

Progress in accessing environmental data and information

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Introduction

Governments, landholders, science agencies, businesses, industry and the community need environmental data to gain an understanding of the environment, make decisions on environmental issues, and plan for a sustainable future. Environmental data are used for a range of purposes, including:

- to understand interactions between the natural environment and human systems
- to identify environmental issues and to provide a basis for the development of actions, strategies and policies aimed at addressing these issues
- to ascertain the effectiveness and efficiency of interventions and investments in environmental issues
- to benchmark environmental performance (for example, by companies and government)
- to report on the current state of the environment and monitor spatial and temporal changes that have occurred over time, as required for state of the environment reporting and sustainability reporting
- to meet international reporting obligations (for example, to the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, the Organization for Economic Co-operation and Development (OECD)).

Adequate and reliable data and the capability to analyse them are key elements in supporting the formulation of good environmental policy and decision-making.

In their 1998 Environmental Performance Review of Australia (OECD 1998), the OECD noted that, despite progress in reporting on the state of the environment, environmental data and environmental monitoring in Australia are often inadequate in terms of coverage and consistency. The need to develop Australia-wide assessment and reporting systems was also stated in some of the first National Land and Water Resources Audit (the Audit) reports (for example, NLWRA 2000; 2001; 2002a).

The environment is intrinsically complex. There are a multiplicity of environmental issues, and many parameters for some variables that make environmental management complex at many scales. Consequently, the identification and collection of relevant data at national, regional or local scales is an enormous challenge. The use of spatial data is an essential element in the assembling of a national picture of the Australian environment and its responses to pressures and management actions.

Australia is a large continent with outstanding natural heritage and a relatively small human population. Commonwealth agencies compile data and information and use it to develop and implement national policy, programmes and legislation. State and territory agencies retain the responsibility for much of the collection and maintenance of environmental data in Australia, while local governments, industry, independent agencies and science agencies are also important sources of information. Regional natural resource management processes are now in place, with 57 regional organisations each having an accredited investment strategy and reporting framework. It is important that Australia applies, as much as is possible, a systematic, coordinated approach and makes informed, collaborative decisions on how to use the limited available resources to maximise the benefits to be derived from environmental data collection, monitoring and reporting.

Australia's environment is not only vast, it is diverse and unique. Effective environmental data programmes will always benefit from the use of modelling and remote sensing. Australia has led the way in using these techniques to analyse vegetation change, rangeland systems and species distributions. It has also used these analyses to support better outcomes with regional land managers, underpinning land management practice with the best available data and information. This has provided a much improved information base, enhanced scientific capability, and effective mechanisms to translate that scientific information to community use.

This paper focuses on the current status of environmental data available for state of the environment reporting and the advances in data collection and accessibility that have been made in the last five years.

Progress since 2001 in accessing data and information for environmental reporting

Since the 2001 state of the environment report (*SoE2001*), major advances have been made in the availability of environmental data, primarily reflecting technological improvements and institutional changes that have made information more accessible and searchable. Progress has been driven by government policy and the development of national frameworks, guidelines and infrastructure for the 'public good' sharing of information and data.

Australian Government data sharing initiatives

The Australian Government Policy on Spatial Data Access and Pricing <<http://www.osdm.gov.au/policy/accessPricing.html>>, administered by the Office of Spatial Data Management (OSDM), provides a whole-of-government approach to ensure that fundamental spatial data collected by agencies in the public interest are used efficiently and effectively to maximise the economic and social benefits to the nation.

The Spatial Data Schedule <http://www.osdm.gov.au/osdm/spatial_data.html> lists almost 300 datasets that have been made available online for free or for marginal costs by their host agencies. These digital maps and databases include information on climate, biological and physical parameters of the land and ocean, management boundaries and tenure, biodiversity, natural resources, agriculture, fisheries and a range of other information considered necessary for the 'public good'. This represents a major effort by the Australian Government to reverse the trend towards privatisation and commercialisation of public data holdings that was identified in *SoE 2001* as an 'area requiring urgent action'.

The Australian Spatial Data Infrastructure (ASDI) <<http://www.ga.gov.au/nmd/asdi/>> is a national initiative that is being implemented by the Spatial Information Council (ANZLIC) to provide better access to essential spatial data, and to increase the effective and efficient use of existing data. It aims to ensure that users of spatial data will be able to acquire consistent datasets to meet their requirements, even though the data are collected and maintained by different authorities. The concept of the ASDI is not to establish a central database, but to set up a distributed network of databases, managed by individual government and industry custodians.

Discovering spatial data

An important first step toward the ASDI initiative was the Australian Spatial Data Directory (ASDD) hosted by Geoscience Australia, which allows users to search for geospatial information from all jurisdictions. The ASDD was launched in 1998 and has since steadily grown in content to become the key gateway for access to spatial information in Australia.

All states and territories now maintain an online directory for the discovery of spatial data (see Table 1). These directories can be accessed directly or through the ASDD, where they

can be searched in conjunction with nodes implemented by Australian Government agencies and commercial organisations. Despite this, Australian Government agencies attempting to achieve national outcomes are still concerned that some state and territory agencies may not fully appreciate the value of spatial data by. The Australian Government considers that the greatest challenge is in raising awareness and building capacity for using spatial data across all jurisdictions.

Table 1: Some key national and state data directories for the online discovery of geospatial information:

Jurisdiction	Internet address of data directory
Australian Capital Territory Geographic Data Directory	http://www.gim.act.gov.au/actLocate/index.dwt
Australian Spatial Data Directory (ASDD)	http://asdd.ga.gov.au/asdd/
New South Wales Spatial Data	http://www.canri.nsw.gov.au
Northern Territory Spatial Data Directory	http://www.ntlis.nt.gov.au/
Queensland Spatial Data (QSIS)	http://www.information.qld.gov.au/
South Australian Spatial Information Directory	(uses the ASDD)
Tasmanian Spatial Data Directory	(uses the ASDD)
Victorian Spatial Data Directory	http://services.land.vic.gov.au/landchannel/content/productCatalogue
Western Australian Land Information System (WALIS) Interragator	http://www.walis.wa.gov.au/interragator/

Further steps towards interoperability

The introduction of the Australian Government Spatial Data Access and Pricing policy in 2002 generated a number of other Australian Government programmes that have since increased the accessibility and usability of spatial and non-spatial data. Such initiatives include a whole-of-government license registration service for scheduled datasets and a new Australian Government metadata profile that is based on international metadata standards (ISO 19115). Metadata are structured summaries of information that describes datasets. Standardising the format of metadata means that datasets can be efficiently catalogued in data directories and, consequently, more easily discovered, accessed and used for many purposes.

