



# Development of a strategy for monitoring Australia's natural resources: a discussion paper

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## Preamble

This discussion paper was prepared under a contract with the National Land and Water Resources Audit 2, in fulfilment of the following agreed aims:

### *Outcomes*

A consistent approach to monitoring land and water resource condition across Australia.

### *Outputs*

A concise report for the National Land and Water Resources Audit that provides a strategy for monitoring the condition of Australia's land and water resources. The strategy will:

- take account of existing technical and resource management programs;
- ensure an integrated approach that balances measurement, modelling and mapping;
- consider the feasibility of tracking change in key natural resource attributes;
- comment on the need for long term monitoring based on sites, catchments, or broader landscape units;
- recommend areas and issues to incorporate into a trial program; and
- be aligned with the monitoring and evaluation framework being developed by the Monitoring and Evaluation Working Group (working within the Natural Resource Management Ministerial Council directions).

### *A discussion paper*

Natural resource management issues are complex, and the monitoring requirements many and varied, and subject to changing priorities with changing community attitudes and political imperatives. There is no single or obvious best way to monitor Australia's natural resources (at least, in the real world of finite funding!).

Furthermore, what to monitor depends on the objectives of the monitoring or natural resource management program. Commentary and advice can be offered on what to monitor for a given set of objectives, but choice amongst objectives is for the community at large or its representatives.

Therefore, we seek to stimulate discussion both of the priorities amongst objectives for monitoring and of the (non-obvious) priorities amongst means. We will welcome your comments, addressed to [Mac.Kirby@csiro.au](mailto:Mac.Kirby@csiro.au).

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## **1. Executive summary and summary of recommendations**

Australia has a National Framework for monitoring and evaluation to assess the health of natural resources, and to assess the performance of programs and policies. Here we identify some requirements and recommend a strategy for implementation of the framework.

Australia has many monitoring and evaluation programs reporting on specific issues such as river health, water quality, forestry, and landscape and soil sustainability. Some programs (such as State of the Environment) report on many issues. Many take advantage of data collection programs commissioned for other purposes, rather than a data collection program associated specifically associated with the monitoring and reporting program.

However, there is no system-wide, integrated assessment of triple bottom line “health”. Whether such an assessment can or should be reduced to a single index is a moot point. Lack of such monitoring and evaluation systems is also recognized internationally.

Natural resource management should be adaptive with the first step being to define objectives (particularly the desired ultimate outcome) followed by planning, action, monitoring and evaluation, and reporting. The reporting is used to re-examine the objectives – have they been fulfilled, should they be refined or changed?

The monitoring and evaluation within this adaptive cycle should also be adaptive. The objectives are given by the natural resources management program. The next step is to develop a conceptual model of the issues to be addressed, then identify and select indicators, design a monitoring strategy, collect and summarise data, interpret and evaluate the data, and report. The reporting is used to re-examine the conceptual model

used for monitoring and evaluation, and also to re-examine the objectives of the natural resource management program.

A national monitoring and evaluation scheme should follow this broad framework. In addition, it should have nationally consistent and long-term measurements, be adequately resourced and sit within a clear framework of institutional responsibility.

We recommend that a national monitoring and evaluation strategy be implemented in two phases. The initial phase is to run a trial using “best bet” indicators (perhaps those suggested by the Monitoring and Evaluation Working Group). The trial will seek to test monitoring and evaluation at the national level of a set of indicators, and to report problems in their use and suggestions for improvement.

The trial should be conducted in several places, with several biophysical regions and different natural resource management issues. Candidate locations should be considered from regions with contrasting climates (eg northern and southern Australia), coastal and inland, and land management ranging from native, through arrangements, to arable and irrigated farming. Locations in different states, and particularly across state borders, and involving different organisations (including community involvement in some monitoring) would help test consistency of methods.

The second phase, implementation of a national strategy, will follow the trial and evaluation of its success, problems, and suggestions for improvement. A national strategy could involve a new monitoring evaluation program, coordination of current programs, or expansion of a lead program (perhaps that on which the trial is to be based). At this stage, it is not clear which is the most effective option, nor what the costs would be. Some of these issues should

become clearer during a trial. The trial should be designed to provide information about this.

Various impediments could make a national strategy unachievable. These include lack of clearly stated and agreed objectives, lack of funds, lack of long-term commitment, lack of institutional responsibility, and lack of long-term research backup. Even if these impediments are dealt with, and a sound monitoring and reporting strategy developed, nevertheless national environmental monitoring and evaluation could fail if it does not inform national debate and policy.

The two broad purposes of the National Framework will not easily fit in a single strategy. Program evaluation has different requirements from long term assessment of health. Without a long term health assessment, program or policy evaluation cannot easily be judged against triple bottom line goals, so long term monitoring is required in a national strategy. Program and policy evaluation can be undertaken program by program.

### ***Overall recommendation***

To implement the National Framework, a national monitoring and evaluation strategy should be established, which:

- has clearly stated and agreed objectives;
- has a clear link to and mandate to inform national debate and policy.
- has clear funding, commitment and institutional responsibility;
- has clear long-term research backup;
- follows the framework outlined in this report;
- has clear reporting and feedback procedures;
- is flexible and adaptive;
- identifies priority areas for earliest and/or most intensive monitoring; and,
- starts with a trial in some contrasting regions.

## 2. Introduction

### *Why monitor and evaluate?*

At the recent Earth Observing Summit in Washington, USA, July 31<sup>st</sup> 2003 it was observed that (see [http://earthobservationsummit.gov/framework\\_discussion\\_paper.html](http://earthobservationsummit.gov/framework_discussion_paper.html), from which the following text is extracted):

**“Vision.** Humanity has entered a new era where human ingenuity must now be applied to developing a deeper understanding of the Earth’s complex systems—an understanding that should begin with Earth observations. The forces of global development and change present serious challenges to world leaders, decision makers, and institutions—challenges that require advancing our existing Earth observation systems to a new level. That new level is an international, comprehensive, integrated, and sustained Earth observation system that provides the tools to “take the pulse of the planet.”

These advanced tools (analogous to the medical community’s diagnostic tools) would potentially allow for a continuous Earth system diagnosis to address the interrelated processes of weather, climate, ecosystems, and cycles of water, energy, and carbon. These advanced tools could also identify potential symptoms that, if left uncorrected, would impair the health of the Earth. An effective IEOS\* would provide information that enables decision makers to take proactive measures. Thus, an IEOS, with combined observations of atmospheric, terrestrial, ocean, and other phenomena, will form the basis for sound science for sound decision-making....

**Need for Immediate Action.** Every day without the IEOS is a lost opportunity and limits our ability to properly address recognized global environmental problems. Every day that an observation is not taken impacts the integrity of the

scientific record and the observation can never be recovered. Having access to existing longer-term records addresses some of our environmental problems, but the lack of critical observations is significantly retarding the environmental understanding we seek and require....

**Current State.** A comprehensive and sustained IEOS currently does not exist, but some essential components are already in place....”

