priority given, and resources allocated to, severe weather forecasting in view of the very significant costs to the community from severe weather;

(b) consider increasing the flexibility of the severe weather roster in NSW to better respond to the variable nature of the severe thunderstorm season. This should aim to cover the 'shoulder' period from April to May, depending on seasonal conditions; and

(c) review the long-term data for severe weather occurrence in other regional centres and consider if any changes to the severe weather roster are required.

Agency Response:

(a) Agreed.

(b) Agreed with qualification.

(c) Agreed.

Recommendation No.10
Para. 4.45

The ANAO *recommends* that the Bureau of Meteorology give higher priority to the implementation of:

(a) consistent and complete reporting of the accuracy and timeliness of severe weather forecasting across regions; and

(b) severe weather performance monitoring as an integral part of the Australian Integrated Forecast System.

Agency Response:

(a) Agreed with qualification.

(b) Agreed.

Audit Findings and Conclusions

1. Background

This chapter provides background to the audit, including a brief description of the Bureau of Meteorology and its relationship with clients, and the audit objectives and methodology.

Legislative and policy framework

1.1 The Bureau is a statutory body and a self-contained agency within the Environment and Heritage Portfolio with responsibility for planned outcome 2—'*Australia benefits from meteorological and related science and services*'. The Bureau is formally established under the *Meteorology Act 1955*. The Act sets out the Bureau's functions which are, *inter alia*:

(a) the taking and recording of meteorological observations and other observations required for the purposes of meteorology;

(b) the forecasting of weather and of the state of the atmosphere;

(c) the issue of warnings of weather conditions likely to endanger life or property;

(d) the supply, publication and promotion of the use of meteorological information; and

(e) cooperation with international meteorological agencies in relation to the functions listed above.

1.2 The Act states that the Bureau:

> *shall perform its functions under this Act in the public interest generally and in particular for the purposes of the Defence Force, for the purposes of navigation and shipping and of civil navigation; and for the purpose of assisting persons and authorities engaged in primary production, industry, trade and commerce.*[2]

1.3 Section 8 of the Act allows the Director, subject to any direction of the Minister, to '*make charges for forecasts, information, advice, publications and other matter supplied in pursuance of this Act*'.

1.4 The functional relationships between the Bureau and its clients examined by the audit are set out in Figure 1.

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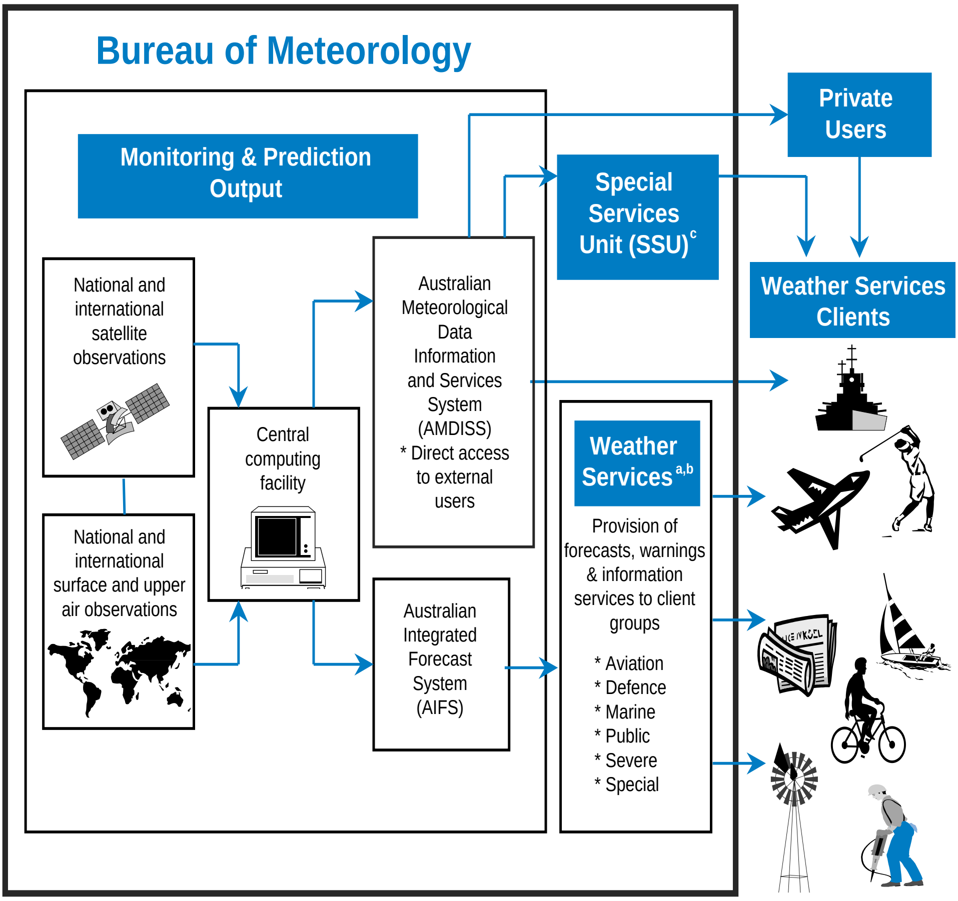
[2] *Meteorology Act (1955)*, Section 6.

Figure 1
Functional Relationships Between the Bureau of Meteorology and its Clients



[a] Weather Services form part of the Services Output, which also includes the Climate Data and Monitoring Services, Meteorology Advisory Service, Special Investigations, Food Warning Service, Hydrometeorological Advisory Service, the cost of maintenance of the Climate Data Bank and the cost of Water Resources Assessment activities. These services are not Weather Services and were not included for examination as part of this audit.

[b] Aviation and Defence Weather Services are provided on an incremental cost-recovery basis, while Marine, Public and Severe Weather Services are provided free to the public. The Special Weather Service encompasses a range of weather service delivery mechanisms including, *inter alia,* internet, telephone and facsimile services.

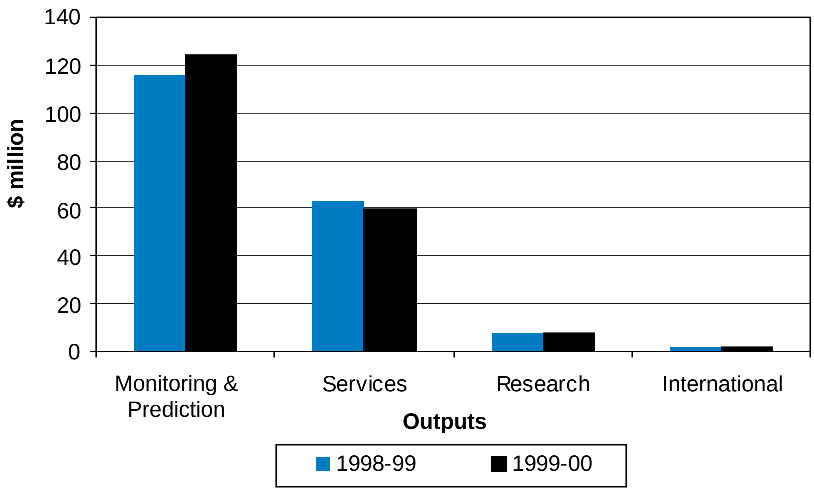
[c] The SSU is functionally part of the Bureau but financially separate from the core, public interest elements of the Bureau and operates on a purely commercial basis, in direct competition with private weather service providers.

Organisational structure

1.5 The Bureau operates within a matrix structure involving seven State/Territory-based RFCs and a Head Office in Melbourne.[3] Head Office serves as both the administrative and operational headquarters of the Bureau and consists of an Executive (Director of Meteorology and two Deputy Directors) and four divisions—Systems, Services, Research and Corporate. These divisions align with the Bureau's four output groups that are designed to contribute to the overall outcomes as outlined in Figure 2.

Figure 2

Outputs for Meteorological Services 1998–99 (actuals) and 1999–2000 (estimates)



Source: Portfolio Budget Statements: Environment & Heritage Portfolio 1990-00

The Bureau's finances and staff resources

1.6 The Bureau accounts for total revenue of some $193 million and appropriations of $180 million in 1999–2000. Table 1 illustrates the Bureau's cost structure since 1995–96 and the primary importance of Commonwealth budget funding. This reflects the largely 'public good' focus of much of the Bureau's work. Other sources of income are asset sales and revenue from both cost recovery and commercial operations.

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3 Bureau of Meteorology (1998b) *Bureau of Meteorology Annual Report 1997–98*, p.9.

Table 1

Total expenditure and Commonwealth funding 1995–96 to 1998–1999 ($ million)[a]

	1995–96	1996–97	1997–98	1998–99	1999–2000
Total Appropriations	159.8	156.8	165.3	151	180
Total Expenses	165.9	176.5	170.9	188.3	192.9

[a] Estimates for 1999–2000, actuals for other years.

1.7 Salaries account for over half of total costs in the Bureau. The former have been relatively stable since 1995–96.[4] Total salaries rose marginally between 1995–96 and 1997–98 from $85.5 million to $88 million. Average salary costs have also marginally increased from $59 253 in 1995–96 to $62 311 in 1997–98 in nominal dollars. These marginal increases have been accompanied by declining staff numbers and increases in the funding of staff from revenue through Section 31 receipts and from trust accounts as illustrated in Table 2.

Table 2

Average staffing levels (ASL) in the Bureau of Meteorology

Year	ASL Funded Through Section 31 Receipts or Trust Accounts	Total ASL
1994–95	14.8	1461.9
1995–96	27.0	1432.0
1996–97	35.9	1415.1
1997–98	48.9	1412.1
1998–99	55.7	1395.4

1.8 Estimates for 1999–2000 indicate further declines in staff numbers to around 1395 (a decline of 4.6 per cent since 1994–95). These declines are expected because of staff retirements, coupled with restrictions on recruitment. The rest of the Australian Public Service declined by 16.1 per cent over the same period.

Operating environment

1.9 The Bureau's environment is characterised by rapid technological change and obsolescence; increasing competition from international private sector meteorological service providers (such as New Zealand's Metservice and Japan's WNI); and increasing pressures from clients for more accurate and reliable forecasts and warnings; increasingly localised forecasts and warnings and more flexible service delivery mechanisms. Under Resolution 40 of the Twelfth Congress of the WMO, Australia is

[4] Salary costs accounted for 54.7 per cent of total costs in 1997–98.

obliged to provide 'free' data to other meteorological agencies and to private weather services providers.[5] Resolution 40 broadly indicates the types of weather services that can be provided on a commercial basis but leaves the detailed interpretation open to individual members. Consequently, different Members have adopted different approaches to commercialisation with some requiring their national meteorological service to operate in a strongly commercial mode and others devolving all commercial activity to the private sector. Some agencies (such as in the UK) now vigorously pursue international commercial activities while others (such as in Australia and Canada) operate in a more traditional, 'public good' environment.

Audit objectives

1.10 The objectives of the audit were to:

a) use national and international benchmarks to evaluate the performance of the Bureau of Meteorology in terms of timeliness, cost and quality of weather services to meet the needs of clients; and

b) assess how well the Bureau is placed in measuring its outputs/ outcomes within the context of the Accrual Budgeting Framework.

1.11 Following a request from the Minister for the Environment and Heritage on 18 May 1999, the audit objectives were expanded to include benchmarking the Sydney RFC against other RFCs in Australia in terms of:

c) risk management planning and practice for severe weather services;

d) the adequacy, sufficiency and reliability of operating and management systems used for severe weather warnings; and

e) the sufficiency and skill levels of staff involved in severe weather forecasting.

These objectives are addressed primarily in Chapter 4. Because the Bureau's systems are integrated with no major items of equipment used exclusively for severe weather forecasting, some related references are also included in Chapter 2.

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5 Resolution 40 says that '*members shall provide on a free and unrestricted basis essential data and products which are necessary for the provision of services in support of the protection of life and property and the well-being of all nations, particularly those basic data and products…required to describe and forecast accurately weather and climate'.*

Audit methodology

1.12 The audit methodology involved fieldwork at both the Head Office and at selected RFCs, including in Melbourne, Sydney, Perth and Darwin. The audit examined recent comparative research for an international benchmarking exercise as well as recent audits of weather services in Canada and the UK. The UK, the USA and Canada were used throughout the audit for comparative purposes because they are regarded by the Bureau as leading meteorological countries. Internal files, reports, records and the Bureau's intranet were also used to collect evidence in relation to the time, cost and quality of Bureau services.

1.13 The audit also included a telephone survey of a representative sample of major clients of the Bureau to test the Bureau's weather services performance quality. Of the 162 clients included in the survey, 131 (81 per cent) responded. The survey questions covered clients' experiences with the Bureau's:

a) free public weather services;

b) weather services to particular client groups; and

c) service standards (including the Service Charter).

1.14 The above survey was conducted by ORIMA Research on behalf of the ANAO. ORIMA Research provided technical expertise in the design and implementation of the survey as part of the audit. They were chosen because of their expertise in the field of survey design and their experience in conducting surveys of public sector agencies and their clients. In working with the ANAO audit team, the contractor was authorised under the *Auditor-General Act 1997*.

Audit conduct

1.15 The audit was conducted in accordance with the ANAO Auditing Standards. The audit commenced in January 1999 and the bulk of the fieldwork was conducted between February and July 1999. The total cost of the audit was $335 000.

Audit scope

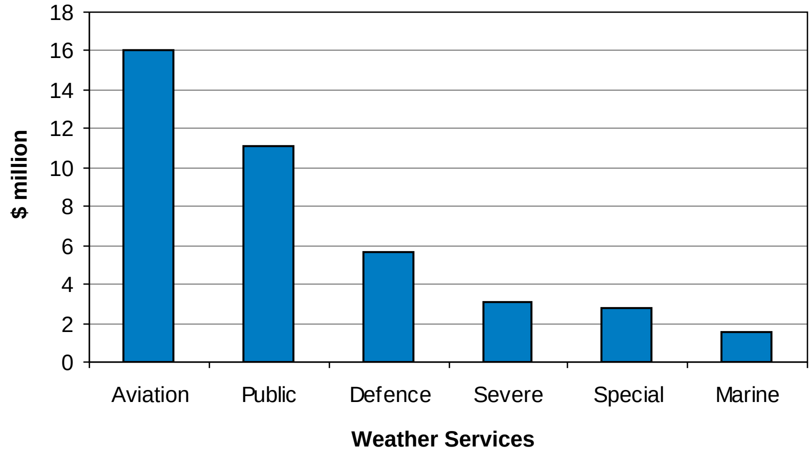
1.16 The audit's scope encompassed key elements of Weather Services and the Monitoring and Prediction Outputs which are the core operational elements of the Bureau, accounting for some 84 per cent of its estimated 1999–2000 expenditure. The audit examined the operations of Head Office (in Melbourne), along with a number of RFCs in the States and Territories.

1.17 Weather Services examined by the audit included Severe Weather Services, Public Weather Services, Marine Weather Services, Aviation Weather Services, Defence Weather Services and Special Weather Services.

Estimated expenditure on these elements for 1999–2000 totals $40.3 million and is separately outlined in Figure 3.

Figure 3

Price estimates for services output for 1999–2000

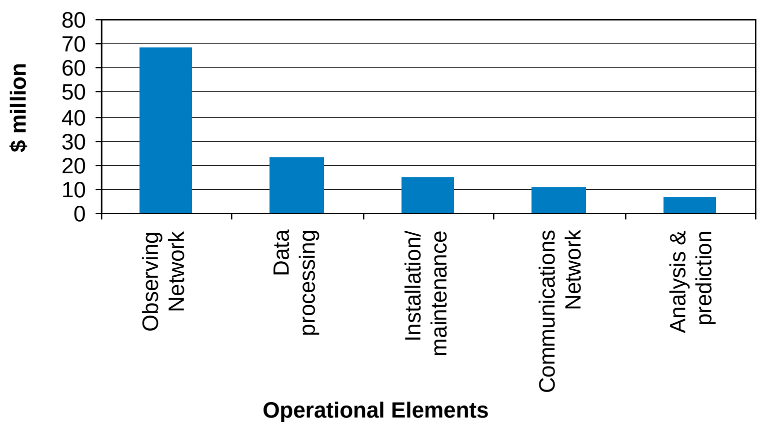


Source: Portfolio Budget Statements: Environment and Heritage Portfolio 1999–2000, p.99 [6]

1.18 The Monitoring and Prediction output includes the capital works and services, plant and equipment and the people to maintain the equipment and to conduct observations. This output provides basic weather information and analysis as input to other Bureau services. Estimated expenditure on these elements for 1999–2000 is $124.1 million and elements are separately identified in Figure 4.

Figure 4

Price Estimates for Monitoring and Prediction Output for 1999–2000



Source: Portfolio Budget Statements: Environment & Heritage Portfolio 1999-00

6 Only those elements covered in the audit are included.

Main findings from recent reviews

1.19 The 1996 Slatyer Review of the operation of the Bureau indicated that the Bureau was among the half dozen or so most advanced National Meteorological Services in the world and that there had been steady improvements in efficiency and productivity in the organisation. However, the Review highlighted a number of areas of concern. For example, the Bureau's basic national observational and climate monitoring networks were considered to have deteriorated substantially since 1991, compared with accepted benchmark standards, in terms of the numbers and spread of observations. Concerns were also raised over the network's overall accuracy and reliability. The Bureau was also considered to be behind other leading National Meteorological Services in developing a strong, outward-looking client focus and needed to adopt a more vigorous approach to the development and promotion of cost-recoverable services.[7] Some $12 million per annum was identified as achievable for cost recovery and commercial activity over the following four years or so.

1.20 The Review found that the Bureau had not adequately defined the exact range of services in its public interest (that is, the basic weather service) and recommended that the Bureau address this as a matter of priority.[8] The Review further emphasised the need for a weather services product set that was transparent so that it was able to:

> *foster the development of a vigorous meteorological services industry utilising readily available, low cost, Bureau products.*[9]

1.21 In accepting the Review's key recommendations, the Government provided the Bureau with an additional $4.6 million per annum, initially for three years, to help offset the deterioration in the Bureau's observation network.[10] In the 1999–2000 Budget, the Government provided an additional $24.2 million over four years ($4.8 million in 1999–2000) to enhance 'public access to the Bureau's databases and upgrade public and marine weather services and services to provincial areas'.[11]

1.22 The Australian Defence Force (ADF) also recently conducted a review of the Bureau's Defence Weather Services.[12] The Review was instituted following changes within the ADF that altered the nature of weather services required for operations. Focusing on Defence aviation

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7 Slatyer, R. (Chair) (1996) *Review of the Operation of the Bureau of Meteorology*, pp. vii–viii.

8 *Ibid.*, p.viii–xi.

9 *Ibid.*, p.x.

10 Bureau of Meteorology (1998a) *Budget and Program 1998–99*, p.42.

11 Budget Measures, Budget Paper No 2, p.77.

12 Australian Defence Force (1997) *Review of Meteorological Services Required by the ADF*.

weather services, the Review indicated that the traditional mode of service delivery was too labour intensive, for example, in relation to the traditional across-the-counter briefings. In addition, there was growth in demand for other services. The Review recommended that a central office staffed on a 24-hour basis would satisfy many of the needs of ADF users, while at the same time reducing under-utilised staff at some bases. It recommended the closure of two on-base offices and the retention of offices at seven other bases. Darwin was chosen as the location for the central office to take advantage of their experience in tropical meteorology and their capability to provide weather surveillance of northern southeast Australia.

Previous audit coverage

1.23 The Bureau was subject to a performance audit in 1984. This audit focused on the Bureau's Observations Program. The audit's major finding was that there was no comprehensive cost accounting system, which both inhibited the Bureau's ability to support the case for investment in technology and also resulted in a lack of precision in the charges levied on users for the Bureau's services, particularly services for aviation. A further finding was that its cooperative observation network was overly labour-intensive, requiring recruitment, training and monitoring procedures in order to reduce the incidence of observation errors and the consequential need for additional observation locations and corrective work by those involved in short-term forecasting and long-term climatological analysis.[13]

1.24 An ANAO cross-portfolio Financial Control and Administration (FCA) audit, which included the Bureau, was conducted in 1998. This audit examined the way public sector organisations process and use cost information and assessed the ability of these organisations to move from a cash to an accrual accounting-based approach. The major conclusions were that the Bureau

> *did not have effective cost or resource management information. While its systems were accurate in terms of cost and revenue centres, the Bureau needed a more direct attribution of costs, a reduced reliance on arbitrary measures and a greater understanding of cost behaviour and the factors which drive the cost of services.*

The Bureau accepted the findings and recommendations from the audit.