To facilitate the online delivery and sharing of information by Australian Government agencies, the Australian Government Information Management Office (AGIMO) is producing a set of standards and guidelines known as the Interoperability Framework <<http://www.agimo.gov.au/practice/framework>>. Interoperability is the ability of systems to exchange and use information and services through the application of open standards. Interoperability is required for data and information to be easily exchanged and used on different computers with different software. Examples of interoperability in action include the

Western Australian Shared Land Information Platform <<http://202.72.132.74/slip>>, Information Queensland <<http://www.information.qld.gov.au/>>, Australia's Virtual Herbarium <<http://www.anbg.gov.au/avh/>> and the ongoing development of the National Data Network <<http://www.nationaldatanetwork.org/ndn/ndnhome.nsf/Home/Home>>, led by the Australian Bureau of Statistics (ABS). The Audit is also working towards the development of standards for natural resources data collection, storage and dissemination using open standards and interoperability.

Use of the Internet for data dissemination and environmental reporting

The Australian Government Online Policy has encouraged the online reporting of data and information. As a result, it was possible to access a great deal more data for the 2006 state of the environment report (*Soe2006*) that was previously available on the Internet in 1996 and 2001.

Early pioneers of electronic systems of data delivery in Australia are to be found in both Commonwealth and state agencies. For example, in January 1993 the Australian National Botanic Gardens went online with an innovative multimedia Internet site that predated the World Wide Web (Hilvert 1996). The Environmental Resources Information Network (ERIN) achieved connectivity with the Internet in 1992 (Kaye 1992) and by the end of 1993, both ERIN and the Tasmanian Parks and Wildlife Service had made information available through the Internet (Boston 1993). The Western Australian Land Information System (WALIS) was influential in establishing whole-of-government strategies for the management and delivery of land information, which were an important developmental step towards statewide, online information delivery. Other pioneers of note include Community Access to Natural Resources Information (CANRI) in New South Wales and the Tasmanian Government's state of the environment reporting website.

Most states and territories are now involved in online reporting of environmental information, including delivery of state of the environment reports. The Australian and Tasmanian governments also provide downloads of background data and information to support their state of the environment reports.

Technological advances in data methodologies

Technological advances in data gathering, storage, analysis and processing have resulted in the accumulation of environmental data at an increasing rate. For example, the National Carbon Accounting System (NCAS) <<http://www.greenhouse.gov.au/ncas/index.html>> tracks emissions (sources) and removals (sinks) of greenhouse gases from Australian land-based systems. The system underpins National Greenhouse Gas Inventory reporting, and provides a basis for emissions projections to assess progress towards meeting Australia's emissions target. NCAS accounts for these activities through a highly integrated, digital map-based information system. It couples remotely sensed landcover change, land use and management,

climate and soils data (including mapped information from thousands of satellite images), with greenhouse accounting and ecosystem modelling to calculate the changes in carbons in a particular area over time.

The Australian Greenhouse Office has significantly improved the National Greenhouse Gas Inventory compilation process through the deployment of the Australian Greenhouse Emissions Information System (AGEIS)

<<http://www.greenhouse.gov.au/inventory/index.html>>. AGEIS is a database system that provides centralised estimates of emissions, inventory compilation, reporting, data verification and storage functionality. It was developed over three years to meet Australia's national inventory reporting commitments under the United Nations Framework Convention on Climate Change. In addition, the system facilitates the effective management of the large volume of data associated with inventory compilation and allows the automated population of a number of reports that form Australia's Greenhouse Accounts. These accounts provide emissions estimates at the national, state and territory and economic sector (ANZSIC) levels. AGEIS also provides enhanced accessibility and transparency of Australia's National Greenhouse Gas Inventory estimates with online, interactive access to more than 100 000 emission results, background supporting data, and time-series analyses.

Sentinel Fire <<http://www.sentinel.csiro.au/sentinel.html>> is the result of collaboration between the Defence Imagery and Geospatial Organisation (DIGO), CSIRO Land and Water, and Geoscience Australia to design and build a system to detect and monitor bushfires at a continental scale. Algorithms are applied to satellite imagery to create surface temperature images that are fed into a spatial database. The database can be queried through the Sentinel Fire Mapping website to produce near real time maps, or to dynamically monitor fire locations across Australia.

The development of reporting tools has streamlined the collection and processing of information into national databases such as the National Pollutant Inventory (NPI) <<http://www.npi.gov.au>>. The NPI, for example, provides web-based reporting of the types and amounts of substances being emitted into the Australian environment. Nearly 4 000 facilities from a wide range of industry sectors are required to report emissions of polluting substances annually for inclusion in the database, along with government estimates of non-industry (or diffuse) sources of pollution.

Progress in environmental data collection

Some sets of environmental data have been collected in a regular and consistent fashion for many years, such as weather and climate data amassed by the Bureau of Meteorology, social and agricultural data collected by ABS, river regulation data held by the Murray Darling Basin Commission

<http://www.test.dwlbc.sa.gov.au/murray/river_condition/rivermurraymanagement.html>, and continental 'greenness' monitoring (using the Normalised Difference Vegetation Index

<<http://www.deh.gov.au/erin/ndvi/index.html>> applied to satellite imagery) carried out fortnightly by the Department of the Environment and Heritage (DEH) since 1991.

Other nationally consistent datasets of use for state of the environment reporting and other environmental reporting purposes include the *Water Account 2000–01* (ABS 2002), the Australian River Assessment System (AusRivAS) dataset on river health established under the National River Health Program in 1994, and environmental databases maintained by the Australian Government Department of Environment and Heritage (DEH) such as the Australian Wetlands Database <<http://www.deh.gov.au/water/wetlands/database/index.html>>, the Australian Heritage Database <<http://www.ahc.gov.au/register/index.html>> and the Species Profiles and Threats Database (SPRAT) <<http://www.deh.gov.au/cgibin/sprat/public/sprat.pl>>.