### \* Integrated Earth Observation System

The statements, of course, apply also to monitoring and evaluation in Australia. In particular, there is no integrated, long term program of monitoring and evaluation, though some essential components are in place.

### *Many interrelated issues*

The box on the next page lists many natural resource management issues which are large, pressing and interrelated. Stopping vegetation clearing or revegetating will help solve salinity, and in turn improve water quality and river health, and all are affected by climate change.

Management of the many natural resource issues is a complex problem with no single answer. Monitoring and evaluation is a key part of addressing these problems. If we don’t monitor, how will we know which problems to address in what order? And how do we know if our actions have been successful and, therefore, whether to continue or redirect actions? We suspect that in the absence of long-term monitoring datasets, many policy decisions to date have been based on informal or qualitative assessment. Monitoring and evaluation is required because many contaminants cannot be seen or tasted, and rigorous scientific testing must be undertaken. Similarly, monitoring and evaluation is required for effects in natural resources that are beyond

### **Box 1**

#### **Key current natural resource management issues include:**

- Salinity  
Area affected predicted to treble to 17 m ha by 2050 (Australian Dryland Salinity Assessment, 2000)
- Vegetation clearing and biodiversity  
Significant national debate and currently subject of a Productivity Commission Inquiry (Productivity Commission, 2003)
- River health  
1/3 of river length in Australia has impaired biota (Norris *et al.*, 2001).
- Water quantity and resource security  
Focus of a major national debate, (Wentworth Group, 2002), with several major cities facing water restrictions.
- Water quality  
Adelaide water supply fails drinking water guidelines for salinity 20 % of the time (Chartres *et al.*, 2003).
- Soil Acidification  
A major and growing problem (Australian Agricultural Assessment 2001).
- Climate change  
Climate change is predicted to significantly affect Australia's water supply, ecosystems, agriculture and fisheries, and the human population including health (IPCC, 2001)

the scale of human understanding either because of their wide (perhaps even global) range or because of their long-term impacts (on the scale of hundreds of years for issues such as salinity or global warming).

The concept of health in natural resource management is ubiquitous and, though often taken as analogous to human health, is not universally accepted (e.g Nielsen, 1999; Wilkins, 1999; Rapport *et al.*, 1999). Here we use the analogy to draw attention to the following:

- Discussions of landscape health (or health of rivers, ecosystems,

catchments, etc.) almost invariably invoke monitoring and indicators as a key element (eg, Walker and Reuter, 1996);

- progress can be made without a definition of health, but with an understanding of the symptoms of ill-health and their indicators (Norris and Thoms, 1991);
- what constitutes ill-health nevertheless requires a clear understanding of its converse, that is healthy or in good condition, and indicators of that condition (eg. Walker and Reuter, 1996);
- the difficulty in defining the health of ecosystems (Norris and Thoms, 1999) leads to notions of functionality or serving the needs of society (eg Rapport *et al.*, 1998).

A set of indicators to define health seems attainable for catchments (Walker and Reuter, 1996), but might not be for rivers (eg Boulton, 1999).

Using the analogy with human health, we will sometimes be concerned with a single issue, and focus our management actions and monitoring on that. Single issues will be important when a problem arises – a case of ill health. In such cases what to monitor will often be fairly clear. At other times we will be concerned with the “health” of an overall natural resources system or region. In these cases, what to monitor might be less clear, but will involve integrated triple bottom line assessment. We do not monitor every physiological aspect of a body to identify health – rather we use an overall feeling of healthiness combined with an absence of specific indications to the contrary<sup>1</sup>.

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<sup>1</sup> The World Health Organisation defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948.

Here we do not describe monitoring and evaluation in detail for each issue. Rather we offer a generic view and framework, with some discussion of particular issues as examples.

**Definitions:**

- Monitoring is the repeated measurement and recording of a variable or variables. The monitoring period could be short, long or indefinite. The variables recorded could be those directly measured, or a summary or integration of directly measured variables.
- Evaluation is the use of monitoring datasets to address specific questions. Examples include “is a specific natural resource management target being met?”, and “what, if any, natural resource management problems are developing in a region?”.

2.1. Context: the National Monitoring and Evaluation Framework

The Natural Resource Management Ministerial Council has established a National Natural Resource Management Monitoring and Evaluation Framework (National Framework) (<http://www.deh.gov.au/nrm/monitoring/evaluation/framework.html>) to assess progress towards improved natural resource condition through the development of accurate, cost-effective and timely information on the:

- health of the nation's land, water, vegetation and biological resources; and
- performance of programs, strategies and policies which provide national approaches to the conservation, sustainable use and management of these resources.

The National Framework is based on a set of principles (that it should be: useful; simple,

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cost-effective, affordable and practical; encompass the range of timescales; support meaningful interpretation of the data; the end, specify the assumptions) for the monitoring, evaluation and reporting on natural resource condition. It also provides a set of indicators for assessing change in resource condition and program performance. The framework identifies roles and responsibilities for meeting national, state/territory and regional level reporting requirements. The framework also requires that a capacity building strategy be part of funded programs.

The National Framework encompasses reporting both on natural resource condition and on program, strategy and policy performance.

The National Framework identifies matters for which natural resource management standards and targets must be set at the regional level (<http://www.deh.gov.au/nrm/monitoring/standards/index.html>). Actual target levels are not specified, but are to be set regionally.

The National Framework thus identifies the policy settings for national monitoring and evaluation. It does not, however, identify the technical requirements, technical feasibility, nor how to implement a strategy. These matters are discussed in this paper.

### 3. Monitoring and evaluation in Australia: current state

#### 3.1. Overview of history of monitoring and evaluation

Humans have monitored many facets of the world around them for thousands of years. Indeed, it is thought that the earliest Sumerian cuneiform writing developed as a means of recording agricultural production (Encyclopaedia Britannica Online, <http://www.search.eb.com/>).

Systematic collection and recording of environmental data in a manner designed for national evaluation began more than a century ago. In the UK, from 1875 until 1947 the Royal Meteorological Society co-ordinated a nation-wide network of recorders to examine the relationship between meteorological events and the natural world, such as the flowering of 13 plants, and the appearance of birds and insects (<http://www.the-woodland-trust.org.uk/phenology/standard/home/what/learning.htm>).

Following these early developments, national surveys or inventories have been established in many countries to monitor the natural or managed environment. In the US, for example, forest inventory began in the early 1900s following the organic act of 1897, and the national resources inventory of conservation in soil, land and water resources was first conducted in 1958 (Olsen *et al.*, 1999).

This trend in national surveys to overview or integrative surveys encompassing a broad range of environmental issues is evident in many countries. Mol *et al.* (2001) comment on the Dutch experience). UK soil quality monitoring began in the 1970s (Church and Skinner, 1986; Skinner and Todd, 1998). Most large-scale, multi-issue monitoring programs are relatively recent and include the State of the Environment reporting in Australia (which reported in 1996 and 2001) and the Report on the Environment in the

US (United States Environmental Protection Agency, 2003). Many programs, however, remained focused on a single issue (such as forest inventory, Norman *et al.*, 2003) or area (such as the Alligator Rivers region, Supervising Scientist Division, 2002).