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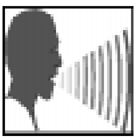
13 Australian National Audit Office (1984) *Report of the Auditor-General on an Efficiency Audit.* Section 3, Observations Program of the Bureau of Meteorology, pp.11–13.

2. Quality of Services

Introduction

2.1 The Management Advisory Board (MAB) and the ANAO *Better Practice Guide to Quality in Customer Service* defines quality customer service as the provision of service which meets customer needs and expectations on the aspects of service which matter most to the customer, within the framework of an agency's legislation, policy and budget.[14]

2.2 For the Bureau, quality embodies the key attributes that comprise the quality of services to clients—for example, whether clients receive forecasts that are accurate and timely and which contribute to decision-making and/or a change in behaviour. Quality should be a key component of the performance information framework and is essential for both accountability and effective management purposes. The introduction of the Accrual Budgeting Framework in the Australian Public Service makes additional demands for measurement and reporting requirements against specified outputs and outcomes. Some of the most important inputs of quality are the client focus of the services, the data processing and modelling capacity of the Bureau's computer systems and the standard and reliability of the observation network. These areas were the focus of the audit within Services and the Monitoring and Prediction functions.



Weather services

2.3. Weather Services are designed to meet the needs of the general public and specialised users for relevant, accurate and timely weather data, information, forecast and warning services. Under the Accrual Budgeting Framework, Weather Services has been incorporated into the Services output where expenditure was an estimated $59.6 million in 1999–2000. Service quality targets have not as yet been finalised, but are under development as part of the Accrual Budgeting Framework that was introduced in July 1999. The 1999–2000 Portfolio Budget Statements

14 Management Advisory Board/Australian National Audit Office (1997) *The Better Practice Guide to Quality in Customer Service*, p.6.

indicate that '*the achievement of service quality targets and lead times associated with each major warning category* [are] *to be developed*'.[15] Services are provided to broad categories of user groups or clients on a free, cost recovery or commercial basis. For example, the aviation sector has specific services provided on a cost recovery basis as has Defence. Special Weather Services provides a range of delivery options for clients such as by phone, facsimile or the Internet. Since 1990, commercial services have been provided through the Special Services Unit (SSU) to smaller, highly specialised client groups, such as the oil and gas operations on the North West shelf, agri-business groups and international clients. As such, the SSU is an important element of the Bureau's capacity to meet diverse client needs on a commercial basis.

2.4. The 1996 Slatyer Review of the Bureau found that it was behind other advanced National Meteorological Services in developing a strong, outward looking client focus. The client survey conducted as part of the review highlighted positive perceptions about the professionalism, responsiveness and presentational quality of services but also concerns about:

- less than accurate forecasts;
- inadequate access to services;
- poor quality marine services; and
- insufficient timeliness in forecasts.[16]

Verification of meteorological forecasts

2.5 The Bureau issues around 500 000 public weather forecasts per year and around 10 000 warnings for some types of severe weather. These forecasts and warnings contain a mixture of text and quantitative information about expected weather for up to seven days ahead. The verification of such a body of complex information is challenging. The Bureau considers that, where simple measures have been used (such as for accuracy of capital city temperature forecasts), these are useful for showing trends over time, but do not provide an assessment of the accuracy, or usefulness to a user, of the full measure of the information in a forecast. In many areas of meteorological verification, new techniques are emerging as increasing computing power is delivering improved capability. The challenge for the Bureau is to keep abreast of the emerging techniques and employ them appropriately and cost effectively.

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15 Department of the Environment and Heritage (1999) Portfolio Budget Statements 1999–2000, pp.98–99.

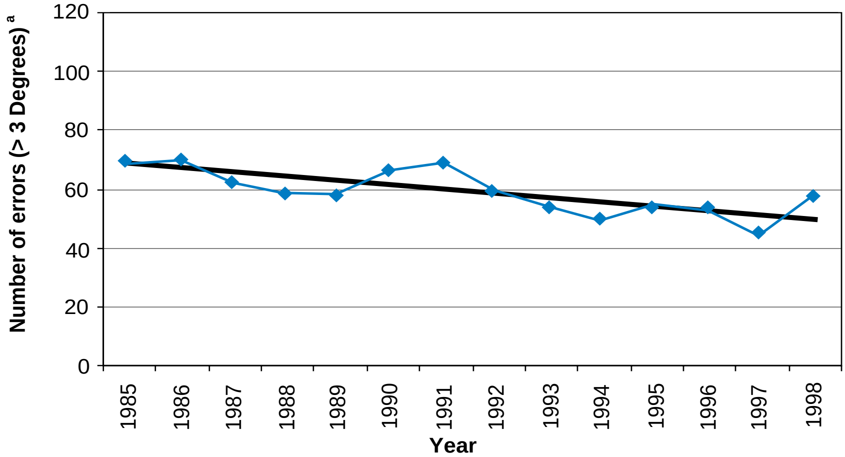
16 *Op. cit.*, Slatyer, R. (1996), p.73.

Performance information on the accuracy of temperature forecasts

2.6 The Bureau currently uses a wide range of indicators for measuring the accuracy of forecasts and verifying performance. These include, *inter alia*, the mean of observed temperature, forecast bias, mean modulus of forecast error, skill scores, errors greater than three degrees, and errors greater than five degrees, as key performance indicators for forecasting. An indicator of errors greater than three degrees is a reasonable proxy for accuracy in that it provides a benchmark for performance that reflects a measure of generalised skill in forecasting. The Canadian Meteorological Office also reports its performance on the percentage of forecasts within three degrees. Between 1985 and 1998 the number of errors greater than three degrees in maximum daily temperature forecasts for Australian capital cities dropped from an average of 64.6 to 55.8). This is a 13.6 percentage point improvement over this period. However, minimum temperature forecasts have shown no significant improvement over this timeframe. This trend pattern is consistent with that in Canada. The number of errors in Australian maximum temperature forecasts over time is illustrated in Figure 5.

Figure 5

Mean maximum daily temperature errors (>3 Degrees) for each year for Australian Capital Cities between 1985–98



[a] Total possible errors in each year are 365 (or 366 in a leap year)

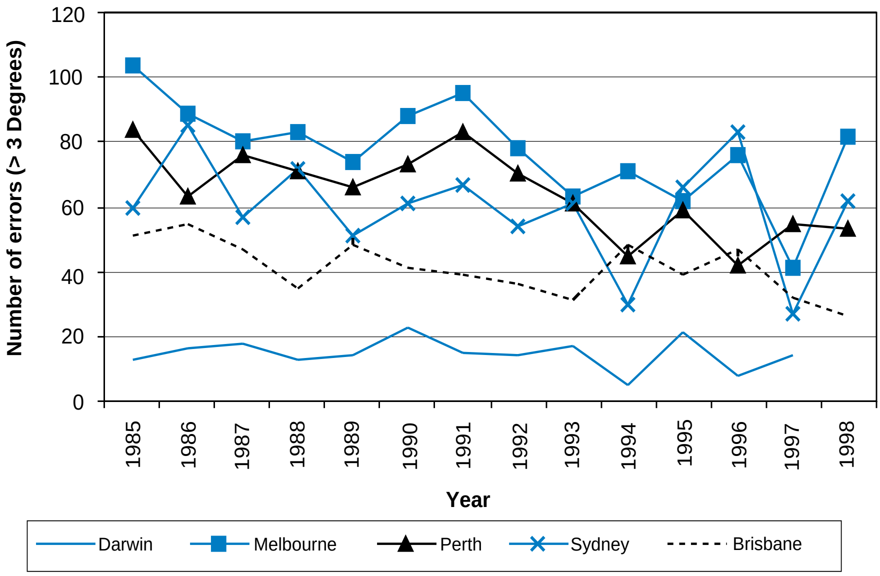
Source: Bureau of Meteorology

2.7 However, there are marked variations across regions as illustrated by Figure 6. These are largely attributable to differences in the difficulty of the forecasting process in the different climatic regions around

Australia. For example, Darwin's very low, stable error rate over time largely reflects the small range of daily maximum and minimum temperatures in that city. Melbourne's higher error rate reflects the more variable conditions at that latitude and the resulting greater difficulty of accurately forecasting large day to day changes.

Figure 6

Mean maximum daily temperature errors (>3 Degrees) for each year in Darwin, Melbourne, Perth, Sydney and Brisbane for 1985–98



Source: Bureau of Meteorology

2.8 The overall temperature error rate over time was not directly influenced by changes in the frequency of observations across the land-based network. The Bureau has indicated that improvement in the overall error rate reflects factors such as improvements in modelling and technology that assist in enhancing the skills of forecasters. Generally, the different regions report their forecast performance on temperature in the regional annual reports and comparisons between regions can be made which assist in identifying any anomalies and providing a basis for improving performance over time. The recent introduction of the Australian Integrated Forecasting System (AIFS) should expedite consistent reporting by allowing the automatic verification of forecasts and providing real time feedback to forecasters to help improve their forecasting skill. It should also expedite the development of a reporting system that reflects a stronger emphasis on the quality and quantity of outputs provided to the community, rather than just for activities undertaken.

Performance information on the accuracy of rainfall forecasts

2.9 Rainfall forecasts are particularly important for warning of flood events, for planning and managing, agricultural production, building and construction and for a large number of life-style choices made on a daily basis. The accuracy of Bureau rainfall forecasts is generally better than 'persistence'.[17] For 1995 (the last year when complete performance information is available for all centres), forecast accuracy was 81.2 per cent while 'persistence' was 72.7. However, rainfall forecast performance has shown no significant improvement and does not indicate any variation with changes in resource levels or the frequency of observations across the land-based network. The ANAO notes that this trend pattern is generally comparable with the USA performance. The Bureau has taken steps to improve performance, such as the upgrade of the numerical prediction models and research into specific aspects of rainfall detection and measurement. Some regional variation in performance is noted across regions but, generally, rainfall forecasting shows no real improvement over time, regardless of climatic zone. Figure 7 compares Brisbane (a sub-tropical climate zone) with Hobart (a temperate climate zone) in terms of forecasts against persistence.

2.10 Performance reporting on rainfall is different from temperature reporting in that there is considerable variation in approaches across regions. NSW does not report rainfall verification at all in their regional reports and there are substantial gaps in performance verification from 1989–1991 and from 1996–97. Gaps in performance verification are also evident across other regions for different years which reduces the capacity of the Bureau to do intra-regional comparisons on a key area of performance. This consistency issue illustrates historical problems in the oversight of performance in the regions. The Bureau has recognised the problem and the introduction of AIFS is intended to address it. The Bureau has recently engaged a consultant to review its verification procedures for weather services. It is now in a process of responding to recommendations of that review. In some instances, the development of AIFS has anticipated the review outcomes. All regions should be able to consistently report performance on rainfall accuracy as well as temperature from 1999–2000.

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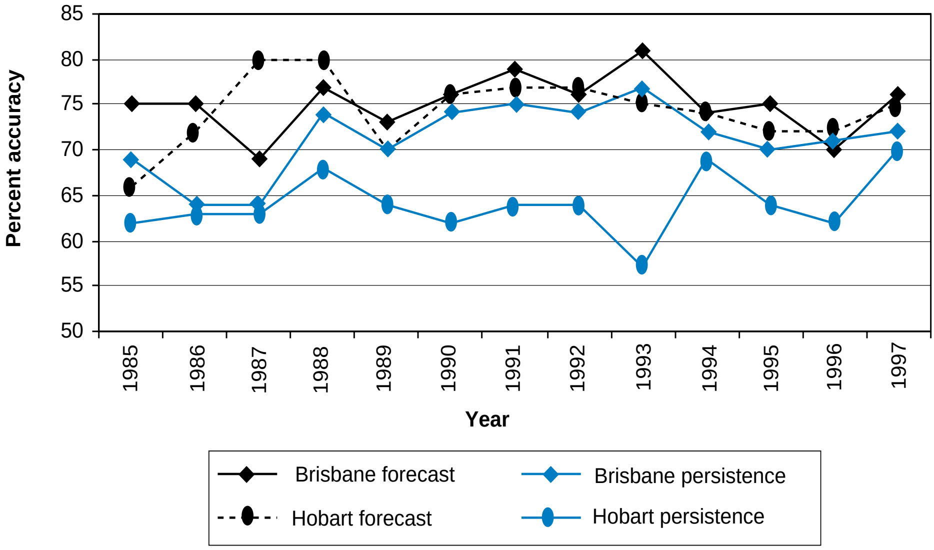
17 Persistence is a measure of continuity—that is, if it rained today it may also rain tomorrow. To be of value, rainfall forecasts should generally be better than 'persistence'.

Figure 7

Percentage Accuracy of Rainfall Forecast and Persistence (Rain/No Rain) for Brisbane and Hobart—6 am Forecast 1985–97



Source: Bureau of Meteorology

Performance information on the accuracy of other forecasts

2.11 In other areas of public weather services it is difficult to make any conclusive comments on performance as regions do not consistently report performance by region or over time. For example, while nationally there were 181 sheep grazier alerts in 1996–97, only Queensland reported fully the accuracy of its performance. The Queensland report indicated 100 per cent accuracy for the eight warnings issued, which represented 4.4 per cent of the national total. These were not reported at all in 1997–98. While there were 273 road weather alerts issued nationally in 1997–98, only Queensland reported its performance. In that State five alerts (two per cent of the national total) were issued and these were regarded as being generally accurate. Performance verification for marine services is minimal, with a focus on gale, wind and storm warnings. However, in this case there is a particular difficulty in that there is usually no observational data available over coastal waters and the high seas on which to base the verification. Because performance reporting is so limited it is not possible to make any definitive conclusions as to the performance of the Bureau in this area, although the available data indicates that ocean warnings are well short of the international target of 12–24 hours lead time for initial warnings. There are no specific AIFS modules yet included for these important services.

2.12 In cost recovery areas of weather services, consistency and adequacy of performance reporting is also patchy. Only South Australia and Tasmania report on performance in aviation weather services and no national verification of aviation weather services has been conducted since 1994. An automated verification system for aviation weather is currently being developed as part of the development of AIFS but so far has only been implemented in a trial mode for Sydney Airport. However, where Terminal Area Forecasts (TAFs) have been verified and reported (for example, in South Australia and Tasmania), the Bureau's performance is consistent with the required aviation standard. For example, TAFs are consistently at, or better than, the 90 per cent accuracy requirement for take-offs and landings.[18] However, the ANAO survey revealed particular concerns amongst aviation clients as to the accuracy of weather services—particularly during adverse weather conditions. The absence of consistent national reporting makes it difficult for the Bureau to either confirm or refute these concerns and highlights the need for credible performance information as a quality assurance product for clients.

2.13 The ANAO notes that in both the USA and the UK there is a history of reporting actual performance against targets for meteorological services. These provide useful lessons for the Bureau in its reporting against outputs. Both the UK and the USA provide examples of performance reporting that could be considered by the Bureau within this context. For example, in the UK, accuracy is verified against a composite index of quality using the 17:55 BBC radio 4 broadcast for a series of locations around the country. The overriding standard is that forecasts should be assessed *'from the viewpoint of an intelligent layman'*[19]. As in Australia, performance has shown a gradual improvement over time with specific targets being achieved or exceeded. In 1997–98, the performance was 108.2 against the actual target of 103.2 on the service quality index. For 1998–99, a target of 104.8 was set in consultation with customers.

2.14 In the USA, performance measures also compare actual performance over time against specific targets for a core set of indicators. These are illustrated in Table 3.

2.15 While the methodology for UK and USA performance measurement differs at this time, the ANAO considers that both reporting options have the benefit of disclosure of performance against

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18 The 90 per cent accuracy standard is a World Meteorological Organization standard.

19 UK Meteorological Office (1999) *Met. Office Key Target 98–99 Service Quality Index, Management Control Documents and Supplementary Documentation.*

specific targets. These provide a useful management tool as well as strengthening accountability.

Table 3

Advance short-term warnings and forecasts services (USA)

Performance Measures	*1996 Target*	*1996 Actual*	*1997 Target*	*1997 Actual*	*1998 Target*	*1998 Actual*
Severe Thunderstorm Warnings						
Lead-time (min)	16	18	18	18	18	18
Accuracy (%)	80	82	83	82	84	84
Temperature						
Correct forecasts (%)	85	85	86	86	86	86
Correct onset freezing (%)	74	74	76	70	77	54
Precipitation Forecast						
Lead-time for 1 inch precipitation forecast with same accuracy as a 1-day forecast in 1971 (days in advance)	2.3	2.3	2.3	2.3	2.3	2.3

Source: US Department of Commerce, Office of Inspector General; *National Oceanic and Atmospheric Administration; Financial Statements, Fiscal Year 1998;* Audit Report No. FSC–10869–9–0001/ March 1999

Recommendation No.1

2.16 The ANAO *recommends* that the Bureau of Meteorology in its development of appropriate service quality targets:

(a) build on its 1999–2000 set of performance indicators to focus on reporting against a core set of challenging but attainable results areas in consultation with key stakeholders and client groups;

(b) ensure that performance information and reporting, as far as appropriate, is consistent across regions for the core result areas;

(c) include all major weather services in the Australian Integrated Forecast System verification system as soon as practicable; and

(d) consider the scope for regular reporting on suitable international benchmarking of performance against leading international meteorological agencies.

Agency response

2.17 The Agency agreed with parts (a), (b), (c) and (d). It agreed to part (b), while noting the inherent regional differences in the difficulty of the forecast process and the nature of the Services needed and provided. The Agency agreed to part (d) where it indicated that the

World Meteorological Organization already facilitates extensive international exchange of experience and performance information to the extent that operational circumstances are comparable between countries and comparable performance information is available.

Access to Bureau services

2.18 For the general public, free to air TV news, (83 per cent) radio (57 per cent) and newspapers (34 per cent) are the most convenient form of access to Bureau services.[20] For institutional clients, the ANAO survey found that severe weather warnings (88 per cent) and weather by fax (88 per cent) were the most frequently used services. The 1996 Slatyer Review noted the particular frustration of clients with getting access to Bureau services. The 1997 Slatyer Review noted the importance of integration and consistency between the different delivery models. This was the basis for the introduction of AMDISS which was implemented in 1997–98. AMDISS was the principal Bureau systems response to the 1997 Slatyer Review recommendations concerning enhanced public access and the introduction of associated revised access charging policies. AMDISS serves all components of the weather services as well as the Climate and Hydrology Programs for both free and cost-recovered programs. Total estimated costs of the AMDISS system varied between $1–2 million between July 1997 and February 1999. The internet and electronic data sets are at the core of the AMDISS system and are likely to provide the basis for the Bureau's future electronic commerce arrangements and a major part of the Bureau's capacity to meet client needs. AMDISS was designed to overcome problems with inconsistencies in the type, quality, presentation and frequency of data from different systems and from different parts of the Bureau.

2.19 As at July 1999, AMDISS is providing an operational internet web site and a new payment system is being tested this year. The internet site is well used and involves around two million 'hits' per week. A product catalogue has recently been developed. Telephone services have not yet been integrated into AMDISS and are not proposed for the immediate future. This creates the risk that services will not be fully integrated or consistent. The main constraint has been the difficulties in integrating the technology. The ANAO survey indicated that Bureau clients surveyed had no significant problem with access to Bureau services or products. Eighty-nine per cent of respondents considered that they had good or very good access to Bureau services.

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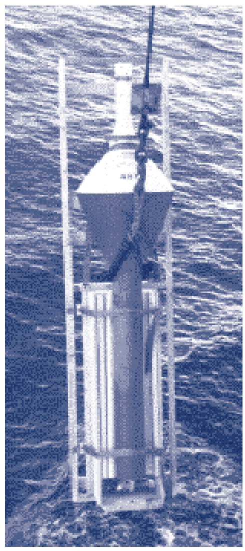
20 Bureau of Meteorology (1998d) *Weather Services Study Monitor: June 1997–June 1998*, p.14.