Improvements have been observed since *SoE2001* in terms of national environmental data collection and management. Some examples of new, better or updated data sets, data collations and methodologies that have become available during the past five years are:

- the Australian Terrestrial Biodiversity Assessment (NLWRA 2002b), which filled a gap in the national collation and interpretation of information on Australia's biodiversity; several other Audit reports have been published since *SoE2001*, including *Australia's Native Vegetation* (NLWRA 2002c), and the *Australian Catchment, River and Estuary Assessment* (NLWRA 2002d)
- the establishment of the Neptune Data Directory <<http://www.neptune.oceans.gov.au>>, by the National Oceans Office in collaboration with CSIRO Marine Division (now CSIRO Marine and Atmospheric Research); this metadatabase enhances public access to marine and coastal spatial data, and has complemented existing geospatial data directories already in place to support the ASDD.
- the greater focus on embedding monitoring and evaluation into natural resource management projects for the Natural Heritage Trust (NHT) and National Action Plan for Salinity and Water Quality (NAP) (NRMMC 2005)
- a number of environmental datasets have been updated or made available during this period, including biodiversity-related data from the Australian Biological Resources Study (ABRS) <<http://www.deh.gov.au/biodiversity/abrs/online-resources/index.html>>, the National Forest Inventory Australia, which includes the National Plantation Inventory <<http://www.affa.gov.au/nfi>>, the Collaborative Australian Protected Areas Database (CAPAD) <<http://www.deh.gov.au/parks/nrs/capad/index.html>> and the SPRAT, Australian Heritage and AusRivAS databases
- significant progress has been made through the Natural Resource Management Ministerial Council Taskforce on Wetlands and Waterbirds in developing a framework for an Australian Wetland Inventory (AWI); the AWI aims to establish a consistent basis for wetland classification and assessment, to inform priorities for management and monitoring, and to provide a platform for the delivery of national data and information

while reducing the duplication across state and territory, regional and local government jurisdictions

- all jurisdictions continue to support and input to the national Directory of Important Wetlands in Australia dataset
<<http://www.deh.gov.au/water/wetlands/database/directory/index.html>>, with new sites having been added since 2001 by New South Wales, Queensland and South Australia, and work progressing in Tasmania.
- the Australian Natural Heritage Assessment Tool (ANHAT) has been developed through a range of collaborative projects with a wide range of institutions. ANHAT includes data from a variety of sources on terrestrial vertebrates, plants and a selection of invertebrate groups and marine animals. While new datasets are being developed for a range of other taxa, work is also being invested in improving data coverage and accessing additional state-based resources.

Benefits of collaboration

There are many examples where increased collaboration among agencies since 2001 has achieved efficiencies in data integration, management and access. Some of these include the following:

- Collaborative efforts between the states and territories and the Australian Government to implement National Environment Protection Measures have meant that data on air quality and the emission of substances to the environment have continued to be collected, resulting in nationally consistent air quality and emissions data. These datasets are publicly available; for example, the NPI <<http://www.npi.gov.au>> and the Environment Protection and Heritage Council <<http://www.ephc.gov.au>>.
- The Australian Government and the states and territories' have collaborated to refresh, update and improve existing datasets such as the National Vegetation Information System (NVIS) <<http://www.deh.gov.au/erin/nvis/index.html>>. NVIS is a detailed database of Australian native vegetation types, developed to enhance natural resource management and planning. NVIS can be applied to practices such as biodiversity conservation, salinity control, fuel load management and improving water quality. Almost all of the data in the NVIS database is provided by the states and territories, having been derived to meet their particular needs over decades of vegetation surveys and mapping using a variety of methods and classifications. The NVIS is managed through the Executive Steering Committee for Australian Vegetation Information (ESCAVI), which comprises senior representatives from the Australian Government and each state and territory. This collaboration represents a major achievement in combining disparate data to form a consistent national collation.
- Australia's Virtual Herbarium (AVH) <<http://www.anbg.gov.au/avh/>> is a botanical information resource that provides immediate access to the wealth of data associated with scientific plant specimens in each Australian herbarium. The AVH is a collaborative

project of the state, territory, and Commonwealth herbaria that is being developed under the auspices of the Council of Heads of Australian Herbaria (CHAH), which represents the major Australian collections.

- ABS and the Australian Bureau for Agricultural and Resource Economics (ABARE) are cooperating to derive a nested survey design to avoid duplication of effort by two different but similar surveys conducted by each agency (the biennial natural resource management survey and the triennial natural resource management on-farms survey respectively). The next set of surveys in 2007 will be based on this new design.
- ABS and ANZLIC have worked in partnership to improve national-level spatial data, for example, in developing ‘Mesh Block’ boundaries that will allow much more flexibility and detail in the spatial mapping of statistical information, particularly in regional areas or for small local areas without breaching privacy guidelines.
- PSMA (Public Sector Mapping Agencies) Australia facilitates the creation of and access to national spatial datasets such as administrative boundaries and other cadastral information for commercial resale to government, industry and the community. PSMA Australia is an unlisted public company wholly owned by the state, territory and Australian Governments, hence such products are examples of the commercially driven development of high quality products that meet fundamental government data priorities.
- The Audit coordinates the development of a framework for natural resource management information, through specific National Coordination Committees comprised of representatives from key Australian, state and territory agencies. The committees advise the Audit on national information needs for each natural resource theme, issue or ‘matter for target’ under the National Monitoring and Evaluation Framework.
- Service agreements between government agencies (bilateral agreements and Memoranda of Understanding) and whole-of-government data purchasing and licensing arrangements are being progressed by an increasing number of agencies. Such collaborations are being actively promoted in Australian Government through the efforts of the Spatial Data Management Group and AGIMO (for example, the National Services Improvement Framework <<http://www.agimo.gov.au/services/services>>).