Together with the trend to encompassing more and more issues, environmental monitoring has become international. The climate change programs and the IPCC reports are one example (eg IPCC, 2001); another is the Global Environment Outlook (<http://geo.unep-wcmc.org/geo3/>) and Agenda 21 of the United Nations Division for Sustainable Development (<http://www.un.org/esa/sustdev/documents/agenda21/>) (which carries obligations which Australia fulfils with its State of the Environment reporting). Environmental monitoring sits within the broader framework of monitoring and evaluation used extensively by many international agencies (eg United Nations Development Programme, 2002; Prensushi *et al.*, 2001).

Notwithstanding these developments, we lack properly integrated assessments both nationally (e.g. in the US by Olsen *et al.* 1999) and internationally (see the quotation from the Earth Observation site in the introduction, section 2).

#### 3.2. Current Australian programs with monitoring and evaluation components

There are many national programs for monitoring natural resources. With the exception of climate data, most programs are recent. In addition to natural resource programs, some other programs, particularly health, involve environmental monitoring. A directory of environmental health data is given at <http://www.health.gov.au/pubhlth/strateg/envhalth/database1.htm>

Current monitoring programs are shown in the following table.

Table: Current natural resource monitoring programs – not an exhaustive list.

Program	Objective	Framework	Scale	Duration / interval	Issues / indicators	Overlap of issues / indicators with other programs - <b>much</b> , some, (weak)
NAP / NHT - MEWG	Assess progress to improved natural resource condition	National Framework	Regional focus, National	5 year program	Land, vegetation, biodiversity, inland waters, estuaries and coast, management actions, socio-economic	<b>SoE</b>
State of the Environment	To track the environment and the impact of human activities	Indicator reports	National	Every five years, done twice	403 indicators for, human settlements, biodiversity, atmosphere, land, inland waters, estuaries and the sea, natural and cultural heritage	Many – <b>NLWRA NFI MEWG</b> Few overlaps in atmosphere
National Forest inventory	Help development of forest policy, forest industries and forest conservation.	Continental Forest Monitoring Framework	national	every five years, done twice	Soil, forests and biodiversity, inland water impacts, socio-economic for forests	<b>SoE, NLWRA MEWG</b>
Sustainable agriculture (Landmark)	(proposed)		regional	?	Air, soil, biodiversity and inland water conservation, water quality, socio-economic for farms	NLWRA SoE, FM500
Sustainable agriculture (RIRDC FM500)	(proposed)		regional	?	Limited land, vegetation and water, farm socio-economic	NLWRA SoE Landmark
NLWRA 1	nationwide assessment of Australia's land, vegetation and water resources	Integration Blueprint	national	once	Wide range of air, land, and water	<b>SoE, MEWG,</b>
Soil monitoring	Proposed (McKenzie <i>et al.</i> 2002)	National framework	national	As required	Soil, including acidification, nutrient balance, soil biology, contaminants, soil physical quality configuration and salinity	<b>NLWRA MEWG</b>
Weather and climate, BoM	Provision of weather and climate data		national	Decades (depend on location) / daily	Rainfall, temperature and other climate variables	SoE reports some descriptors (extremes, averages, etc)
Sustainable rivers audit	(proposed)	River function models	MDB	Reports annually	River biology and hydrology	<b>Waterwatch NRHP</b> SoE NLWRA MEWG
Waterwatch	Conservation, education		National	Ongoing since 1992	Water quality and quantity	<b>NHRP SRA</b> SoE MEWG

Table: Current natural resource monitoring programs, continued – not an exhaustive list.

Program	Objective	Framework	Scale	Duration / interval	Issues / indicators	Overlap of issues / indicators with other programs - <b>much</b> , some, (weak)
National River health program			National	Ongoing	River health, biology and hydrology	<b>Waterwatch</b> <b>SRA</b> SoE <b>MEWG</b>
Coastal catchment initiative			National		Pollutants in coastal catchments	
National water quality management strategy			National	Ongoing		
Fishery status reports	Review of fish stocks		National	Reports annually, since 1992	67 primary target stocks	
Marine and estuarine water quality standards	Integrated planning and management maintenance of resource values		National	Ongoing	Water quality	

### 3.3. Data holdings and access

Some individual programs (eg National Land and Water Resources Audit) provide wide coverage and access from a consolidated data archive, and there are moves to provide wider and more uniform access. However, no single data repository or metadata archive provides access or quick links to Australia's natural resources data.

The first National Land and Water Resources Audit provided a successful model for the provision of spatial data. Many, but not all, spatial natural resource data sets for under the Commonwealth Spatial Data Policy. The Office of Spatial Data Management (<http://www.osdm.gov.au/>) provides information about these data sets, and institutions where they are held.

Under the spatial data policy, spatial data will be provided free of charge (no more than the cost of transfer), there will be no restrictions on commercial value-adding (though it will be licensed), Internet public access will be developed, and states and territories will be brought into the system.

It is important to recognise that spatial datasets rarely provide a sufficient baseline for monitoring – point-based prediction from these data sets is uncertain so sensitivity to change is poor McKenzie *et al.* (2002).

### 3.4. Overlaps and gaps

There are similarities and overlaps in the data collected in the various programs. Many programs collect and/or report data about land or soil (though few if any are true soil monitoring programs, apart from a few long-term field experiments), vegetation and biodiversity, water, and socio-economics.

In some instances the overlaps are recognised and different programs report the same data. Thus, the National Forest Inventory supplied data to the State of the Environment, and the National Land and

Water Resources Audit and State of the Environment shared data.

Climate data are free from overlaps and gaps. They are collected and reported by the Bureau of Meteorology, and used and reported by some other programs. At the national level, however, all reported sets are based on the same underlying data collection, and are thus consistent.

Climate data differ from many others in the length of the record. Many datasets have been kept for decades. Some other datasets such as river gauging also extend for many years or decades. In general, however, natural resource datasets at the national scale are recent.

With the exception of climate, then, there appears to be scope for more common data collecting and reporting.

### 3.5. Limitations to the use of the programs and datasets

- Many data sets are too short to readily identify trends in natural resources.
- Many datasets are not collected uniformly across the nation. Norris *et al* (2001) pointed out that, whereas the National River Health Program provided uniform data from river health, neither hydrology nor water quality were collected uniformly across the nation, and the data are not appropriate for large-scale assessment of environmental conditions.
- The overall health of a region cannot be identified quantitatively. We lack rigorous, quantitative, triple bottom line models of health. We can make the assessment qualitatively, by mentally integrating the indications for a range of issues. We can also make the assessment quantitatively issue by issue. In the case of rivers, for example, the AUSRIVAS score gives an index of health.

#### 4. Frameworks for monitoring and evaluation (mapping, monitoring and modelling as complementary activities)

In this section, we consider the place of monitoring and evaluation within natural resources management and frameworks for monitoring and evaluation. We emphasise the importance of clearly defining the objectives and basing the monitoring and evaluation program on a clear conceptual model. We discuss implementation of monitoring and evaluation within the framework, and examine some current programs in the light of the overall framework.