Marine services

2.20 The monitoring and prediction of wind speed and direction over the sea and the height and direction of sea waves and swell are among the most difficult routine functions for Weather Services. However, while recognising the difficulties, the 1996 Slatyer Review found that Marine Weather Services needed considerable improvement—particularly in regard to the effectiveness of presentation and delivery of products from the Bureau's Basic Weather Services. A recommendation was accepted by the Government to develop new and improved products for marine users and to centralise the production and delivery of services to users on the high seas. A number of new initiatives have been introduced following the Review. For example, a new facsimile service (Boat Weather Service) was established in Victoria to provide key geographic areas with presentations that integrate forecasts, warnings, observations, weather charts, tides and sunrise/sunset information. The Bureau considers that the service has been popular with clients. In Western Australia and Queensland, a new VHF radio service provides forecasts and current weather information to marine users, supplementing the existing nationwide service delivered through Telstra's coastal radio service. The most frequently occurring criticism from clients in one State was that they wanted more detailed forecasts for the areas in which they operated.[21]

2.21 Concern was also expressed about marine services in relation to the Sydney to Hobart Yacht Race in December 1998. The race was regarded as the most disastrous event in the 54-year history of the race. In this case, only 44 yachts reached their destination from a fleet of 115. This was due to the fleet encountering a severe storm and winds off the NSW coast and in eastern Bass Strait. A Bureau meteorologist provided a special briefing session for the competitors and organisers of the race on 24 December. The 250 people who attended this meeting were made aware of the possibility of hazardous weather conditions during the race, although the eventual nature and strength of the development were not foreseen at this time. However, conditions deteriorated rapidly in the race



Drifting buoys are used to collect meteorological data from marine environments.

[21] Bureau of Meteorology (1998c) *Results of a survey of the Bureau of Meteorology's Marine Weather Forecast Service in Tasmania.*

area. A gale warning was issued for the southern NSW coast 4 hours in advance of the start of the race through normal channels (internet, radio and facsimile). This was upgraded to a storm warning for the southern NSW coast and eastern Bass Strait about one hour into the race and at around 18–21 hours before the race fleet first encountered storm force winds. The updated forecast, with the storm warning, was sent to the vessel responsible for relaying forecasts and warnings to competitors during the official radio schedules. The Bureau considers that the high resolution computer model was an important factor in alerting forecasters to the need for a storm warning. The storm warning forecast means wind speeds of 45–55 knots (under these conditions gusts of up to 70 knots could have been expected) and seas of 4–7 metres. While verification was limited because the weather event occurred over the sea, actual conditions were reported as being winds of 54–56 knots with frequent gusts to 75 knots and seas 5–8 metres and occasional waves up to 15 metres.

2.22 The consequences of the storm during the race are currently subject to a coronial inquiry. However, the recorded forecast for the race illustrates the importance of timeliness and accuracy of warnings for clients. In this case the limited observational data used to verify accuracy suggests that the main difficulty was the speed of the change in conditions and the limited observational data to monitor this change. The limited amount of observational data is a consequence of the event occurring over the sea where there are few observational points (apart from offshore platforms and ships) and where satellite data is often the only source of many observations.

2.23 Overall, for marine services, individual regional initiatives have demonstrated steps forward in service delivery. However, there is considerable scope for the Bureau to develop at least some of these into a national marine service. The ANAO considers that the national implementation of useful initiatives across regions could be expedited through greater Head Office coordination and facilitation, particularly in relation to better practice within the regions.

Recommendation No.2

2.24 The ANAO *recommends* that the Bureau of Meteorology examine ways to expedite nationally coordinated meteorological services to marine users.

Agency response

2.25 The Agency agreed with this recommendation.

Timeliness of services

2.26 The timeliness of services is important as it is a key measure of quality. For example, a cyclone warning issued within a 24-hour time frame enables preventative measures to be taken to protect lives and property to the extent possible. Currently, the Bureau has some timeliness targets that are usually based on, or related to, WMO standards. For example, the Bureau aims to give 24 hours lead time warning for the onset of gales for communities threatened by tropical cyclones. (See Case Study 2 for more details on tropical cyclone warnings). However, timeliness performance is not generally verified or reported against. Service quality targets have yet to be developed although there are general WMO guidelines. Lead times for warning categories are also being developed. Currently, public weather forecasts are provided four days ahead, with an outlook for a further three days for capital cities. This service has been in place since at least 1994.

2.27 Improvements in timeliness have been assisted by internet services which allow rapid dissemination of weather information to clients. Ninety-one per cent of respondents from the ANAO survey considered that the Bureau was good or very good in relation to providing forecasts within sufficient time to meet client needs. The primary client concerns were in relation to severe weather warnings. These are discussed in more detail in Chapter 4.

Client satisfaction

2.28 Client satisfaction is a key measure of performance quality for service delivery agencies and a key component of the Government's reforms to the public sector. The Bureau has established a quality target of 85 per cent of users surveyed indicating that public weather forecasts and warnings are accurate or getting more accurate. In addition, the Bureau has set a target of 90 per cent of users being satisfied or very satisfied, with weather forecasts, warning and information services.

2.29 A client survey undertaken by the Bureau between June 1997 and July 1998 noted a generally high approval rating of Bureau information services. Ninety-three per cent of respondents were satisfied with the service. The principle concern was over the accuracy of forecasting and/or the need to improve technology. Over one-third of respondents rated forecasts as completely accurate (36 per cent) and almost half (49 per cent) rated them as partly accurate.[22] Tasmanian respondents (89 per cent) were more likely to rate the weather forecasts as completely or partly accurate while those from NSW (16 per cent) were more likely to rate it as not accurate. Overall, 53 per cent said that the weather

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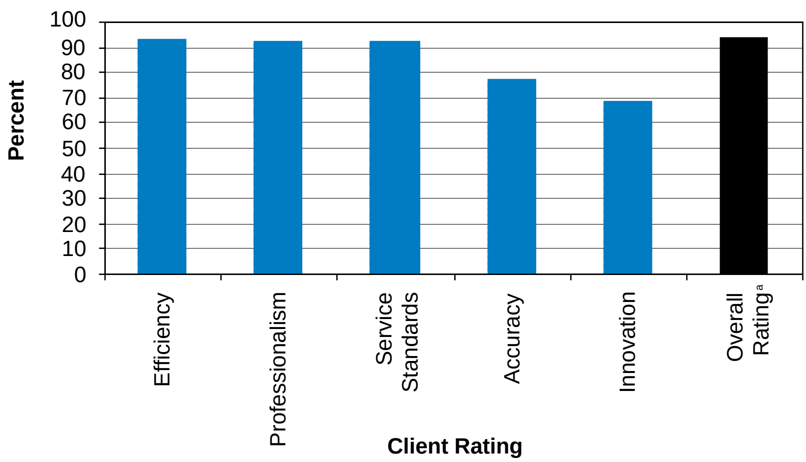
[22] *Op. cit.*, Bureau of Meteorology (1998d) pp.5–6.

information was getting more accurate and a third found that it had not changed over the past few years. Rain (86 per cent) and maximum temperature forecasts (54 per cent) were the most frequently sought items of information.

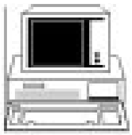
2.30 The ANAO client survey in April 1999 found that clients perceptions remained high regarding the professionalism, responsiveness and presentational quality issues discussed in the Slatyer Review in 1996. Ease of access to Bureau services/products has improved since 1996 and generally reflects the development in internet services which were largely embryonic at that time. The survey found that, overall, clients had a very high regard for Bureau services. Of the clients surveyed, 94 per cent considered that they were satisfied or very satisfied with Bureau services. The highest rating scores for good, or very good, were recorded against efficiency of service delivery (93 per cent), professionalism of staff (92 per cent) and service standards being relevant to client needs (92 per cent). The lowest ratings continued to be for accuracy of forecasts (77 per cent) and innovation (68 per cent). These are outlined in Figure 8. The full results of the ANAO survey are at Appendix 1.

Figure 8

Percentage of Clients Rating the Bureau as at Least 'Good' in the ANAO Survey



[a] The 'Overall' rating was the percentage of clients that were at least 'satisfied' with the Bureau.



Data processing, analysis and prediction

2.31 Computer capacity is important for weather forecasting as it provides the power for the development and operation of a suite of numerical weather prediction models operated by the Bureau. The computing program provides infrastructure and support for all Bureau programs. The major component of the computing system is the Bureau's supercomputer that was installed in 1997 in Melbourne Head Office. The computer is shared with the CSIRO. The new computer has a capacity of 64 Gigaflops, significantly greater than the 1.2 Gigaflops previously available.[23] A further upgrade is planned to increase the capacity to 104 Gigaflops that will bring the capacity closer to other leading meteorological countries. There is a clear relationship between the computer capacity and the performance of the models. Consequently, where models do cover the same geographic area, such as for the full globe, Australia's models are not as accurate as models generated by the leading centres, such as the European Centre, USA or UK. Figure 9 illustrates the comparison with eight leading meteorological services in terms of peak computer capacity and indicates the comparative impact of the upgrade. The Bureau has indicated that the type of computer operated by the UK, USA and Germany is quite different from that of the other centres and delivers a significantly lower proportion of the peak rate at a sustained rate. Direct comparisons therefore need to be treated with some caution.

2.32 The Bureau runs five atmospheric models on a routine basis from the Global Assimilation and Prediction System (GASP) for seven day prognoses through to a series of Limited Area Prediction Systems (LAPS) for more detailed 1–2 day predictions at the regional level. The increase in computer power over the last two years has substantially increased the level of resolution in the models. For example, the global model has improved from a horizontal resolution of 250 km to 75 km.

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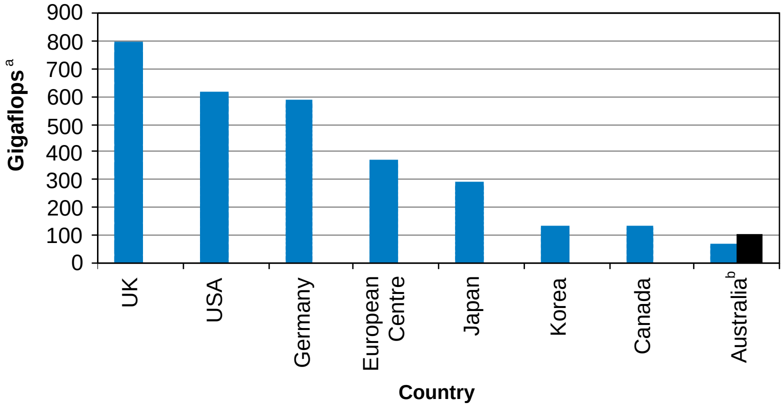
23 Gigaflops is a measure of supercomputer capacity. 1 Gigaflop represents 10^9 floating point instructions per second.

Figure 9

Comparisons in computer power across meteorological centres by country

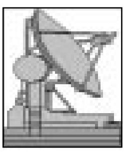


[a] The scale is in Gigaflops which is 10^9 floating point instructions per second.

[b] The two Australian figures are the current 64 and the proposed 104 gigaflop capacity.

Source: Bureau of Meteorology

2.33 The vertical resolution has improved from 19 levels to 29 levels. The regional models used by the Bureau have been improved to 37.5 km resolution with a new model shortly being introduced that will further improve the resolution to 12.5 km. If the integrity and reliability of the observation and communications network can be maintained, these improvements should enable the Bureau to provide greater forecasting accuracy and quality. AIFS further reinforces this scenario as it allows product preparation and automatic product dissemination, as well as database management, intelligent alerting to deteriorating weather and advanced visualisation of data. Clients should be able to benefit from a more accurate, timely and focused array of services particularly at the regional level where localised weather events, such as thunderstorms and bushfires, should be better able to be predicted and tracked.



The observation network

2.34 The Monitoring and Prediction function aims to 'provide, operate and maintain the basic observation, communications and data processing systems necessary to maintain a round-the-clock nation-wide weather watch and to meet present and future national and international needs for raw and processed meteorological data'.[24] The quality of the Bureau's performance is significantly dependent upon its observational network,

[24] *Op. cit.*, Bureau of Meteorology (1998b).

which is the single largest component of the $124 million Monitoring and Prediction function and the single largest cost centre in the Bureau.[25] The observation network accounts for nearly 55 per cent of the total estimated cost of the Monitoring and Prediction function in 1999–2000.

The mix of sources within the network

2.35 The land-based network, comprising a combination of human observers and AWSs is supplemented by data collected from ships, aircraft, drifting buoys and satellites. The different elements involve different costs and value in terms of their contributions to the total observations used by the Bureau for a number of high priority tasks, including the forecasting of the weather. This is illustrated in Figure 10.

2.36 Observational data underlie all weather forecasting and include the combination of data sources illustrated in Figure 10. The combination of different inputs enables the Bureau to expand its data points both geographically and in time to get as close as possible to an accurate representation of the weather events occurring in and around Australia and its seas.[26] Inevitably, there is some degree of overlap between the different observational data sources. For example, AMDAR, radiosonde and satellite data points overlap the same geographical areas in south eastern Australia. The Bureau considers that this overlap is essential in that it enables the Bureau to calibrate and cross check the accuracy of the data from the different sources and, depending upon the weather phenomenon in question (for example, tropical cyclone, thunderstorm or active cold front), allows the Bureau to choose the most effective surveillance method. However, each data source comes at a different cost and a different level of value to the accuracy and timeliness of forecasts.[27]

Satellite remote-sensing systems provide vital data over vast areas of the ocean surface.

[25] Department of the Environment & Heritage (1999) *Portfolio Budget Statements 1999–2000*, p.97.

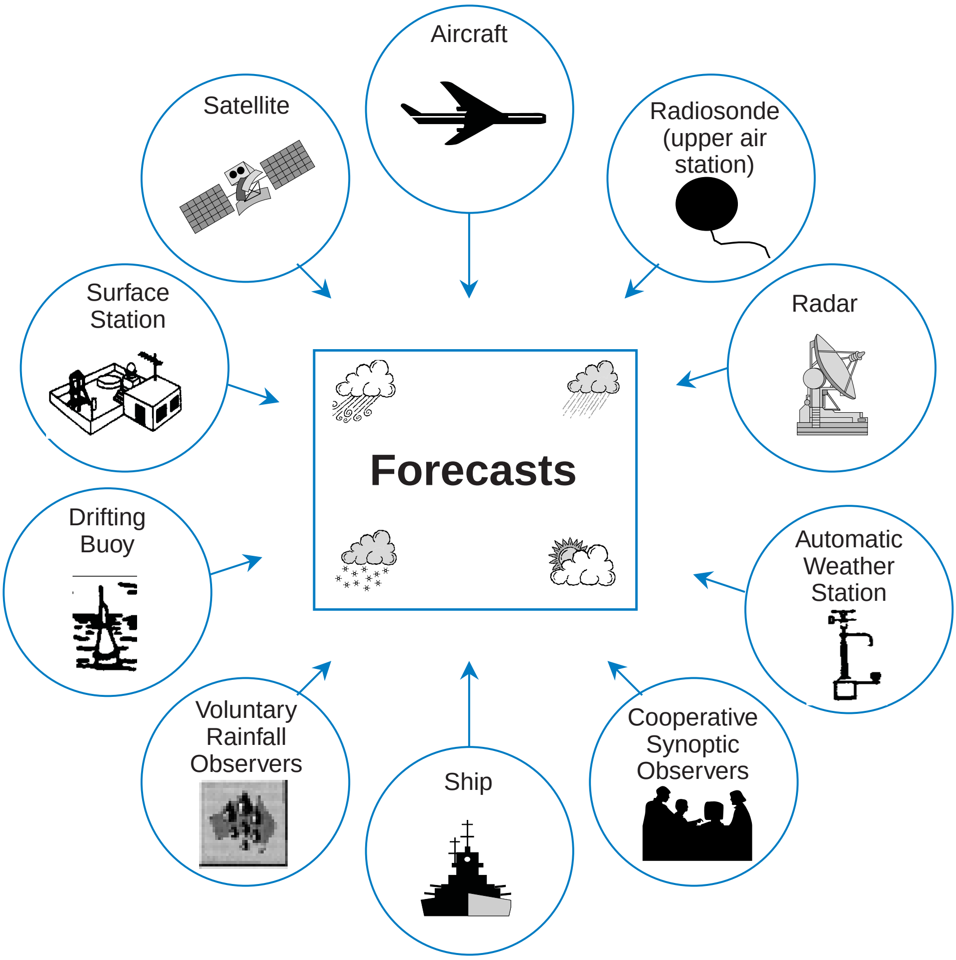
[26] The Bureau also makes a significant contribution to the total global weather observation effort. For example, Australia provides three per cent of global surface observations; four per cent of upper air radiosonde data; eight per cent of ship data; five per cent of drifting buoy data; and 21 per cent of AMDAR (that is, aircraft) data world wide. However, the focus of the audit was on the client focus of the Bureau.

[27] For example, radiosondes (small instrument packages carried aloft by a weather balloon and transmit back data on temperature, pressure and humidity via radio) cost around $200 each and are consumed once or twice daily with each upper air observation. Automatic weather stations cost $40 000 and last for several years with annual recurrent costs of approximately $5000. Radar units cost some $1.1 million each and last for up to 20 years.

2.37 Upper air stations are amongst the most expensive data collection methods but are regarded by the Bureau as being particularly important for the climate record and for providing, *inter alia*, critical information on the potential for severe weather. They also underpin the basic integrity of the entire network. In 1998–99, upper air observations accounted for 64 per cent of administrative expenses and 57 per cent of capital expenses of the observation network. In the same year, the satellite system accounted for four per cent of administrative expenses and six per cent of capital expenses. This is because data from satellites, such as geostationary and polar orbiting satellites, are essentially provided by the other countries at minimal cost to Australia.

Figure 10

Inputs into Bureau forecasts and climate record



2.38 To complicate the picture, the relative value and cost of each data source also changes over time with technological advances. For example, autosondes[28] will increasingly enable the Bureau to improve the frequency of upper air observations at marginally lower cost—particularly at critical times for severe weather events. The expected trend in satellite data is for a massive increase in the quantity and quality of data from satellites as part of increasing international trends towards the implementation of fully integrated global observing systems. The challenge for the Bureau will be to manage these changes efficiently, both within the limitations of its budget and the need to meet all of its statutory functions, including weather forecasting. The key issue is determining the optimal combination of observation sources—that which adequately balances the capacity for meteorological science with the costs to the taxpayer. The ANAO notes that this is changing over time, which magnifies the degree of difficulty for the Bureau. The Bureau has also indicated that the issue is being examined through the WMO. However, at present the Bureau has very limited linkages between its financial and performance management systems. This issue is being considered as part of the implementation of a new financial management information system. Consequently, it is not clear what is the most cost effective mix for accurate forecasting, what is the most cost effective overlap between observation sources to optimise risks and what impact the growth in satellite and remote sensing technology will have on this mix in the future. These are important considerations within the context of Accrual Budgeting and in the estimation of future output pricing.

Recommendation No.3

2.39 The ANAO *recommends* the Bureau of Meteorology ensure that proposed changes to financial management systems are directly linked to performance information to enable:

(a) the identification and monitoring of optimum costs and benefits within the mix of data sources required for the operation of an integrated observation network for both weather and climate;

(b) redundant or obsolete elements to be more easily identified over time; and

(c) future technologies to be better assessed for their cost effectiveness within an integrated observation network.

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28 Autosondes are automatic, semi-robotic upper air systems with similar functions to radiosondes. Eight are currently installed and operating in isolated parts of Australia . Two more are planned for installation within the next two years.

Agency response

2.40 The Agency agreed with qualification to part (a), indicating that it will upgrade its financial management system to report observing system component (existing and proposed) costs. In addition, it indicates that, despite difficulties in quantifying the benefits flowing from the operation of individual components of an integrated observing system, it will endeavour to develop estimates, with the limiting assumptions clearly identified. Part (b) was agreed, noting the practical considerations raised under part (a) and the essentiality of maintenance of long-term continuity in some cases. Part (c) was agreed, noting the practical considerations raised under part (a) and Australia's heavy reliance on international experience and information exchange on the development and assessment of new technologies.

Standards of service delivery

2.41 Standards of service delivery are important in that they provide a benchmark to judge actual performance as well as indicating to clients what standards they can expect. General standards and procedures for the collection of meteorological data are set out by the WMO and provide a general guide against which the performance of the observations program can be measured.[29]

2.42 In 1984, the ANAO found that the Bureau's observation network was below acceptable standards and, while recognising the resource constraints, the ANAO considered that the Bureau had

> *not developed a network which maximised the quantum and quality of information obtained with minimum duplication, redundancy and resource use generally. Opportunities for cost-effective application of technology used elsewhere had not been taken up.*[30]

The 1996 Slatyer Review found that

> *the effectiveness of the Bureau's basic national observation and climate monitoring networks had deteriorated significantly since 1991, compared with accepted benchmark standards.*

In response to the Review, the Government provided the Bureau with an additional $4.6 million per annum for three years from 1996–97 to, *inter alia*,

> *avert further reductions in the basic national meteorological monitoring system and contribute to restoring the national and climate networks to near accepted 1991–92 benchmark levels.*

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29 *Op. cit.*, Bureau of Meteorology (1998b), p.40.

