Towards a Water Quality Monitoring and Management Framework for the Katherine and Daly River Catchment

Authors: Lyz Risby, Simon Townsend and John Bennett

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TRaCK

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TRaCK receives major funding for its research through the Australian Government's Commonwealth Environment Research Facilities initiative; the Australian Government's Raising National Water Standards Program; Land and Water Australia; the Fisheries Research and Development Corporation and the Queensland Government's Smart State Innovation Fund.

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For further information about this publication:
Simon Townsend, TRaCK
Email: simon.townsend@cdu.edu.au

Or to find out more about TRaCK

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1 Acknowledgements

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Stakeholders and community members are also gratefully acknowledged for their contribution of opinions, information and ideas.

2 List of Abbreviations

ADWG – Australian Drinking Water Guidelines

ARG – Aboriginal Reference Group

ANZECC & ARMCANZ Guidelines –Agriculture and Resource Management Council of Australia and New Zealand and Australia New Zealand Environment Conservation Council *Guidelines for Fresh and Marine Water Quality*

BU – Beneficial Use

CDU – Charles Darwin University

COAG –*Council of Australian Governments*

CSIRO – (Australia's) Commonwealth Science and Industrial Research Organisation

DHF - Department of Health and Families

DPI – Department of Planning and Infrastructure

DRDPIFR – Department of Regional Development, Primary Industry, Fisheries and Resources

DRMAC – Daly River Management Advisory Committee

EPA – Environmental Protection Agency

EV – Environmental Value

FARWH – Framework for the Assessment of River and Wetland Health

GANT – Greening Australia Northern Territory

ML - Megalitres

NGO – Non-Government Organisation

NRETAS – Department of Natural Resources, Environment, the Arts and Sports

NRMB – Natural Resource Management Board

NWQMS – National Water Quality Management Strategy

TRaCK – Tropical Rivers and Coastal Knowledge

WAP – Water Allocation Plan

3 Executive Summary

The development of the Katherine and Daly River Water Quality Monitoring and associated management framework was funded by the Northern Territory Natural Resources Management Board and undertaken by Tropical Rivers and Coastal Knowledge (TRaCK) in collaboration with Charles Darwin University (CDU) and the Department of Natural Resources, Environment, the Arts and Sport (NRETAS).

The project was instigated following community concerns regarding:

- the impact catchment development may be having on water quality, in particular through land clearing and increased water resource use;
- the need for more collaboration between water quality projects; and
- the absence of long-term, systematic water quality monitoring.

Monitoring is essential for management. For example, to inform managers of the state of the resource, to ensure water quality is fit for its intended use, to understand how land activities impact water quality and to test the effectiveness of policies and management actions.

This report is deliberately titled – ***Towards a Water Quality Monitoring and Management Framework for the Katherine and Daly River Catchment*** – to reflect that it is a key initial step in developing the Monitoring framework for the catchment, and equally important is the associated Management framework that monitoring will support.

The report details both the (adaptive) Management framework which monitoring will support and then focuses on the Monitoring framework and its initial details. This will allow key managers to progress high ranking priorities for management, and hence monitoring program objectives. Once they set those priorities, water quality monitoring specialists can design and cost monitoring programs to meet those objectives for managers to consider, prioritise and fund as appropriate.

The purpose of the Monitoring Framework is therefore to guide the planning and implementation of water quality monitoring for the Katherine and Daly River Catchment within the associated Management Framework, and to do this in an integrated and comprehensive manner, taking into consideration stakeholder and community values and concerns. The Framework includes useful references, website links and examples that can assist in the development of water quality monitoring plans, as well as recommendations from the project's consultation with stakeholders and community.

This report firstly provides an overview of the Water Quality (WQ) Management Framework from the national to the catchment level. It also details the components of that framework, mainly the conceptual modelling and community input into the catchment's beneficial uses/environmental values.

The report then provides the WQ Monitoring Framework and its detailed steps, as well as reporting on the key components of that Framework that were progressed by this project. These are mainly legislative responsibilities, current and past water quality monitoring, and conceptual models and their associated information on key water quality issues and indicators to be monitored.

Finally, the report provides recommendations on future directions for developing, implementing and utilising water quality monitoring programs in the catchment. These include the next steps as well as the ongoing adaptive management process.

Key considerations and recommendations include:

- The Monitoring Framework addresses water quality monitoring, which is one component of river health monitoring. Nevertheless, the components of this Framework can also be applied to river health monitoring in general and specifically the national Framework for the Assessment of River and Wetland Health, currently being trialled in the Katherine and Daly River catchment.

- The values the community and stakeholders place on water quality in the catchment underpin the Management and Monitoring Frameworks. These are referred to as Beneficial Uses (also known as environmental values) and were identified through consultation with the community and stakeholders. Future water quality monitoring programs should manage both the surface water and groundwater resources to protect these Beneficial Uses, notably Aquatic Ecosystem Protection and Raw Drinking Water.

- The Management Framework is an adaptive management cycle which, in its simplest form comprises (1) management actions including monitoring, (2) reporting, (3) decision making based on reporting, and (4) a further management response, followed by continued monitoring.

- Monitoring is based on the “Pressure-Stressor-Impact on Beneficial Use” model for environmental monitoring. The Pressures (or potential threats) are the “causes” of water quality degradation. The Stressors refer to the water quality indicators that are changed by the pressures, for example dissolved oxygen. The water quality change then impacts on the Beneficial Uses.

- Prior to the establishment of a management plan, and associated monitoring program, a conceptual model of how the aquatic environment responds to pressures/threats should be articulated. This will assist in targeting management and monitoring efforts and selecting appropriate indicators. Conceptual models for the main pressures/threats in the catchment are contained within this report. As the understanding of the environment increases, the models should be reviewed and updated. This is a component of the adaptive management cycle.

- There are several pressures/threats that may impact water quality and Beneficial Uses in the Katherine and Daly Catchment. The most significant are large scale land use change (the clearing of native vegetation and its replacement by agricultural land use), water extraction, mining and fire. Monitoring needs to focus on these as a priority. The water quality indicators that are affected by these pressures/threats are presented in the report.

- Water quality monitoring programs needs to be complemented by monitoring of changes to the pressures/threats to provide interpretative information about the relationship of changes in water quality to management interventions.

- Before long-term monitoring commences, pilot studies may be necessary to provide information for the conceptual model and to assess whether a perceived impact warrants monitoring.

- There are many groups and organisations currently monitoring water quality, and even more undertaking activities that affect water quality or who will be affected by changes in water quality. For this reason, water quality monitoring needs to be collaborative to facilitate monitoring efficiencies, and the collective ownership and management of the resource.

- The requirement and need for water quality and catchment monitoring is based on the intent and specific sections in Northern Territory legislation. The legal basis for most water quality monitoring lies within the *Water Act* which is administered through the Minister for Environment by the Department of Natural Resources, Environment, the Arts and Sport (NRETAS). For example, monitoring can be required for Water Allocation Plans and as a condition of wastewater discharge licences. NRETAS is best placed to take a leadership role in water quality monitoring and management. Other Acts and departments also have responsibilities for water quality monitoring and management.

- The Daly River Management Advisory Committee (DRMAC) can play a significant role in the management of water quality (and river health) because it is the only established group that brings together key stakeholder representatives from both Government and non-government sectors.

- To facilitate an integrated, comprehensive approach to water quality and catchment monitoring, coordination of WQ monitoring activities is recommended. The report recommends the establishment of a River Health Scientific Advisory Committee to collaborate monitoring, and report to DRMAC on the water quality and general health of the Katherine and Daly River catchment for management purposes. Such reporting however would not displace Northern Territory Government departmental and other reporting obligations.

- A central repository for all water quality data is recommended to hold data collected from different sources. To facilitate the dissemination of the data and enhance transparency, the data should ideally be made available from a web-based interface to the water quality database. The NRETAS Maps website linked to the NRETAS HYDSTRA database is suggested.

4 Context / Background

Tropical Rivers and Coastal Knowledge (TRaCK) have been working in collaboration with Charles Darwin University (CDU) and the Department of Natural Resources, Environment, the Arts and Sport (NRETAS) to develop the Katherine and Daly River Catchment Water Quality Monitoring and associated Management Framework. This has been done in consultation with stakeholders and the community. The development of the Framework was funded by the Northern Territory Natural Resource Management Board.

The project was instigated following community concerns regarding catchment development, in particular land clearing and increasing demands on water resources, and their potential impact on water quality.

Further to this, it was identified that a number of river health projects were being undertaken, with little collaboration between projects. A report prepared by the Daly Region Community Reference Group (2004) identified 12 different organisations undertaking river health related projects in the Katherine and Daly River Catchment in 2004, and reported that the community had expressed concern that the activities were poorly coordinated.

The Daly Region Community Reference Group (2004, pg. 24) further reported that "there has been no systematic water quality assessment of the rivers and wetlands for river health purpose, and water quality data collection has been opportunistic or associated with site-specific research and other activities". While opportunistic or site-specific data provides information for a point in time, long-term monitoring data is needed to be able to detect changes in water quality over time and determine the possible causes of the change.

That report showed that monitoring is essential to inform resource managers of the state of the resource, to ensure that the quality of water is fit for its intended use, to understand how land activities impact on water quality and to test the effectiveness of management policies and actions. It also provides the context for the title of this report – ***Towards a Water Quality Monitoring and Management Framework for the Katherine and Daly River Catchment***. The title deliberately includes the words "Towards a" as it is the initial step in developing the Monitoring framework but equally important is the associated Management framework that the monitoring will support. Hence this report will show both the (adaptive) Management framework which the monitoring will support and then focus on the Monitoring framework and its initial details. This will allow key managers to then set priorities for management, and hence monitoring, objectives. Once priorities are set, water quality monitoring specialists can design and cost monitoring programs to meet those objectives for managers to consider and fund as appropriate.

The purpose of the Monitoring Framework is therefore to guide the planning and implementation of water quality monitoring for the Katherine and Daly River Catchment within the associated Management Framework, and to do this in an integrated and comprehensive manner, taking into consideration stakeholder and community values and concerns. The Framework can also be applied to river health monitoring, where water quality is one component.

The Management Framework is detailed in Section 4.3 and is based on the following principles of the National Water Quality Management Strategy (NWQMS) *Implementation Guidelines* (ARMCANZ and ANZECC 1998):

- Ecologically sustainable development;
- An integrated approach to water quality management;
- Community involvement in setting water quality objectives and developing water management plans; and
- Government endorsement of the water quality objectives.

4.1 Scope

This report firstly provides an overview of the WQ Management Framework from the national to the catchment level, as well the components of that framework that were addressed by this project which were mainly the conceptual modelling and community input into the catchment's beneficial uses/environmental values. It then provides the WQ Monitoring Framework and its detailed steps, as well as the key components of that Framework that were progressed by this project. These were mainly the reviews and consultations on legislative responsibilities, water quality monitoring, conceptual models, and information on key water quality issues and indicators to be monitored.

The report provides an overview of water quality monitoring, a component of river health monitoring, which underpins one of the key beneficial uses/environmental values of ecosystem protection. The focus of the Monitoring Framework is mainly on (physical-chemical) "water quality" which naturally refers to the physical and chemical properties of water; for example nutrient content, pH and turbidity.

Whilst the Monitoring Framework focuses on water quality, its components are also applicable to the planning and implementation of a broader program of river health monitoring. Section 6.2 provides contextual information on river health monitoring including the National Water Commission's *Framework for the Assessment of River and Wetland Health* (FARWH). A trial is currently being undertaken in the Katherine and Daly catchment (refer to Figure 1) which assesses catchment disturbance, hydrological disturbance, water quality, physical form, fringing zone and aquatic biota as components required for the assessment of river health.

The Management and Monitoring Frameworks are based on the NWQMS's Frameworks, and include the involvement of stakeholders and the community in this water planning. The NWQMS and related documents can be accessed online at: http://www.environment.gov.au/water/quality/nwqms/index.html

The report concludes with suggested future directions for implementing the Monitoring Framework in association with the Management Framework.