Frameworks for monitoring and evaluation have been proposed many times in the literature, for activities from human development to natural resources management (eg United Nations Development Programme, 2002; Prennushi *et al.*, 2001; Bosch *et al.*, 1996; Australian and New Zealand Environment and Conservation Council, 2000; Vos *et al.*, 2000). Although they differ in detail, many follow a general pattern of: set objectives; plan the monitoring and evaluation; implement the monitoring and evaluation; review, adapt, feedback and report.

Monitoring and evaluation sits within a wider framework, such as adaptive management or ecological risk assessment frameworks. We here follow the scheme outlined by CSIRO (1998), with monitoring

and evaluation within an overall management cycle as shown in Figure 1. Ecological risk assessment frameworks follow the same general pattern (eg. USEPA, 1998; Hart *et al.*, 2003), but with risk assessment rather than management being the object of the exercise.

#### *The adaptive management cycle*

The crucial first step in the adaptive management cycle is to define the objectives. Natural resource management programs vary greatly in scale (local to national to international), timeframes (single activity of short duration to indefinite), and the range of issues considered (single clearly defined issue to “health” of the national natural resources). Defining the objectives will determine the management activities to be undertaken, and the relevant monitoring and evaluation.

Having defined the objectives, the rest of the cycle proceeds as shown in the figure.

There are some monitoring activities which might be regarded as pure monitoring, in which monitoring, or monitoring and evaluation, dominate almost to the exclusion of deciding objectives, planning and action. The Marsham example (to be described in greater detail later) is a case in point.

The arrows linking the phases of the cycle represent the transfer of information from one phase to the next. A key reporting phase is from the evaluation feeding back into the definition – or redefinition if that is indicated by the evaluation - of objectives. Depending on the program, the reporting could be within the program or could be reporting to the community at large. In national programs, reporting will often be to the community.

The closing of the loop and re-evaluation of the objectives is the hallmark of adaptive management.

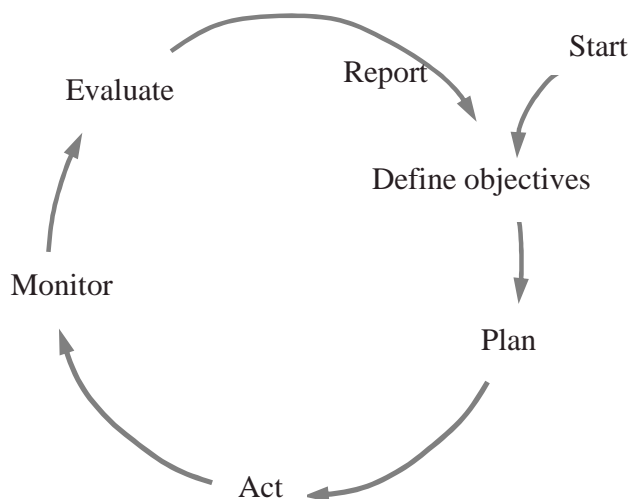


Figure 1 The adaptive management cycle

### ***The monitoring and evaluation cycle***

Within the adaptive management cycle, the phases identified above each involve several steps. These too can be represented as cycles. Since we are here concerned with monitoring and evaluation, we shall describe the steps only within the monitoring and evaluation cycle. We take the objectives of monitoring and evaluation as defined in the management cycle.

The crucial first step is to develop a conceptual model (possibly, but not necessarily a quantitative model). The conceptual model will guide choosing the indicators and designing the strategy. This environmental narrative should provide context for scales of variation over time – these need to consider events and processes acting over millennia, centuries, decades, years, weeks... Without this context, monitoring may be inconclusive. The monitoring program is then implemented.

As in the overall management cycle, a key reporting phase is from the evaluation step feeding back into the development of the conceptual model. New data will permit the testing and refinement of the conceptual model, or, if necessary, construction of a new one. The monitoring and evaluation cycle can thus operate as a closed cycle, and it also operates by reporting into the management cycle.

Thus, the monitoring and evaluation cycle is also an adaptive cycle. The monitoring and evaluation is subject to continuous improvement (see Hoenicke *et al.*, 2003).

Any monitoring and evaluation framework must consider the elements identified in these cycles (CSIRO 1998).

This phased approach to monitoring and evaluation is, with variations, promoted

widely in the monitoring evaluation literature. Examples are the Australian Guidelines for Water Quality Monitoring and Reporting (Australian and New Zealand Environment and Conservation Council, 2000).

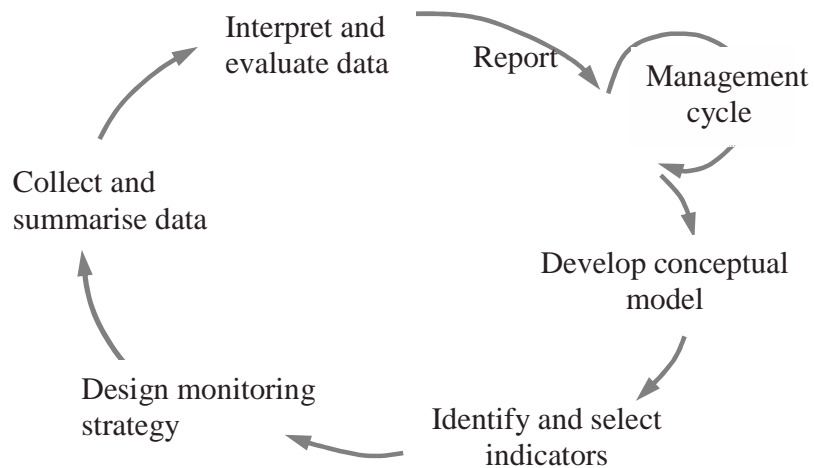


Figure 2. The monitoring and evaluation cycle.

#### 4.1. Objectives of a monitoring and evaluation program.

The objectives will be given by the overall natural resources management objective, nevertheless, a few general remarks may be made. The general objective of monitoring and evaluation is to reduce the risk in decision-making (Pannell and Glenn, 2000).

Specific objectives can vary, and they will determine the form of a monitoring and evaluation program. Objectives include:

- assessment against targets;
- surveillance or “watching brief”;
- policy / program resource targeting;
- evaluation of compliance;
- research;
- education; and,
- national pride!

The first three purposes will generally dominate at the national scale. Compliance and experimentation will often be at local level, and relate to particular programs or trials. They could be at the national scale

where a program is at national scale, or where a new national scale technique is being developed, such as new methods in satellite remote sensing.

#### 4.2. Developing the conceptual model

A conceptual model, or systems understanding, is crucial. Conceptual frameworks or models:

- help translate objectives into a monitoring and evaluation program;
- determine the variables or indicators likely to be useful;
- set requirements for sampling frequency, both spatial and temporal;
- set requirements for the length of time likely to be required to discern (or disprove) trend;
- determine how the variables can be summarised;
- determine the analysis and what conclusions can be drawn;
- lead to the calculation of new, output variables, which are often more useful than the directly measured variables and indicators; and,
- set constraints and provide possibilities for presentation of the data.