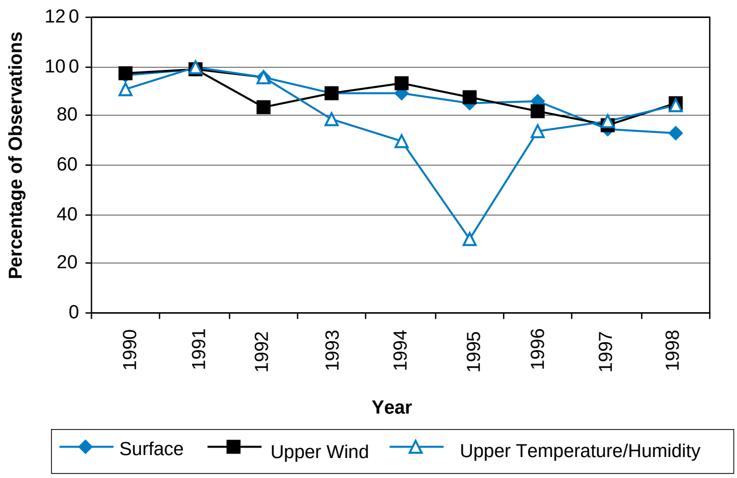
30 *Op. cit.*, Australian National Audit Office (1984), p.12.

2.43 As a consequence of the additional funding, the performance of the observation system has improved in the short term from 1995 in the frequency of upper air temperature and humidity data as illustrated by Figure 11. It also shows that there has been a long-term decline in the network across all three categories of performance, although this is improving from 1997 compared to the 1991–92 benchmark.

2.44 The observation network varies in its quality (that is, in terms of the frequency and distribution of observations measured against WMO standards) and broadly reflects population concentrations. For example, the spatial density for upper air stations is close to required levels only in some parts of the south east of Australia and falls below WMO guidelines elsewhere. Overall, Australia has about half the number of upper air stations as the USA, but more than in Canada, which has 35, and in the UK, which has 13. In addition to their central role for global analysis and modelling, upper air data are essential to the forecasting of localised events, such as severe thunderstorms, and for the accurate estimation of maximum temperatures that are critical in assessments of fire weather potential.[31] The data are also a critical component of the national climate record. The Bureau has indicated that the requirement is a primary driver in the overall design of the network. One estimate from the Bureau has put the cost of reaching the WMO standard at $44.2 million in capital start up costs and $20.9 million per annum in running costs. These estimates encompass the upgrading of upper air and surface stations.

Figure 11

Percentage of observations performed at staffed stations at 9:00pm EST for 1990–1998 [a]



[a] Sample taken at July at each year as full year data not yet available.

Source: Bureau of Meteorology

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[31] *Op. cit.*, Slatyer, R. (1996), p.98.

Equipment maintenance

A bureau officer uses a laptop computer during a maintenance check on an AWS.

2.45 Equipment maintenance is critical to overall systems quality as consistent, reliable data is a pre-requisite for accurate forecasts. Over the last decade, the Bureau has embarked on a continuous program of modernisation and automation. For example, introduction of the AWS has been a major initiative, with a sunk cost of some $26.5 million. There are currently about 396 AWS in operation around Australia, compared with 165 in 1994. An AWS measures and reports parameters such as temperature, wind, pressure, humidity and rainfall. They are particularly suited to remote locations and can cost effectively increase the density and frequency of some observations.[32]

2.46 An audit of the USA Weather Service found that AWS in that country did not meet accuracy or performance specifications and overall reliability requirements.[33] While the Bureau also had initial problem in equipment reliability, (average days out of service were 40 in 1990) these had dropped dramatically to 13 by 1992. However, outages have been slowly increasing in recent years as the number of AWS installed increase relative to the staff numbers available to maintain the network effectively. In 1998 the average days out of service per year had increased to approximately 23.5 days.[34] This is illustrated by Figure 12.

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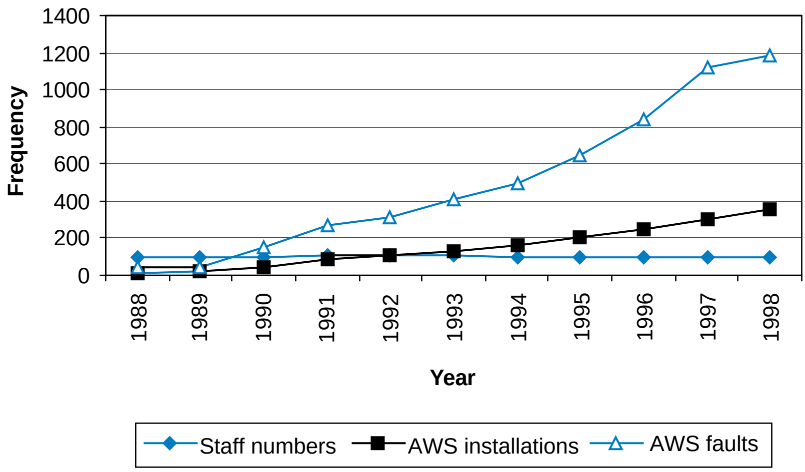
32 The Bureau considers that a basic AWS is a cost effective substitute for an observer station if the loss of visual observations is acceptable. An AWS can pay for itself after about three years if replacing full-time observers but it is unable to conduct all of the functions of a human observer.

33 General Accounting Office (USA) (1995) *Weather Forecasting: Unmet Needs and Unknown Costs Warrant Reassessment of Observing System Plans*, Report to Congressional Requesters.

34 Bureau of Meteorology (1999a) *Engineering Plan*, July 1999, p.23.

Figure 12

Frequency of AWS faults in relation to the number of AWS installations and staff



Source: Bureau of Meteorology

2.47 The Bureau has indicated that the number of faults is predominantly affected by the amount of equipment and obsolescence. The number of AWS faults continues to increase as more equipment is installed in the field and now represents approximately 60 per cent of the total faults for all equipment. However, average faults remain relatively constant. For other equipment, such as radar and radiosondes,[35] the Bureau has indicated that the progressive introduction of new technology or software has enhanced the reliability of the equipment and improved operational performance.

2.48 The cost of maintenance shows a decline from $1.44 million in 1992–93 to $1.26 million in 1998–99. This cost reduction has occurred without an increase in equipment spares. While improved equipment reliability has reduced the demand for spares, the Bureau has some concern that the shortage of funds for spares will contribute to a gradual degradation in overall network performance over the longer term. A further issue is the frequency of inspection and calibration of equipment to ensure optimal accuracy and reliability. Frequent problems encountered during inspections have included drifts in pressure calibration and biases in wind direction and speed, and changes in the aspect of the observation site as a result of vegetation growth or new

35 A radiosonde is a small instrument package that is carried aloft by a weather balloon and transmits back data on temperature, pressure and humidity via radio.

buildings. The 1996 Slatyer Review noted that, at a national level, 30 per cent of observing stations have not been inspected within the required period. WMO performance standards require inspections every one to two years for manual stations and calibrations / inspections six months to one year for AWS, depending on the sensors. Table 4 outlines the variable performance of different regional offices in Australia.

Table 4

Total inspections/calibration of equipment in 1998 by region

Region	*Number of Key Synoptic Stations*	*Percentage Inspected/Calibrated in 1998*
NSW	195	85
QLD	132	82
Victoria	94	78
SA	75	64
NT	54	63
TAS/Antarctica	68	62
WA	142	58
Total	**760**	**(National Average) 72**

2.49 The additional resources provided by the Government in 1996–97 have allowed an increase in the number of inspectors in each region as well as a rise in the average staffing levels from three to four. This has enabled some ‘claw back’ of the lengthening periods between equipment inspections and calibrations. However, the current number of sites not inspected for over one year is approximately 28 per cent. While the additional resources provided since the 1996 Slatyer Review has resulted in much higher volumes of equipment requiring inspection and maintenance, the percentage rate for actual inspection is similar to that in 1996. The Bureau considers that the continued program of automation requires an additional four inspectors and four maintenance technicians nationally to bring the maintenance program up to WMO standards. This should be achievable by re-ordering existing Bureau resources.

Equipment replacement

2.50 Field equipment places an increasingly important role in terms of providing the raw data for observations. The age of equipment is also a major issue in terms of capital replacement. For example, the weather watch radar network has a substantial amount of aging units with about one-third of the units in the network still operating with 1950s technology, even after completion of recent upgrades. The Bureau has indicated that the current staged replacement program involves two units per year at a cost of some $1.1 million per unit. At this rate it will take up to 25 years to replace the entire network at a cost of some $55 million. This timeframe is unlikely to be acceptable and suggests that the Bureau will need to consider priorities within its capital works program and offsetting revenue sources to expedite the replacement program.

2.51 While obsolete units can still be functional, a particular challenge facing the Bureau is the higher operating costs likely from any change to GPS radiosondes from the current wind-finder radars.[36] GPS radiosondes have higher cost consumables (of the order of several million dollars per annum) which will only be partially offset by lower maintenance costs. However, the obsolete wind-finder radar is no longer manufactured and can only be maintained as part of the weather watch radar unit through 'cannibalising' existing units. The latter cannot continue far into the future and the issue of replacement will need to be addressed as part of the capital replacement program.

2.52 Overall, the observation network is vital to the accuracy of forecasts and to the maintenance of an adequate national climate record. Emerging technologies provide the opportunity for better quality observational data but there are trade-offs against the need to maintain and update mission-critical components of the existing network. The ANAO notes that benchmarks have yet to be established for indicators of performance in the maintenance area as part of the Accrual Budgeting Framework.

Recommendation No.4

2.53 The ANAO *recommends* that the Bureau of Meteorology:

(a) ensure that priority is given to resourcing the maintenance and capital replacement program to achieve optimal performance standards consistently over time and across regions;

(b) consider options to move closer to World Meteorological Organization standards for the observation network including redeploying resources; and

(c) consider the scope for at least market testing and possibly outsourcing all, or part, of the network maintenance and inspection program where cost effective.

Agency response

2.54 The Agency agreed to parts (a), (b) and (c). The Agency noted that part (b) is subject to the limit of available resources and with careful regard for the most cost-effective overall deployment of resources.

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36 GPS Radiosondes do not require radar tracking as they have a Global Positioning System recorder (GPS) and a transmitter that communicates the position to a ground receiver.

Conclusions

2.55 The Bureau of Meteorology has shown a consistent improvement in forecast accuracy for maximum temperatures over time. Between 1985 and 1998 maximum temperature forecasts improved by 13.6 percentage points. However, the accuracy of rainfall and minimum temperature forecasts have remained relatively unchanged. This is consistent with trends in Canada and the USA. Differences in performance are evident between capital cities but this is explained largely by variations in forecasting conditions. Inconsistent and incomplete verification of performance in other areas, such as in relation to aviation, marine or specific services to primary industries, make it difficult to measure or report performance. The Bureau needs to give priority to ensuring consistency in performance measurement and reporting for management purposes as well as for accountability. The recently developed AIFS has a particularly important role to play in this regard.

2.56 The client focus of the Bureau's services has improved since the Slatyer Reviews in 1996 and 1997. The ANAO survey of clients found that, overall, 94 per cent of clients surveyed were satisfied or very satisfied with Bureau services. Access problems to Bureau services have been addressed by the Bureau through the implementation of internet services and AMDISS but further work is needed to fully integrate telephone services into AMDISS.

2.57 The Bureau's integrated observation network fulfils a number of roles and involves a mix of overlapping sources such as upper air stations, radar, surface stations, aircraft, AWS, satellites and drifting buoys. This configuration provides a mechanism to calibrate data as well as providing a cross check on the accuracy of the data. However, this overlap comes at a cost with different sources having different costs and benefits. Upper air stations are amongst the most expensive components of the data collection system and are very important for the climate record and for severe weather forecasting in particular. Satellite data are currently of low cost to Australia because most of the cost is borne by other countries as part of the international system of data exchange. For forecasting purposes, it is expected that the impact of satellites will continue to increase in significance in the future as part of the evolution towards fully integrated global observing systems. This could have significant cost implications. The challenge for the Bureau will be to manage these changes efficiently within the limitations of its budget. While this is subject to change, it is important for the Bureau to determine the optimal combination of observation sources that adequately meets all of its statutory requirements and adequately balances the capacity of meteorological science with the costs to the taxpayer. The lack of efficient financial linkages between the Bureau's financial and performance systems limits the capacity of the Bureau to demonstrate cost effectiveness at the present time.

2.58 Since the capital injection provided by the Government in 1996–97, the Bureau has improved the frequency of upper temperature and humidity observations but a long term decline in observations relative to the frequency of those conducted in 1991–92 is evident. Australia's network is still below WMO standards but is nevertheless comparable with other international meteorological countries like Canada in terms of the number of upper air stations and computer modelling capacity. While management of the maintenance program to date has been good, risks are emerging in terms of increasing equipment outages and in terms of the cost of replacing obsolete equipment. These require careful consideration as part of the Bureau's outsourcing strategy and in terms of the priorities within the capital works program. It also suggests that the Bureau will need to consider offsetting revenue generation activity to expedite the equipment replacement.

3. Cost of Services

This chapter examines the overall cost of total meteorological services compared with international providers, the financial management of the Bureau and cost recovery and commercial services as well as overall value for money.

Introduction

3.1 *The Financial Management and Accountability Act 1997* sets down the financial, regulatory, accountability and accounting framework for Commonwealth agencies. Section 44 of the Act requires that 'agency heads manage the affairs of the agency in a way that promotes efficient, effective and ethical use of Commonwealth resources'. Within this context, agencies need to have a good understanding of the full cost of delivering goods and services and the means to control those costs. This is also important under the recently introduced accrual-based budgetary framework whereby agencies must be able to fully specify and cost outputs and measure outcomes. While the Bureau has no required financial targets, the audit:

(a) compared the relative performance of the Bureau with overseas meteorological offices in terms of cost;

(b) examined changes in costs and revenue generation within the Bureau over time; and

(c) surveyed key clients on their assessment of value for money as costs need to be considered within the context of overall effectiveness.

International cost comparisons

3.2 International comparisons of costs can be difficult because of differences in accounting policy and functions, even for similar meteorological agencies. In January 1999, the Canadian Atmospheric and Environmental Service (CAES) conducted a survey of 29 international meteorological organisations. The survey obtained broadly comparable data on costs and staffing. However, caution must be exercised in comparing the data because major cost centres in the US Meteorological Service (such as expenditure on satellites and the recent modernisation program, aviation, research and military weather services and most climate services) have not been included. This would increase the total cost of the US meteorological Service by at least six times.[37] While

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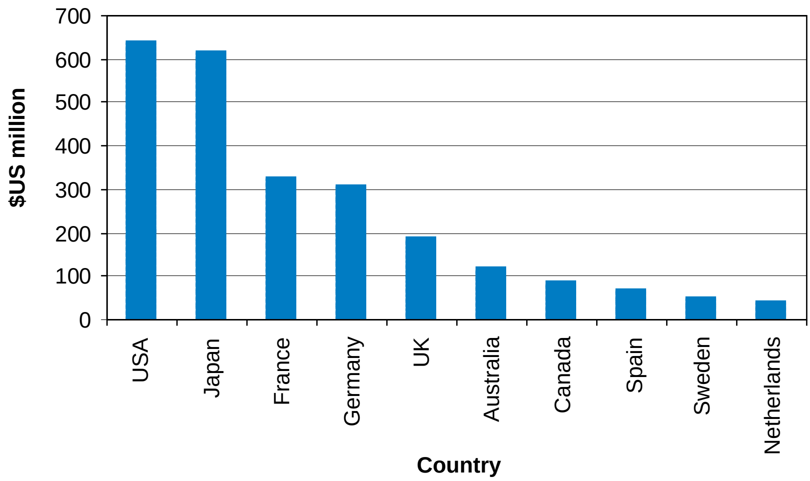
[37] The USA public sector financial statements for 1998 indicate that total expenditure for the three primary weather related goals is $US 1.458 billion. However, while this figure includes the modernisation program, it still omits defence, satellite and aviation expenditure.

recognising these limitations, the study provides an indicative overview of the costs of providing meteorological services in different countries. Figure 13 illustrates the relative costs in 10 leading meteorological countries.

3.3 The Canadian study showed that the USA and Japan had the highest cost, followed by France, Germany and the UK. On a world scale Australia was 6th highest of the 29 countries examined. However, on staffing levels, Australia was 11th—well behind all 10 of the highest cost countries except Sweden and the Netherlands. This reflects Australia's higher levels of automation and the much larger component of the total cost of operation of the Bureau tied to its higher cost upper air observation network.

Figure 13

Ten highest cost meteorological services 1997–98 by country[38]



Source: Bureau of Meteorology

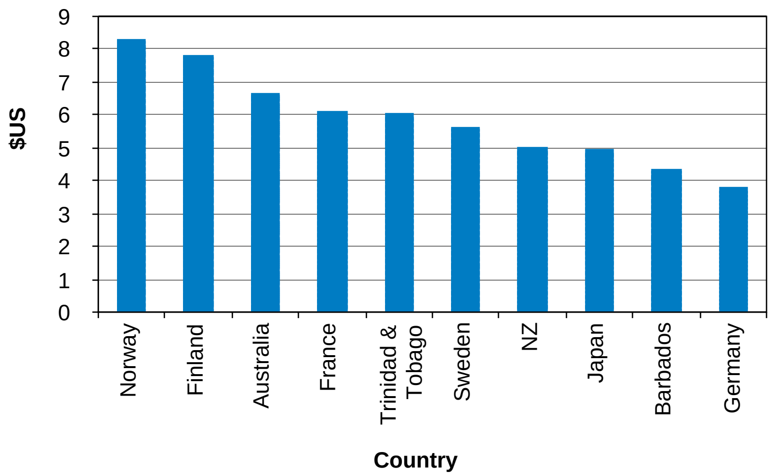
3.4 When examined on a per capita basis, Australia (with $US6.56) was one of the higher cost services of the 29 examined. Only Finland ($US7.81) and Norway ($US8.33) were higher, although France ($US6.08) and Sweden ($US5.64) were roughly equivalent. A figure for US expenditure of $US1.458 billion would indicate rough comparability with Australia. The figure of $US5 billion would indicate considerably higher

[38] The ANAO notes that Canada's costs do not include all the defence or aviation weather costs which, along with Coast Guard services would put Canada ahead of Australia in terms of actual cost for comparative purposes. However, Australia has no equivalent coast guard service and it is difficult to specify exactly what aviation and defence weather services are fully comparable. This suggests that the benchmarking exercise should be considered as indicative only and illustrative of broad patterns.

per capita expenditure than Australia. The difficulty is separating US national expenditure from expenditure that has a more specific international focus. In relation to Canada there is also the difficulty of whether all related program elements (such as aviation and defence weather) have been included in the figures and whether non-comparable program elements (such as the coast guard weather service) have been excluded. However, on balance, while Canada and Australia have roughly comparable costs, Australia is a higher cost service on a per capita basis.[39] This is largely a function of Australia's lower population and the Bureau's greater focus on upper air stations. Figure 14 compares budget costs across different countries on a per capita basis.

Figure 14

Ten highest cost meteorological services 1997–98—per capita by country



Source: Bureau of Meteorology

3.5 When national Budgets are compared on the basis of GNP, Australia again is a higher cost meteorological service. Barbados and Trinidad and Tobago are the only countries with Budgets higher than Australia, although Australia is roughly comparable with New Zealand. Figure 15 illustrates this point.