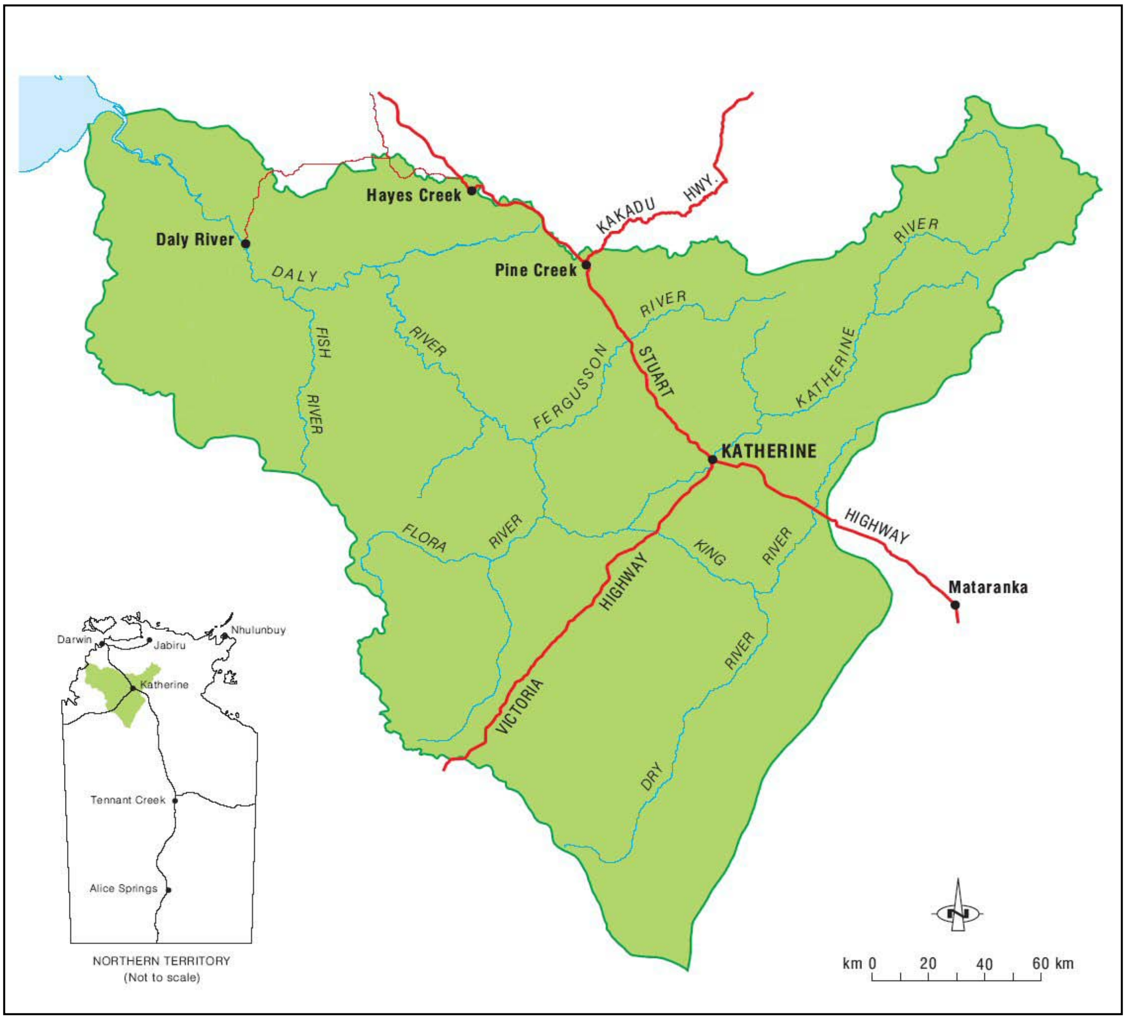
4.2 Catchment Overview

The Katherine and Daly River Catchment is located approximately 200 km to the south of Darwin and includes the townships of Katherine, Pine Creek and Nauiyu. The area of the catchment is approximately 52 500 km^2. Major rivers in the catchment are the Katherine, Dry, Flora, Fergusson, Douglas, Fish and Daly Rivers. The main aquifers are the Cretaceous Sandstone, Oolloo Dolostone, and the Tindall Limestone aquifers. Annual rainfall over the catchment averages approximately 1000 mm with 90% falling between the months of November to March (Jolly 2002). As a result river and stream flow is highly seasonal, with many streams ceasing to flow in the dry season (i.e. seasonally flowing). The Daly, Katherine, Douglas and Flora Rivers continue to flow throughout the dry season because they are supplied by groundwater (i.e. perennial).

The median annual stream flow for the Daly River recorded at Mt Nancar gauging station for the 30-year period from 1970 to 2000 was 6 200 000 megalitres (ML)[1] per year, of which groundwater discharge contributed an estimated 600 000 ML per year (Daly Region Community Reference Group, 2004).

The two major land uses within the catchment (van Dam et al. 2008)[2] are agriculture and conservation. In 2002, grazing of native vegetation was the most extensive land use (22 000 km^2), followed by grazing of modified pastures (2 000 km^2), cropping (350 km^2; e.g. hay, silage, peanuts) and horticultural production (52 km^2; e.g. mangoes;).

Figure 1 Katherine and Daly River Catchment



Source: NRETAS

Conservation parks and reserves make up roughly 5 500 km^2 (Daly Region Community Reference Group 2004). These areas attract a large number of visitors to the region and support a variety of cultural and recreational activities. The region is renowned for

[1] 1 ML = 1,000,000 litres = 1,000 kilolitres (kL). There are 2.5 ML in an Olympic size swimming pool.

[2] Areas are is based on figures cited in van Dam et al. (2008) derived from Land Use Mapping of the Northern Territory (2002) data. Other sources of data display different values. These should be used as an approximation only.

its near-pristine waterways and relatively undisturbed environment compared to southern Australia.

The conceptual models developed by this project focused on the key pressures that these land uses put on water quality in the catchment. Hence Section 6.6 further describes relevant features of these land uses and indicators of those pressures and their impacts on water quality and hence the beneficial uses of the catchments waters.

5 Water Quality Management Framework

5.1 The National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) is part of the Council of Australian Governments' (COAG) Water Reform Framework, to which the Northern Territory Government is a signatory. COAG (1994) agreed to support "development of the National Water Quality Management Strategy, through the adoption of a package of market-based and regulatory measures, including the establishment of appropriate water quality monitoring and catchment management policies and community consultation and awareness". The current National Water Initiative continues COAG's commitment to implement the NWQMS.

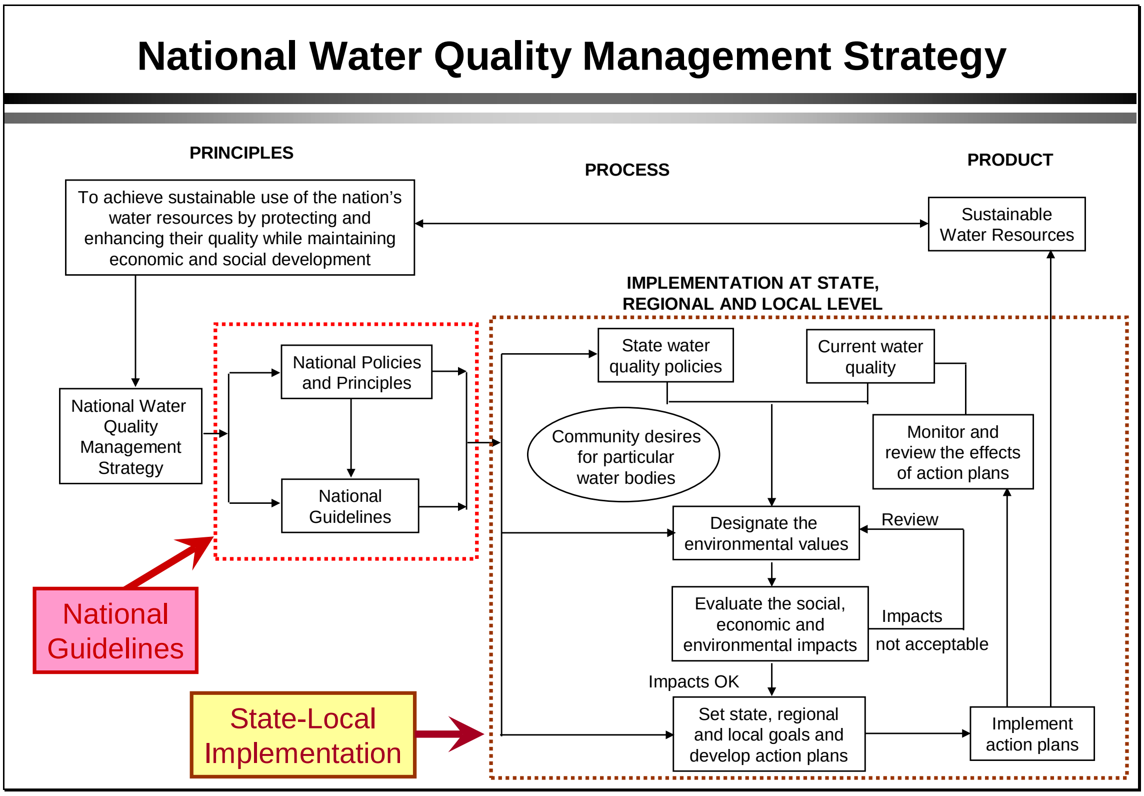
As shown in Figure 2, the NWQMS provides nationally agreed policies, processes and guidelines for the effective management of water quality. The primary objective of the NWQMS is to "achieve sustainable use of the nation's water resources by protecting and enhancing their quality, while maintaining economic and social development" (ARMCANZ and ANZECC, 1994, p 6).

The *NWQMS Implementation Guidelines* recognise that water management is a State and Territory responsibility and each State and Territory will have its own legislative framework (see Section 5.4). Another key component of State/Territory-Local implementation of the NWQMS is catchment-based water quality management plans.

The work of this project has been consistent with the recommendations of the NWQMS *Implementation Guidelines*, through:

- Working with lead agencies and establishing a Water Quality Monitoring Co-ordinating group;
- Identifying key stakeholders;
- Raising awareness of water quality issues and the development of the Monitoring Framework;
- Involving the community and key stakeholders in development of the Monitoring Framework;
- Seeking community input to identify Beneficial Uses of water resources to inform management and monitoring objectives;
- Seeking community input in identifying risks or threats that may prevent achievement of desired WQ objectives; and
- Seeking community input to identify the preferred method of reporting outcomes of water quality monitoring.

Figure 2 National Water Quality Management Strategy



5.1.1 Stakeholder and Community Consultation

Stakeholder and community consultation has been a key component in the development of the Monitoring Framework. For the purpose of this report, a stakeholder is defined as a person or group with an interest in water quality and may include industry representatives, government departments, community groups, environmental groups, research bodies, land owners, indigenous groups and traditional owners. Community members are any individuals residing within the Katherine and Daly River Catchment.

A Water Quality Monitoring Co-ordinating Group (Co-ordinating Group) was established to provide advice and guidance throughout the life of the project. The Co-ordinating Group's role was to:

- Assist with compiling information on current monitoring activities and identifying gaps;
- Provide advice and technical information relevant to development of the Monitoring Framework; and
- Provide comment on the draft Monitoring Framework.

The Co-ordinating Group was made up of representatives from both the Territory and Federal Governments, Non-Government Organisations (NGO) and technical experts.

To guide and assist with stakeholder and community engagement, a consultation strategy was developed. The aim of the consultation strategy was to:

- Raise awareness of the project;
- Identify key stakeholders;
- Seek input from stakeholders and the community to inform development of the draft Monitoring Framework; and

- Seek comment on the content of the draft Monitoring Framework.

A number of tools were used to raise awareness of the project and engage stakeholders and community members. These included:

- Media releases via newspaper and radio;
- Development and distribution of a project flyer;
- Advertising public meetings in both local and regional newspapers and encouraging involvement in development of the draft Monitoring Framework;
- Advising identified stakeholders of upcoming meetings via a letter;
- Presenting and running workshops at stakeholder group meetings;
- Presenting and running workshops at public meetings;
- Distributing surveys to stakeholders;
- Telephone calls to key stakeholders asking if they would like a presentation or further information;
- Establishing a project website and advising stakeholders and community members of the website via a letter; and
- Advertising availability of the draft Monitoring Framework via newspapers and letters seeking written submissions on content.

The purpose of the consultation was to ensure that the Monitoring Framework was locally relevant, and addressed key issues of concern. Input from stakeholders and the community was invaluable and has:

- Identified uses and values of water resources that people want to protect;
- Identified threats and emerging issues that may pose a risk to water quality and hence achievement of water quality objectives. This will assist setting objectives and priorities for detailed water quality monitoring plans;
- Identified a willingness within the community to participate and contribute to future water quality monitoring provided there is adequate and ongoing resourcing and support; and
- Provided insight to preferred methods of communicating water quality results to a broad range of stakeholders and community groups.

Raising stakeholder and community awareness of water quality issues is a key component of the WQ Management Framework (Section 5.2). Increased awareness of water quality issues will result in a more informed debate about water quality monitoring and management. Because many pollutants originate from land-based activities, individual land holders and land managers are in the best position to implement practices that will reduce pollution[3] of rivers and aquifers in the catchment.

5.2 Water Quality Management Framework

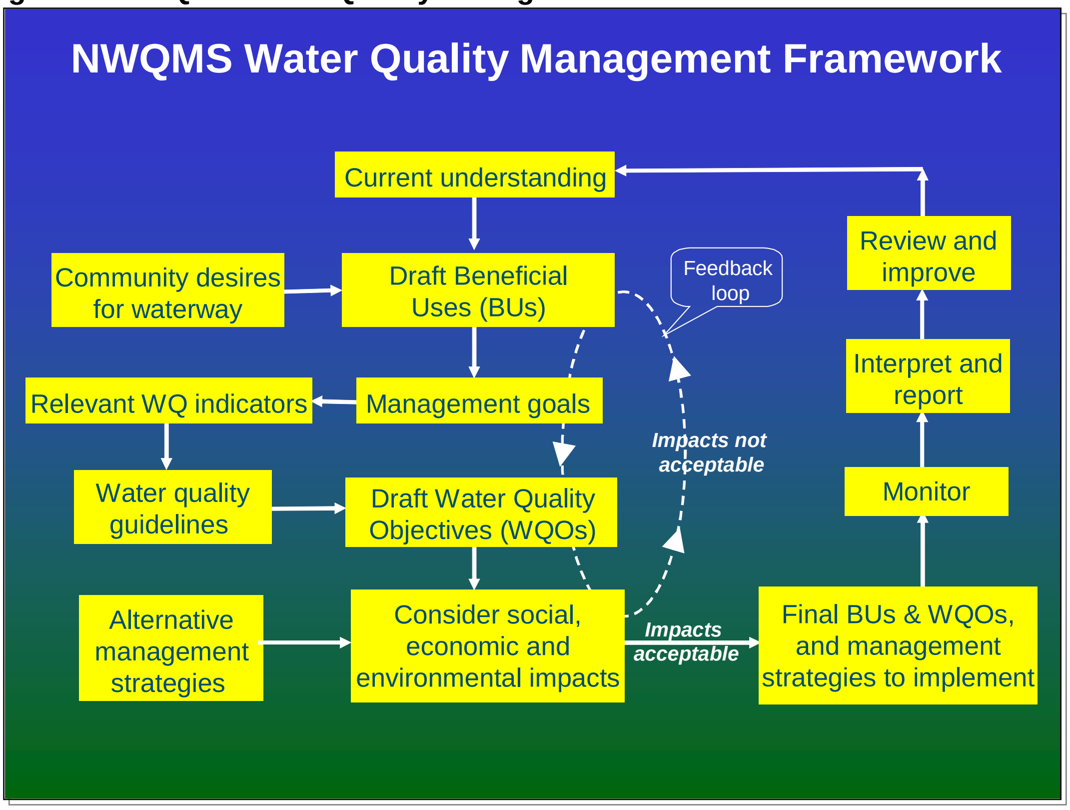
The NWQMS *Implementation Guidelines* (ARMCANZ and ANZECC 1998) and the *Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000) detail the key components of the WQ Management Framework shown graphically in Figure 3. It has a strong focus on adaptive management. Adaptive management is a cycle of continual review and improvement of management actions by learning from the outcomes of previous actions. Adaptive management requires implementation, monitoring, evaluation of results, and adjustment of objectives and practices (Salafsky, et al. 2001).