Quantitative models must be employed to make predictions of trends and targets. Salinity, for example, requires prediction as it develops over decades or longer. Understanding whether salinity will develop, where, and over what timescales requires projection from current data. Furthermore, groundwater hydrology is important in salinity prediction, and data are often sparse, both spatially and temporally. Salinity prediction can only be undertaken reliably with quantitative hydrological models.

#### 4.3. Identifying and selecting indicators

Some preliminary considerations are: the type of program; what the indicators will be used for; and scale.

- Type of monitoring program

Vaughan *et al* (2001) distinguish four types of monitoring. *Simple monitoring* is the tracking of a single variable, such as the temperature records now being used to show global warming. *Survey monitoring* is used in the absence of an historical monitoring record, to understand developing problems by surveying and comparing regions with and without the problem. *Proxy monitoring* is also used in the absence of an historical monitoring record, by measuring proxy information to infer historical conditions. Tree ring and ice core records used to infer past climates are examples. *Integrated monitoring* is long-term, multidisciplinary monitoring designed to elucidate both what changes are occurring and why. Simple, survey and proxy monitoring generally cannot link cause and effect. Integrated monitoring aims to: establish cause and effect; derive scientifically defensible resource management programs; major environmental response to control measures; and provide early warnings of new problems.

A national strategy requires an integrated monitoring program, with survey and proxy elements designed to provide historical perspective.

- What the indicators will be used for  
Indicators are used for several purposes including to provide a general overview or quick indication of “health”, as data input for quantitative models, as verification of models, and as direct indicators of the exceedance of a critical threshold.

For the first purpose, proxy or integrated indicators will be suitable. For data input for verification of models, direct measurement of key variables is generally required. Threshold indicators can be of any type.

Directly measured variables include things such as air temperature, water electrical conductivity, and soil pH. Derived variables are calculated from directly measured

variables in a way that preserves a direct link to the measured quantities.

**Box 2**

**Examples of indicators by type** – drawn from MEWG

<http://www.deh.gov.au/nrm/monitoring/indicators/>

Direct – groundwater level, soil pH

Proxy – soil carbon content, often used as a proxy to indicate general soil condition.

Integrated – soil physical condition, wetlands

Proxy indicators may be quantitative or qualitative, and include things such as tree rings, ice core measurements, and the first arrival of a bird in spring. Means, standard deviations, and differences amongst directly measured variables are examples.

Integrated indicators result from reduction of many variables, either directly measured or proxy indicators, into a simple index and / or contain qualitative information. River and soil conditions are examples: they result from the integration of many variables into a single index.

- Indicators

By analogy with human health, it is often convenient to measure an indicator of condition, rather than all the detailed process

**Box 3**

**Robert Marsham recorded "Indications of Spring"** from 1736 until his death in 1798. His descendants continued recordings until 1958. The work is now continued by the UK Phenological Network. The record contains a number of indicators such as the first opening of oak leaves.

Recent interpretations of the record and correlation to climate records reveal a trend to earlier and warmer springs. This is often cited in the climate change debate. See Sparks and Carey, 1995

parameters necessary for a complete description. A classic example of indicators for natural resources is described in Box 3.

The example demonstrates that indicators can be valuable in giving clues to trends in natural systems, especially when they are linked to a conceptual model (once again underlining the importance of conceptual models). Continuous, consistent records of environmental monitoring become valuable in ways unforeseen when collection commenced. It also demonstrates that bringing together datasets leads to greater insights

- Indicators versus direct measurement

Directly measured and derived variables are generally suitable for use as input into predictive models and/or verification of their output. Proxy indicators are generally unsuitable for use as model input, unless there is a direct correlation between the indicator and directly measured variable. Proxy indicators might be suitable for model verification where there is a direct correlation between model output and the indicator. Integrated indicators are generally unsuitable for either input or verification. Many factors go into an integrated indicator, with general loss of connection between change in the indicator and cause attributable to any one effect.

Where the objective includes prediction, the monitoring program should collect data that can either be used as direct input to a model, or is directly comparable to model output to verify or test the model against. This will be particularly true for long-term projections involving climate change, demographic change, and long-term processes such as the development of salinity.

Proxy and integrated indicators are often easier to measure and record. They are often also easier to use in presenting information. A single index of river condition mapped across the country, for example, gives a

rapidly assimilated visual picture of the state of rivers nationwide.

- Scales in space and time

It is widely recognised (eg CSIRO 1998) that natural resource management issues vary from the local (eg management of a paddock) to the global (eg climate change), from brief (eg erosion in a flash flood) to centuries or longer (eg groundwater processes in a large aquifers). This range of scales places great demands on monitoring programs.

The scale or duration of management actions is often dissimilar to those of a natural resource process. A river or groundwater catchment might cross several local government areas or even state boundaries. The management action might last four months or perhaps years, whereas the outcomes for salinity affected by a groundwater system might take decades or even centuries to manifest themselves.

Furthermore, managers at different scales might require different information. Managers at the paddock or farm scale will be more interested in productivity and farm sustainability, whereas at the national scale issues such as climate change and integrated natural resource condition (natural resource “health”). At the local scale managers will have control over direct actions such as fencing, tillage, rotations and stocking rates. At regional scales, action can be taken through measures such as regional land use planning and program funding. At the national scale, measures include national policy, program funding and incentives, and market regulation.

With this range of scales in space and time, a monitoring and evaluation program must consider the aggregation of data from a detailed to more general scale. The conceptual model underlying the monitoring and evaluation strategy should be chosen to accommodate the range of scales.

#### 4.4. Designing a monitoring strategy – some considerations

- Community monitoring and science monitoring (eg remote sensing)

Some types of monitoring lend themselves to community participation – indeed, by their very nature are better pursued by the community. Proxy indicators may be effectively monitored by the community. The UK Phenology Network ([www.phenology.org.uk/](http://www.phenology.org.uk/)) involves the community in monitoring of climate change indicators. The Australian Bird Atlas (<http://www.abc.net.au/birds/>) is compiled from community monitoring.

Some types of monitoring require specialist knowledge or equipment. Remote sensing requires access to satellite information, and the computer power and specialist packages necessary for interpretation of the raw data.

- Sampling requirements and feasibility

The sampling in both space and time must be sufficient to determine or disprove the trends of interest (see, for example, McKenzie *et al.*, 2002).

- Reference sites and catchments – long-term ecological research

McKenzie *et al* (2002) pointed out the need for a restricted number of substantial long-term scientific studies of ecosystem and landscape processes in catchments representing the main biophysical regions of Australia. At these sites, many variables and many biophysical processes would be studied, with the aims of increasing understanding and providing a detailed reference for correlating proxy indicators (which would often be measured elsewhere) to detailed processes.

The United States (<http://lternet.edu/>) and Canada (Vaughan *et al*, 2001: <http://www.eman-rese.ca/eman/>) both have long-term ecological research sites, aimed at

providing understanding of ecological phenomena over long periods and large areas, and providing information to help solve ecological problems. Some long-term studies have been established in Australia, such as the Warra forest management study in Tasmania (<http://www.warra.com/warra/>).