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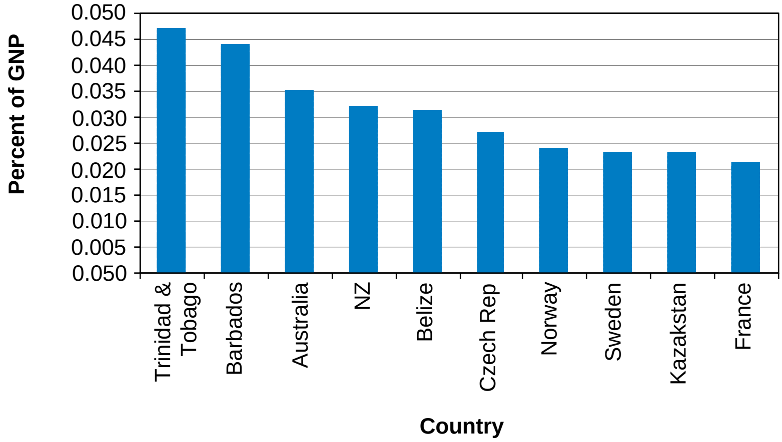
39 For the 1998–99 financial year, appropriations in Australia are higher than Canada ($A180 million for Australia compared to $A173 million in Canada). However, if all aviation and defence weather services are added from the trading accounts, Canada is likely to have roughly comparable costs with Australia for meteorological services.

Figure 15

Ten highest cost meteorological services 1997–98—per cent of GNP by country



Source: Bureau of Meteorology

3.6 Allowing for the likely error bounds in the data and whether all costs have been fairly compared, the Canadian study nevertheless demonstrates that overall, Australia has a significant investment in meteorological services with relatively higher costs on a per capita basis and as a proportion of GNP. This is not surprising given Australia's low population, relative isolation in the southern hemisphere and the considerable fixed costs involved in maintaining an observation and communication network across a continent the size of Australia. Australia and Canada both have very low costs when budgets are compared to the size of the respective continents. On the basis of cost to area of coverage, the Canadian study showed that Australia was one of the lowest cost services of the 29 examined (21st out of the 29 examined). The Bureau has completed some additional analysis of these figures, which confirm that on a cost to area basis, Australia has one of the lowest cost structures amongst leading meteorological agencies. A further consideration is that unlike Australia, some countries receive much of their data free of charge under Resolution 40 of the World Meteorological Organisation. For example, the United Kingdom receives over 95 per cent of its data for national forecasts from outside the country.[40] This further reduces the UK fixed cost requirements. While Australia has fifty upper air stations the UK has thirteen.

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40 National Audit Office (UK) (1995) *The Meteorological Office Executive Agency: Evaluation of Performance*, p.7.

3.7 When the costs of the Bureau's weather services are compared with other international providers, they are relatively low. For example, Aviation and Defence weather services in Australia accounted for 7.1 per cent of total costs in Australian weather services in 1997–98 ($11.4 million) while public weather costs were 5.8 per cent of total costs ($9.3 million). In Canada, Aviation and Defence accounted for some 11.5 per cent of total expenditure in 1998–99 ($27 million Canadian dollars). A Bureau of Meteorology international benchmarking study of aviation costs and services in 12 countries supports this conclusion, as it showed that Australia had the fourth lowest cost in aggregate, the lowest cost per aerodrome forecast location, second lowest in the cost per aircraft departure and fifth lowest cost per passenger/kilometre flown. Overall, Australian aviation weather services were found to be lower cost than leading meteorological countries, except in the cost of per passenger by kilometres flown, where Australia was more expensive than the USA, Japan, France and South Africa.[41]

Financial management

3.8 Ideally, an agency's financial management information system (FMIS) should provide the basis for the accurate and timely allocation of costs to output classes so that management has a reliable basis for measuring expenditure and revenue over time and a basis for accountability requirements each financial year. As such, it is an important accountability and management tool. When linked to performance information, the FMIS can also provide the basis for demonstrating cost effectiveness. This is particularly important within the context of Accrual Budgeting, which requires the specification and costing of outputs and the measurement of outcomes.

3.9 The ANAO notes that Bureau is in the transition phase of improving its financial management information systems following recent reviews and the introduction of Accrual Budgeting. The design of the financial management system produces accurate cost figures for accountability purposes, but does not provide the Bureau with effective cost or resource management information. Difficulties with the Bureau's financial management system were noted by the Slatyer Review in 1996.[42] The Review found that there were 'some inefficiencies in the Bureau's internal resources allocation and attribution processes which detracted from the formulation of consistent, high quality advice for executive decision making on resource management strategies.'

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41 Dear, J.R. (1998) *Aviation Weather Services: Report on International Benchmarking.*

42 *Op. cit.*, Slatyer, R. (1996), p.42.

3.10 A more recent ANAO Financial Control and Administration audit (1998) noted that,

> *the Bureau does not have effective cost or resource management information. While its systems are accurate in terms of cost and revenue centres, the Bureau needs a more direct attribution of costs, a reduced reliance on arbitrary measures and a greater understanding of cost behaviour and the factors which drive the cost of services.*[43]

3.11 The Bureau still has problems with attributing costs to outputs at operational levels below the primary outputs for accountability purposes. The Bureau considers that the multipurpose nature of its operations and the complexities of program / region linkages within a matrix management structure make attributing costs to outputs less than meaningful. However, the ANAO considers that much of the problem stems from the lack of consistency between regions and programs in the attribution of costs. For example, it is very difficult to reasonably compare recurrent expenditure on severe weather services across regions because of inconsistencies in the attribution of costs by different regions. This is compounded by problems arising from the financial management system not being closely linked to the performance information system. This also makes it difficult to demonstrate cost effectiveness. The Bureau is seeking to implement a better financial management system. However, the ANAO considers that this improvement would be assisted through clearer guidelines to regional and program managers and greater central management oversight.

Recommendation No.5

3.12 The ANAO recommends that the Bureau of Meteorology, in implementing their financial management system:

(a) provide clear guidelines to regional and program managers to ensure greater consistency in the attribution of costs to outputs; and

(b) establish clear linkages to performance information so that cost effectiveness can be appropriately assessed and demonstrated.

Agency Response

3.13 The Agency agreed to this recommendation.

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43 Australian National Audit Office (1998) *Costing of Services*, Audit Report No.21 1998–99, AGPS, Canberra.

Commercial and cost recovery services

Classification of services

3.14 Commercial and cost recovery services accounted for more than 16 per cent of total expenditure in 1998–99. Commercial services are provided through the SSU and are designed to provide a return to Government and to taxpayers. The Bureau considers that cost recovery services are essentially public interest services—that is, low cost services to the community or a relatively large group of clients. External access to enhanced or specially packaged services is provided on the basis that the user meets the incremental costs of the enhancement, packaging and access. The aim is to provide low cost access to services. The primary cost recovery programs in 1999–2000 include Aviation ($16.1 million), Defence ($5.7 million) and Special Weather Services ($2.8 million).[44] A range of other cost recovery services are provided for specific events ($4.4 million, which includes services for events such as the Olympics). As noted from the benchmarking study mentioned earlier, Aviation Weather Services are relatively low cost compared with other leading meteorological countries. Defence Weather Services were reviewed in 1997 and as a consequence of restructuring of services, costs were estimated to save 1.3 per cent by 1997–98.[45] Actual savings in 1997–98 were some 0.58 per cent in 1997–98 and 0.86 per cent in 1998–99.

3.15 The principles for calculating the rate of return for both services are documented in the Bureau's Charging Manual. While the ANAO considers that the definitions in the manual are both reasonable and appropriate, the difficulty has been in the implementation.

3.16 One of the major implementation challenges facing the Bureau is the allocation of activity to basic, cost recovery or commercial services. This has revenue implications for the Bureau and also implications in terms of the range of services provided to different client groups. As the Slatyer Review noted in 1996, the Bureau needed to promulgate clearer guidelines on the definitions of its basic and specialised weather services, and the relative roles, responsibilities and organisation of staff involved in provision of these

Northwest Shelf Offshore Platform.

44 Special Weather Services are a range of different service delivery options such as on-line access to the Bureau's data via facsimile, radio, phone, the internet or direct connection.

45 These savings were in Defence as well as the Bureau as there is a mix of both military and civilian staff in the provision of weather services.

services. While the Bureau has recognised the problem and has taken steps to clarify the basic service, some anomalies remain. For example, the services to the North West Shelf oil and gas operations are provided at commercial rates through the SSU, while the BHP Bass Strait operations are provided on a cost recovery basis. The Bureau advises that this situation will be remedied when the current contract expires.

3.17 A further example is in Aviation Weather Services. It could be argued that these services, which are funded on a cost recovery basis, could be reasonably provided as a commercial service to the aviation industry. The cost recovery approach to delivering public interest services restricts participation from private weather services providers but enables the Bureau to provide a nationally consistent service with a focus on public safety. In 1997–98 the Bureau commenced a major internal re-assessment of the provision of Aviation Weather Services as a result of 'increasing international competition in the airline industry, the flow-on effects of the commercialisation of *Airservices Australia* and the February 1998 decision of the Federal Court of Australia in the Monarch Airlines case with respect to the legal basis for air navigation and, meteorological services charges'.[46] The review was expected to be completed in 1998–99 but this did not eventuate. It is not clear what the timetable is for the matter to be resolved. The ANAO considers that given the relevance of the issue to Government priorities, the matter should be expedited for consideration as soon as practicable.

3.18 Another illustration is the national media graphics service, which provides high presentational quality, meteorological data to the print media as part of the basic service. This service is of a high standard and effectively precludes participation from commercial re-packagers. The Bureau argues that there is a partnership between it and the media which enables the delivery of the basic weather service to all Australians at no cost to taxpayers. It can also be argued that this type of service reflects current technological capacity and is reasonably a part of the basic service to the community.[47] On the other hand, it could be argued that the print media is willing, or able, to pay for services that eliminate requirements for editing by newspaper staff and taxpayers should not have to meet the additional costs involved in providing them. There are links to policy as well as administration in these examples and the ANAO considers that in future reviews of the basic product set, the Bureau should phase out remaining anomalies and provide greater clarity and consistency on

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[46] *Op. cit.*, Bureau of Meteorology (1998b), p.83.

[47] The ANAO recognises that the print media now incurs charges for services over and above the basic service.

the services that should form the basic product set as opposed to what is commercial or what should be funded through cost recovery.[48] At the present time the process of allocating activity to either commercial or cost recovery is too ad hoc. While recognising that individual decisions may be authorised, a more strategic approach to the classification of activity would enable the Bureau to demonstrate greater transparency while also providing greater certainty and fairness to all clients.

Recommendation No.6

3.19 The ANAO recommends that the Bureau of Meteorology:

(a) phase out anomalies in service definitions and clarify the services to be included in the basic, cost recovery and commercial service categories as part of the regular review of the Basic Product Set; and

(b) expedite the review of Aviation Weather Services to enable consideration of the options for more open competition with private service providers.

Agency response

3.20 The Agency agreed with qualification to part (a) of this recommendation. It considers that the policies it has in place to delineate its free, cost recoverable and commercial services are soundly based and clear but agrees that continuing guidance to staff and other stakeholders on this matter needs to be given. The Agency agreed to part (b) of the recommendation.

Revenue from commercial and cost recovery services

3.21 The 1997 Slatyer Review was designed to, *inter alia*, advise on the scope for enhanced meteorological services funded through cost recovery and commercial activities. The Government accepted 11 of the recommendations, rejected the one that concerned integration of the SSU into the Bureau and has yet to finalise its response to seven others.[49] The Review found that services provided on a cost recovery basis, (other than services to Aviation and Defence) could be increased to a level of about $7 million per annum. Services provided on a commercial basis within Australia could be increased to about $5 million per annum. No estimate of the revenue stream from international meteorological services

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48 One of the recommendations of the 1997 Slatyer Review accepted by the Government was that the contents of the basic product set be regularly reviewed by the Director of the Bureau of Meteorology.

49 The Special Services Unit is the commercial arm of the Bureau.

was provided because of uncertainties over market size. The Review indicated that the future of the cost recovery stream was crucially dependent on how the Bureau managed the distribution of the basic data and products on the internet.[50]

Commercial services

3.22 Commercial services through the SSU have been provided since 1990. The first year that revenue exceeded expenditure was 1995–96. The margins have been expanding since then with an improvement in the operating surplus from $400 000 in 1997–98 to $500 000 in 1998–99. Total revenue for 1998–99 was $6.1 million. While this figure exceeds the 1997 Slatyer Review estimate of $5 million, approximately 40 per cent of this revenue was derived from international sources. This suggests that there is further scope for enhancing SSU revenue from domestic sources. Sectors such as aviation have largely been excluded from commercial activity because of a focus on cost recovery. While the ANAO notes that the Australian market for meteorological services is likely to be smaller than in Europe, the UK commercial services components had returns of 34.4 per cent in 1997–98 as opposed to Australia's more modest seven per cent return. Another indication of relative performance is that commercial revenue in Australia is roughly 36 per cent of that in Canada.[51] These discrepancies reflect differences in Government policy and varying priorities between agencies. In some cases differences in accounting practices may influence how commercial revenue is calculated.

Special Weather Services and other user charges

3.23 Special Weather Services comprise a range of forecasts, warnings and related information that have been enhanced or specially packaged to meet specific client needs. Special Weather Services were a major focus for the 1997 Slatyer Review into the scope to enhance revenue generation in the Bureau of Meteorology. Consideration was also given to 'Other User Charges'. Trend data on Special Weather and Other User Charges from 1995–96 to 1999–2000 are set out in Table 5.

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50 Slatyer, R. (Chair) (1997) *Capturing Opportunities in the Provision of Meteorological Services*, p.7.

51 Environment Canada/Price Waterhouse/Coopers (1999) *Atmospheric Environment Program, Capital Investment Strategy—Final Draft.*

Table 5

Revenue ($,000) from Special Weather Services and 'other user charges' (as defined in the 1997 Slatyer Review) 1995–96 to 1999–2000

	1995–96 actual	*1996–97 Slatyer 2 estimate (Jan 1997)*	*1996–97 actual*	*1997–98 actual*	*1998–99 actual*	*1999–2000 estimate*
	($,000)	($,000)	($,000)	($,000)	($,000)	($,000)
Special Weather Services	1160	1102	1421	1438	1115	800
Other User Charges	1783	2392	2838	2624	3676	4389
Total	**2943**	**3494**	**4259**	**4062**	**4791**	**5189**

3.24 Table 5 illustrates that the 1997 Slatyer Review revenue estimate of $7 million by 1999–2000 will not eventuate. The shortfall is likely to be of the order of $1.8 million. This is because of factors such as:

(a) the impact of the Bureau's internet service whereby clients can obtain a better quality product than the fax services often at lower cost as foreshadowed in the 1997 Slatyer Review (p.6);

(b) the impact of overseas internet services that provide satellite data over Australia free of charge thereby undercutting returns;

(c) the possible saturation point being reached for fax services; and

(d) the removal of the compulsory disclaimer page requirement for every fax product.[52]

3.25 The ANAO notes that the Bureau is yet to implement an electronic commerce system (that is, transaction charging) on its Web site. While the Bureau has indicated that this will to be implemented shortly, the delay has not assisted in maintaining the revenue stream for Special Weather Services. The Bureau is not optimistic about the future revenue from these services, largely because of the high overheads involved and the competition being provided by overseas agencies with free access to satellite data. Nevertheless, there are 203 registered users, most of whom pay for cost recovered services on a daily basis. The ANAO considers that the priority is to institute the electronic commerce system as soon as practicable and consider market opportunities for expanding commercial services, including web-based services through the SSU.

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[52] The Bureau has advised that in the Weather-by-Fax service 61 per cent of the revenue comes from the provision of satellite imagery. The revenue from this component has dropped from $471 000 in 1996–97 to $291 000 in 1998–99 as people now find they can access this information more conveniently on the web. In addition, there has been an erosion of the SSU's Farmweather revenues by about 25 per cent. The removal of the compulsory disclaimer page resulted in lower costs to clients because it reduced the cost of the call.

3.26 The ANAO notes that in the UK the development of business planning, including the marketing of weather services, was instituted in 1984 as an integral part of the development of a stronger client focus. The UK Meteorological Office has noted that without a marketing perspective it is difficult to develop a rationale for allocating scarce resources to areas of highest need. The ANAO recognises that it is not possible to turn every opportunity into a commercial success and that the Bureau must be selective about the services it is going to include as commercial or cost recovery. It must also identify and treat risks, and ensure consistency with competitive neutrality principles. For a public sector agency, commercial considerations are not the primary objective or an end in themselves. The main objective should be compliance with legislation and Government policies. However, the Government's endorsement of the 1997 Slatyer Review recommendations regarding cost recovery and commercial services suggests that revenue from some cost recovery services and commercial services should be enhanced.[53] The focus should be on Special Weather Services to at least meet the estimated revenue expectations outlined in the 1997 Slatyer Review as soon as practicable.

Recommendation No.7

3.27 The ANAO *recommends* that the Bureau of Meteorology give greater priority to implementing revenue generation to complement budget funding in the provision of a full range of services. This should involve:

(a) implementing, as soon as practicable, the electronic commerce system for web-based cost recovery and commercial services;

(b) consideration of market opportunities for expanding commercial services, including web-based services, through the Special Services Unit as part of a more strategic business planning approach to the provision of commercial weather services; and

(c) setting challenging, but attainable, financial targets for cost recovery and the provision of commercial services.

Agency response

3.28 The Agency agreed with qualification to this recommendation. It agreed with the specified initiatives identified in parts (a), (b) and (c) but noted the importance of distinguishing clearly between the funding of its public good functions and that for its user-pays Services. It further noted that it will vigorously pursue revenue generation opportunities

53 There would be few benefits in the Commonwealth increasing charges for Defence Services as these are already operating at full cost recovery rates.

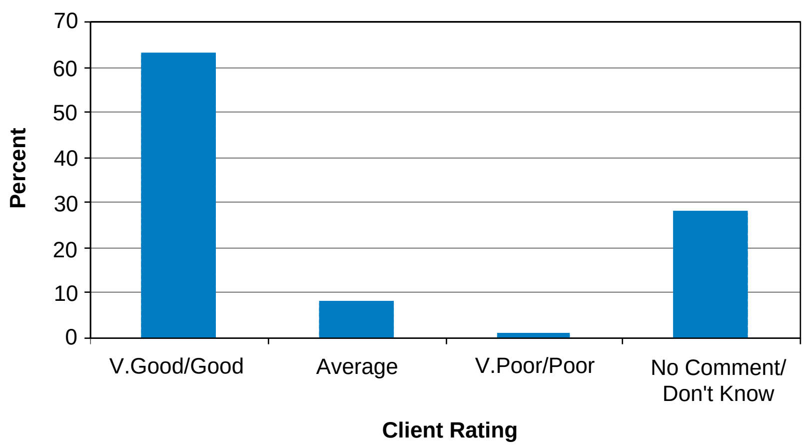
only when this can be done in a competitively neutral way, where it will not contribute to the destabilisation of international cooperation and data exchange and where the initiatives involved are consistent with its functions under the *Meteorology Act 1955*.

Value for money

3.29 For Commonwealth agencies, demonstrating value for money is an important component linked to section 44 of the *Financial Management and Accountability Act 1997*. The Act requires that agency heads manage the affairs of the agency in a way that promotes efficient, effective and ethical use of Commonwealth resources. The ANAO survey found that a significant number of clients surveyed (63 per cent) rated the Bureau as very good or good on this criteria. However, some 28 per cent could not comment on whether they receive value for money or not. This is illustrated in Figure 16.

3.30 The significant proportion of missing respondents largely reflects the difficulty many clients had in responding to whether the Bureau provides value for money. While, overall, the survey found that 63 per cent of clients considered that they received value for money, many had difficulty commenting. Qualitative comments were varied, covering the positive nature of the relationship, the lack of competition in Aviation Weather Services through to the need for a more tailored program with training for personnel, better weather intelligence, mobile weather stations and Bureau staff at on-site weather offices.

Figure 16
Client ratings from the ANAO survey of the Bureau in terms of value for money



3.31 The quantification of the benefits from weather services is intrinsically difficult to calculate with any degree of precision. However, one estimate puts the average benefit-cost ratio of meteorological services at 20:1.[54] This figure is hard to verify but not surprising when it is considered that the total insurance cost from storms, cyclones and bushfires in total was $6.9 billion between 1967–99.[55] The Bureau has also completed other economic studies of the benefits from meteorological services and these have shown high benefit-cost ratios for meteorological services. They ranged from 2.7:1 for terminal aerodrome forecasts to 66:1 for tropical cyclone warning forecasts. The economic value of the basic public weather services (when expressed as householder's average annual willingness to pay) was estimated at $24 per adult. Two separate studies on the evaluation of the tropical cyclone warning service in Queensland indicated that the service was regarded as being valuable with the average economic value to home-owners estimated to be between $30 and $200 per annum. A study of commercial services from the SSU to the cotton industry in NSW showed that enhanced weather information led to about one per cent reduction in the cost of producing cotton in that State. The Study also highlighted the scope for further development of specialist commercial services in the mining industry and possibly in other business sectors of the economy.[56]

Conclusions

3.32 International comparisons indicate that the Bureau is a relatively high cost service when measured on a per capita basis or when considered as a proportion of GNP. However, on the basis of cost to area of coverage, the Bureau has one of the lowest cost meteorological services. These conclusions are consistent in that they reflect Australia's low population and the relative size of Australia's land mass and the Bureau's considerable investment in an upper air observation network. The limited opportunities for sharing the high cost of upper air observations with other countries in the southern hemisphere is also a contributing cost factor. The provision of weather services, such as to the aviation industry, are relatively low cost compared to other international service providers.