[3] Pollution – an unusually high amount of a chemical in a waterbody that has the potential to cause an environmental impact.

The WQ Management Framework and adaptive management cycle displayed in Figure 3 involves a number of key components, namely:

- Synthesising the current understanding of the processes affecting water quality in the catchment. This project has significantly assisted this component by developing conceptual models of the key pressures on water quality in the catchment;
- Establishing beneficial uses/environmental values for the waters in the catchment. The project has assisted this component by providing community input to the identification of uses listed in the *Water Act*;
- For river health, establishing more detailed management goals/outcomes (e.g. goals/outcomes for specific biota, flow, riparian vegetation, physical form, water quality);
- Setting water quality objectives (WQOs) for the relevant WQ indicators, based on the beneficial uses to be protected and the technical water quality guidelines to protect each use/value;
- Then, based on measuring the deviation of the actual water quality data from the objectives, planning and implementing preventative action (where WQ meets the WQOs) or corrective action (where WQ does not meet the WQOs);
- In planning the corrective actions, alternative management strategies must be formulated, then assessed and prioritised based on their relative social, economic and environmental impacts;
- Implementing the priority actions and tracking their progress; then
- Measuring, evaluating and reporting change as a result of the corrective action. This report and its Monitoring Framework will greatly assist with this component; and
- Reviewing understandings, plans, actions, etc. and taking further corrective action if necessary.

Figure 3 NWQMS Water Quality Management Framework



The WQ Management Framework is incorporated to some degree in existing Northern Territory legislation. As water management is a Territory responsibility, it is essential to work within the existing legislative framework, which maintains consistency with the NWQMS. A summary of the Northern Territory Government's legislation in relation to water and land activities is described in Section 5.3.

5.3 Legislative Framework

There are a number of Acts that govern both land and water management in the Northern Territory. Since water quality may be affected by natural events and processes as well as land- and water-based human activities, it is particularly important to establish who is responsible for planning and implementing corrective action in the WQ management framework.

The responsibility for administering and implementing the relevant land and water management Acts is shared between four Northern Territory Government Departments and some responsibilities are delegated to Boards and/or Advisory Committees. These departments are:

- Department of Natural Resources, Environment, the Arts and Sport (NRETAS);
- Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR);
- Department of Planning and Infrastructure (DPI); and
- Department of Health and Families (DHF).

Because land-based activities can impact water quality, there is no one Department solely responsible for implementing land management action to minimise impacts to water quality. As a consequence, the responsibility for decision making with respect to water quality monitoring will often require a collaborative approach.

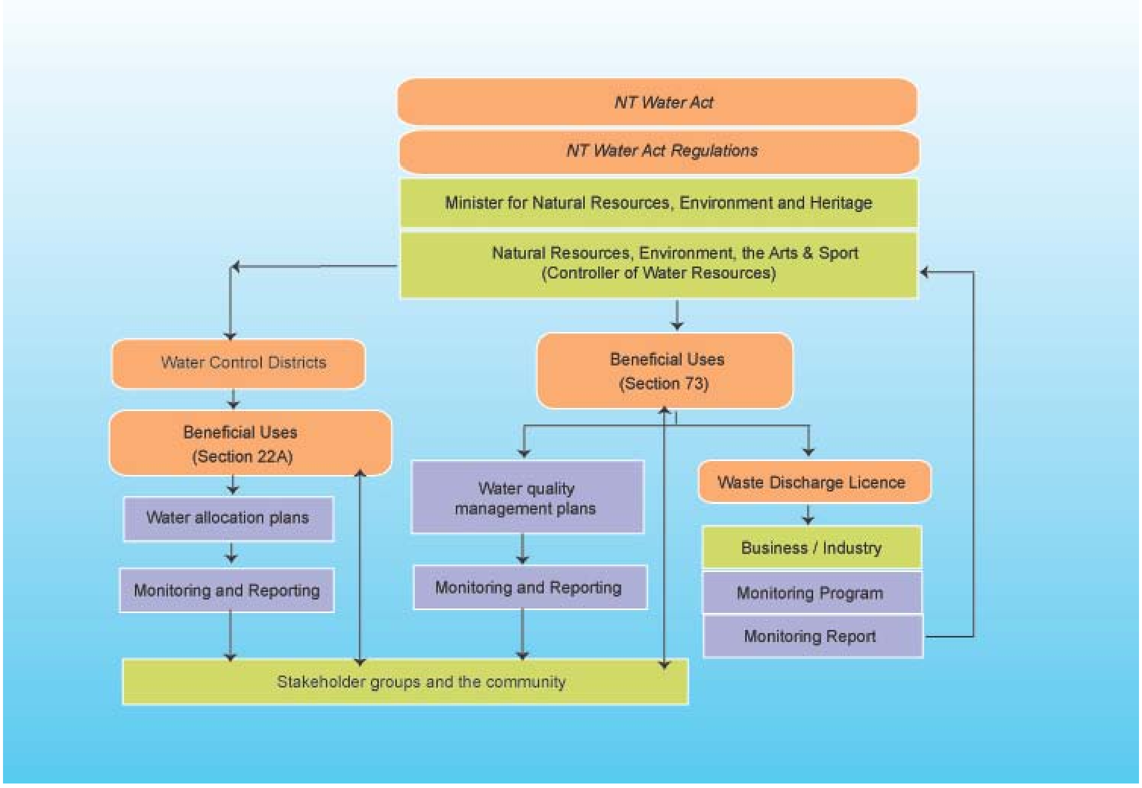
5.3.1 Water Quality Governance

The *Water Act 2004* is the main piece of legislation that governs water resource development and management in the Northern Territory (Appendix 1). The objective of the *Water Act* is "to provide for the investigation, allocation, use, control, protection, management and administration of water resources, and for related purposes". The Act is administered by the Minister for the Environment, through the Controller of Water Resources who resides in NRETAS (as shown in Figure 4). In accordance with section 34 of the *Water Act*, the Controller of Water Resources is under a general obligation to monitor water resources, including water quality. NRETAS is the primary department responsible for governance of the environment.

The responsibility for ensuring water is suitable for public water supply is detailed in the *Water Supply and Sewerage Services Act* and is administered by the Department of Health and Families (refer to Appendix 1 for more specific details of water governance in the Northern Territory).

The *Water Supply and Sewerage Services Act* provides a system of licensing for water supply services by the Utilities Commission (an independent industry regulator). Under the Act, the Power and Water Corporation requires a licence to supply water, and is required to meet minimum standards for drinking water quality specified by the Minister for Health. These standards currently refer to the *Australian Drinking Water Guidelines* (National Health and Medical Research Council and NRM Ministerial Council, 2004).

Figure 4 Water Quality Governance under the NT *Water Act*



NRETAS is also responsible for the administration and implementation of a number of other Acts that relate directly and indirectly (i.e. through land-based activities) to water resources. These include:

- *Waste Management and Pollution Control Act;*
- *Environmental Impact Assessment Act;*
- *Soil Conservation and Land Utilisation Act;*
- *Weeds Management Act;*
- *Pastoral Land Act; and*
- *Bushfire Act.*

Monitoring undertaken under these Acts can provide contextual information about water quality, and help to determine the cause of water quality degradation. This complements the "pressure-stressor-impact on beneficial uses" model of monitoring, where catchment activities are considered potential pressures on water quality degradation. This model is discussed in Section 6.3.

Because NRETAS has responsibility for several relevant Acts, this places the Department in a good position to take a leadership role in water quality management as it has the ability to implement corrective action internally.

Acts not administered by NRETAS that relate either directly or indirectly to water resources include:

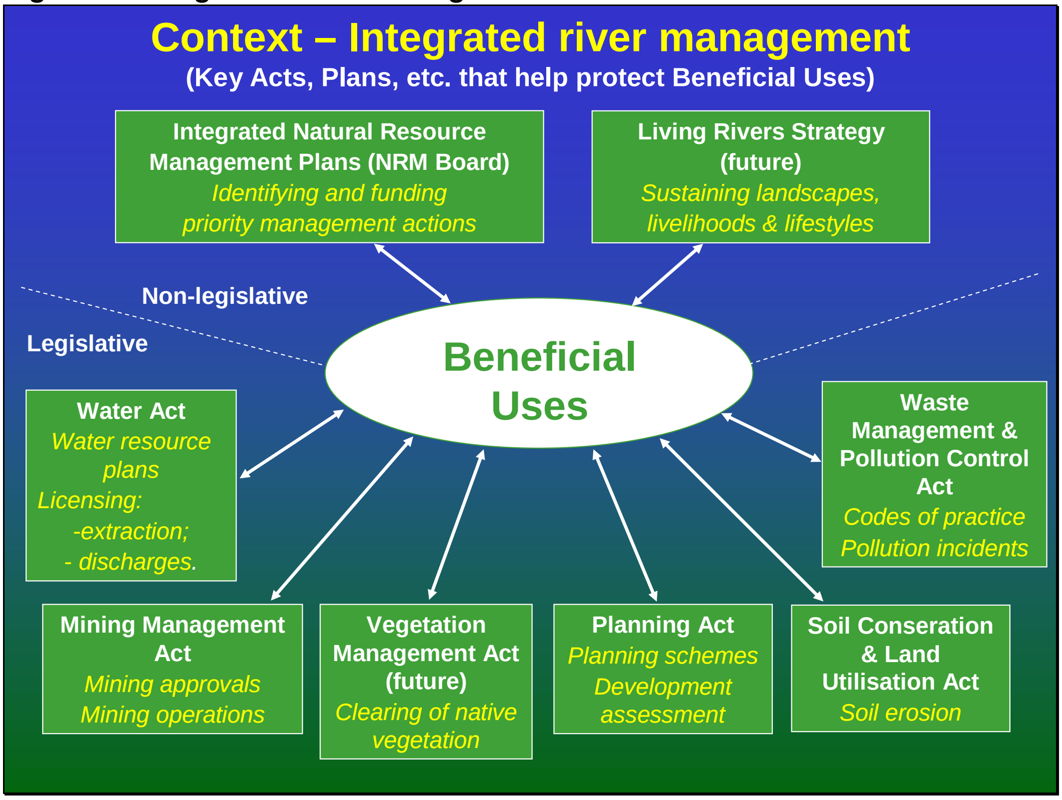
- *Water Supply and Sewerage Services Act (as described above);*
- *Agricultural and Veterinary Chemical (Control of Use) Act;*
- *Mining Management Act;* and
- *Planning Act.*

When considering departmental and ultimately ministerial responsibility for water quality management, the relevant statutory obligations need to be taken into account.

Further details of water quality management governance arrangements in the Northern Territory are outlined in Appendix 1. The objectives or purpose of the above-mentioned Acts, in relation to the environment or water quality, are further described in Appendix 2.

Figures 5 shows graphically how the key legislative and non-legislative mechanisms need to be managed in a complementary and integrated manner to achieve protection of the beneficial uses of the catchment's rivers.

Figure 5 Integrated River Management



5.4 This Project's Support for Management

This project has mainly assisted with implementing WQ management in the Katherine and Daly catchment by developing and providing initials details and future directions for its WQ Monitoring Framework (see Section 6).

However, it has also assisted WQ management by:

1. Developing conceptual models for the key pressures on water quality in the catchment; and
2. Providing community input to the beneficial uses/environmental values of the catchments waters to complement the beneficial uses in the *Water Act*;

Section 5.4.1 introduces conceptual models developed in further detail in Section 6.6. Section 5.4.2 then describes the background to, and this project's work on, identifying beneficial uses nominated by stakeholders and the community.

5.4.1 Conceptual Models

Conceptual models are visual tools useful for displaying a large amount of information and complex interactions. Conceptual models can take a variety of forms, and there are numerous methods of displaying conceptual models such as pictorials, tables and matrices, flow diagrams, and box and arrow diagrams.

Conceptual models serve numerous purposes and can be used to:
- educate and facilitate communication of water quality issues;
- identify important linkages and interactions in catchments and rivers;
- assist in identifying gaps in our current understanding;
- identify priority water quality issues for management and possible solutions;
- identify where further research is required to improve our understanding; and
- provide information regarding appropriate pressures and water quality indicators to monitor.