The National Water Initiative

The National Water Commission is an independent statutory body in the Prime Minister’s portfolio. Its role is to drive the national water reform agenda. Established under the *National Water Commission Act 2004*, the Commission provides advice to the Council of Australian Governments and the Australian Government on national water issues. The Council of Australian Governments has developed a blueprint for reform—the National Water Initiative—and significant funding is available to invest in water resource projects that support water reform objectives.

Continuing challenges

SoE2001 recognised a pressing need for research and monitoring of the state of the environment. In discussing data and information management, the report identified the following as common problems across all state of the environment reporting themes:

- important gaps in primary data
- lack of access to some data because of institutional barriers
- confusion about intellectual property and copyright
- lack of trend data for many variables
- some data cannot be aggregated and compared on a continental scale because of differences in scales, map projections, boundaries and geographical divisions, and inconsistencies in the way attributes are described and recorded.

While some progress has been made on these issues, these same problems still restrict the quality and completeness of state of the environment reporting in 2006. From 2006 onwards, Australia faces new challenges in ensuring the consistent supply of source data for environmental reporting, in particular, continued satellite remote sensing monitoring data and ground-based primary data collection. Furthermore, there are ongoing challenges for state of the environment reporting that are associated with the complexity of environmental data and with the values-based nature of heritage appraisal.

Gaps in primary data

The National Land and Water Resources Audit (the Audit) in its first phase (1997–2002) delivered a comprehensive national appraisal of Australia's natural resource base and addressed several of the gaps in land, water and vegetation data required for *SoE2001*. At that time, the Audit recognised the need for more strategic data collection to maximise future return on investments in natural resource management. Since then, while vast improvements have been made in the accessibility and online delivery of environmental information, this appears to have been at least partly at the expense of Australian, state and territory government investment in the collection and compilation of primary data (Campbell 2006). Furthermore, lower investment has apparently favoured methods of remotely gathering data over ground-truthed data collection, which has benefited some state of the environment reporting themes but reduced the availability of information suitable for others. Hence, in 2006 there are still gaps in primary environmental data (see Table 2 for examples) and fundamental spatial data (Table 3) for aspects of Australia's land and marine resources, most particularly in the availability of nationally consistent environmental datasets.

Table 2: Some of the gaps in primary Australian environmental data observed when preparing *SoE2006*

Up-to-date land use change data

Water resources data at a national scale

Information about weeds, pest and feral animals at a national scale

The fate of pollutants such as fertilisers and herbicides in the environment

Rural and regional air pollution monitoring

The actual distributions of threatened species

Vegetation and habitat mapping data

Information describing the condition of the environment, such as habitat condition, soil condition

Condition of natural heritage places

Freshwater species and habitats

Marine species and habitats, condition and extent

Coastal ecosystems, such as seagrasses, coral reefs

Estuarine and coastal water quality

Environmental impacts of uses of the marine environment

Natural resource management trend information, in particular, the effectiveness of management and recovery actions

Information on potentially useful biological compounds

National mapping of fire and fire regimes

Measures for monitoring sustainability in human settlements

Table 3: High priority gaps in fundamental datasets for environmental monitoring identified by an OSDM survey of Australian agencies (December 2004, 2005)

Marine park boundaries

Seafloor topography and bathymetry

Ocean parameters, such as temperature, salinity, currents

Land tenure and land use

Commonwealth interests in land

Natural resource management: soil condition and socio-economic census

River catchments

Cropping and irrigation areas

Antarctic remote sensing products

Datasets that deliver on monitoring and evaluation framework indicators at a national, state and territory, and regional level

There is considerable scope for agencies to pool resources and collaborate on the collection or procurement of primary data. A number of agencies are already working together on projects to develop and deliver fundamental and nationally consistent environmental data. Examples include the Australian Collaborative Land Use Mapping Program (ACLUMP) <<http://www.affa.gov.au/content/output.cfm?ObjectID=88F4306A-07B9-4CBD-BF47430BC51F6D55>> and the Australian Collaborative Land Evaluation Program (ACLEP) <<http://www.clw.csiro.au/aclep/>>. An important first step will be for government and science agencies, industry and non-government organisations to discuss, and agree on, data collection priorities that will fill the gaps in key national environmental datasets.

Access to environmental data

National initiatives promoting interoperability have meant that the issues regarding technological barriers are rapidly being addressed. In contrast, institutional barriers continue to prevent efficient use of the data that are available within Australian agencies and jurisdictions. These barriers include:

- the lack of trust or agreement between agencies and jurisdictions about who has responsibility for the collection, management, reporting and analysis of data
- a lack of coordination within jurisdictions and agencies, leading to fragmentation of monitoring efforts within and between agencies in all jurisdictions
- the failure to systematically standardise and collate local data to obtain the ‘big picture’ within and between jurisdictions
- a misalignment between the needs of the information users and the objectives of the information providers

- confidentiality, privacy and commercial concerns that increasingly impede access to the data available within agencies.

Cooperation appears to have improved across Australian Government agencies, but this is not necessarily filtering down to lower levels where, for example, copyright and licensing issues have impeded the collegial sharing of data between agency staff.

Intellectual property, copyright and licensing issues

Data accessibility is reduced by intellectual property issues, such as restrictions on the use of commercially confidential data and data that were previously publicly available but are currently not available due to the corporatisation of organisations. This barrier has particularly affected access to waste generation data and, to some extent, waste recycling data.

While NVIS provides a good example of the collaboration between state, territory and Government agencies to produce a standardised, nationally consistent dataset, the process of formalising the necessary license agreements for data sharing was considerably simpler in 2001 than during the recent update of the dataset in 2005. Agencies have shown increased concern over the risk of litigation arising from the supply and use of their data. This has resulted in source agencies being more constrained in their capacity to share data and the agencies responsible for compiling the data instigating overly cautious procedures for approving the acceptance of liabilities associated with incoming license agreements. Hence, licensing issues have considerably slowed and in some cases have prevented the collaborative sharing of data between agencies and jurisdictions. There is still an issue of how to gain in-principle agreement on data sharing between jurisdictions for all government activity.