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54 Zillman, J. (1999) *The National Meteorological Service*, World Meteorological Organization Bulletin, Vol.48, No.2, pp.129–159.

55 This was the estimated total insurance payout cost as estimated by the Insurance Council of Australia.

56 Anaman, K.A. & Lellyett, S.C. et. al. (1997) *Economic and Social Benefits of Meteorological Services Provided by the Australian Bureau of Meteorology*, Macquarie University.

3.33 Since at least 1996, the Bureau has had ongoing difficulties with its FMIS in that it does not readily provide a firm basis for allocating costs to output classes substantially beyond the highest order level. The financial systems are not sufficiently developed for accrual purposes and are not sufficiently linked to the performance information system so it is difficult to calculate cost effectiveness. The Bureau has recognised the problem and is introducing a new FMIS. However, clearer guidelines are needed to be given to regional and program managers, along with greater executive oversight to ensure consistency in cost attribution. The allocation of activity to either cost recovery or commercial categories is also somewhat ad hoc, although individual decisions may be fully justified. A more strategic approach would enable the Bureau to demonstrate greater transparency while providing greater certainty and fairness to clients.

3.34 The Bureau's cost recovery and commercial services contribute less than some comparable meteorological services such as the UK and Canada. Combined, Special Weather Services and Other User Charges revenue is likely to be some $1.8 million below the estimates foreshadowed in the 1997 Slatyer Review for 1999–2000. This is largely because of the impact of internet services on facsimile services. However, delays in implementing electronic commerce have not assisted in maintaining the internet weather services. The ANAO considers that the electronic commerce system should be implemented as soon as practicable and that market opportunities should be considered for expanding commercial weather services through the SSU as part of a strategic planning approach to the provision of weather services. Setting challenging, but attainable, financial targets for cost recovery services would also assist in guiding the implementation of weather services. Important lessons can be learned from the experiences in the UK and North America in business planning and the marketing of weather services. The significant cost pressures on the Bureau suggest that every effort should be made to enhance cost recovery and commercial services so as to complement budget funding in providing the full range of services. Overall, there is good evidence that the Bureau is providing value for money and that the majority of clients do not consider that the costs are excessive when charges are applied.

4. Severe Weather Services

Introduction

4.1 The *Meteorology Act 1955* lists one of the functions of the Bureau as, 'the issue of warnings of gales, storms and other weather conditions likely to endanger life or property.' Australia has particular risks from severe weather. For example, in the 10 years to 1998 the Australian region had 16 per cent of global cyclones.[57] In the USA some 10 000 severe thunderstorms are reported each year while in Australia the number is around 350.[58] Although bushfires occur throughout Australia, the greatest risk is in the southeastern states. This area ranks with parts of California and southern France as one of the most fire-hazardous zones in the world.[59] While the likelihood of severe weather events occurring in Australia is high on a world scale the consequences are mitigated by Australia's smaller, dispersed population in lower density towns and cities compared to other developed countries.

4.2 Severe weather is generally regarded by meteorologists as being very difficult to forecast because it is unstable, of short duration (in the case of severe thunderstorms this can be less than three hours) and erratic in motion (in the case of cyclones and severe thunderstorms). The dangers from severe thunderstorms, in particular, are often underestimated. In NSW six people have died over the last two years from severe thunderstorms. While NSW has the highest frequency of severe thunderstorms in Australia, they can occur anywhere in Australia and are more frequent than any other major natural hazard.[60]

4.3 Across Australia between 1967 and 1999 severe weather events were responsible for some $6.9 billion in insurance payouts alone.[61] The average insurance payout for damage incurred by a single severe weather

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57 UK Meteorological Office (1999) Tropical Cyclone Activity by Strength: <www.met–office.gov.uk/sec2cyclone/tcgraphs/tcactivity>.

58 The Bureau estimates that Australia probably has roughly equivalent numbers of thunderstorms to the USA but many go un-reported because they occur over remote areas or areas where there is no means to record their presence, for example, national parks.

59 Bureau of Meteorology (1995) Bushfire Weather, information pamphlet.

60 Bureau of Meteorology & Emergency Management Australia (n.d.) *Severe Storms: facts, warnings, protection*, information pamphlet.

61 Figures supplied to the ANAO by the Insurance Council of Australia. Includes only events likely to cost $10 million or more and events declared a disaster by an appropriate government authority, irrespective of extent of loss sustained. These figures are consequently an understatement of the true cost.

event was about $73 million. Of all insurance payouts, 59 per cent were related to severe thunderstorms, while cyclones and bushfires accounted for 32 and nine per cent of severe weather insurance payouts, respectively. The April 1999 Sydney hailstorm resulted in the single largest insurance payout in Australia's history at some $1.5 billion (some 22 per cent of *total* payouts between 1967 and 1999). In real terms, the two next most significant severe weather events were Cyclone Tracy ($837 million) and the 'Ash Wednesday' bushfires ($324 million).

4.4 The then Department of Environment, Sport and Territories Portfolio Evaluation noted that a totally effective warning system could save about 40 per cent of lives and 20 per cent or more of the damage bill resulting from severe weather.[62]

4.5 Prior to 1987, Australia's Severe Weather Service was part of the public weather forecasting service. While the cyclone warning service was operational, the Bureau had limited capacity to respond to bushfires or severe thunderstorms. Following upgrade of the Bureau's capital and human resources from 1987, the Bureau's capacity has been enhanced to the point where severe weather warnings for thunderstorms and fire weather are now part of a specialised Severe Weather Service. These services are provided through the Bureau's RFCs, with national coordination by Head Office's Services Policy Branch.[63] 'Warnings' have a higher alert status and shorter duration (for example, up to two hours for severe thunderstorms) than 'Advices', which are based on broad geographical areas such as the Bureau's weather forecast districts, which have a longer validity time (for example, up to six hours for severe thunderstorms).

Managing risk from severe weather

Planning, analysis and priority setting

4.6 The Bureau does not have a formal risk management plan for severe weather. However, some qualitative risk assessment is undertaken and resources are allocated on an on-going operational basis to areas of highest vulnerability to severe weather (that is, the major urban centres of Australia). The Bureau meets regularly with Emergency Services Australia and other relevant agencies to discuss their operational needs. Planning for severe weather has been largely based on the 1994 evaluation of the Severe Weather Program. The evaluation followed a substantial

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62 Department of Environment, Sport and Territories (1994) *Severe Weather Warning Services Program*, Portfolio Evaluation Program, Bureau of Meteorology, p.vi.

63 *Op. cit.*, The Bureau of Meteorology (1998b), p.70.

upgrade of severe weather capacity involving eighteen additional staff and $1.4 million for capital equipment over the period from 1987 to 1990. The evaluation demonstrated significant improvements in severe weather performance following the upgrade, with both the tropical cyclone and fire weather services being comparable with those provided in the USA at that time. However, the quality of service provided for severe thunderstorms was found to be well below that provided in the USA, both in terms of the skill of Australian forecasters and the standard of the surface observing network. A client survey also indicated some concerns with severe thunderstorm warning services.[64]

4.7 The Bureau has documented major risks to Australia from severe weather. For example, severe weather databases are kept in all regions, while tropical regions keep cyclone databases. Databases on fire weather events are maintained in Tasmania only. This is because of the importance of fire weather in Tasmania and because fire weather forecasting is normally a routine activity, not tied to specific events. Consequently, fire weather events are synonymous with the climate database of standard meteorological observations. All databases provide the basis for the Bureau’s performance reporting and analysis. The databases also provide a historical record of the damage, loss of life (if any) and the consequences of severe weather.

4.8 Rural and regional centres have a more generalised advice service, although Darwin and the northern regions have a dedicated cyclone warning service. Standards of service are broadly defined in the Weather Services Handbook and the Severe Weather Directives. NSW has a clear focus on severe thunderstorm warnings. In NSW, the Bureau has indicated that the severe thunderstorm warning service is one of the Bureau’s highest priority programs and operates to minimise the loss of life, property damage and community disruption generated by severe thunderstorms.

Treating risks and allocating resources

4.9 Total recurrent funding for severe weather in 1998–99 was $2.7 million. This was primarily for staff and running costs and did not include the cost of the extensive weather watch radar system or those elements of the observation network crucial to severe weather forecasting. Table 6 illustrates that resources allocated to severe weather from 1994–95 to 1998–99 were reasonably stable.

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64 *Op. cit.*, Department of the Environment, Sport and Territories (1994), pp.vi–xiii.

Table 6

ASL and expenditure on severe weather 1994–95 to 1998–99

	1994–95	1995–96	1996–97	1997–98	1998–99
ASL	34.50	34.80	35.10	32.20	Not available
Expenditure ($ million)	2.11	2.19	2.65	2.47	2.73

4.10 Regional comparisons indicate a roughly proportionate allocation of resources to the regions but, as discussed in Chapter 3, cost attribution difficulties make comparisons difficult to confirm.

Equipment

4.11 Severe Weather Services are provided by the Bureau as part of an integrated service. Consequently, most of the equipment used in the observation network is multi-purpose and not exclusively dedicated to severe weather. However, the performance of, and standards for, different components of the observation network have varying significance for severe weather. For example, upper air observations are crucial for fire weather and for severe thunderstorm forecasting. As noted in Chapter 2, the spatial density for upper air observations is variable across Australia but is close to required levels only in some parts of the south-east. This limits the capacity of the Bureau to deliver effective fire and thunderstorm services outside of south-eastern Australia (with the exception of fire weather services for Tasmania).

A Bureau officer releases a radiosonde to collect upper air data.

4.12 The national weather watch radar network is also a critical component of the Bureau's severe weather warning capability and is especially important in the accurate prediction of tropical cyclone landfall and for tracking severe thunderstorms. While coastal coverage is good, except for the gaps along the north-west coast of Western Australia and in north-east Victoria, it lacks the extensive Doppler capability now being implemented in Canada and already in place in Japan and the USA.[65] Doppler is a relatively new technology that has the particular advantage

[65] Environment Canada estimates indicate that for 1999–2000 its top priority is the installation of 10 new Doppler radar units and the upgrading of 16 others by 2003–2004. Canadian research on weather detection and forecasting will be targeted to extreme weather and climate prediction. The Slatyer Review (1996) also found that Australia lacked the Doppler radar capacity of other developed countries (see p. 101) and noted the gap in NE Victoria. The Bureau has plans to install additional radar to cover this region as part of its capital works program.

of providing information on the internal dynamics of storm systems. It measures the speed at which precipitation is moving in the area covered by the radar, as well as wind shifts, gust fronts and cyclonic patterns. Sydney had a Doppler radar unit installed in February 1999, while an experimental unit operates from Darwin. Neither unit is fully operational. However, the ANAO notes that a World Weather Research project planned for late 1999–early 2000, should enable the Bureau to consider world best practice radar-based warning systems and high resolution computer models from international several meteorological agencies and universities. This, in conjunction with the implementation of the Doppler capacity in Sydney, should provide scope for future operational improvements in severe weather equipment.

4.13 Equipment obsolescence is a major issue for the Bureau as it impacts on the capacity to respond to severe weather effectively. For example, even allowing for planned radar re-equipment, about one-third of the units left in the national network will be operating with 1950s technology in 1999. This increases maintenance costs and can result in sub-optimal reliability during critical weather events. Radar equipment or software malfunctions have occurred prior to the development of severe thunderstorms on three of the thirteen days that severe thunderstorms were reported in the Greater Sydney Warning Area during 1998–1999. On one occasion, no three-dimensional radar data was available during the most severe stage of a storm, while in another two cases, there were radar malfunctions prior to the reported severe weather. While the ANAO notes that NSW has the best record of any region in equipment inspection and calibration, it illustrates the importance of having reliable systems to support accurate forecasting.[66]

Recommendation no.8

4.14 The ANAO *recommends* that the Bureau of Meteorology continuously review the reliability of 'mission critical' equipment and systems used in severe weather forecasting and introduce maintenance schedules to improve the reliability of such equipment.

Agency response

4.15 The Agency agreed with this recommendation.

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66 Eighty five per cent of synoptic stations in NSW had been inspected/calibrated in 1998 compared to the national average of some 70 per cent.

Staffing

4.16 In addition to equipment, a key factor influencing the quality of forecasts is the number of skilled experts available to analyse the meteorological data and issue forecasts. Table 7 provides the distribution of these experts across the regions.

4.17 The total number of dedicated Severe Weather staff has increased by four since the 1994 Severe Weather Services' Review to satisfy demand in areas where there is a heavy severe weather workload, such as in Western Australia, which experiences significant demand under each of the three severe weather services.[67] In addition, all operational forecasters in all RFCs support the Severe Weather Services program, in so far as they are expected to maintain a weather watch and issue severe weather warnings as needed. In the RFCs, the shift supervisor has ultimate responsibility for the issue of all severe weather warnings, whether issued by specialist severe weather forecasters or others. Severe weather forecasting is seasonal. For example, in NSW the season extends from mid-September to the end of March, during which, specialist staff are on duty on a roster basis. Outside the season severe weather experts are engaged in training to update their skills and research and also provide training to other staff in the RFC. The ANAO notes that the NSW severe weather staff are among the best trained in Australia. Each severe weather staff member spent one month, on average, in training in 1998–99, compared to around 15 hours for other centres.

Table 7

Expert staff dedicated to severe weather

State/Territory	*Number of Staff*
NSW	4
QLD	4
Victoria	3
NT	3
SA	3
WA	3
Total	**22**

4.18 Some regions, such as Sydney, have severe weather rosters during the severe thunderstorm season using specialist severe weather staff and other RFC staff. In NSW, the roster is comprised entirely of severe weather experts. In contrast, in Victoria all regional forecasters are rotated through the roster. The NSW approach has the advantage of having the best available staff on duty at highest risk times. However, it

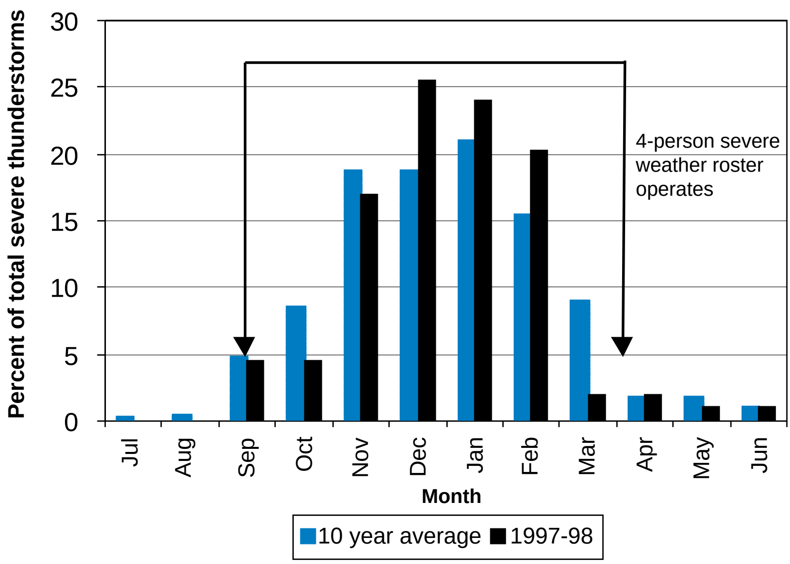
[67] *Op. cit.*, Department of the Environment, Sport and Territories (1994), p.vii.

has the disadvantage of the experts not being generally available during the off-season, even though severe weather can and does occur at this time. The ANAO notes that the Sydney hailstorm occurred approximately one week after the severe weather roster had finished for 1999. Figure 17 illustrates the incidence of severe weather events in NSW and the duration of the roster in that region.

4.19 Figure 17 also illustrates the variability in severe thunderstorms over a 12-month period in Sydney. However, while the likelihood of severe weather occurring is lower 'out of season,' the costs to the community of severe thunderstorms are such that risk management principles would suggest that having greater expert resources available is highly desirable, especially during the 'shoulder' period from April to May. As the Bureau has noted, 'the lack of experience by non-expert forecasters on the severe weather roster has diminished the effectiveness of the warning service during the off-season—despite the training emphasis provided by the Bureau to non-expert staff.' While noting that there is always the option of 'calling in' specialist staff, the ANAO considers that the NSW RFC could manage its risks more effectively by extending the forecasting role of its expert severe weather staff to cover the period from at least April to May. The ANAO notes that the Bureau has extended the season, as necessary, in the past. If this requires additional resources, then the priority suggests that a re-allocation from lower priority areas should be considered. The Sydney hailstorm is illustrated in Case Study 1.

Figure 17

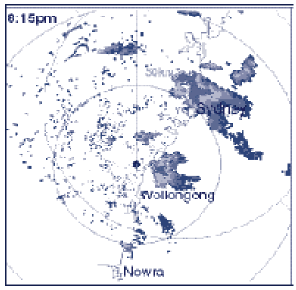
Monthly distribution of severe thunderstorms in Sydney



Source: NSW RFC, Bureau of Meteorology

Case Study 1

The Sydney Hailstorm



Radar image of the Sydney Hailstorm, April 14 1999.

In the evening of 14 April 1999 eastern Sydney experienced a severe thunderstorm that caused extensive damage making it Australia's most costly natural disaster (estimated at $1.5 billion). The hailstorm had a structure, intensity and movement that was significantly different from ordinary thunderstorms, which made forecasting particularly difficult. In this case, the Sydney Airport Management Unit (SAMU) provided some advanced warning to the aviation community of the hailstorm, while the RFC in Sydney did not provide any public warning.[68] No severe weather expert was on duty at the time, as the storm occurred one week after the completion of the severe weather roster.

The radar image of the storm originating near Wollongong suggested that the storm was likely to be going out to sea. Instead, the storm tracked to the NNE over the eastern suburbs of Sydney. A complicating factor was the intensity of the storm, which increased and decreased rapidly. These features were characteristic of the 'supercell' nature of the storm, which were not immediately identified by the Bureau. This was despite reports of hail to the south of Sydney from a number of sources, including from one volunteer storm spotter. However, based on the available information, the RFC forecaster made the judgment that the storm would not impact on Sydney and therefore issued no warning to the public.

A complicating factor during the event was that there was a communications failure before the storm reached Sydney. The SAMU forecaster was unable to contact the RFC because the phone lines were engaged while the forecaster handled reports of hailstorm activity from the public and also inquiries from the media. This meant that the airport was operating in isolation from the RFC. The RFC was itself unable to respond effectively in terms of disseminating the information required by the public because of the volume of incoming calls.

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68 Bureau of Meteorology (1999b) *Report by the Director of Meteorology on the Bureau of Meteorology's forecasting and warning performance for the Sydney hailstorm of 14 April 1999, 7 May 1999.*

Lessons Learned

There are many parallels between the Sydney hailstorm and the recent tornadoes in the USA. Tornadoes are also a 'supercell' event and are highly unstable and unpredictable and can result in either hailstorms or tornadoes. Only 20 per cent of supercells go on to produce tornadoes and so it is difficult to issue definitive warnings until tornadoes are actually occurring. Even with significant funds allocated by the US Government to severe weather warnings, lead-times for tornadoes are very short (less than 18 minutes). This is because extreme weather events are the most difficult events to forecast accurately.[69] However, in the case of Sydney, the lack of available experts within the regional office at the time of the event was a factor in reducing the capacity of the Bureau to provide a timely warning.

The Bureau has taken steps to improve its performance in the future through measures such as acceleration of the Bureau's program for training in the use of radar for severe thunderstorms, implementation of a new secure telephone line between the RFC and SAMU and the implementation of 3-D Rapic capability within the integrated workstation system. An expert review is also being conducted with experts in operational systems and other advanced technologies.