Prior to the establishment of any WQ management plan, a conceptual understanding of how a system responds to specific pressures should be examined.

A number of conceptual models are provided in the Monitoring Framework section. They are a starting point to inform future water quality monitoring programs, and will also greatly assist in planning and implementing management actions.

5.4.2 Beneficial Uses / Environmental Values

This project has built on the current legislated beneficial uses under the Water Act for the Katherine and Daly River Catchment by undertaking further community consultation on those beneficial uses. This Section (5.4.2) provides definitions, national and Territory context, and existing declared beneficial uses for the catchment. Sections 5.4.3 and 5.4.4 then describe the process and results of stakeholder and community consultation that was undertaken by this project for the purpose of identifying Beneficial Uses in areas where they had not previously been declared.

5.4.2.1 Definitions (NWQMS)

<u>Beneficial Uses / Environmental Values</u>

In the NWQMS (1994), Beneficial Uses / Environmental Values are defined as "…particular values or uses of the environment that contribute to public or private benefit, welfare, safety or health. There may also be particular environmental qualities which the community wishes to preserve". Examples of Beneficial Uses / Environmental Values of water resources are, amongst others, ecosystem protection, irrigation or the supply of raw drinking water.

In the Northern Territory, Beneficial Uses (BUs) is the commonly referred to term, instead of Environmental Values (EVs)[4].

[4] For the purpose of the Monitoring and associated Management Framework, Beneficial Uses have been used instead of environmental values because it is referred to in the *Water Act*, and the stakeholders and community are familiar with the term Beneficial Uses.

Water Quality Guidelines

Water quality guidelines are defined in the NWQMS (1994) as “maximum levels of contamination (for relevant indicators) which can be tolerated based on a combination of scientific evidence and informed judgement”. Water quality guidelines describe the water quality which must be maintained in order to sustain specific uses or protect specific values.

Water quality guidelines for aquatic ecosystems can also vary according to particular water types e.g. rivers, creeks, billabongs, estuaries and marine waters.

The same indicator can have guideline values at different levels for different Beneficial Uses. For instance, low counts of faecal bacteria are unacceptable for drinking water use but may not negatively impact aquatic ecosystems.

The *Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000) provide scientifically based water quality criteria to apply to each of the Beneficial Uses with the exception of Cultural or Industrial uses. Those guidelines also advocate the development of regional/local guidelines based on direct impact studies and/or reference sites in undisturbed condition.

Water Quality Objectives

In accordance with the NWQMS *Implementation Guidelines* (1998), water quality objectives are defined as the set of water quality guidelines (for all relevant indicators) that satisfy all Beneficial Uses selected for a particular water resource. This is shown graphically in Figure 3. An example of a Water Quality Objective (WQO) would be to “Maintain nutrient concentrations below 5 mg/L”.

Water Quality Indicators and Metrics

A water quality indicator is a descriptor of water quality, for example dissolved oxygen, and is monitored using a water quality metric, which for dissolved oxygen can be the concentration (mg/L) or the percentage saturation (%) of dissolved oxygen. The water quality metric is therefore the measurable or quantifiable characteristic of water.

Conceptual models, like those developed by this project, assist with selecting appropriate indicators for monitoring programs and consideration of the following:

- What affects the indicator?
- How responsive is the indicator to pressures?
- Can human influences on the indicator be distinguished from natural ones?
- Will the indicator demonstrate that the Beneficial Uses are either met or not met?
- Can the indicator be measured reliably and consistently?

The suitability of indicators will depend on the monitoring objectives and the aims of the monitoring program. Commonly used indicators are presented in Table 1.

Table 1 Commonly used WQ Indicators and Metrics

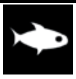
Indicators	Metrics	Description
Nutrients	Nitrogen Organic nitrogen Nitrate plus nitrite Ammonia Total nitrogen (mg/L) Phosphorus Filterable reactive Total phosphorus (mg/L)	The nutrients nitrogen and phosphorus are essential for plant growth. High concentrations indicate potential for excessive weed and algal growth. Total nutrients are made up of a dissolved component (e.g. nitrate plus nitrite, ammonia and filterable reactive phosphorus) and non-dissolved component, which is mostly organically bound. Nutrients in the dissolved state can be readily used by plants.
Water clarity	Turbidity (NTU)	A measure of light scattering by suspended particles in the water column which provides an indirect indication of light penetration.
	Secchi depth (m)	The depth to which the black and white markings on a Secchi disc can be clearly seen from the surface.
Oxygen	Dissolved oxygen (mg/L OR %saturation)	Essential for life processes of most aquatic organisms. Low concentrations of dissolved oxygen usually indicate the presence of excessive organic loads in the system or high night-time autotrophic respiration caused by eutrophication.
pH	pH units	A measure of the acidity or alkalinity of the water, and affects metal toxicity. Changes to pH can be caused by a range of potential water quality problems (e.g. acidity due to mine wastewater).
Salinity	Conductivity (mS/cm)	A surrogate measure of the amount of dissolved salts which conduct electricity in the water, and therefore an indicator of salinity. In fresh water, low conductivity indicates suitability for agricultural use.
Toxicants in sediments	Trace elements in sediments (mg/g dry weight).	Trace elements are present in the environment naturally and are principally derived from weathering of rocks. Many elements are essential for aquatic organisms. However, high concentrations of some elements in sediments can be toxic to aquatic organisms and may indicate contamination from domestic or industrial sources.
	Pesticides in sediments (mg/g dry weight)	Commonly used pesticides accumulate in the sediments of aquatic environments and may reach concentrations toxic to aquatic organisms.
Recreational health	Faecal coliforms (CFU/100 ml)	Faecal coliforms are used as indicators of faecal pollution.

Source: Modified from Environmental Protection Agency Queensland Government. http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/assessing_water_quality/water_quality_indicators/ accessed on 17 January 2009.

5.4.2.2 NWQMS Beneficial Uses / Environmental Values

The NWQMS identifies six categories of BUs / EVs that can be further divided into the sub-categories as shown in Table 2.

Table 2 Beneficial Uses / Environmental Values identified in the NWQMS

Beneficial Use / Environmental Value	Symbol	Definition / Description
Aquatic Ecosystem Protection		Supporting pristine or modified aquatic ecosystems. Three levels of protection are recognised depending on level of disturbance i.e.: • High conservation value • slightly to moderately disturbed system, and • highly disturbed system
Primary Industry		**Irrigating** crops such as sugar cane, lucerne , etc
		Water for **Farm Use** such as in fruit packing or milking sheds etc.
		**Stock Watering**
		Water for **Aquaculture** such as barramundi or red claw farming
		**Human Consumption** of wild or stocked fish or crustaceans
Recreation and Aesthetics		**Primary recreation** with direct contact with water such as swimming or snorkelling
		**Secondary recreation** with indirect contact with water such as boating, canoeing or sailing
		**Visual appreciation** with no contact with water such as picnicking, bushwalking, sightseeing
Drinking Water		**Raw Drinking Water** supplies
Industrial		Water for **Industrial Use** such as power generation, manufacturing plants
Cultural		**Cultural and spiritual** values

Source: Modified from Environmental Protection Agency Queensland Government

To be consistent with the NWQMS, when more than one Beneficial Use is identified (e.g. those relating to Ecosystem Protection and Raw Drinking Water), water quality needs to be managed to meet the WQO for each indicator. In practice, this often means the use of the most stringent water quality guideline.

Future water quality management planning may require the identified Beneficial Uses to be altered to allow for development within the region. For example, if an industry is developed in an area that deteriorates the locally water quality to the extent where water quality objectives are no longer achieved, the particular stream reach or area within an aquifer, may be designated an alternative beneficial use, allowing an acceptable level of deterioration in water quality.

Where areas are protected or designated for conservation purposes, water resources with high ecological value need to be managed to maintain current water quality for

Aquatic Ecosystem Protection. Examples of such areas are waters in National Parks and World Heritage Areas or waters that support protected species[5].

5.4.2.3 Declaring Beneficial Uses in the Northern Territory

Beneficial use declarations identify the uses or values of water resources within a particular area to assist in its protection and management. Although community consultation is not a legal requirement under the *Water Act*, it is undertaken to determine Beneficial Uses because the Northern Territory Government is a signatory to the NWQMS (Michael Lawton pers. comm. NRETAS December 2008).

There are two mechanisms within the *Water Act* that enable the declaration of Beneficial Uses (as shown in Figure 4). An area may be declared a Beneficial Use Area pursuant to section 22A, however, this can only occur once the area has been declared a Water Control District under section 22. Alternatively, in accordance with section 73, Beneficial Uses may be declared without the necessity to first declare the area a Water Control District. Section 73 is most commonly used when issuing discharge licences. Discharge licenses allow for the discharge of pollutants to receiving water under certain conditions. It is a requirement of the *Water Act* to declare Beneficial Uses prior to the issuing of such licences. .

Section 73 of the *Water Act* allows for the adoption of water quality guidelines applicable to the declared Beneficial Uses. These guidelines can be developed from data collected at a regional level or adopted from the *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC and ARMCANZ 2000).

There are seven categories of Beneficial Uses defined in section 4(2) of the Water Act (refer to Table 3). Although these are mostly consistent with the BUs / EVs of the NWQMS, there are some differences. For example, the NWQMS distinguishes between drinking water for humans and drinking water for stock (stock water), because the water quality guidelines required for human drinking water are significantly more stringent than those required for stock. In addition, the NWQMS separates cultural uses from recreational uses.

Beneficial Uses have already been declared for much of the Katherine and Daly River Catchment (refer to Table 4) for both surface water and groundwater resources. Maps of the Declared Beneficial Use Areas are given in Appendix 5.

[5] "Protected species" means species protected either under Federal legislations (i.e. *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)) or Northern Territory legislation and included species listed as threatened, vulnerable, rare and endangered.

Table 3 Beneficial Uses and Definitions in the Northern Territory *Water Act*

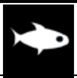
Beneficial Uses	Symbol	Definition
Environment		Water to maintain the health of **aquatic ecosystems**
Agriculture		**Irrigation** water for primary production including related research
Aquaculture		Commercial production of aquatic animals including related research
Cultural		Water to meet aesthetic, recreational and cultural needs
Public water supply		Water for drinking purposes delivered through community water supply systems
Rural stock and domestic		Water for domestic and/or stock purposes
Industry		Water for industry including secondary industry and mining or petroleum activity and other industry uses.

Table 4 Declared Beneficial Uses and Regions in the Katherine and Daly River Catchment

Region	River / Tributary / Region	Declared Beneficial Use(s)
Katherine River and Tributaries	• Seventeen Mile Creek • McAddens Creek • Maud Creek • King and Dry River • Other tributaries of Katherine River • Katherine River above Donkey Camp Pool • Katherine River Donkey Camp Pool • Katherine River below Donkey Camp Pool http://www.nt.gov.au/nreta/water/beneficial/pdf/Katherine_River_Tributaries.pdf http://www.nt.gov.au/nreta/water/beneficial/pdf/Katherine_River.pdf	• Protection of Aquatic Ecosystems • Protection of Aquatic Ecosystems • Protection of Aquatic Ecosystems and Recreational Water Quality and Aesthetics • Protection of Aquatic Ecosystems, Recreational Water Quality and Aesthetics and Agricultural Water Use • Protection of Aquatic Ecosystems • Protection of Aquatic Ecosystems and Recreational Water Quality and Aesthetics • Protection of Aquatic Ecosystems and Raw Water for Drinking Water Supply • Protection of Aquatic Ecosystems, Recreational Water Quality and Aesthetics and Agricultural Water Use
Edith River and Tributaries	http://www.nt.gov.au/nreta/water/beneficial/pdf/Edith_River.pdf	• Protection of Aquatic Ecosystems
Copperfield Creek and Tributaries	http://www.nt.gov.au/nreta/water/beneficial/pdf/Copperfield_Creek.pdf	• Raw Water for Drinking Water Supply • Protection of Aquatic Ecosystems
Katherine Groundwater	http://www.nt.gov.au/nreta/water/beneficial/pdf/Katherine_Area_Groundwater.pdf	• Raw Drinking Water, Agricultural Water Use and Industrial Purposes

Source: http://www.nt.gov.au/nreta/nretamaps/ viewed on 1 December 2008

5.4.3 Community Consultation on Beneficial Uses

Although Beneficial Uses have been declared for much of the Katherine River catchment (see Appendix 5), there is still a large part of the Katherine and Daly River catchment where Beneficial Uses have yet to be declared or identified. This applies particularly to the surface and ground water resources of the Douglas-Daly region where there is land clearing, agricultural land use and groundwater extraction.

As described above, identifying Beneficial Uses of water resources provides the foundation for setting water quality objectives. Stakeholder and community consultation was undertaken for the purpose of identifying Beneficial Uses in areas where they had not previously been declared. Meetings and workshops were held throughout the Katherine and Daly River Catchment and included key stakeholder groups such as the Aboriginal Reference Group, the Daly River Management Advisory Committee and the Northern Territory Cattlemen's Association. Public meetings were held at Darwin, Katherine, Edith Farms, Douglas-Daly and Woolianna.

The Beneficial Uses identified for the Katherine and Daly River Catchment are displayed in Table 5. Given the catchment supports a wide variety of land uses, cultural and recreational activities, it is not surprising all six categories of Beneficial Uses were identified.