Availability of trend data

The picture is variable, but it reflects the reluctance or capacity of government at all levels to commit ongoing funding for long-term environmental monitoring. Consistent, ongoing trend data can be relied on for reporting of the atmosphere theme, the human settlements theme (especially population data from ABS), and some indicators for the Antarctic theme. Trend data are available for some rangelands features (Watson 2006) and certain individual monitoring datasets; examples include a 30-year record of whale sightings at Southern Cross University, Birds Australia data, and particular attributes of the Great Barrier Reef. Studies of particular species or ecosystems have been carried out over long time periods but, by their nature, these records are spatially constrained by the character and extent of the ecosystem or species being studied. For other themes and issues, such as biodiversity, land condition, and the state of marine and freshwater biota, there are no nationally available trend data. There are little available trend data for any attribute of 'condition', largely because the term is value laden: values change constantly and it is difficult to obtain institutionalised agreement on what the term constitutes. While *SoE2001* recommended that it was essential to instigate an ecological monitoring programme to track changes in biodiversity (ASEC 2001), such a

programme still does not exist. Similarly, there are no systematic long-term national programmes in place to monitor key features of Australia's oceans and coasts.

A typical example of attempts at regional monitoring that have been hampered by limited trend data is the Australian Collaborative Rangelands Information System (ACRIS) <<http://www.deh.gov.au/land/management/rangelands/acris/reporting.html>>, which tested the reporting of change in the rangelands from 1992 to 2002 across a number of pilot regions. ACRIS reported not only a lack of suitable monitoring data to adequately report change in biodiversity but a decreasing information base for monitoring change during the period of their study. ACRIS observed that most jurisdictions had shown a decreasing capacity to sustain future monitoring activity.

The lack of natural resource management trend data was noted in early Audit reports (for example, NLWRA 2000) and the situation has not improved. More recent works undertaken by the Audit suggest a continuing reduction in the basic mapping and monitoring of the environment (Campbell 2006). Audit publications prepared between 1997 and 2002 reported on the condition of Australia's natural resources and were intended to provide a baseline for monitoring the effectiveness of national land and water policies and programmes. In most cases, the data have not been updated since 2001. Whether or not monitoring to support the Monitoring and Evaluation Framework takes place will depend on the future commitment from relevant jurisdictions and regional organisations.

Diversity of data scales and geographies

The obstacles to building nationally consistent environmental datasets include incompatible formats, different map projections and scales, and inconsistent categorisation and recording of data attributes by the data providers. A typical example of such problems can be observed in the compilation of the NVIS; state and territory agencies independently collect vegetation data for their own purposes, which vary considerably from agency to agency. When these data are incorporated into NVIS, problems with data integration occur, particularly at the state or territory borders. The most common inconsistencies are due to definitional issues (the allocation of the same vegetation type to a different community class), the lack of consistent schemas for vegetation mapping, and the use of different boundaries to delimit the state or territory extent of mapping (for example, cadastral boundaries versus state and territory borders). Nonetheless, the states and territories have cooperated with the Australian Government to iron out these problems and an updated version of the NVIS national map of native vegetation types was completed in 2006.

ABS data are generally supplied in spatial units defined by a minimum population size for the purpose of census data collection and privacy considerations (the smallest unit currently used is the Census Collection District). The land area covered by these units varies enormously from urban to rural regions and bears no relationship to cadastral or land management boundaries. In many cases, this restricts the use of the data for effective mapping and geographic comparisons or analysis with natural resource information. The ABS is aware of

these limitations and is making concerted efforts towards improving the spatial usability of their data sets (for example, the development of ‘Mesh Blocks’).

Technological advances that promote interoperability between applications are beginning to overcome some of the processing issues related to data integration. The more difficult problems to overcome will be those that stem from the different needs and objectives of the agencies collecting the data.

Ensuring a continuing supply of remote sensing data

Remote sensing imagery underpins a large and growing number of map products and analyses used for state of the environment reporting and, more importantly, many of the products that monitor long-term environmental trends. It is very easy to overlook the importance of satellite and airborne image data since many products are sourced as finished maps without acknowledgement of the remote sensing data and processing works used in their development. The Bureau of Meteorology, the Bureau of Rural Sciences (BRS) and the Australian Greenhouse Office (AGO) depend heavily on satellite data for many of their applications. Remote sensing is being increasingly applied to produce nationally relevant datasets as a complement to the integration of data collected at the state and territory level and there is considerable potential for further use of this efficient and cost-effective approach to national data collection.

The Landsat series of satellites have provided the foundation for much of Australia’s long-term environmental monitoring since the 1970s. With the impending demise of the current Landsat 5 and 7 satellites, and doubts over NASA’s commitment to continuation of the program, there is concern in the Australian spatial science community about continued access to cost-effective, stable, well-calibrated imagery that has the spatial and spectral characteristics suited to such a wide range of environmental applications. Australian Government agencies are currently investigating replacement options to ensure the continued supply of these fundamental monitoring data.

Complexity of environmental data

Some environmental data are intrinsically challenging to collect and thus slow progress has been achieved in establishing integrated datasets.

The condition of biodiversity is inherently difficult to measure because it refers to the condition of all species that make up an ecosystem, how they contribute to each other, and the resulting stability and resilience of the ecosystem as a whole. There is very little understanding of how the population of any one species may vary depending on physico-chemical factors or the presence, population and distribution of each other species comprising the ecosystem. The responses of an ecosystem to perturbation or disturbances are complex, often unexpected and inherently difficult to describe or measure. Hence, the focus of data gathering has been at the level of population and distribution of individual species and, to a

lesser extent, the distribution and character of ecological communities and landscapes. The monitoring of ecologically significant species (such as 'keystone' or 'indicator' species) has proven to be a useful management tool (see Soulé and Kohm 1989), but in reality Australia does not have a comprehensive understanding of whether changes in the distribution and abundance of any particular species reflect positively or negatively on biodiversity as a whole.

Even in the absence of a direct measure of the 'condition' of Australia's biodiversity, valuable information for conservation planning and management can be provided through the assessment and monitoring of individual species and communities, habitat quality, and the extent and distribution of key threatening processes. Some significant progress has been made. For example, the Audit's landscape health and biodiversity assessment reports (NLWRA 2000, 2002b) provided a national overview of key environmental threats and the health of landscapes.