Recommendation No.9

4.20 The ANAO *recommends* that the Bureau of Meteorology:

(a) consider increasing the priority given, and resources allocated, to severe weather forecasting in view of the very significant costs to the community from severe weather;

(b) consider increasing the flexibility of the severe weather roster in NSW to better respond to the variable nature of the severe thunderstorm season. This should aim to cover the 'shoulder' period from April to May, depending on seasonal conditions; and

(c) review the long-term data for severe weather occurrence in other regional centres and consider if any changes to the severe weather roster are required.

Agency response

4.21 The Agency agreed to parts (a) and (c), indicating that it regards severe weather forecasting and warning as its highest priority function and will constantly monitor its resourcing decisions to ensure the best

69 Walker, G. et al (1999) *Out of the wreckage*, New Scientist No.2186, May 1999, pp.4–5.

possible support of its warning services within the integrated operational framework of the Bureau. It added that, this has been a priority function since the establishment of a Severe Weather Services program in the 1980s. The Agency agreed with qualification to part (b) noting that it does not believe that extending the roster to the shoulder period is necessarily the best use of resources and would propose to further consider this issue in the light of internal and external reviews of the operation of the Sydney RFC's severe weather warning functions.

Performance monitoring and review

Measuring performance

4.22 Standard performance indicators of the accuracy and timeliness of Severe Weather Services are outlined in the Bureau's Weather Services Handbook (WSH—the WSH outlines procedures to be followed throughout the severe weather season for each warning service). Each warning service has its own set of indicators to measure performance. These indicators are based on WMO performance measurement conventions.

4.23 The Bureau has set performance targets for the Severe Thunderstorm and Tropical Cyclone Warning Services. For example, for severe thunderstorms the Bureau aims for a 70 per cent Probability of Detection (POD) and a 40 per cent False Alarm Rate (FAR) and at least 30 minutes warning lead-time on 70 per cent of occasions. For Tropical Cyclone Warning Services the international standard is that warnings should be issued at least 24 hours before gales affect the coast. Position errors are also used to determine the accuracy of cyclone tracking. There are currently no targets for the Fire Weather Service. However, the Bureau has operational performance indicators including maximum and dew point temperatures, and wind speed and direction. These performance indicators help to determine overall Fire Danger Ratings (FDRs) and Fire Weather Warnings (FWWs).

4.24 These targets are being considered within the Bureau's overall review of lead-times associated with each warning category.[70] The Bureau's Service Charter does not contain targets, although it does contain broad statements about the kind of service clients can expect.

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70 *Op. cit.*, Department of the Environment and Heritage (1999), p.98.

Severe thunderstorm warning service

4.25 Table 8 illustrates the high degree of variability between both regions and years between 1993–94 and 1998–99 for both POD and FAR.

Table 8

Probability of Detection (POD) and False Alarm Rate (FAR) of severe thunderstorm warnings in selected Australian Capitals for the period 1993–94 to 1998–99

	1993–94	*1994–95*	*1995–96*	*1996–97*	*1997–98*	*1998–99*	*Six Year Average*
Probability of Detection (POD) Target 0.7 or greater							
Melbourne	0.73	1.00	1.00	0.73	0.45	0.93	0.81
Brisbane	0.67	0.53	0.76	0.57	0.80	0.75	0.68
Sydney	0.30	0.33	0.62	0.00	0.46	0.57	0.38
Perth	0.20	0.57	0.00	0.00	1.00	0.50	0.38
Adelaide	0.00	0.20	0.25	0.17	0.00	0.00	0.10
Australia	**0.42**	**0.53**	**0.62**	**0.40**	**0.39**	**0.57**	**0.49**
False Alarm Rate (FAR) Target 0.4 or less							
Adelaide	n/a	0.00	0.00	0.00	1.00	n/a	0.25
Brisbane	0.48	0.22	0.24	0.17	0.43	0.34	0.31
Melbourne	0.27	0.31	0.13	0.62	0.50	0.26	0.35
Perth	0.67	0.43	n/a	n/a	0.00	0.80	0.48
Sydney	0.64	0.70	0.50	1.00	0.68	0.67	0.70
Australia	**0.50**	**0.28**	**0.26**	**0.40**	**0.49**	**0.40**	**0.39**

4.26 The performance target of 0.7 (that is, 70 per cent) is rarely achieved for POD although the target of less than 0.4 (that is, 40 per cent) for FAR is reached relatively frequently. Nationally, the average for POD in 1998–99 was 0.57, well below the target, but an improvement on 1993–94 when the average for POD was 0.42. However, in no year between 1993 and 1999 did the Bureau actually reach the POD target—the closest the Bureau came was in 1995–96, when they reached 0.62. Yearly fluctuations between the national POD figures means that no real improvement (or deterioration) in POD performance is apparent. Relative to Brisbane and Melbourne, Sydney's POD is poor, although it is generally better than for either Adelaide or Perth. Overall, the FAR for Sydney is higher than for any of the other cities, indicating a less conservative approach to issuing severe thunderstorm warnings. Nationally, the value of FAR generally meets, or is better, than the target of 0.40 for the period 1993–1999.

4.27 A further consideration is that performance during a given year is variable, depending on whether the severe weather roster is operational. For example, in NSW during the peak severe weather period for 1998–99, the POD is as high as 0.87. In Victoria the deterioration in performance in 1997–98 was largely attributable to the absence of severe weather experts. This was also apparent in the case of the Sydney hailstorm in April 1999, as illustrated by Case Study 1.

4.28 The ANAO notes that Australia's performance is not as good in comparison with the USA, which is regarded as a world leader in severe thunderstorms. For example, in 1998 the USA POD was 0.83 compared with Australia's 0.57 (Table 9). However, Australia's FAR was roughly comparable with that of the USA. The better performance of the USA can be explained by factors such as the higher density of the observation network in the USA (roughly twice the number of synoptic stations), the higher number of storm spotters (the USA has 122 000 compared to Australia's 2850) and the more powerful NEXRAD radar system operating in the USA.[71]

Table 9

A Comparison of USA and Australian severe thunderstorm POD and FAR values between 1993 and 1998 [a]

	1993	*1994*	*1995*	*1996*	*1997*	*1998*
USA POD	0.70	0.72	0.75	0.82	0.82	0.83
Aus POD	0.42	0.53	0.62	0.40	0.39	0.57
USA FAR	0.48	0.51	0.53	0.49	0.50	0.48
Aus FAR	0.50	0.28	0.26	0.40	0.49	0.40

[a] USA use the calendar year as the basis for producing performance figures. Australian data are for the financial years beginning at the indicated year.

4.29 The ANAO notes that the Bureau's performance system was based on the USA approach. However, there are a number of methodological factors that mitigate against their value. For example, the number of severe thunderstorms in a region in a given season impacts on POD and FAR. For example, a POD of 1, the best result possible, was achieved in Melbourne for the years 1994–95 and 1995–96 and in Perth in 1997–98. At first glance the performance of both Regions appears excellent for those years. However, in Melbourne there were a total of 23 severe thunderstorms, while in Perth there was one. Clearly, the skill required to achieve a POD of 1 on 23 occasions is much greater than that to achieve a POD of 1 on one occasion.

4.30 Variation in the size of forecasting areas between regions also impacts on the performance of POD and FAR. The use of large warning areas increases the likelihood of thunderstorm detection in those areas

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[71] The USA has a network of 123 NEXRAD units that provide nationwide Doppler radar coverage for detection of severe weather events.

whereas a smaller area has a greater margin for error. The Brisbane and Melbourne RFCs, which have among the largest warning areas of all regions, tend to out-perform the other RFCs. A further issue is the configuration of the warning area. For example, Sydney's relatively poor POD performance could be attributed to the fact that its warning area is sub-divided into 10 smaller zones stretching from Kiama in the south to Wyong in the north and the Blue Mountains in the west (31 000 km^2). However, each of the 10 areas is classed as a separate warning area. Every other capital city has one forecasting area only, although of varying size.

4.31 Some of the other problems include, *inter alia*, the lack of verification in sparsely populated areas (for example, in national parks and rural areas) and the lack of accounting for occasions when a correct decision is made *not* to issue a warning. The variability in climate and meteorological conditions also influences the degree of difficulty in forecasting.

Fire weather warning service

4.32 Regional comparisons of Fire Weather Warning POD and FAR for the period 1993–94 to 1998–99 are given in Table 10. Australia-wide, there is some improvement over time in the accuracy of FWWs, particularly for POD. However, regional forecast performance for both POD and FAR is highly variable. This reflects varying degrees of difficulties in relation to different seasonal conditions. For example, in Tasmania the FAR ranges from around 0 in the 1993–94 season to 0.67 in the 1995–96 season, and back to 0.08 in the 1997–98 fire season. Similarly, in the Northern Territory the POD ranges from 0 in the 1995–96 fire season to 1 in the following season. There is currently no fire weather POD and FAR information from overseas agencies to compare with the Bureau's performance.

4.33 Improvements in FWW accuracy are partly a consequence of improved observational data from the growing AWS network, which both improves the Bureau's ability to forecast meteorological conditions affecting fire behaviour and its ability to verify FWWs. However, apparent improvements in the accuracy of FWWs are also influenced by the inherent variability in weather from one season to the next. For example, in New South Wales in the 1996–97 fire season a total of 10 severe weather events occurred, while in the following season (1997–98) this increased to 162. This means that in seasons where the conditions are not conducive to fire, individual events have a disproportionate impact on the POD and FAR in that year.

4.34 Other reasons for caution over the apparent improvement in FWW accuracy include:

- differences between regions in the way in which severe weather events are counted; and
- the changes in fire danger thresholds and in counting methods over time.

Table 10

Regional comparisons of fire weather warning (FWW) forecast performance—Probability of Detection (POD) and False Alarm Rate (FAR) 1993–94 to 1998–99[72,73]

	1993–94	*1994–95*	*1995–96*	*1996–97*	*1997–98*	*1998–99*	*Six Year Average* [a]
Probability of Detection (POD)							
NT	n/a	n/a	0.00	1.00	0.64	1.00	
NSW	-	-	-	n/a	n/a	0.43	
QLD	n/a	0.89	n/a	1.00	0.85	n/a	
SA	0.43	0.51	0.50	0.50	0.65	n/a	
TAS	0.71	0.58	0.50	0.89	0.57	n/a	
Victoria	n/a	n/a	0.60	0.63	n/a	n/a	
WA	0.42	0.10	0.38	0.38	0.36	n/a	
Australia	**0.52**	**0.52**	**0.40**	**0.73**	**0.62**	**0.71**	**0.58**
False Alarm Rate (FAR)							
NT	0.00	0.00	1.00	0.40	0.50	0.33	
NSW	-	-	-	0.67	0.31	0.57	
QLD	0.00	0.11	1.00	0.00	0.21	0.00	
SA	0.51	0.52	0.43	0.45	0.38	n/a	
TAS	0.00	0.27	0.67	0.20	0.08	n/a	
Victoria	0.40	0.27	0.00	0.55	0.12	0.10	
WA	0.66	0.83	0.79	0.81	0.74	n/a	
Australia	**0.26**	**0.33**	**0.65**	**0.38**	**0.32**	**0.20**	**0.36**

[a] A six year average was calculated for the Australia-wide figures only because of a lack of data in several regions.

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[72] Fire weather POD/FAR performance is monitored using the following three elements: 1. a 'warnable' event occurred and a warning was not issued (x); 2. a warnable event occurred and a warning was issued (y); and 3. an event did not occur but a warning was still issued (z). POD = y/(y+x) and FAR = z/(z+y). If there are no x or y values then POD can not be calculated and 'n/a' is given in the table. If there are no z or y values FAR can not be calculated and a n/a is given.

[73] Performance information from 1993–94 to 1996–97 is unavailable for the New South Wales Region. The Bureau has indicated that this is a result of problems with earlier software, which was used for creating the database on which the verification figures were calculated. Installation of the AIFS system during the 1996–97 fire season resolved this problem and verification of FWWs was performed for the first time in New South Wales at the end of the 1996–97 season.

Tropical cyclone warning service

4.35 The Bureau operates three Tropical Cyclone Warning Centres (TCWCs) from the regional offices in the Queensland, Western Australia and the Northern Territory. A comparison between selected Australian and international TCWCs indicates that Australian centres have equivalent accuracy in position and forecast errors with the Joint Typhoon Warning Centre (JTWC) in Hawaii and the National Hurricane Centre (NHC) in Miami (Table 11).

4.36 The accuracy target listed in Table 11 for +24-hour forecasts represents the WMO's ultimate long-term target value for this performance measure. Bureau staff consider that this target is probably unattainable, a view supported by the comparable international data given in Figure 4.7 (although the +24-hour forecast during Tropical Cyclone Thelma in December 1998 (112 kilometres) approached the estimated accuracy limit). This was due to accurate radar and satellite-derived initial position fixes and the cyclone's reasonably steady direction of movement.

Table 11

A Comparison of Initial Position and Forecast Position Errors for the Standard Forecast Periods +12 and +24 Hours from Australian and USA Tropical Cyclone Warning Centres (TCWCs) [a]

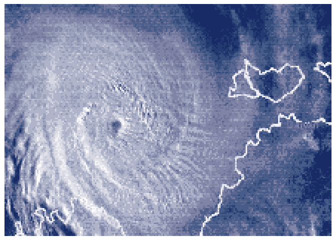
TCWCs	*Initial Position Error (km)*	*+12-Hour Forecast Error (km)*	*+24-Hour Forecast Error (km)*
Australia-wide 1993–94—1998–99	40	106	188
JTWC 1981–95	44	-	202
NHC 1975–84	-	104	205
WMO Accuracy Limit	-	-	110

[a] +12 and +24 refer to the 12- and 24-hour periods before gales hit the coast

4.37 Evidence from the Bureau's TCWCs indicates that there has been consistent improvement in tropical cyclone forecasting accuracy over the past 25 years. For example, in the Northern Territory, great circle track errors of 12-hour position forecasts issued by the Darwin TCWC averaged over 155 kilometers in 1972–73, while just over 60 kilometers in 1997–98. This gradual improvement is largely due to the introduction of more sophisticated observational equipment including orbiting and geostationary meteorological satellites, increasing networks of weather radars and AWSs and the development and introduction of powerful super-computers and numerical weather prediction techniques. However, the ANAO survey noted client concerns about the timeliness of warning services for tropical cyclones. This is illustrated in Case Study 2.

Case Study 2

Timeliness of Tropical Cyclone Warning Services



Cyclone Thelma (Dec. 1998), off Darwin and Melville Island.

While the Bureau has yet to fully develop specific timeliness targets, one of the key WMO targets for timeliness is that warnings should be used 24 hours before gales affect the coast. The Weather Services Handbook (WSH) indicates that performance information is related to procedural compliance and client satisfaction surveys. However, the WSH notes that a key performance factor is that the duty meteorologist must be advised if an area of potential cyclone formation is detected in or near the area of warning responsibility or if an existing cyclone is expected to cause gales in the area of warning responsibility with 24 hours.

Warning lead times from the Northern Territory RFC indicate that the 24-hour target was not achieved between 1992–1998 although there was some improvement over time for the eight events recorded. The target was reached at the Queensland RFC on 45 per cent of occasions (11 events) and at the Western Australian RFC on 80 per cent of occasions (10 events) between 1992–1999. The differences between the three RFCs reflects the proximity of the cyclone genesis to the warning area. In the Northern Territory it is very close to the coast and so consequently the 24-hour lead time has not been achieved. The greater distances between genesis and the warning areas in Queensland and Western Australia enable higher performance to be achieved on this indicator. In the USA, a world leader in severe weather forecasting, the 24-hour lead time was achieved in 44 per cent of cases in 1997 (the target was 90 per cent).

ANAO Comment

The ANAO recognises that the major variations between the characteristics of different regions for cyclone warnings suggests that the WMO standard may not be particularly relevant. However, given the importance of lead times for cyclone warnings an attainable but challenging standard should be introduced as a standard part of performance measurement.

Client views

4.38 The 1994 evaluation of Severe Weather Services indicated that almost 90 per cent of respondents were either satisfied or very satisfied with the level of service being provided. However, the level of satisfaction with the tropical cyclone and fire weather services was somewhat higher than that for severe thunderstorm services. For example, only 63 per cent of clients considered that severe thunderstorm warnings provided adequate lead-time, while over 90 per cent of clients considered that cyclone and fire weather warnings provided adequate warning lead-time.[74] While using a different sample, the ANAO client survey in 1999 found that client satisfaction with Severe Weather Services was generally comparable with the 1994 survey (95 per cent were satisfied or very satisfied). However, some specific concerns were noted in relation to severe weather warning lead-times and accuracy. From the survey, 13 respondents indicated some concern with the timeliness of severe weather warnings—particularly cyclone weather warnings. These respondents were from the tourism industry, local government, the aviation industry, marine industries and the media. One respondent's comment, which captures the sentiment of several clients' views, was

> *my only complaint would be regarding wind warning and cyclones. The time of forecasts is important and yet they are not always provided on time. Sometimes they are not able to provide the forecast at the agreed times.*

4.39 Few comments were received on thunderstorm warnings or advice. However, those that were received concerned the accuracy of thunderstorm warnings. For example, one aviation client indicated that they had

> *three cases in the last month where members were injured as a result of no warning, or a warning being given too late for the member to take appropriate action.*[75]

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[74] *Op. cit.*, Department of the Environment, Sport and Territories (1994), p.67.

[75] Current wind-find radar units have a dual role where they track storms but also are used for meteorological functions such as upper wind observations. They can not do both functions simultaneously and may not be available for storm tracking for up to an hour. These units are largely obsolete and are being gradually replaced with more advanced systems. Capital cities have back up radars but this is not available in other areas. The problem should be resolved through the replacement program but this will not be achieved within the next five years because of the capital costs involved.

Reporting performance

4.40 The high priority given by the Bureau to severe weather events suggests that performance reporting of the Severe Weather Service should be an important part of the Bureau's accountability requirements under the *Financial Management and Accountability Act 1997*. The end-of-season report for each of the severe weather types is an integral feature of the Bureau's reporting process. These reports include a general description of the climate, as well as the times and dates of occurrence of major severe weather events, estimates of damage and a brief resume of the effectiveness of the warning system. An abridged version of this information is also prepared for inclusion in the Regional Director's Annual Report.[76] Every major severe weather event is also the subject of a full report that includes discussion of the meteorology of the event, description of the related damage and, where appropriate, an analysis of the forecasting performance. A recent example of this was the Director's report into the Sydney hailstorm. Severe weather events are also reported in the Bureau's Annual Report.

4.41 While noting the current transition to a full Accrual Budgeting, performance reporting in the Bureau is often inconsistent and of variable quality. There is a tendency to report against inputs rather than outputs. Where outputs are reported (such as in relation to warnings) the emphasis is too frequently on the numbers issued rather than their accuracy, timeliness or capacity to meet client needs. For example, the Department's Annual Report documents the numbers of warnings against all the severe weather categories. However, only cyclone position errors are reported as an indicator of performance.[77] This contrasts with the USA and the UK where there is results-focused reporting with actual performance being compared with specified targets over time.[78]

4.42 There is little consistency of reporting across regions at present in terms of end-of-season reports and annual regional reports for severe weather events. For example, the New South Wales and Queensland fire season reports from the period 1993–94 to 1997–98 contain no verification of key indicators.[79] Without consistent and regular regional performance reporting the Bureau cannot achieve its stated aim '*to assess the effectiveness of the fire weather system*'[80]. For severe thunderstorms most performance

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[76] Bureau of Meteorology (1998e) *Weather Services Handbook*, Chapter 8.

[77] *Op. cit.*, Bureau of Meteorology (1998b), pp.70–76.

[78] US Department of Commerce, Office of Inspector General (1999) *National Oceanic & Atmospheric Administration, Financial Statements for Fiscal Year 1998*, p.v.42. Met Office Charter Standard for the Public 1996–97, <http://www.meto.gov.uk>.

[79] Although, NSW Regional Office reported the performance of Fire Weather Warnings for the first time in their 1997–98 end-of-season report.

[80] *Op. cit.*, Bureau of Meteorology (1998e), paragraphs 66–67.

information relates to the number and severity of severe thunderstorms in their region in a given season. Only the South Australian regional report included actual performance information in their 1997–98 report, although it lacked trend information to demonstrate improvement (or otherwise) over time. End-of-season reports, which offer a more comprehensive coverage of severe thunderstorm activity in each region every year, are still predominantly activity-based.