To assess regional “health”, including socio-economic issues, the idea can be extended to a reference region, in which biophysical and socio-economic indicators are used with integrated models. The CSIRO Healthy Country Flagship Program provides a partial model of a reference region.

#### 4.5. Evaluation

- Short-term versus long-term

Short-term monitoring and evaluation is relevant to ensuring compliance, or setting priorities amongst programs or program objectives. Long-term monitoring and evaluation is relevant to the continuing assessment of trends in natural resource condition and management.

- Trends and uncertainty

The variability of natural resource data makes it difficult to reliably estimate trends. Much of the criticism of environmental science in “The Sceptical Environmentalist” by Bjorn Lomborg concerns this point (caveat: the book itself is roundly criticised!). Only recently has it become fairly widely accepted that spring has become warmer and earlier in the UK (Sparks and Caery, 1995).

We thus distinguish two types of uncertainty in trends – that of whether the trend is statistically significant, and that of cause and effect. The first is a matter of monitoring: sampling programs must be adequate and continued for long enough, and include establishment of adequate baselines. The second is a matter of the conceptual framework or modelling. It must be demonstrated that the measured effect can be attributed to a particular cause.

What is said above of temporal trends is also true of spatial trends. Soils, for example, show considerable spatial variability. Sampling must be adequate to determine trend, and conceptual models are important. See, for example, McKenzie *et al.* (2002).

4.6. Reporting, data holdings and access  
Closing the adaptive cycles is a key step. Reporting the data and findings, and assessing the objectives in light of the new information enhances both the monitoring and evaluation program and the management program that it serves.

Just as the uses of indicators will vary in space and time (section 4.3), so too will be adaptations. Actions found to be ineffective are likely to be changed quickly, whereas objectives are likely to be changed on longer timescales (CSIRO, 1998).

Natural resource management issues affect many stakeholders, often the whole community. Keeping these stakeholders informed is an important part of reporting.

Access is important. The greater the access, the more the data are likely to be used, and the more effective the monitoring and evaluation program will be. Providing access was a key recommendation of the first National Land and Water resources Audit (NLWRA, 2002), and is also a key part of the Commonwealth spatial data policy ([http://www.osdm.gov.au/osdm/data\\_acc\\_policy.html](http://www.osdm.gov.au/osdm/data_acc_policy.html))

With modern technology, data should be accessible by the web. In principle, it is unimportant where the data are held but, in practice continued quality control and access more likely where there is institutional responsibility for storage, archiving and disseminating information. Good metadata are important.

## 5. Strategies for future monitoring and evaluation in Australia

In this section we briefly examine the gaps in current programs, discuss the general features of a national strategy, recommend a trial incorporating these features, and outline three candidate approaches for implementing a national strategy following the trial. We also discuss knowledge management, and impediments to the adoption of a national monitoring and evaluation strategy.

We take it as a given that a strategy is required to implement the National Framework.

### 5.1. Gap analysis

Current programs cover the spectrum of natural resource management issues. They often permit meaningful comment on natural resource condition for individual issues.

Nevertheless, there are significant gaps.

- Not all current programs have consistent data measurement and recording methods across the nation.
- Different natural resource management issues and programs have not been integrated to provide overall assessments of natural resources “health”.
- Socio-economic evaluations are similarly not integrated with the biophysical (though in some programs they are reported), precluding qualitative triple bottom line evaluations.
- currently only qualitative assessments can be made of system-wide (including impact on human systems) consequences management actions, trade-offs and hence assessment of priorities in different areas. This is an area of current research. The CSIRO Healthy Country Flagship Program, for example, is investigating water benefits accounting as an integrating principle for all natural resource

management (including impact on human systems).

- As a consequence, Australia has no means currently of quantitatively predicting what the nation will look like overall (natural resources and human systems) in the future. There are excellent futures tools in particular areas (such as climate change models, or the CSIRO stocks and flows resource futures model), but none that integrates the issues.
- An integrated framework will also alleviate another problem, that of monitoring unlike indicators which require measurement at different frequencies and spatial densities, and also require different forms of presentation. Indicators of landscape condition are very different from those of rivers. Current programs generally simply present the data, any comparisons or evaluation being qualitative.
- Remote sensing technologies have to date not been fully utilised in national monitoring strategies. We discuss here incorporating remote sensing into monitoring strategies. For terrestrial monitoring and evaluation, the development by the Earth Observation Centre of a consistent, corrected 20 year AVHRR / NDVI dataset for Australia will provide invaluable historical information. The opportunities provided now by higher resolution (spatial, temporal, and number of frequency bands) will provide new opportunities in both terrestrial and aquatic monitoring. Opportunities for aquatic monitoring had recently been discussed in a study for the Sustainable Rivers Audit (Environmental Remote Sensing Group, 2003).

There are suggestions for improvements to current programs (such as the enhanced monitoring programs under the National

Forests Inventory), and for new programs (such as the Long Term Ecological Research Network), but none addresses these gaps.

In the research arena, various integrated frameworks are being developed. The CRC for Catchment Hydrology has developed the Catchment Hydrology Toolkit (<http://www.toolkit.net.au/>), for integrated catchment assessment. Current developments include consideration of economic and biodiversity issues. A more integrated modelling framework is the subject of the CSIRO Healthy Country program, which will tackle integrated conceptual models, and integrated frameworks are also proposed in the new CRC for Desert Knowledge.

The general conclusion is that Australia lacks an integrated monitoring and evaluation system with which to assess regional “health”. This was also the conclusion of the Earth Observing Summit, quoted in the introduction, section 2. Olsen *et al.* (1999) concluded that in the USA the many individual natural resource monitoring and evaluation programs similarly fail to add up to an integrated national program.

Given these gaps, what is the best way to proceed to a national monitoring and evaluation strategy? We address this next.

### 5.2. A national strategy

We discuss here some general features, choosing the objectives, and a general implementation strategy.

#### **General features:**

A national monitoring and evaluation strategy should:

- follow the framework discussed previously (section 4), as shown by the monitoring and evaluation cycles even in Figure 2, set within the wider context of an adaptive management or ecological risk assessment framework (Figure 1), and hence;

- have agreed and explicitly stated objectives - these have been explicitly stated for current programs such as State of the Environment, but have not yet been explicitly stated for an overarching national monitoring and evaluation program;
- have a relevant conceptual framework or model - an integrated system model for regional health being the most pressing need;
- have nationally consistent and long-term measurements, data storage and analysis, with assurance of backward compatibility when there are changes to methods or conceptual models resulting from further research – this implies standards and protocols for measurement, storage, analysis and consistency through time;
- include consideration of the spatial framework for monitoring, which sets the basis for priorities\* and location of monitoring sites and provides a framework for interpretation and extrapolation (the groundwater flow systems defined in the Audit is an example for salinity while a more geomorphic and climatic stratification is needed for soils and rivers);
- be flexible and adaptive (eg Mol *et al.*, 1998; Hoenicke *et al.*, 2003);
- be adequately resourced; and,
- sit within a clear framework of institutional responsibility.