A number of government agencies are progressing 'benchmark-based' approaches to habitat quality assessment for aquatic and terrestrial ecosystems. For example, the *National Natural Resource Management Monitoring and Evaluation Framework* (NRMMC 2002) established nationally agreed indicators, including one on native vegetation condition, which provide the basis for ongoing reporting of progress in regional planning against reference points or benchmarks. Other reporting systems using this approach include the Australian Collaborative Rangelands Information System

<http://audit.deh.gov.au/ANRA/rangelands/docs/tracking_changes/Track_change_RIS.html>, the Victorian Government's methods for Vegetation Quality Assessment <<http://www.dse.vic.gov.au/DSE/nrence.nsf/LinkView/EBF7B20C008E24F5CA256F16001671778062D358172E420C4A256DEA0012F71C>> and the (former) New South Wales National Parks and Wildlife Service's BioMetric Tool <http://www.nationalparks.nsw.gov.au/npws.nsf/content/biometric_tool> that facilitates the preparation of property vegetation plans.

In some cases, because of the multifaceted and dynamic nature of the natural environment, it could simply be impossible or impractical to collect sufficient, appropriate field data at suitably regular intervals to satisfy reporting and management needs. Modelling can provide the next best solution for monitoring landscape condition or predicting environmental change in certain situations where the suitable data cannot be obtained.

Due to the inherently values-based nature of heritage and the tendency for values (and therefore what is being measured) to change over time, attempts to describe, maintain and report on heritage data have continued to be challenging (Johnston 2006).

Future initiatives

A large number of initiatives for the collection, collation, processing and sharing of environmental data are presently underway in Australia and are expected to come to fruition

in the next five years. Some of these are highlighted below, but there are potentially many more such projects that other stakeholders are developing. All of them could have positive outcomes for state of the environment reporting.

National Data Network

A good example of how agencies holding disparate datasets could cooperate to provide an integrated data management system is the National Data Network (NDN) <http://www.nationaldatanetwork.org>, which has been developed by ABS in collaboration with Department of Transport and Regional Services, AGIMO, the Australian Institute of Health and Welfare, Australian Research Alliance For Children And Youth, Centrelink, CSIRO, the New South Wales Department of Health, and the Queensland Office of Economic and Statistical Research.

The NDN will create a distributed library of statistical data holdings that are relevant to policy analysis and research. Like the ASDD, the NDN will provide a catalogue of available data sources to allow users to easily search for and access data that remain held and controlled by the custodian organisations. The purpose of the NDN is to promote stronger integration of data by providing access to metadata, standards and guidelines, and to do so in ways that meet custodian obligations to maintain confidentiality, protect intellectual property and comply with privacy principles.

ABS Statistical Geographies

ABS continues to work on improving the relevance of census and agricultural census data to both government and industry users. The recent 'Mesh Blocks' project is a practical initiative towards facilitating the spatial application of statistical data for natural resource management and environmental monitoring. Mesh Blocks offer more detailed geographic units that aggregate and align more closely with administrative, social, economic and environmental boundaries while preserving confidentiality.

ABS and BRS are also trialing the functionality of the 'land parcel' survey method as an alternative spatial, land-based area framework for natural resource surveys that facilitates better spatial outputs at the sample design stage.

National Water Initiative

The National Water Initiative, established under the Council of Australian Governments in June 1994 has responsibility for a number of key areas that will be critical to water reform:

- water access entitlements and a planning framework
- water markets and trading
- best practice water pricing
- integrated management of water for environmental and other public benefit outcomes

- water resource accounting
- urban water reform
- knowledge and capacity building
- community partnerships and adjustment.

To implement the water reform agenda, the National Water Commission has contracted a consortium to undertake a Baseline Water Resources Assessment that will support the work on water reform.

Water 2010

The Bureau of Rural Sciences' Water 2010 project is developing an interactive website and CD-ROM to enable users to explore factors influencing Australia's dynamic water balance. The Water 2010 project applies a land use mapping approach to show how and where water is generated and used including runoff, transpiration, irrigation and groundwater. The website will be integrated with a national water database maintained by state and territory and Australian Government agencies and dynamically updated to ensure the most current data are available.

National Agricultural Monitoring System

The National Agricultural Monitoring System (NAMS) is being developed by BRS to streamline the exceptional circumstances (drought relief) application and assessment processes. The proposed website will provide maps, graphs and reports to demonstrate the production situation for major agricultural systems, as well as the state of their climatic drivers. NAMS will contain current and historical data on measured and modelled agricultural production, financial impacts, remote sensing and climate. Collectively, the information in the NAMS will show conditions for production and prospects for dryland and broadacre agricultural systems.

Australian Soil Resource Information System

The Australian Soil Research Information System (ASRIS) is a product of the Australian Collaborative Land Evaluation Program (ACLEP), which is jointly funded by CSIRO Land and Water and the Natural Heritage Trust. ASRIS will provide the best available information on soil and land resources across Australia in a consistent format. The programme entrains significant contributions from all state, territory and Australian government agencies that are involved in land resource assessment. The goal of ACLEP is to enable natural resource management in Australia to be undertaken with an appropriate land resource information base to generate economic and environmental benefits.

Australia's Resources Online

The objective of the Australia's Resources Online (ARO) project is to provide a dynamic, online application to report on the condition and trend of the land, water and biological resources in Australia using interoperable, authoritative data sources. ARO is a cooperative project being undertaken by the Audit through the ERIN.

The innovative concept of the ARO application is to allow custodians from jurisdictional agencies to deliver web services that are based on agreed theme-based schemas and interoperability standards. The products are then accessed through the ARO application to deliver a collated view, thus eliminating the need for centralised national collations. The complexity of the system lies in the application technology and design as there are a number of issues to consider. These include effective delivery of data for use at regional to national scales, performance issues related to large volumes of data, access to previous datasets for enabling trend analysis, and the continual availability of online data services. Institutional arrangements are also being facilitated to develop agreed standards and capacity to deliver services.