Table 5 Beneficial Uses for the Katherine and Daly River Catchment identified through Stakeholder and Community Consultation 2008

Beneficial Use	Symbol	Definition / Description	Surface water	Ground-water
Aquatic Ecosystem Protection		Supporting pristine or modified aquatic ecosystems.	✓	✓
Primary Industry		**Irrigating** crops	✓	✓
		Stock Watering	✓	✓
		Water for **Aquaculture** - commercial production aquatic foods	✓	✓ [6]
Recreation and Aesthetics		**Primary recreation** with direct contact with water such as swimming or snorkelling	✓	✓ [7]
		Secondary recreation with indirect contact with water such as boating, canoeing or sailing	✓	
		Visual appreciation with no contact with water such as picnicking, bushwalking, sightseeing	✓	✓
Drinking Water		**Raw Drinking Water** supplies	✓	✓
Industrial		Water for **Industrial Use**, such as mining and manufacturing plants	✓	✓
Cultural		**Cultural and spiritual** values	✓	✓

[6] Groundwater is pumped from the Tindall aquifer and used for aquaculture. While this occurs near Mataranka, i.e. outside of the Katherine and Daly River Catchment, the water is sourced from the same aquifer that extends throughout the Katherine and Daly River Catchment.
[7] Groundwater is used for swimming at numerous springs throughout the region.

5.4.4 Beneficial Uses Summary

- Consultation identified support for all the Beneficial Uses listed by the Water Act. Of these, Environment and Raw Drinking Water are the most stringent. Therefore both surface and ground water resources need to be managed for this high level of protection unless the area is already a declared beneficial use area;
- Water quality guidelines can be either derived from local data or adopted from the *Guidelines for Marine and Fresh Water Quality (*ANZECC and ARMCANZ 2000);
- To enable future development, a review of declared Beneficial Uses may be necessary;
- In accordance with the NWQMS, the beneficial use and corresponding water quality objectives for Aquatic Ecosystem Protection must be maintained where there are existing areas of conservation significance or protected species.

6 Water Quality Monitoring Framework

The purpose of this Monitoring Framework is to provide a locally relevant, comprehensive and integrated set of steps and considerations for the planning and implementation of water quality monitoring in the Katherine and Daly River catchment.

The Framework is not a comprehensive plan. It is the structure on which future monitoring programs can be built, taking into consideration the NWQMS, Northern Territory governance arrangements, priority management and monitoring objectives, and community and stakeholder input.

This report provided an overview of the WQ Management Framework (Section 5) from the national to the catchment level. The latter level provides the management context for developing monitoring programs in the Katherine and Daly River catchment. This section provides the WQ Monitoring Framework and its detailed stages, as well as the key components of the Framework that were progressed by this project which are the legislative responsibilities, water quality monitoring objectives, as well as conceptual models and their associated information on key WQ issues and indicators.

This section firstly provides an overview of the Monitoring Framework and its component stages, with reference to the details on each stage that are included in Appendix 6. It then provides contextual information on “river health” monitoring, as one of the key beneficial uses/environmental values is the protection of aquatic ecosystems. Then the focus of the Monitoring Framework is mainly on (physical-chemical) “water quality” which naturally refers to the physical and chemical properties of water; for example nutrient content, pH and turbidity. Whilst the Monitoring Framework focuses on water quality, its components are also applicable to the planning and implementation of a broader program of river health monitoring.

This project has reviewed the legislative requirements for monitoring, historical monitoring programs and sought community inputs into possible future monitoring programs. This section provides details of all these and aims to consolidate them into a common format that will be useful to water quality managers in progressing related water quality monitoring programs in the catchment. Then the substantial work from this project in developing conceptual models of the key pressures in the catchment is presented to assist in both designing monitoring programs and supporting water quality management in the catchment.

6.1 Overview of the Monitoring Framework

Effective water quality investigations and monitoring systematically collects physical and chemical information, and analyse, interpret and report those measurements according to a carefully pre-planned design which follows a basic structure.

This NWQMS Monitoring Guidelines document (ANZECC and ARMCANZ 2000) sets out a standard structure for the design of a monitoring program (see the Figure below reproduced from the NWQMS Monitoring Guidelines). This has been adopted as the WQ Monitoring Framework for the Katherine and Daly River catchment. The chapters in the NWQMS Guidelines lead the monitoring team through the details of all the stages in the Figure below. Each chapter contains a summary flowchart with more detailed steps for each stage (copied and discussed in Appendix 6 and referred to with the links shown on the Figure below). These chapters discuss how to:

- define information requirements and objectives for monitoring programs (Chapter 2);

• design a study, including its type, scale, measurement parameters and sampling programs, and preferred methods for sampling (Chapters 3 and 4);
• design a laboratory program including preferred methods for laboratory and field analysis (Chapters 4 and 5);
• set up quality assurance and quality control procedures (Chapters 4 and 5);
• be aware of occupational health and safety concerns (Chapters 4 and 5);
• statistically analyse and interpret the data (Chapter 6 and Appendix 5);
• report and disseminate information to various audiences, and collate feedback (Chapter 7).

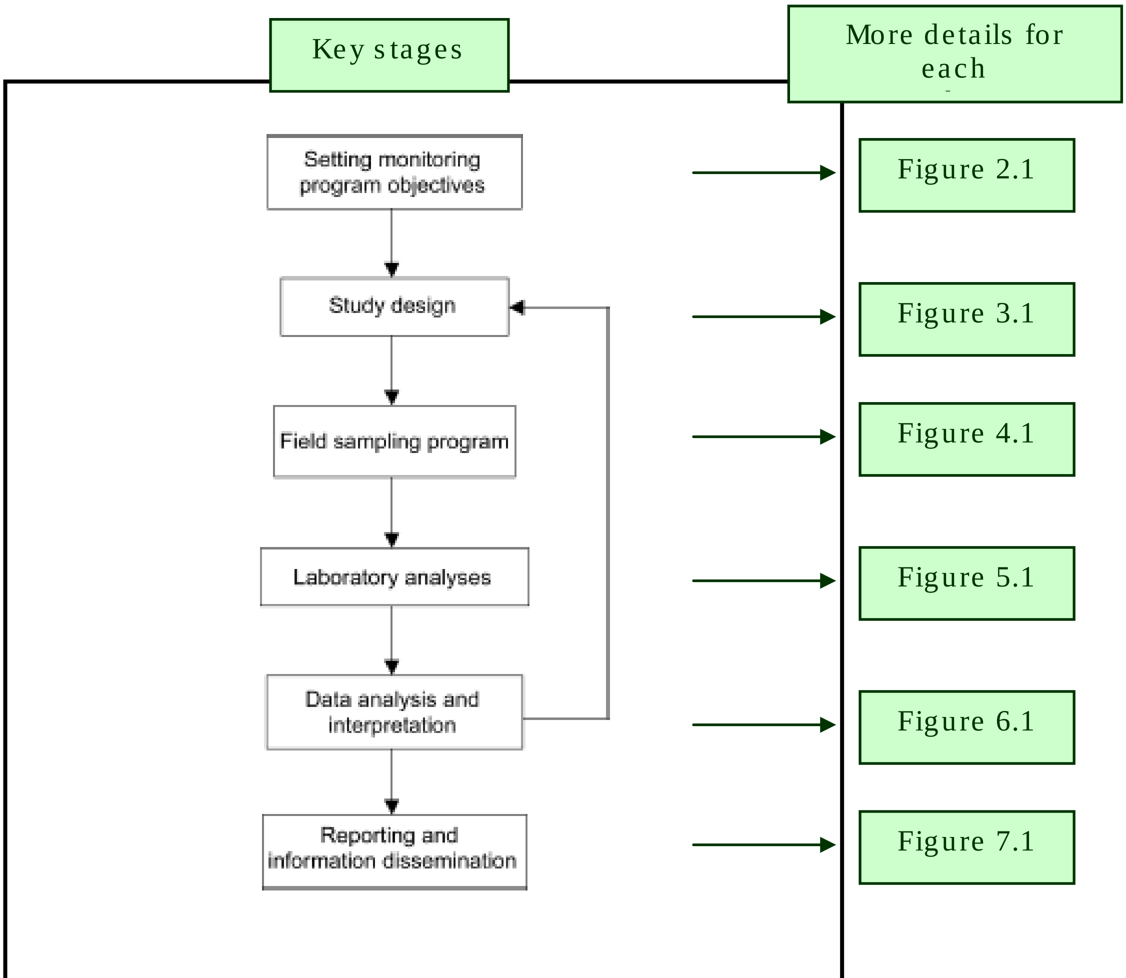


Figure 1.1. Framework for a water quality monitoring program. Each box is dealt with by one chapter of the Monitoring Guidelines, from Chapter 2 to Chapter 7.

Sometimes, more detailed advice will be required and this can either be found in the appendices to the NWQMS Guidelines or in references or other listed sources.

It is important to remember that the design of a monitoring program is an iterative process, as indicated in Figure 1.1, and that earlier components in the structure should be refined on the basis of findings in later stages.

Appendix 6 of this report not only provides further detail on each of these stages but also provides contextual information for the Katherine and Daly River catchment. However, the main component that this project provides support for is the first and key stage, namely: “Setting monitoring program objectives”. Figure 2.1 from the NWQMS

Monitoring Guidelines is reproduced below to help show how this project supported this stage of future monitoring programs for the catchment.

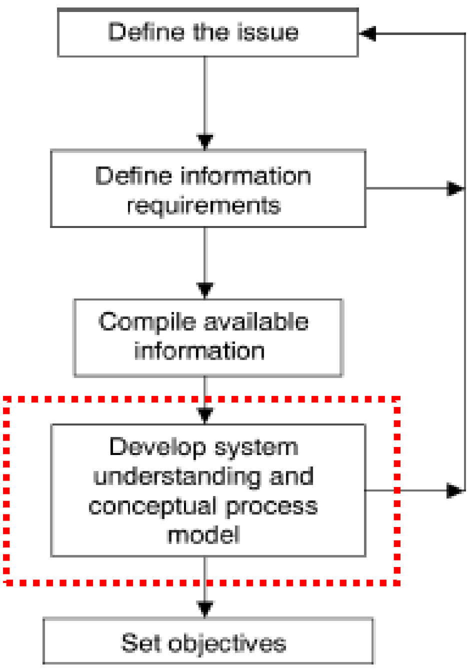


Figure 2.1. Framework for setting monitoring program objectives

The following sections and Appendix 6 detail this project's outputs including the water quality issues (Section 6.4), presented using the pressure-stressor-impact on beneficial use model (Section 6.3), as well as helping to define information requirements and start compiling that information. Section 6.6 details the conceptual models developed by the project. These models, together with the detailed WQ monitoring program objectives, aim to assist WQ managers in designing and implementing future WQ monitoring programs in the catchment. As indicated above, this stage is a critical first step in any WQ monitoring program and results in the monitoring program objectives that the subsequent stages can then be designed to deliver.

6.2 Context for River Health Monitoring

This Section provides contextual information on "river health" monitoring, as one of the key beneficial uses/environmental values is the protection of aquatic ecosystems. As indicated above, the main focus of the Monitoring Framework is on (physical-chemical) "water quality" but its components are also applicable to the planning and implementation of a broader program of river health monitoring. Such a program may result from current management activities at a national level (e.g. a National River Health Assessment), or a Territory/catchment level (e.g. draft Living Rivers Strategy).

The National Water Commission has developed an overall framework for the assessment of river and wetland health (FARWH) that can be applied to surface water management areas around Australia to deliver a national overview or any smaller areas of interest. The framework analyses data for six key river health themes, namely:

1. Catchment disturbance;
2. Water quality and soils;
3. Physical form;
4. Hydrological disturbance;
5. Fringing zone; and
6. Aquatic biota.

There is general agreement around Australia to these key "themes" (or components) of a river health monitoring program. These are the key "themes" that are being trialled around Australia (including the NT). More details can be found at:
http://www.water.gov.au/RiverandWetLandHealth/Assessmentofriverandwetlandhealth/

These themes are similar to other river health monitoring programs around Australia; for example, the Victorian Index of Stream Condition program, the Murray-Darling Basin Sustainable Rivers Audit program, the Southeast Queensland Ecosystem Health Monitoring program.

6.3 Pressure-Stressor-Impacts on Beneficial Uses Model

As indicated above, a key component of establishing WQ monitoring program objectives is the conceptual understanding of how a system responds to specific pressures in the catchment that are the subject of the monitoring programs.

A number of conceptual models are provided to support this Monitoring Framework (see Section 6.6). They are to be used as a starting point to inform future water quality monitoring programs. If river health programs are undertaken that examine detailed ecosystem responses, then additional conceptual models will need to be constructed. Useful information on conceptual models can be accessed online at: http://science.nature.nps.gov/im/monitor/docs/Conceptual_Modelling.pdf

The conceptual models contained within this Framework are based on the "Pressure-Stressor-Impacts on Beneficial Uses" model for environmental monitoring. The Pressure refers to pressures or potential threats that can result in water quality degradation. The Stressor refers to the water quality indicator that is impacted; for example, dissolved oxygen. Ultimately the Stressor impacts on the Beneficial Uses that are being protected and hence the key reason that management responses will be implemented to address the pressures. This Framework therefore allows managers to address the Pressures on water quality degradation, the stressor, that have an impact on beneficial uses (e.g. the "causes" of low dissolved oxygen concentrations that result in fish deaths). These pressures are discussed in detail in Section 6.4. Table 6 shows some examples of pressures, stressors and impacts on beneficial uses.