\* Note that, depending on the objectives of the program, some areas might not need monitoring, or might need only a low spatial density of monitoring, since they are known from pilot studies not to exhibit natural resource problems.

In the absence of explicitly stated objectives and an agreed conceptual framework, we offer here some candidate objectives and an implementation strategy.

***Candidate objectives:***

The purpose of the National Framework is to assess progress towards improved natural resource condition through the development of accurate, cost-effective and timely information on the:

- health of the nation's land, water, vegetation and biological resources; and
- performance of programs, strategies and policies which provide national approaches to the conservation, sustainable use and management of these resources.

Other objectives could be considered for a national monitoring strategy. The table on the next page shows candidate objectives and some of the requirements of monitoring.

As shown in the table, different objectives require different programs. Monitoring to evaluate or target policy or programs has different timescales and indicators to long-term assessment of landscape or ecosystem health. A national strategy should clearly identify the objective.

Without a long term health assessment, program or policy evaluation cannot easily be judged against triple bottom line goals, so long term monitoring is required in a national strategy. Program and policy evaluation can be undertaken program by program.

It is therefore recommended that a national strategy address long-term health assessment. Other goals are not precluded, but might require other programs.

Objectives and requirements of monitoring programs.

Objective	what to monitor	Types of indicators	scale	timescales	comments
A. Resource condition	By issue	Mixture, sometimes integrated	Local to national	Program to indefinite	Often covered by current programs.
B. Regional / national triple bottom line health	Health indicators	Integrated	Regional to national	Often indefinite	Requires sound and agreed integrated conceptual model of regional or national triple bottom line health.
1. Assessment against national or international natural resource management targets, eg Kyoto	By issue	Mixture	Local to national	Program to indefinite	1. Salinity, for example, requires prediction as it develops over decades or longer, so assurance that current trends will not fail targets requires projection over those timescales. 2. For international programs, indicators should be comparable internationally.
2. Surveillance or “watching brief” for early identification and correction of problems	Wide range, or via integrated “health” indicators	Mixture, often integrated	Local to national	Indefinite	1. Arguably a particular case of Objective 1. 2. Wide range of natural resources should be included. 3. Databases will undoubtedly become of enormous value in future. 4. Opportunity for economies of scale with centralised measurement, data management and storage.
3. Policy / program resource targeting	Issue or via “health” indicators	Mixture, sometimes integrated	Local to national	Program to indefinite	Before resource expenditure.
4. Evaluation of policy / program	Program / issue	Mixture, sometimes integrated	Usually local, can be national	Program	Compliance function.
5. Research	Program	Often direct	Local to national	Program	Includes the development of more effective monitoring methods and more effective conceptual models.
6. Education	Any	Often integrated	Local to national	Indefinite	Can be a program objective, or a side-benefit of other program.
7. National pride!	“health”, or wide range, or issue	Often integrated	National	indefinite	1. Demonstrating in international forums that Australia monitors and cares for its environment. A particular case of Objective 1. 2. Indicators should be comparable internationally.

Note: objectives 1 to 6 can all be of either of the two types A or B

### ***A generic implementation strategy***

Two phases are proposed: firstly, a trial; secondly, extending the trial to the national scale. Each phase follows the frameworks of the management cycle and monitoring and evaluation cycle shown in Figures 1 and 2.

#### **5.3. Phase 1: trial**

Implementation of the national strategy should start with a trial, to enable testing monitoring and evaluation at the national level of a set of indicators, and reporting problems in their use and suggestions for improvement.

The implementation strategy for the trial is shown in Figure 3 below.

A significant feature of the suggested trial is to use current “best bet” indicators from other programs. This appears to be the best way forward in the absence of fully developed, tested, system-wide conceptual frameworks, especially for integrated / triple bottom line assessment of regional health. It is suggested, however, that research into integrated models be pursued concurrently. The National Framework and the Monitoring and Evaluation Working Group indicators will be a main candidate for the “best bet” indicators. In addition, however, greater use should be made of remote sensing than is currently done.

Since the trial is designed to test monitoring and evaluation for a national strategy, it should be conducted in several places, with several biophysical regions and different natural resource management issues. Candidate locations should be considered from regions with contrasting climates (eg northern and southern Australia), coastal and inland, and land management ranging from native, through rangelands, to arable and irrigated farming. Locations in different states, and particularly across state borders, and involving different organisations (including community involvement in some monitoring) would help test consistency of methods.

The trial should also be designed to provide information about which of three general options for implementation of a national strategy (see next section) is likely to be the most effective.

At some stage, the trial will be deemed complete according to an agreed set of criteria, and the monitoring and evaluation framework is then ready to implement nationally. The trial might have achieved its objectives, and the piloted method shown to be applicable, useful and cost-effective at the national scale. Extending a trial to the national scale does not preclude further trials to improve methods.