Australian Collaborative Land Use Mapping Program

The Australian Collaborative Land Use Mapping Program (ACLUMP) is a coordinated and cooperative effort between various state, territory and Australian government agencies to promote the development of nationally consistent information about land use and land management. This is a vast improvement on previous approaches, which were independent of each other and used a range of scales and a variety of cartographic methods and classification systems.

ACLUMP delivers a number of key benefits, including nationally consistent land use mapping coverage for Australia at both continental and catchment scales, a national information system for land management practices, agreed national technical standards including the Australian Land Use and Management Classification, a national land use data directory, and the maintenance of land use datasets on Australian, state and territory government data repositories, and regional and national reporting of land use and land management practices. An interactive website has been proposed to replace the CD-ROM 'Land Use Mapping for Australia' that is currently available to the public and land use managers.

Air quality database

The State of Air Quality database will compile state and territory data on measured levels of air toxic and criteria air pollutants in a consistent and therefore comparable format for the whole of Australia. The database will be a welcome step in accessing nationally consistent air quality trend data: the only information that is currently reported is exceedances of standards rather than actual trends in air quality. Development will be promoted through a

Memorandum of Understanding between DEH, the Bureau of Meteorology and the National Environment Protection Council Service Corporation.

OZCAM Australia's Fauna

The Online Zoological Collections of Australian Museums (OZCAM) 'Australia's fauna' website <<http://www.ozcam.gov.au/index.php>> will provide an online, distributed network of databases containing information about the faunal collections held in Australian museums and other institutions such as CSIRO. The portal is being designed to parallel the query network that Australia's Virtual Herbarium provides for flora collections, and it is currently in a 'proof of concept' stage of operation. OZCAM is being funded through contributions from participating institutions and the DEH.

Australian and Global Biodiversity Information facilities

The Global Biodiversity Information Facility (GBIF) <<http://www.gbif.org/>> is an international non-profit organisation that is working towards free and universal Internet access to the world's store of primary data about biodiversity, which are currently held in natural history collections, libraries, databases and other institutions around the world. The GBIF prototype data portal (a work in progress) currently provides access to checklists of species names and allows for searching of specimens and observations held in distributed databases. GBIF will also offer a range of analytical tools for interrogation of the data such as the Biodiversity Assessment Tool, which can be used to detect biodiversity hot spots. The Australian Biodiversity Information Facility (ABIF) <<http://www.abif.org/index.htm>>, managed through the ABRS, will provide the gateway for real-time access to Australian biodiversity data. ABIF functions as the Australian node of GBIF.

Ocean Portal Project

The National Oceans Office's Oceans Portal Project involves the development of three distinct and physically separate components: a web-based portal, a marine catalogue and a network of interoperable service and content providers. The Oceans Portal is the interface that will allow users to discover and access information and data, and create and manipulate maps online from distributed sources using international standards. Data sources will include the National Oceans Office, CSIRO Marine Research, Geoscience Australia, the Royal Australian Navy, Australian Antarctic Division, Bureau of Meteorology, BRS, OZCAM, DEH and the Australian Institute of Marine Sciences.

Opportunities for the future

The 'Future directions' section of *SoE2001* (ASEC 2001) observed that the unique nature of the Australian environment presented managers and decision makers with particular challenges. The Australian continent is large, its environments are diverse and the biota are highly endemic, yet the Australian human population is small.

A key challenge that environmental managers will continue to face in Australia is in targeting investment of limited resources to maximise benefits to the environment. The path to achieving a targeted approach is not simple in a country where three levels of government (national, state and territory, and local), industry and non-government organisations each have commitments to environmental monitoring and reporting, and thus need to obtain relevant and up-to-date environmental data and information on a regular basis.

Australian government initiatives have encouraged progress in the development of cooperative frameworks for information collation and use, and have therefore promoted the development and implementation of nationally consistent standards and protocols. There has been progress in environmental data collection, and there are notable examples where synergies have been obtained through collaboration between agencies, but there are still substantial gaps in knowledge of Australia's environment and current monitoring programmes are often inadequate for supplying the data essential to understanding the interaction between humans and the natural environment.

Much progress in accessing environmental data and information has already been made since *SoE2001* through technological advances in information delivery, including tools and systems for the discovery and sharing of data, and associated improvements in interoperability.

Environmental data and information have been made increasingly accessible by electronic means in the past five years, and this trend is likely to continue. However, while the energy being devoted to initiatives aimed at improving the availability and accessibility of environmental data is heartening, the *ad hoc* development of often very similar databases, datasets or online reporting systems shows a lack of coordination between agencies. In addition, efforts directed towards improving data and information availability are often limited in their purpose and scope (to the needs of the organisation funding the initiative), and are frequently duplicated.

If the limited resources available for environmental data collection, monitoring and reporting are to be used more effectively, then the agencies responsible for these functions will need to communicate with each other and work together. The difficult questions that arise, however, are how to coordinate agencies and jurisdictions and who will lead the process.

The National Land and Water Resources Audit is facilitating the process for those data and information sets that are relevant to the National Monitoring and Evaluation Framework for natural resource management. The Audit has continued the development of an agreed framework of indicators, standards and protocols across all jurisdictions that can enable consistent and authoritative monitoring and reporting for natural resource management, as long as quality data are gathered consistently in the future to populate the framework (Campbell 2006).

A more systematic approach to environmental data collection

Australia needs to apply a more systematic approach to environmental data collection and monitoring (NLWRA 2001; Beeton et al. 2006; Campbell 2006). This would involve communication and collaboration between all jurisdictions to develop cooperative frameworks for information collection, access and use, supported by investment in a national data and information infrastructure.

Certain first steps will need to be taken to initiate a cooperative, coordinated approach to environmental data collection, management and use in Australia. These are listed below.

Step 1: Formal discussion on a better designed environmental reporting system

The current environmental data reporting system has a plethora of players with little or no incentives for agencies and organisations to collaborate in the collection, management and sharing of specific data. The 2006 Australian State of the Environment Committee advised two Ministerial Council Standing Committees in September 2005 of the lack of access to environmental data that was hindering their attempts to report on the state of Australia's environment. The committees found that for many environmental domains, data are still patchy or only available at either local or regional scales. The standing committees, comprising the chief executives of environment and heritage agencies, agreed that the system for environmental reporting did need to be improved.