Table 6 Pressure-Stressor-Impact on Beneficial Uses Model

Pressure	Water Quality Stressor	Impact on Beneficial Use
Land clearing and soil erosion	Increased suspended solids and turbidity	Reduced photosynthesis; Sediment deposition; Clogging of irrigation pipes
Nutrients from sewage discharge	Increased nutrient concentrations	Increased algal growth, smothering of vascular plants
River water extraction	Change in river chemistry	Growth of different algae that affects invertebrate grazing
Fire in the riparian zone	Increased suspended sediment.	Reduced photosynthesis; Sediment deposition; Clogging of irrigation pipes
Release of mine waste water	Increased acidity and toxic metals, low pH.	Water not suitable for drinking; fish deaths.

6.4 Katherine-Daly River Pressures/Threats

6.4.1 Identifying pressures and potential threats to Beneficial Uses

Through identifying Beneficial Uses (see Section 5), water quality objectives can be developed. Monitoring can then be used to determine whether or not the WQ objectives are being met. However, before developing and implementing monitoring programs, it is important to identify pressures and potential threats that may prevent the achievement of WQ objectives. This has a number of benefits and can:

- identify where there are gaps in our current understanding;
- inform where monitoring could or should be targeted and therefore inform future water quality monitoring planning;
- determine the level of the pressure/threat (i.e. severe, moderate, slight or negligible) once data has been collected. This provides valuable information to improve our understanding of the pressure/threat;
- assist in identifying and prioritising where remedial efforts should be focused; and
- inform whether or not the remedial action has been effective and again improves our understanding of the pressure/threat.

Stakeholder and community consultation, coupled with technical guidance from the Water Quality Co-ordinating Group, was used in this project to determine the main pressures / threats to achieving water quality objectives in the catchment and hence maintaining Beneficial Uses.

No formal risk assessment process was undertaken by this project, however, a qualitative risk assessment was undertaken by van Dam et al. (2008). Further information on risks to water quality and ecosystem health is detailed in reports published by the Daly River Community Reference Group Draft Report (2004a), and the Northern Territory Natural Resource Management Board Integrated Natural Resource Management Plan (2005).

The outcomes of the stakeholder and community consultation are detailed in Section 6.4.3.

6.4.2 Literature Review of Pressures/Threats to Water Quality

Numerous studies have been undertaken in the Top End of the Northern Territory focusing on impacts to water quality, including studies specific to the Katherine and Daly River catchment. These studies have identified a number of pressures/threats, both natural and those due to human activities, that adversely impact water quality.

The main pressures/threats identified by these studies and through stakeholder and community consultation are summarised below and include:

- pollution during early wet season, storm runoff events;
- soil erosion;
- agricultural production and excessive use of fertilisers and pesticides;
- water extraction;
- fire regime;
- mining; and
- geology and its effect on water quality.

Other pressures/threats identified through community and stakeholder consultation were:

- urban stormwater runoff;
- waste water treatment plant discharges;
- septic tank pollution;
- leachate from landfills;
- pollutants associated with recreational water use; and
- weeds and feral animals.

These pressures/threats are briefly discussed in Section 6.4.2.8. There is lack of information available for the Katherine and Daly River catchment in relation to these pressures/threats. As a consequence they are only discussed in general terms.

6.4.2.1 Early wet season storm runoff events

Storms during the transition between the dry and wet season (October to December) can produce large runoff events that cause rapid rises in river water levels. The magnitude and frequency of these storm runoff events depends on rainfall intensity and catchment characteristics. Catchments with hills, and poor ground and canopy cover, are particularly susceptible to erosion of soil and movement of organic matter to streams. Whilst these events are often considered natural, land management that reduces vegetation cover in the catchment could increase the number of these events and their impact on river water quality.

A runoff event that caused marked water quality degradation in Donkey Camp Pool, on the Katherine River, is described by Townsend et al. (1992). Runoff from a storm in the Maude Creek catchment, a tributary upstream of Donkey Camp Pool, caused a loss of oxygen in the pool, high turbidity and high concentrations of iron, manganese and faecal bacteria [8]. The low oxygen concentrations caused the death of an estimated 5000 fish and posed a health risk to Katherine township drinking water that required the issue of an order for drinking water to be boiled. A similar event occurred in the 1960s.

6.4.2.2 Soil erosion from land clearing

When vegetation is cleared and replaced by pasture, crops, and other more intensive forms of land-use, the land’s surface can become more vulnerable to soil erosion. This can result in an increase in the amount and concentration of sediment being transported by rivers to the estuary, and the deposition of sediment along the river channel. Due to concerns regarding land clearing and sedimentation of the Daly River, Wasson et al. (2008) examined the sources of sediment to the river and concluded that the primary source of sediment deposited in the river was subsoil from gullying and channel bank erosion (i.e. scouring and slumping). Channel bank erosion was due to increased overbank flows since 1990. Wasson et al. (2008) also concluded that there was no discernable input of top soil to the river from the areas of cleared land adjacent the river.

Land clearing and the replacement of native vegetation by pastures however may have an indirect effect on bank slumping by increasing groundwater levels. Investigations undertaken by Wilson et al. (2006) examined the impact of land clearing on aquifer recharge rates and spring flows and found that native woodlands use more water than pastures. As a result, the recharge rate (i.e. the rate at which water in the aquifer is replenished) could increase following clearing and was found to be at least two times greater. This increase in the recharge rate could result in an increase in the discharge

[8] Faecal bacteria are sometimes referred to as “faecal coliforms” due to the test undertaken. They are microorganisms found in animal and human waste. E. coli is an example of such an organism.

of groundwater to the river. Wasson et al. (2008) also suggested that the increased recharge rate is likely to be a major contributor to active bank slumping (erosion), and recognised that clearing contributed to increased recharge to aquifers. This suggests that while there is little evidence that past clearing directly contributes to increased sediment input to the Daly River via erosion of top soil, secondary impacts of land clearing may contribute to sedimentation through an increased vulnerability to bank slumping. Newly cleared land however is vulnerable to erosion and producing increased suspended sediment in rivers and streams.

6.4.2.3 Agricultural production and excessive use of fertilisers and pesticides

Agricultural primary production often involves the use of fertilisers to improve crop yields and pesticides to control crop and livestock pests. While the correct use of fertilisers and pesticides will minimise the risk of their entry to water resources, there is still the potential for contamination. In addition, livestock production and animal waste also has the potential to increase loads of nutrients and faecal bacteria to our waterways and aquifers.

The input of nutrients to waterways is a common factor contributing to algal blooms. Studies by Ganf and Rea (2007) examined the response of algal growth to nutrient enrichment and found that all Northern Territory tropical rivers had the algae naturally present that had the potential to produce algal blooms with enrichment. They recommended that nutrient management strategies should accompany future land use development as increased nutrient runoff could result in algal blooms.

Investigations by Schult and Metcalfe (2006) examined nitrate concentrations in the Douglas River and found elevated nitrate concentrations in the lower reaches of the river during the dry season, 10–20 times higher than that measured in the Daly River, Hayes Creek, Stray Creek and upstream reaches of the Douglas River. This is probably due to past land-use activities that have resulted in high groundwater nitrate concentrations, as is supported by some high concentrations of nitrate in bores. The Katherine River downstream of Katherine township also has relatively high nitrate concentrations. Although the nitrate levels were high, there was no apparent impact on algal growth because the growth of algae requires both nitrogen and phosphorus (see Townsend et al. 2008), and unless both nutrients were present at elevated levels, nuisance algal growth was unlikely.

Wilson et al. (2006) attributed approximately 70% of the water that replenishes the aquifer to bypass flow (i.e. through sinkholes and macro-pores). This increases the risk of contaminants such as nutrients and pesticides entering the aquifer and subsequently streams because there is less time for contaminants to be naturally attenuated.

While the risk of algal growth can be reduced with appropriate land management practices, nutrient, pesticide and faecal contamination has the potential to impact both groundwater and surface water resources and the assigned Beneficial Uses.

6.4.2.4 Water extraction

Water extraction in the Katherine and Daly River catchment is predominantly from groundwater through the use of bores. However, water is also drawn directly from rivers to supply drinking water to Katherine town residents, and agricultural and residential needs of landholders adjacent to rivers.

The effects of water extraction on water quality are most likely to be indirect, and have not been studied in this catchment. The consumptive use of water from either groundwater or from the river will reduce river flow during the dry season. One way this may affect water quality is through the increased retention time of water in river pools. If water does not pass through pools as quickly as before, this could conceivably increase the likelihood of thermal stratification and reduce dissolved oxygen concentration in the bottom waters of pools. It will also increase the likelihood that algae will grow in the pool if there are sufficient nutrients. An increase in pool retention time could also favour an increase in water clarity because suspended material has more time to settle out to the bottom of the pool.

Water Allocation Plans current being developed in the catchment will include requirements for both water quality and aquatic ecosystem monitoring (NRETAS 2008).

If water is harvested during the wet season to be stored for the dry season, the impact on wet season water quality will depend on the volume extracted and its water quality, and the time when harvesting occurs.

6.4.2.5 Mining

In 2008, there were four mines within in the Katherine and Daly River catchment; Pine Creek, Mt Todd and Maud Creek Gold Mines, and the Dorisvale Barite Mine. Although none of these mines were operational in 2008, nevertheless they can still pose a threat to downstream water quality. The Pine Creek site has been rehabilitated to reduce the risk of impacts to downstream water quality. Currently, ongoing water quality management is required as part of waste discharge licences issued by NRETAS for the Pine Creek and Mt Todd mine sites (Michael Welch pers. comm. DRDPIFR February 2009). There are also numerous abandoned copper, tin and gold mine sites within the catchment that date back to the nineteenth century. These are small, often consisting of only a shaft or two, with no sulphide rock stock piles or tailings dams. Due to their small size, they are unlikely to pose a significant threat to overall water quality - however, no specific investigations have been undertaken.

Mining can impact water quality through oxidation of exposed rocks and sediments. Runoff from mined areas and rock stock piles that contain sulphide rocks can be highly acidic. The high acidity causes the mobilisation of metals such as cadmium, lead, zinc and copper which are toxic to aquatic life. This is often referred to as Acid Mine Drainage (AMD). Investigations conducted by van Dam et al. (2008) at the decommissioned Mt Todd Mine found low pH and elevated concentrations of metals and other substances within a retention pond. Van Dam et al. (2008) reported the contaminants caused toxicity to six local aquatic species (including algae, plants, macro-invertebrates, snails and fish) which required significant dilution of the retention pond water to protect aquatic ecosystems. Controlled releases of water from the retention pond have been conducted during the wet season. These releases do not pose a risk to aquatic ecosystems as there is sufficient dilution to reduce the concentrations of contaminants.

Investigations undertaken by DRDPIFR have found that, although there is a reduction in water quality in creeks draining the mine site, this has generally been ameliorated by dilution upon entering the Edith River. It was also found that, despite the decreased water quality, there is little or no measurable impact on macro-invertebrate communities downstream in the Edith River (Michael Welch pers. comm. DRDPIFR January 2009). However, in the past, fish kills have been linked to unintentional releases of polluted water from the Mt Todd site.

Mining activity poses a threat to achieving WQ objectives and protecting Beneficial Uses of water resources. However, provided releases are managed appropriately, the risk of impact to the environment and to other water uses can be reduced.

6.4.2.6 Fire regime

The frequency and intensity of fires in the Top End, including the Katherine and Daly River catchment, has increased since European settlement. Fires occur more frequently, especially late in the dry season when intensities are generally greatest. The prevailing current management paradigm is to reduce fuel loads with early dry season burns, with some managers also applying wet season burns. The burning of savanna woodland vegetation late in the dry season (i.e. August/September) has been shown to double the amount of sediment being carried by small streams compared to catchments either left unburnt or burnt early in the dry season (Townsend and Douglas 1999). Late dry season fires reduce catchment canopy cover and groundcover, as well as riparian vegetation, resulting in increased soil erosion.

The loss of riparian vegetation canopy cover increases light penetration to small streams (Douglas et al. 2003), which can increase water temperatures and, through the promotion of aquatic plant growth, alter dissolved oxygen concentrations.

Late dry season fires also increase the frequency of episodic storm runoff events during the dry-wet season transition. These events have poor water quality, with high concentrations of sediment, nutrients, iron and manganese, and may have contributed to fish kills (refer to Section 6.4.2.1 above). The water quality of catchments degraded through fire can recover within a few years if less intense fires occur, as this allows recovery of the catchment vegetation (Townsend et al. 2004). Whilst the build-up of fuel increases the threat of high intensity fires, fire may have no significant impact on water quality if the fire intensity is low, even after 10 years of no burning (Townsend and Douglas 2004).

6.4.2.7 Geology

Local geology can impact assigned Beneficial Uses to water resources. The chemical nature of water stored within an aquifer is influenced by the rock or sediment that groundwater moves through or is stored within. For example, water stored within limestone aquifers typically have higher carbonate concentrations (or hardness) than water stored within fractured sandstone aquifers. In the Katherine region, elevated levels of radium have been detected in numerous bores. Investigations by Qureshi and Martin (1996) found groundwater with naturally occurring elevated radium concentrations within 20 metres of the interface of the Jinduckin Formation and the Tindall Limestone. They noted that bores drilled directly in the Tindall Limestone[9] did not have elevated levels of radium, nor did any of the Katherine water supply bores. Some of the levels of the naturally occurring radioactive isotope of radium-226 (^{226}Ra) were found to exceed the Australian Drinking Water Guidelines.