4.43 The ANAO notes that AIFS aims to address problems of inconsistency in reporting across regions. However, last season's fire weather forecasts were *fully* verified in AIFS for the first time in Victoria only. AIFS is not yet fully operational for all aspects of Severe Weather. The severe thunderstorms component of AIFS is at this stage embryonic. Links still need to be made between Bureau databases and AIFS for severe thunderstorms and cyclones in terms of data analysis, automatic verification and reporting. The Bureau anticipates that it will be probably up to two years before being fully implemented.

4.44 In terms of completeness of performance reporting, particular problems have been noted in relation to fire weather and severe thunderstorms. For example, no region currently reports against the full suite of performance indicators, as listed in the WSH, in their end of season fire weather reports. Verification of fire weather warnings, maximum and dew point temperatures and wind speed form the core verification elements reported, although even this information is not included in all regional reports. In relation to severe thunderstorms, only South Australia's annual regional report documents performance against warning lead-times, which is one of the key indicators listed in the WSH.

Recommendation No.10

4.45 The ANAO *recommends* that the Bureau of Meteorology give higher priority to the implementation of:

(a) consistent and complete reporting of the accuracy and timeliness of severe weather forecasting across regions; and

(b) severe weather performance monitoring as an integral part of the Australian Integrated Forecast System.

Agency response

4.46 The Agency agreed with qualification to part (a). That is, to the extent that it is appropriate and practicable to adapt a consistent approach to inherently different forecasting problems. The Agency agreed to part (b), subject only to the need to give highest priority to activities aimed at enhancing the quality of the service.

Conclusions

4.47 Severe weather events are recognised globally as being particularly difficult to forecast because they are extreme weather events that can be unstable, of short duration and erratic in motion. However, severe weather events have a major impact involving loss of life and some $6.9 billion in insurance payouts alone in Australia over the last 32 years. Prior to 1987, Australia had only a cyclone warning service with negligible capacity to respond to bushfires or severe thunderstorms. Following an upgrade of the Bureau's capital and human resources from 1987 this capacity has improved to the point where the major population centres are now covered by a comprehensive Severe Weather Service. The then Department of Environment, Sport and Territories Portfolio Evaluation noted that a totally effective warning system could save about 40 per cent of lives and 20 per cent or more of the damage bill resulting from severe weather.

4.48 The Bureau does not have a formal risk management plan but resources are allocated largely to the population centres around the coast which are the areas of highest vulnerability to severe weather. In each State and Territory a continuous weather watch (24 hours per day, 365 days per year) is maintained by forecasters authorised to, and capable of, issuing severe weather warnings as required. Skills and resources are focused on the specific weather characteristics for each region. The Bureau has documented major risks to Australia from severe weather. Severe storm databases are kept in all regions that provide the basis for the Bureau's performance reporting and analysis.

4.49 Bureau financial data indicates a roughly proportional allocation of resources to the different regions. However, historical and cost attribution problems makes these comparisons difficult to confirm. Equipment such as the national weather watch radar network are critical to the Bureau's severe weather warning capability. While coverage is good, except for gaps along the north-west coast and in north-east Victoria, radar lacks the extensive Doppler capability now being implemented in Canada and already in place in countries such as Japan and the USA. Sydney and Darwin currently have Doppler units but these are not yet fully operational. Equipment obsolescence and reliability are important issues in terms of the capacity of the Bureau to respond effectively to severe weather events. Allowing for planned radar re-equipment, about one-third of the units in the national radar weather watch network operate with 1950s technology. The ANAO considers that the incidents of radar equipment or software malfunctions prior to severe storms need to be reduced through more effective, fail-safe systems and cost-effective back-up services. This would strengthen the Bureau's capacity to manage its risks. Nevertheless, NSW has the best equipment and the best record in terms of equipment inspection in Australia. NSW also has amongst the best trained severe weather forecasters in Australia. These experts are crucial to the accuracy of severe weather forecasts. However, the severe weather roster in NSW has the disadvantage of not having experts on duty 'out-of-season' when the Sydney hailstorm occurred. Fluctuations in the duration of the thunderstorm season from year to year also suggests that a more flexible approach is warranted, along with greater priority to the management of severe weather events. The ANAO considers that because of the prevalent risks from severe thunderstorms, the NSW RFC should extend the forecasting role of its expert severe weather staff to cover the period from at least April to May. This would enable the Bureau to better manage the risks.

4.50 Performance information for severe weather indicates steady improvement in cyclone tracking, improvements in fire weather warnings but patchy performance in relation to severe thunderstorms. Compared with the USA, a world leader in severe weather forecasting, the Bureau's severe thunderstorm performance was less accurate. The USA's better performance can be explained by a number of factors, including the higher density of the observation network, the greater number of storm-spotters and the greater sophistication of their radar systems. The performance information needs to be viewed with some caution as seasonal conditions and methodological issues relating to factors such as the area covered and the probability of verification impact on the utility of the data for inter-regional and international comparisons. Greater attention is required in the central coordination of performance information and reporting in terms of consistency and completeness. This is important for both management purposes as well as for public accountability. While AIFS aims to address this problem, it may take up to two years before all severe weather categories are included in the system.

Canberra ACT
22 December 1999

P. J. Barrett
Auditor-General

Appendices

Appendix 1

Client Survey Results

Do you use the Aviation Weather Services?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	45	34	36	36
	No	80	61	64	100
	Total	125	95	100	
Missing	System	6	5		
Total		131	100		

Do you use the Defence Weather Services?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	14	11	12	12
	No	107	82	88	100
	Total	121	92	100	
Missing	System	10	8		
Total		131	100		

Do you use the weather by fax?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	76	58	61	61
	No	48	37	39	100
	Total	124	95	100	
Missing	System	7	5		
Total		131	100		

Do you use the telephone weather services?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	76	58	61	61
	No	48	37	39	100
	Total	124	95	100	
Missing	System	7	5		
Total		131	100		

Do you use the registered weather services on the web?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	70	53	56	56
	No	56	43	44	100
	Total	126	96	100	
Missing	System	5	4		
Total		131	100		

Do you use the commercial weather services?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	29	22	24	24
	No	91	69	76	100
	Total	120	92	100	
Missing	System	11	8		
Total		131	100		

Do you use the daily weather forecasts?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	85	65	70	70
	No	37	28	30	100
	Total	122	93	100	
Missing	System	9	7		
Total		131	100		

Do you use the current weather condition?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	81	62	69	69
	No	36	27	31	100
	Total	117	89	100	
Missing	System	14	11		
Total		131	100		

Do you use the longer-term forecasts?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	73	56	62	62
	No	45	34	38	100
	Total	118	90	100	
Missing	System	13	10		
Total		131	100		

Do you use the severe weather warnings?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	109	83	88	88
	No	15	11	12	100
	Total	124	95	100	
Missing	System	7	5		
Total		131	100		

Do you use the marine weather forecasts?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	63	48	52	52
	No	59	45	48	100
	Total	122	93	100	
Missing	System	9	7		
Total		131	100		

To what extent has the Bureau communicated to your work area the standard of service that it will attempt to deliver?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Fully	60	46	46	46
	Partially	39	30	30	76
	Not at all	31	24	24	100
	Total	130	99	100	
Missing	System	1	1		
Total		131	100		

To what extent has your work area been involved in establishing standards for the services the Bureau provides to you?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Fully	40	31	40	40
	Partially	39	30	39	80
	Not at all	20	15	20	100
	Total	99	76	100	
Missing	System	32	24		
Total		131	100		

In your opinion, have these communicated service standards…?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Improved over time	59	45	60	60
	Stayed the same	36	27	37	97
	Deteriorated over time	3	2	3	100
	Total	98	75	100	
Missing	System	33	25		
Total		131	100		

How would you rate the Bureau's intended service standards in terms of being easily understandable?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Very Good/Good	86	66	88	88
	Average	11	8	11	99
	Very Poor/Poor	1	1	1	100
	Total	98	75	100	
Missing	System	33	25		
Total		131	100		

How would you rate the Bureau's intended service standards in terms of being easily measurable?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Very Good/Good	73	56	77	77
	Average	22	17	23	100
	Total	95	73	100	
Missing	System	36	27		
Total		131	100		

How would you rate the Bureau's intended service standards in terms of being relevant to your organisation's needs?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Very Good/Good	90	69	92	92
	Average	6	5	6	98
	Very Poor/ Poor	2	2	2	100
	Total	98	75	100	
Missing	System	33	25		
Total		131	100		

How would you rate the Bureau's intended service standards in terms of being challenging but attainable?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Very Good/Good	83	63	91	91
	Average	8	6	9	100
	Total	91	69	100	
Missing	System	40	31		
Total		131	100		

Have you received or been informed of the Bureau's Service Charter?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	23	18	18	18
	No	105	80	82	100
	Total	128	98	100	
Missing	System	3	2		
Total		131	100		

How well does the Service Charter reflect your work area's or organisation's priorities?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Fully	20	15	87	87
	Partially	2	2	9	96
	Not at all	1	1	4	100
	Total	23	18	100	
Missing	System	108	82		
Total		131	100		

How well does it describe the level and quality of service that you can expect?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Fully	18	14	78	78
	Partially	4	3	17	96
	Not at all	1	1	4	100
	Total	23	18	100	
Missing	System	108	82		
Total		131	100		

To what extent has your work area or organisation been consulted in the development of the Service Charter?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Fully	12	9	52	52
	Partially	5	4	22	74
	Not at all	6	5	26	100
	Total	23	18	100	
Missing	System	108	82		
Total		131	100		

How does the Bureau currently provide you with the information you require (multiple response)?

Delivery Mechanism	*Count*	*Percent by case*	*Per cent by response*
Through its free internet service	61	50	13
Through tailored internet service	46	38	10
Fax	108	89	23
CD-ROM	7	6	1
Newspaper	41	34	9
Radio	59	49	13
Television	59	49	13
Telephone	83	69	18
Other	8	7	2

Does the Bureau currently provide you with the information you require in your preferred form/method?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	116	89	94	94
	No	8	6	6	100
	Total	124	95	100	
Missing	System	7	5		
Total		131	100		

How would you prefer to receive information from the Bureau (multiple response)?

Delivery Mechanism	*Count*	*Percent by case*	*Per cent by response*
Through its free internet service	2	18	15
Through tailored internet service	1	9	8
Fax	3	27	23
Telephone	2	18	15
Other	5	45	38

How important are the weather services from the Bureau to your work area in achieving its goals and outcomes?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	High/Very High	121	92	93	93
	Moderate	4	3	3	96
	Low/Very Low	5	4	4	100
	Total	130	99	100	
Missing	System	1	1		
Total		131	100		

How important are the weather services from the Bureau to your work area in achieving its financial objectives?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	High/Very High	62	47	50	50
	Moderate	26	20	21	70
	Low/Very Low	37	28	30	100
	Total	125	95	100	
Missing	System	6	5		
Total		131	100		

How important are the weather services from the Bureau to your work area in achieving public safety?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	High/Very High	119	91	92	92
	Moderate	7	5	5	98
	Low/Very Low	3	2	2	100
	Total	129	98	100	
Missing	System	2	2		
Total		131	100		

How important are the weather services from the Bureau to your work area in achieving occupational health and safety?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	High/Very High	105	80	81	81
	Moderate	14	11	11	92
	Low/Very Low	10	8	8	100
	Total	129	98	100	
Missing	System	2	2		
Total		131	100		

How important are the weather services from the Bureau to your work area in achieving its future planning?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	High/Very High	87	66	67	67
	Moderate	24	18	19	86
	Low/Very Low	18	14	14	100
	Total	129	98	100	
Missing	System	2	2		
Total		131	100		

To what extent would your work area be able to provide a service to your clients without the weather services that you are currently receiving from the Bureau of Meteorology?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fully	12	9	9	9
	Partially	60	46	47	56
	Not at all	57	44	44	100
	Total	129	98	100	
Missing	System	2	2		
Total		131	100		

How would you rate the Bureau's current performance in terms of efficiency of service delivery?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	118	90	93	93
	Average	7	5	6	98
	Very Poor/ Poor	2	2	2	100
	Total	127	97	100	
Missing	System	4	3		
Total		131	100		

How would you rate the Bureau's current performance in terms of providing you with forecasts within sufficient time to meet your needs?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	114	87	91	91
	Average	9	7	7	98
	Very Poor/ Poor	2	2	2	100
	Total	125	95	100	
Missing	System	6	5		
Total		131	100		

How would you rate the Bureau's current performance in terms of value for money?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	82	63	87	87
	Average	11	8	12	99
	Very Poor/ Poor	1	1	1	100
	Total	94	72	100	
Missing	System	37	28		
Total		131	100		

How would you rate the Bureau's current performance in terms of responsiveness to your needs?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	105	80	85	85
	Average	13	10	11	96
	Very Poor/ Poor	5	4	4	100
	Total	123	94	100	
Missing	System	8	6		
Total		131	100		

How would you rate the Bureau's current performance in terms of ease of access to Bureau services/products?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	112	85	89	89
	Average	8	6	6	95
	Very Poor/ Poor	6	5	5	100
	Total	126	96	100	
Missing	System	5	4		
Total		131	100		

How would you rate the Bureau's current performance in terms of professionalism of Bureau staff?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	108	82	92	92
	Average	8	6	7	99
	Very Poor/ Poor	1	1	1	100
	Total	117	89	100	
Missing	System	14	11		
Total		131	100		

How would you rate the Bureau's current performance in terms of accuracy of forecasts?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	95	73	77	77
	Average	27	21	22	98
	Very Poor/ Poor	2	2	2	100
	Total	124	95	100	
Missing	System	7	5		
Total		131	100		

How would you rate the Bureau's current performance in terms of providing information for your specific requirements?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	112	85	92	92
	Average	8	6	7	98
	Very Poor/ Poor	2	2	2	100
	Total	122	93	100	
Missing	System	9	7		
Total		131	100		

How would you rate the Bureau's current performance in terms of ease of understanding the information provided?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	112	85	88	88
	Average	14	11	11	99
	Very Poor/ Poor	1	1	1	100
	Total	127	97	100	
Missing	System	4	3		
Total		131	100		

How would you rate the Bureau's current performance in terms of sufficiency of information provided?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	114	87	91	91
	Average	7	5	6	97
	Very Poor/ Poor	4	3	3	100
	Total	125	95	100	
Missing	System	6	5		
Total		131	100		

How would you rate the Bureau's current performance in terms of presentation of information in a manner that enables you to easily access the information you need to make decisions?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good/Good	109	83	89	89
	Average	12	9	10	99
	Very Poor/ Poor	1	1	1	100
	Total	122	93	100	
Missing	System	9	7		
Total		131	100		

How would you rate the Bureau's current performance in terms of quality of presentation?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Very Good/Good	110	84	89	89
	Average	14	11	11	100
	Total	124	95	100	
Missing	System	7	5		
Total		131	100		

How would you rate the Bureau's current performance in terms of innovation?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Very Good/Good	79	60	68	68
	Average	31	24	26	94
	Very Poor/ Poor	7	5	6	100
	Total	117	89	100	
Missing	System	14	11		
Total		131	100		

How would you rate the Bureau's current performance in terms of dealing with client complaints?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Very Good/Good	52	40	83	83
	Average	7	5	11	94
	Very Poor/ Poor	4	3	6	100
	Total	63	48	100	
Missing	System	68	52		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of efficiency of service delivery?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	64	49	53	53
	Stayed the Same	54	41	45	98
	Worse/Much Worse	2	2	2	100
	Total	120	92	100	
Missing	System	11	8		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of providing you with forecasts within sufficient time to meet your needs?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
	Better/Much Better	58	44	48	48
Valid	Stayed the Same	61	47	50	98
	Worse/Much Worse	2	2	2	100
	Total	121	92	100	
Missing	System	10	8		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of value for money?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
	Better/Much Better	43	33	42	42
Valid	Stayed the Same	58	44	57	99
	Worse/Much Worse	1	1	1	100
	Total	102	78	100	
Missing	System	29	22		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of responsiveness to your needs?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
	Better/Much Better	65	50	54	54
Valid	Stayed the Same	52	40	43	98
	Worse/Much Worse	3	2	3	100
	Total	120	92	100	
Missing	System	11	8		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of access to Bureau services/products?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
	Better/Much Better	65	50	53	53
Valid	Stayed the Same	55	42	45	98
	Worse/Much Worse	2	2	2	100
	Total	122	93	100	
Missing	System	9	7		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of professionalism of Bureau staff?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Better/Much Better	68	52	59	59
	Stayed the Same	46	35	40	98
	Worse/Much Worse	2	2	2	100
	Total	116	89	100	
Missing	System	15	11		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of accuracy of forecasts?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Better/Much Better	54	41	44	44
	Stayed the Same	67	51	55	99
	Worse/Much Worse	1	1	1	100
	Total	122	93	100	
Missing	System	9	7		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of providing information for your specific requirements?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Better/Much Better	62	47	52	52
	Stayed the Same	55	42	46	98
	Worse/Much Worse	2	2	2	100
	Total	119	91	100	
Missing	System	12	9		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of understanding the information provided?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Better/Much Better	63	48	52	52
	Stayed the Same	57	44	47	99
	Worse/Much Worse	1	1	1	100
	Total	121	92	100	
Missing	System	10	8		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of sufficiency of information provided?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	58	44	49	49
	Stayed the Same	60	46	50	99
	Worse/Much Worse	1	1	1	100
	Total	119	91	100	
Missing	System	12	9		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of information in a manner that enables you to easily access the information you need to make your decisions?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	66	50	55	55
	Stayed the Same	53	40	44	99
	Worse/Much Worse	1	1	1	100
	Total	120	92	100	
Missing	System	11	8		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of quality of presentation?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	62	47	52	52
	Stayed the Same	57	44	48	99
	Worse/Much Worse	1	1	1	100
	Total	120	92	100	
Missing	System	11	8		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of innovation?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	56	43	50	50
	Stayed the Same	56	43	50	99
	Worse/Much Worse	1	1	1	100
	Total	113	86	100	
Missing	System	18	14		
Total		131	100		

Do you consider that the Bureau's services are getting better, static or getting worse in terms of dealing with client complaints?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	37	28	49	49
	Stayed the Same	38	29	50	99
	Worse/Much Worse	1	1	1	100
	Total	76	58	100	
Missing	System	55	42		
Total		131	100		

Do you currently use weather services provided by any organisation other than the Bureau's?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Yes	25	19	19	19
	No	105	80	81	100
	Total	130	99	100	
Missing	System	1	1		
Total		131	100		

How would you rate the services you receive from this provider compared to the Bureau's in terms of quality?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	3	2	30	30
	Stayed the Same	2	2	20	50
	Worse/Much Worse	5	4	50	100
	Total	10	8	100	
Missing	System	121	92		
Total		131	100		

How would you rate the services you receive from this provider compared to the Bureau's in terms of timeliness?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	3	2	30	30
	Stayed the Same	5	4	50	80
	Worse/Much Worse	2	2	20	100
	Total	10	8	100	
Missing	System	121	92		
Total		131	100		

How would you rate the services you receive from this provider compared to the Bureau's in terms of costs?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Stayed the Same	5	4	71	71
	Worse/Much Worse	2	2	29	100
	Total	7	5	100	
Missing	System	124	95		
Total		131	100		

How would you rate the services you receive from this provider compared to the Bureau's in terms of quality?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	6	5	55	55
	Stayed the Same	4	3	36	91
	Worse/Much Worse	1	1	9	100
	Total	11	8	100	
Missing	System	120	92		
Total		131	100		

How would you rate the services you receive from this provider compared to the Bureau's in terms of timeliness?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	6	5	55	55
	Stayed the Same	3	2	27	82
	Worse/Much Worse	2	2	18	100
	Total	11	8	100	
Missing	System	120	92		
Total		131	100		

How would you rate the services you receive from this provider compared to the Bureau's in terms of costs?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	Better/Much Better	1	1	25	25
	Stayed the Same	1	1	25	50
	Worse/Much Worse	2	2	50	100
	Total	4	3	100	
Missing	System	127	97		
Total		131	100		

Considering all your dealings with the Bureau, how would you rate your overall level of satisfaction with the Bureau's weather services?

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
Valid	**Satisfied/Very Satisfied**	123	94	94	94
	Neither Satisfied nor Dissatisfied	4	3	3	97
	Dissatisfied/Very Dissatisfied	4	3	3	100
	Total	131	100	100	

Appendix 2

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