A better designed system would establish a common set of questions and indicators that could satisfy the most important environmental reporting needs of all levels of government and would have the characteristics of synchronicity, with mechanisms and protocols in place to facilitate data and information collection, aggregation, management and sharing by all users. It should be possible for any participating jurisdiction to collect data at any scale, which can subsequently be aggregated or disaggregated for reporting purposes at a different scale (Beeton et al. 2006). The data and information would be accessible to decision makers and environmental reporters at all levels, and preferably made available online.

Step 2: Establish the data collection priorities

Once the mechanisms are in place to ensure that data collection occurs, and occurs in a way that provides scalable information that can be used by all jurisdictions, it will be necessary for agencies and organisations to reach agreement on Australia's priorities for environmental data and information collection, based on the agreed questions. Prioritisation should address the establishment of long-term trend monitoring programmes (applying remote sensing or ground-based data collection as appropriate) and the filling of gaps in primary data wherever this is considered necessary to meet the most pressing needs of the majority of data users.

Step 3: Ensure the technology and protocols are in place to make it happen

Despite the significant advances that have been made in the past five years, there is still work to be done to ensure that the technology, mechanisms and protocols are in place to allow for the collection and sharing of environmental data. The technological environment in which data providers are working is constantly changing, and with it the expectations of information users. Users are becoming more sophisticated, technologies are rapidly advancing (especially on the spatial side) and demands are higher. Technology continues to develop at an increasing rate, with the result that vast improvements in the collection, storage, analysis and delivery of environmental information are likely to be observed every five years. Since technological advances will occur regardless, effort should be aimed towards coordinating the work being put into online reporting and database development to reduce duplication, improve efficiency and avoid the incidence of systems becoming rapidly superseded.

It is important that activities that raise awareness of custodianship rights and responsibilities and implementation of the ISO metadata profile are continued, as are activities that lead to the development of policy, standards and procedures for data interoperability, integratability and licensing.

Step 4: Institutional arrangements

The problems of intellectual property, copyright, licensing and access outlined in this report would need to be addressed to break down current interagency barriers to data sharing and information use. It is likely that the collaborative effort put into the development of a cross-jurisdictional environmental reporting system would, as a matter of course, encourage a sense of common purpose and the dissolution of many institutional barriers.

Advances in institutional cooperation have already been achieved for environmental and natural resource management through the considerable leadership efforts of bodies such as ESCAVI and the Audit. The Spatial Data Management Group and working groups managed by the OSDM continue to encourage interagency cooperation by facilitating the sharing of experience and expertise amongst Australian Government agencies.

In addition, many of the challenges facing Australia today call for a national approach. Examples include the Australian Government Spatial Information for National Security (AGSINS) all hazards approach to emergency management and national security and the National Water Commission's efforts to drive the national water reform agenda. These drivers help to minimise interagency and intergovernmental barriers because they force disparate agencies to collaborate on data and information collection and use. While environmental issues are rarely considered as immediate or pressing, longer-term benefits will flow into this area from the institutional arrangements created to meet the needs of the 'higher' priority information needs.

Diverse sets of managers from varied jurisdictions are involved in environmental management and reporting in Australia. Most have come to recognise that the best way forward is to combine the knowledge, plan together for outcomes that benefit all, pool resources, invest wisely and cooperate to ensure a continued supply of integratable environmental information and monitoring data.

Groundwork towards this (albeit complex) aspiration will be laid through new cooperative initiatives, for example, a working group is currently being established to improve Australia's environmental reporting system. The Audit has already put effort into the framework and institutional arrangements that would allow for a better designed and integrated reporting system for regional natural resource management.

Conclusion

There are many questions that must still be answered with regards to the appropriate leadership, the correct forum and the best model for renovating the environmental reporting system in Australia, and for ensuring better access to environmental data and information. Future progress will depend on sustained effort and strong leadership.

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Acronyms

ABARE	Australian Bureau for Agricultural and Resource Economics
ABIF	Australian Biodiversity Information Facility
ABRS	Australian Biological Resources Study
ABS	Australian Bureau of Statistics
ACLEP	Australian Collaborative Land Evaluation Program
ACLUMP	Australian Collaborative Land Use Mapping Program
ACRIS	Australian Collaborative Rangelands Information System
AGEIS	Australian Greenhouse Emissions Information System
AGIMO	Australian Government Information Management Office
AGO	Australian Greenhouse Office
AGSINS	Australian Government Spatial Information for National Security
ANHAT	Australian Natural Heritage Assessment Tool
ANZLIC	Australia New Zealand Land Information Council
ARO	Australia's Resources Online
ASDD	Australian Spatial Data Directory
ASDI	Australian Spatial Data Infrastructure
ASRIS	Australian Soil Research Information System
the Audit	National Land and Water Resources Audit
AVH	Australia's Virtual Herbarium
AWI	Australian Wetland Inventory
BRS	Bureau of Rural Sciences

CANRI	Community Access to Natural Resources Information
CAPAD	Collaborative Australian Protected Areas Database
CHAH	Council of Heads of Australian Herbaria
CSIRO	Commonwealth Scientific, Industrial and Research Organisation
DEH	Australian Government Department of Environment and Heritage
DIGO	Defence Imagery and Geospatial Organisation
ERIN	Environmental Resources Information Network
ESCAVI	Executive Steering Committee for Australian Vegetation Information
GBIF	Global Biodiversity Information Facility
ISO	International Standards Organisation
NAMS	National Agricultural Monitoring System
NAP	National Action Plan for Salinity and Water Quality
NCAS	National Carbon Accounting System
NDN	National Data Network
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NPI	National Pollutant Inventory
NVIS	National Vegetation Information System
OECD	Organization for Economic Co-operation and Development
OSDM	Office of Spatial Data Management
OZCAM	Online Zoological Collections of Australian Museums
PSMA	Public Sector Mapping Agencies
QSIIS	Queensland Spatial Data
SPRAT	Species Profiles and Threats Database
WALIS	Western Australian Land Information System