Within the Katherine and Daly River catchment are karst limestone aquifers which have large sink holes, cave like solution features, and macro-pores that facilitate rapid recharge to the aquifer. An investigation by Wilson et al. (2006) suggests 70% of

[9] Drilled directly into the Tindal Limestone means drilled into the outcrop area of the Tindall Limestone where Jinduckin Formation has been removed by erosion (Steven Tickell pers. comm. NRETAS, March 2009)

recharge is via sinkholes and macro-pores. As a consequence of rapid recharge, there is a reduced capacity for attenuation[10]. The implication of rapid recharge is the greater potential for contamination of water within the aquifer. The Katherine rural, residential and industrial areas are located where large volumes of water are rapidly recharged via sinkholes, solution features and macro-pores, hence increasing the risk of contamination. In addition, there are open caves which feed directly into the groundwater, south of the township of Katherine, adjacent the Stuart Highway. Chemical spills in these regions are a significant threat to the water within the aquifer (John Sumner pers. comm. NRETAS, March 2009).

6.4.2.8 Other pressures/threats to Beneficial Uses

Urban stormwater runoff and recreational activities can also pose a threat to Beneficial Uses. These have not been discussed above as no studies relating to these threats have been undertaken in the Katherine and Daly River catchment.

Urban runoff is well studied throughout Australia, including the Darwin Harbour catchment (see Skinner at al. 2009). Common contaminants include pesticides and nutrients from gardens and parks, faecal bacteria from pet faeces, nutrients from septic tank seepage, asbestos and hydrocarbons from roads, metals from roofs and cars, and sediments from development sites.

Discharges from waste water treatments plants (WWTP) and pollution from septic tanks are a potential source of nutrients and microbiological pollution. They are also a potential source of pharmaceutical contaminants to rivers and groundwater. Pharmaceuticals are chemicals such as hormones and other medications that have been found to adversely impact fish and amphibians (Utah State University 2009). Generally, pharmaceuticals are detected in only very low concentrations, however they are a potential threat to both aquatic ecosystem health and raw drinking water beneficial uses.

Recreational water use can also pollute rivers and springs. Common contaminates include nutrients and faecal bacteria due to human activities, nutrients (derived from detergents) from washing dishes, and hydrocarbons and suspended sediment from boating activities. Litter is also commonly associated with recreational activities.

Weeds and feral animals also pose a threat to the Beneficial Uses. For example, investigations of the impact of the aquatic weed Salvinia on water quality, undertaken by the Weed Management Branch of NRETAS, have found water under the weed has lower oxygen levels, higher carbon dioxide and hydrogen sulphide concentrations, lower pH and lower temperatures compared to water not affected by the weed. Feral animals can cause nutrient and sediment pollution.

The significance of these threats to beneficial water uses should to be assessed. Short-term investigations are required to assess the risk of these contaminants, relative to the generally broader pressures discussed above, to determine the necessity for long-term monitoring.

[10] Attenuation is a natural process where concentrations of contaminants are reduced to background levels through physio-chemical and microbiological processes.

6.4.3 Community consultation of pressures/threats to Beneficial Uses

A series of public meetings was held and survey responses collated to obtain stakeholder and community views on pressures/threats to water quality (refer to Table 7). This information should be taken into account when more detailed planning is undertaken.

The most commonly reported threat to water quality was associated with large scale land use change (including activities such as land clearing, horticultural production and forestry), followed by water extraction. These threats are also identified and quantified in risk assessments undertaken by van Dam et al. (2008) and the Daly Region Community Reference Group (2004). Those risks were assessed in terms of ecological sustainability, which differs from the Monitoring Framework where the pressures / threats are identified in terms of the potential to impact water quality and the identified Beneficial Uses.

Table 7 Threats to Beneficial Uses identified through Community Consultation

Primary Issue	Secondary Issue	Contaminant / pollutant
Land use change including: • Land clearing • Irrigated horticultural production • Forestry	Water extraction / abstraction Erosion Application of fertilisers Application of pesticides Runoff to sinkholes	Altered hydrology[11] Sediments Nutrients Pesticides Micro-organisms
Extraction and abstraction[12]		Altered hydrology Salinity
Mining		pH Metals
Fire	Erosion Eutrophication	Sediment Nutrients
Tourism and recreational water use, including boating	Wave action due to boating causing erosion	Sediments Litter Nutrients Micro-organisms Hydrocarbons
First runoff events, and wet season floods	Erosion Organic matter / leaf litter Large debris i.e. trees Debris from Katherine waste depot Contaminants i.e. fertilisers	Sediment Organic Matter / debris Nutrients
Stock grazing and feed lots Feral animals pressures	Erosion Eutrophication	Sediments Nutrients Micro-organisms
Weeds and weed control	Clogging of watercourses Use of pesticides	Altered pH Pesticides
Urban runoff and stormwater discharge (Katherine) and urban development. Leachate from Katherine waste depots (dump)	Erosion Inappropriate waste disposal Contaminates entering groundwater	Sediment Hydrocarbons Metals Nutrients Pesticides

[11] Altered hydrology refers to both surface water and groundwater and includes water levels, flow and recharge rates.
[12] Abstraction means the extraction of groundwater

Primary Issue	Secondary Issue	Contaminant / pollutant
Sewage discharge (Katherine) and septic seepage	Eutrophication Impact to human health	Nutrients Micro-organisms
Geology	Impact to human health	Radium
Sedimentation in estuary including; • Natural occurrence (tidal influence) • Altered flow regimes • Climate variability		Altered hydrology Salinity
Impact of pipeline construction to aquifer and river beds	Altered hydrology	
Climate Change	Sea level rise and salt water intrusion	Salinity
Bat excrement (roofs connected to rainwater tanks)	Risk to human health	Micro-organisms

A consistent message from the stakeholder and community consultation was that water extraction and water quality should be managed together. Water quality and aquatic ecosystem monitoring is currently proposed in the Draft Water Allocation Plan (WAP) for the Tindall Limestone Aquifer (NRETAS 2008). A WAP for the Oolloo Dolostone Aquifer is currently under development and will detail water quality monitoring requirements. The purpose of the monitoring will be to evaluate the effectiveness of the WAPs and the impact of water extraction on beneficial uses.

In general, WAPs manage the risk of impacting water quality through setting sustainable extraction limits (Kelly Howitt pers. comm. NRETAS October 2008).

The WAP also proposes both water quality and aquatic ecosystem monitoring. Specifically, the WAP requires monitoring groundwater quality (from the monitoring bore network) and Katherine River water quality under baseflow conditions at sites between Donkey Camp Pool and Galloping Jacks.

6.4.4 Pressures/Threats to Beneficial Uses - Summary

There are a number of pressures/threats that may impact on water quality and hence Beneficial Uses. The most significant pressures/threats in the Katherine and Daly River catchment are:

- large scale land use change (e.g. land clearing, agricultural production, forestry);
- water extraction;
- mining; and
- fire.

The extent to which these pressures and potential threats are realised will depend largely on land and water management practices. Appropriate management practices can significantly reduce the risk of adverse impacts to water quality and should be encouraged and supported.

6.5 Water Quality Monitoring Requirements and Programs

6.5.1 Reviews of Water Quality Monitoring

Prior to designing a water quality monitoring program, it is important to review past and current monitoring programs. This will:

- Highlight where there are gaps in our understanding and identify where there is limited or no information;
- Identify where additional monitoring can be used to build upon existing data;
- Minimise the risk of duplication;
- Provide opportunities for paired or multi-parameter sites (e.g. a combination of flow, water quality parameters and aquatic biota indicators);
- Provide the opportunity for collaboration and cost sharing with other agencies or groups which can reduce overall costs; and
- Assist to prioritise future monitoring activities.

A review of water quality monitoring in the Katherine and Daly River catchment was undertaken by the Daly Region Community Reference Group (2004). The report states that "there has been no systematic water quality assessment of the rivers and wetlands for river health purposes". Water quality monitoring has generally been short term and project specific, with the majority of data collected in the dry season. There is a lack of data for the wet season and for wetlands in the catchment.

In 1999, Padovan et al. (1999) concluded that most water quality data in the catchment had been collected for potable water supplies, with negligible monitoring for indicators of river health such as nutrients, dissolved oxygen and water clarity. Since then, some specific projects (e.g. Schult et al. 2005) have been undertaken that have helped address this paucity in data.

Monitoring in the catchment is currently undertaken by Northern Territory Government departments, the Power and Water Corporation, research organisations (e.g. Charles Darwin University), consultants and community groups. These activities have their own project specific objectives, and are not part of a broader, integrated catchment monitoring program.

The following sections aim to present, in a common format, a review of the legislative requirements for monitoring, historical monitoring programs, and the community inputs into possible future monitoring programs from the consultation for this project. This aims to be a useful basis for water quality managers in progressing future related water quality monitoring programs in the catchment.

6.5.2 Legislative Water Quality Monitoring Requirements

As identified in Section 5.3, there are a number of Acts that govern both land and water management in the Northern Territory. Since water quality may be affected by natural events and processes as well as land- and water-based human activities, it is particularly important to establish who is responsible for planning and implementing corrective action in the WQ management framework.

The responsibility for administering and implementing the relevant land and water management Acts is shared between four Northern Territory Government Departments and some responsibilities are delegated to Boards and/or Advisory Committees. These departments are:

- Department of Natural Resources, Environment, the Arts and Sport (NRETAS);
- Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR);
- Department of Planning and Infrastructure (DPI); and
- Department of Health and Families (DHF).

Table 8 provides a summary of the Acts, examples WQ monitoring program objectives, the waters they cover and related WQ indicators. As there is no one Department or group solely responsible for implementing land management action to minimise impacts to water quality, the responsibility for decision making with respect to water quality monitoring will often require a collaborative approach.

Table 8 Legislative WQ Monitoring Requirements

Act	Example WQ Monitoring Program Objective(s)	Waters covered	Water Quality Indicators	Comments
Water Act	• Determine ambient water quality and river health in NT waters. • Determine impacts of water allocations on water quality and river health. • Assess impact of licensed wastewater discharges to rivers. • Monitor river discharge and the consumptive use of water.	All NT surface and ground waters, notably waters with declared beneficial uses	Nitrogen and phosphorus, turbidity, light attenuation, conductivity, dissolved oxygen, pH and temperature.	• Principal legislation for water resource and river health management.
Waste Management and Pollution Control Act	• Determine impact of pollution events on water quality and river health.	All NT surface and ground waters	Pollutant concentrations.	• Implementation of the Act seeks to prevent pollution, and provides for penalties for those responsible for pollution.
Environmental Impact Assessment Act	• Determine impacts of approved developments.	All NT surface and ground waters	Water quality indicators relevant to specific developments	• Water quality monitoring can be a condition of development approval.
Soil Conservation and Land Utilisation Act	• Assess effectiveness of soil conservation measures on river sediment loads.	All NT land.	Suspended sediment.	•
Weeds Management Act	• Monitor for the occurrence of aquatic weeds	All NT waters.	Water quality of rivers and lakes can be degraded by aquatic weeds (e.g. dissolved oxygen).	• Monitoring activities supported by public education on aquatic weeds to prevent the release of aquatic weeds to the environment. Territory-wide monitoring not practical but restricted to areas of known infestations.
Pastoral Land Act	• Monitor land condition as a pressure on river water quality degradation.	Pastoral leases.		• Monitoring relevant to assessment of catchment condition, a principle pressure on river water quality.
Bushfire Act	• Monitor the extent and frequency of fires as a pressure on river water quality degradation.	All NT land.		• Satellite derived monitoring of fire scars relevant to assessment of catchment condition.
Water Supply and Sewerage Services Act	• Monitor the suitability of water for potable (drinking) water supply	Licensed water supplies	Microbiological and chemical indicators	• Power and Water Corporation licensed to provide water under the Act.
Agricultural and Veterinary Chemical (Control of Use) Act	• Monitor pesticides in groundwater		Pesticide concentrations	•
Mining Management Act	• Assess impact of mining on river and groundwater quality		Pollutant concentrations	•
Planning Act	• Protect the beneficial uses of rivers and groundwater			• Provides for land-use planning,

6.5.3 Historical Water Quality Monitoring Programs

In December 2008, a survey of stakeholders identified the following recent monitoring programs by different organisations:

NRETAS

- baseline monitoring of dry season water quality in major rivers; and
- baseline monitoring of groundwater.

DRDPIFR

- assessment of contaminant contributions from surface water from Mt Todd Mine site; and
- ongoing regulatory program to assess performance of the Mt Todd Mine surface water and groundwater management.

Power and Water Corporation

- monitoring to check if water quality is fit for public supply and to verify that water treatment processes are adequate; and
- monitoring to check of discharges to rivers in accordance with licence conditions.

TRaCK (Tropical River and Coastal Knowledge research hub; CDU, NRETAS, CSIRO and others)

- monitoring of Daly River and tributary wet and dry season water quality.
- Katherine study that includes water quality dry season assessment.
- Trial of the Framework for River and Wetland Health.

Greening Australia Northern Territory (GANT)

- monitoring water quality as part of the *Grazing for Biodiversity* program and *Water for Life* program.

Katherine Landcare Group, Waterwatch,

- Community water quality and water management education.

Monitoring of river flow has also been undertaken and provides contextual information for water quality data. River flow is determined by gaugings at a network of hydrographic stations which continuously record water level. These stations are operated by NRETAS, and located on the Daly River and its major tributaries. Additional new stations are proposed or under construction to provide discharge information for Water Allocation Plans (WAPs) for the Tindall and Oolloo aquifers. Groundwater levels are also monitored in the catchment by NRETAS.