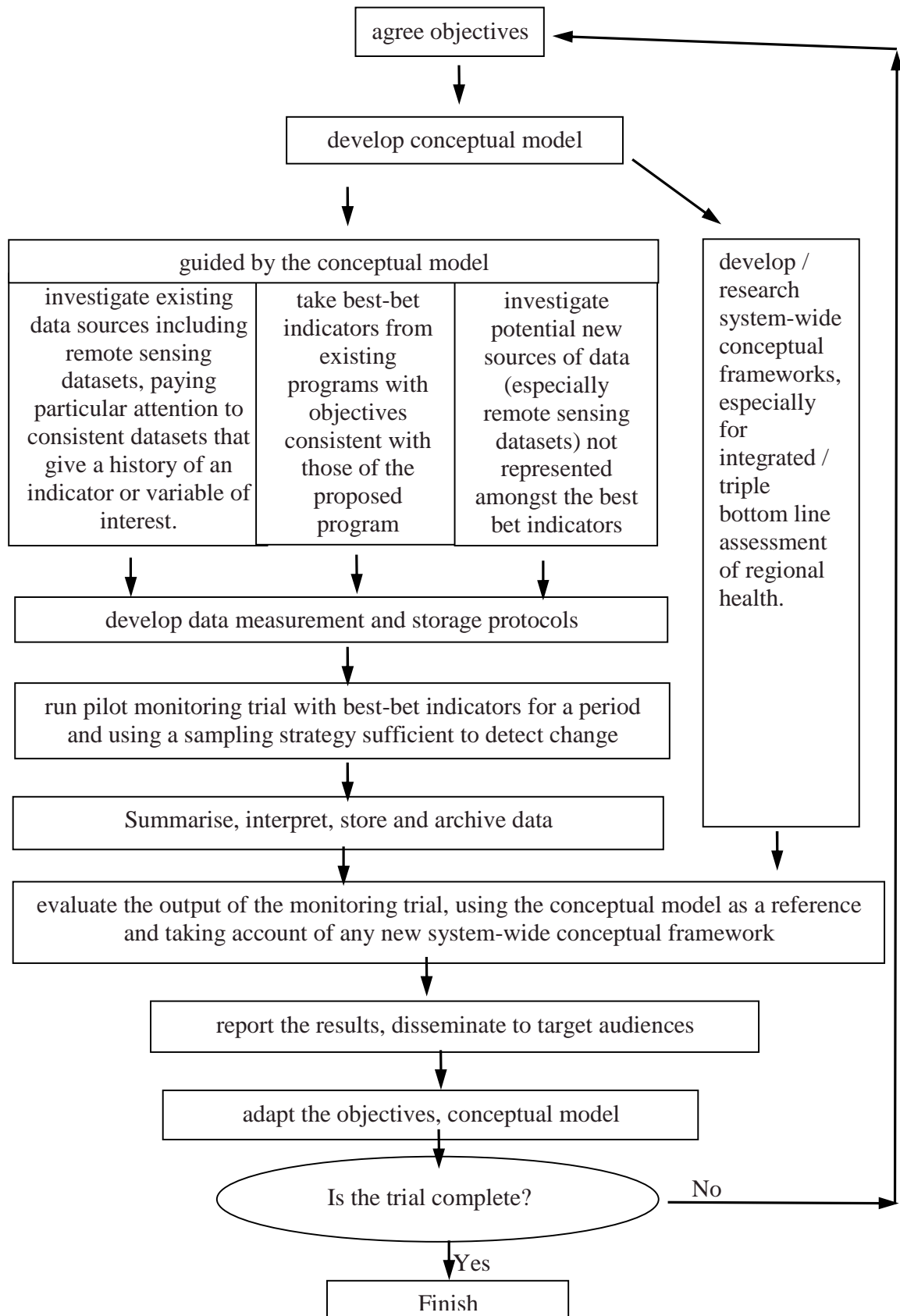


Figure 3. Schematic for a national monitoring and evaluation trial

#### 5.4. Phase 2: national monitoring and evaluation

Olsen *et al.* (1999) suggested three options for a national natural resource monitoring and evaluation scheme in the US:

- an entirely new program;
- a coordination of current programs;
- expansion of lead programs.

The options are relevant to Australia, and have different pros and cons. A new program would presumably incorporate a fresh assessment of objectives and conceptual models, and address gaps and defects in current programs, but would be costly and take time to establish, potentially overlook the experience of and fail to incorporate effort in current programs and therefore be inefficient and not cost-effective.

Coordinating current programs would lead to a quick start, take advantage of programs underway, and potentially be cost-effective, but would inherit defects and gaps in current programs, potentially lack clarity amongst the different programs, potentially contain inconsistencies (such as time and space scales of sampling) amongst current programs, and lack an overall conceptual model.

Expanding a lead program would also potentially have a quick start, potentially be cost-effective, and address gaps and defects in current programs, but would have the potential for the objectives (which might be inconsistent with the overall national program objective) of the lead program to dominate, potentially have inconsistencies (in time and space scales, type of monitoring, etc) between the lead program and the national program requirement, and potentially lack a conceptual model.

At this stage, it is not clear which is the most effective option, nor what the costs would be. It seems likely, however, that a combination of coordination and expansion of a lead program will be the most effective,

because of the quick start and probable cost-effectiveness. The National Framework and the Monitoring and Evaluation Working Group indicators will be a main candidate for a lead program to be expanded.

However, this framework currently suffers from the gaps identified in section 5.1. A sound conceptual framework, consistency of measurement and recording methods and integration of different issues will all require attention. Some of these issues should become clearer during a trial, which should be designed to provide information on these matters.

Whichever option is chosen, implementation of a full national monitoring and evaluation strategy will follow essentially the scheme shown in Fig 3, except that the question “is the trial complete?” is irrelevant, and the box with develop and research system-wide conceptual frameworks does not appear. Research and development might still be required, but is not explicitly part of the routine monitoring and evaluation. If required, it would be a separate activity in another trial.

It is important to start a national strategy again at the objectives, since these will differ from those of the trial.

It is also important to build in the reporting, and adaptive continuous improvement. Any national strategy will be a long-term and costly exercise (though likely cheaper in the long run than not monitoring and providing information for effective decision-making), so it is important to ensure effective reporting to all stakeholders and particularly to those charged with decision-making.

#### ***Knowledge management***

It is becoming increasingly recognised that modern technology offers scope to go beyond traditional reporting and dissemination. Knowledge management techniques can be used within programs to

coordinate and integrate information, assess priorities and gaps, leading to continual program development and enhancement. They also allow the program to interact with the community at large, with discovery of community perceptions and priorities, community demands for styles of and detailed in presentation, and community engagement in the program.

It is suggested that a national monitoring and evaluation program contain a knowledge management component to realise these opportunities.

***Some knowledge management sites...***

***The UK Phenology Network***

The UK Phenology Network web site ([www.phenology.org.uk/](http://www.phenology.org.uk/)) allows members of the community to enter their own records of phenological indicators of climate change, and view records in the form of maps or graphed trends.

***Agricultural and environmental monitoring and forecasting***

Agrecon offers a service to subscribers for agricultural and environmental monitoring and forecasting, including use of their own data <http://www.agrecon.canberra.edu.au/>

***Is the strategy achievable? What will stop it?***

A long term national monitoring and evaluation strategy will be a serious undertaking, requiring significant commitment of resources. It could easily fail through:

- lack of clearly stated and agreed objectives;
- lack of funds;
- lack of long-term commitment;
- lack of institutional responsibility; or,
- lack of long-term research backup.

It must also be recognised that some types of system behaviour make phenomena difficult or impossible to monitor (e.g. rare and

chaotic events, such as catastrophic floods in tropical rivers).

Against this background of impediments, it would appear that the appropriate commitment would enable the establishment of infrastructure, collection of data and reporting. However, a national strategy will only have succeeded if the data and findings are used. In particular, they should be used to inform national debate and policy.

Mol *et al.* (2001) sound a caution about policy impact, based on the Dutch experience. They note that “success... should be determined on the basis of implementation of integral measures and this still appears problematic”. In the Netherlands, integrated monitoring is used to help debate and formulate environmental policy plans at national, provincial and municipal levels every four years. Mol *et al.* conclude that most systems are designed for plain environmental quality monitoring and not for environmental policy or target group monitoring.

Mol *et al.* emphasise that environmental monitoring should have clear objectives based on solid scientific insights, reiterating one of the main points made in this paper. They note however that “currently the strong political influence exerted on monitoring activities inhibits the development of sophisticated and robust monitoring designs that truly support integrated management of our complex environment”.

These issues lead us to our overall recommendation.

***Overall recommendation***

A national monitoring and evaluation strategy should:

- have clearly stated and agreed objectives;
- have a clear link to and mandate to inform national debate and policy.

- have clear funding, commitment and institutional responsibility;
- have clear long-term research backup;
- follow the framework outlined in this report;
- have clear reporting and feedback procedures;
- be flexible and adaptive;
- identify priority areas for earliest and/or most intensive monitoring; and,
- start with a trial in some contrasting regions.

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## **7. Appendix – consultation**

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