Table 9 is provided to allow comparison of these programs in a common format to Table 8 above and Table 13 below. While a reasonable amount of water quality monitoring is undertaken in the Katherine and Daly River catchment for both regulatory and research purposes, there is little collaboration between projects and there is no long-term systematic water quality monitoring that can be used to detect changes or trends.

Table 9 Historical WQ Monitoring Programs

Organisation	Example WQ Monitoring Program Objective(s)	Waters covered	Water Quality Indicators	Comments
NRETAS	• Assess dry season river water quality, and groundwater quality. • Measure river discharge (flow) and groundwater table.	• Water quality analysis of new bores, and monitoring of the Oolloo and Tindal aquifers. • Major rivers.	• Nitrogen and phosphorus, turbidity, light attenuation, conductivity, dissolved oxygen, pH, temperature and chlorophyll *a*.	• Project specific activities for river water quality. • River water quality guidelines being developed. • Monitoring river discharge and groundwater levels provides contextual information for water quality monitoring.
CDU & NRETAS	• Determine dry season river water quality. • Determine wet season water quality and material loads. • Trial Framework for River and Wetland Health	• Major rivers in catchment, and perennial streams in the dry season.	• Suspended and volatile sediment, nitrogen and phosphorus, turbidity, conductivity, dissolved oxygen, pH and temperature.	• Specific research activities for the Daly, Douglas and Katherine Rivers, and some smaller perennial streams. Current example: Trial of the Framework for River and Wetland Health in the wet/dry tropics.
DRDPIFR	• Assess contaminant contributions from the Mt Todd Mine site to the Edith River and its tributaries. • Ongoing regulatory 'check monitoring program' to assess performance of the Mt Todd Mine Operator's surface water and groundwater monitoring program	• Surface and ground waters around Mt Todd Mine site.	• Metals, ionic chemistry.	• DRDPIFR environmental monitoring program.
Power and Water Corporation	• Assess whether water quality is suitable for public supply. • Verify that water treatment processes are adequate. • Assess whether discharges to watercourses are in accordance with licence conditions.	• Katherine River Donkey Camp Pool. • Katherine River in the vicinity of Katherine wastewater treatment plant.	• Water chemistry and bacteriological quality.	• Wastewater discharge licence requirement.
Community Groups	• Assess the impact of grazing on river biodiversity. • Community education programs	• Sites around Katherine township and Nyuiai	• On site water quality measurements.	• Water for Life and Landcare group programs. • General water quality monitoring, sometimes for educational purposes.
Primary industry	• Assess impact of agricultural development on groundwater quality	• Surface and groundwaters.	• Nitrogen	• Proposed water quality monitoring

6.5.4 Monitoring of Land Activities that Impact Water Quality

Section 6.3 introduced the pressure-stressor-impact on beneficial uses model as the basis for conceptual understanding of catchment impacts on water quality (and the development of conceptual models in Section 6.6). These models show that it is important to have an understanding of land use and management changes within the catchment to determine what activities are responsible for changes to water quality, either beneficial or detrimental, and assist in informing future management and monitoring decisions.

Hence, a monitoring program that aims to understand the impacts of changes in land uses and management on water quality must both (i) monitor changes in the catchment land uses and management, and (ii) the changes in water quality.

For the former, land monitoring information is available from the NRETAS website detailing rangelands monitoring and soil and land use capabilities[13]. The website also displays a land clearing and environmental impact register. A brief summary of the available data and links to the relevant websites is displayed in Table 10. This information may be useful in monitoring land-based changes in conjunction with water quality monitoring programs.

Geographic Information Systems (GIS) are a useful tool for examining spatial data and the distribution and extent of land use, soil types, vegetation cover, land clearing, etc.. This information can also help to determine possible future changes in water quality and hence the impact of different land use scenarios.

NRETAS Maps is a web-based mapping application that enables the viewing of spatial data related to natural resources, including water resources. The application can be accessed at: http://www.nt.gov.au/nreta/nretamaps/ .

In addition, information regarding pressures/threats to water quality and sources of spatial data useful for examining such pressures/threats was recently collated by van Dam et al. (2008a). The data sources are presented in Appendix 3. Additional information on available spatial data for other pressures/threats not included in this summary is detailed in the Relative Risk Model developed by van Dam et al. (2008b).

[13] Soil and land use capabilities assess the suitability of land for particular land uses.

Table 10 NRETAS Land Monitoring Activities

Act / Guidelines	Monitoring information	Responsibility / Data availability
Water Act	Register of waste discharge licenses issued for activities that include mining and sewage effluent disposal. The actual monitoring results are not available however the register can be used to identify regions where waste discharges are occurring.	NRETAS http://www.nt.gov.au/nretas/environment/waste/register/waste.html
Pastoral Land Act	Rangelands Monitoring Natural resource condition over time including pasture composition. Two tiers of monitoring: • Tier 1 – photo points • Tier 2 – trends and conditions at regional scale using remote sensing data	NRETAS http://www.nt.gov.au/nretas/natres/rangeland/monitor/index.html
Pastoral Land Act *Planning Act* Clearing Guidelines	• Approved pastoral land clearing register • Approved land clearing register Property details, purpose of use post-clearing, date application approved and area of land approved for clearing in hectares (ha) • Clearing Statistics Update 2006 Area of land cleared in a particular catchment.	NRETAS http://www.nt.gov.au/nretas/natres/natveg/register/index.html
Soil Conservation and Land Utilisation Act	Land capabilities mapping and land use mapping Land systems mapping Land unit mapping Advice available concerning erosion and sediment control	NRETAS http://www.nt.gov.au/nretas/natres/soil/landuse/mappingnt.html
Environmental Impact Assessment Act 1994	Environmental impact register with: • Proposals for comment • Current proposals • Projects on hold • Projects already assessed	NRETAS http://www.nt.gov.au/nreta/environment/assessment/register/index.html
Bushfire Act	Meteorological data, topographic data, lightning, recent hotspots, fire scars and time since last burnt. Spatial data can be exported to ESRI spatial software and Google Earth.	North Australia Fire Information http://www.firenorth.org.au/nafi/app/init.jsp Link to bushfire monitoring via NRETAS website at: http://www.nt.gov.au/nretas/natres/bushfires/nafi.html

6.5.5 Community Inputs for Future WQ Monitoring

Stakeholder and community consultation was undertaken as part of this project at a number of locations throughout the Katherine and Daly River Catchment. Inputs were sought on Beneficial Uses as well as matters that could be considered in future monitoring programs, including:

- What are the issues that may harm water quality?
- What places do you want monitored? (i.e. related to the locations you are concerned about)
- Who should monitor water quality?
- How do you want results to be reported?
- What places do you want monitored? (i.e. related to the locations you are concerned about or general places of interest)
- When should monitoring occur?
- How should monitoring be integrated into the current management systems?
- What frequency should monitoring occur?
- Data acquisition; and
- Data storage.

The details of responses to all these matters are in Appendix 4 and summary information is provided and discussed below.

6.5.5.1 Stakeholder and Community Consultation – Sites to Monitor

Stakeholder and community consultation identified a number of locations throughout the Katherine and Daly River Catchment that could be considered in future monitoring programs. These sites and corresponding reasons to monitor these sites are displayed in Table 11.

As discussed previously, sites should also be considered in terms of national, regional or local interest. National interest sites include sites protected under the Federal Governments *Environmental Protection and Biodiversity Conservation Act 1999.* Regional interest would include areas under water allocations plans. Places of local interest may include conservation parks and reserves.

Table 11 Suggested Monitoring Sites in the Katherine and Daly River Catchment

River/Creek	Site	Rationale
Katherine River	Donkey Camp Pool	• monitor suitability for extraction of Raw Drinking Water
	u/s[14] gorge	• establish baseline condition
	d/s[15] gorge	• assess impact of recreational activity on water quality
	d/s township	• assess impact of urban runoff including effluent discharge and stormwater runoff
	Railway bridge d/s of township	• assess impact of urban runoff including effluent discharge and stormwater runoff • provides opportunity for paired site (flow data collected here)
	Knotts Crossing and Galloping Jacks	• monitor Tindall aquifer groundwater discharge to Katherine River.

[14] u/s = upstream
[15] d/s = downstream

River/Creek	Site	Rationale
Katherine Groundwater	Tindall aquifer	• assess impact of leachate on groundwater quality down gradient of waste depot • monitor impact of groundwater extraction on water quality
	Katherine Hot Springs	• assess impact of recreational activity on water quality
Flora River	Kathleen and Djarrung Falls and Noon Springs	• establish baseline condition pristine in comparison to Katherine • assess impact of recreational activity on water quality
Edith River	u/s and d/s of Mt Todd mine	• assess impact of mine and releases from detention ponds •
	Edith Falls	• assess impact of recreational activity on water quality
Edith Groundwater		• assess impact of mining on groundwater • assess impact of leachate from retention ponds to groundwater
Fergusson River	Flat rocks i.e. confluence of the Edith and Fergusson	• assess impact of mining on water quality
Daly River	regular intervals from headwaters to mouth	• monitor changes in water quality throughout the entire catchment.
	all river crossings	• monitor changes in water quality through out the entire catchment • accessible
	d/s confluence Fergusson	• assess extent of impact on water quality due to mining
	d/s Oolloo crossing	• to monitor changes in water quality due to groundwater discharges to the Daly River
Daly Region Groundwater (Oolloo aquifer)		• routine observations from observation and production bores
Douglas River		• assess impact of land use on water quality
Tjuwaliyn [16]		• assess impact of recreational activity on water quality
Cullen River		• representative of relatively undisturbed catchment land use predominately grazing
Green Ant Creek		• assess impact of land clearing
Stray Creek		• assess impact of forestry
Fish River		• representative of pristine catchment (low level of development, very few weeds) monitor baseline water quality
Browns Creek / Bamboo Creek		• monitor baseline water quality • assess impact of weed infestation on water quality
Florina Station (Yuwaiyunn Creek)	Florina Station	• place of interest
Billabongs	Coppermine billabong	• assess impact of abandoned mine site on water quality

[16] Douglas Hot Springs

River/Creek	Site	Rationale
	Ruby Billabong back of Douglas Daly Research Farm	• assess impact land use on water quality

Many of the sites suggested above are based on perceived pressures/threats to water quality. Prior to the establishment of long-term water quality monitoring sites, it is recommended that pilot studies be undertaken to assess whether or not a particular activity is having an impact.

Table 12 displays additional generic suggestions for site selection from stakeholders and the community.

Table 12 Locations to consider monitoring (non-specific)

Other suggestions	Comments
Pre-disturbance	• Obtain before and after water quality information
Control points	• For suitable comparison
Where threats are identified	• urban runoff • monitor impact of dewatering of mine sites
Reference site	• Sites outside of the Katherine and Daly River Catchment
Pristine area	• For comparison to disturbed areas
u/s major confluences	• Detect differences in water quality between major tributaries
Small tributaries	• Detect what is being picked up as runoff travels off land
Previous Waterwatch sites	• Build on existing information.

These recommendations from stakeholders and the community should be considered by resource managers when designing a water quality monitoring program. Some of suggested sites are currently being monitored, e.g. the Mt Todd mine site. Reporting and information dissemination is discussed further in Appendix 6.

6.5.5.2 Monitoring Recommendations

Monitoring recommendations are provided in Table 13 (in a common format to Tables 8 and 9). The table summarises the water quality threats, proposed regions to monitor[17], appropriate water quality indicators and monitoring design types as discussed in Appendix 6. Example WQ monitoring program objectives have also been included to consider in combination with the objectives in Tables 8 and 9. These will hopefully assist as a starting point for planning and designing future water quality monitoring programs, as they relate to threats to Beneficial Uses of water resources.

Prior to systematic monitoring, there is a need to understand processes and interactions. For example, threats such as recreational water use have not been monitored in the Katherine and Daly River catchment and a short-term investigation or pilot study is necessary to fill current information gaps, build conceptual models and determine the significance of the threat.

[17] Specific sites require more detailed planning, consequently only regions are suggested.

Table 13 Stakeholder Monitoring Recommendations for the Katherine and Daly River Catchment

Issue	Example WQ Monitoring Program Objective(s)	Proposed site location	Water Quality Indicators	Comments
Soil erosion from recently cleared land and established land uses (pastoral, agricultural, horticultural and urban)	Assess impact of land-use and management on sediment loads compared to natural loads	Douglas Daly and Katherine regions	Suspended sediment and turbidity	• BACI (before and after control and impact) design • Duration: several wet seasons • Best measure of impact suspended sediment amount (load) which requires flow data as well • Impact site immediately downstream (d/s) cleared area • Ability of monitoring to detect the impact of land clearing will reduce with distance downstream of the impact area • Needs to be accompanied by monitoring of catchment condition (e.g. area of catchment burnt, vegetation cover)
Pollutants from agricultural horticultural and urban land uses (excluding sediment)	Assess impact of land-use and management on river nutrient and pollutant concentrations compared to natural loads	Douglas Daly and Katherine regions	Nutrients (nitrogen and phosphorus) Pesticides Chlorophyll Micro-organisms	• BACI (before and after control and impact) design • Duration: several years • Wet season concentrations and loads of nutrients and pesticides in rivers • Dry season concentrations of soluble nutrients and pesticides in groundwater and river water • Impact site immediately downstream (d/s) agricultural / horticultural areas • Needs to be accompanied by monitoring of catchment land use and management (e.g. amount and location of nutrient and pesticides applied) • Chlorophyll measured in rivers during dry season • Concentrations of micro-organism indicators of faecal pollution in water used for drinking and swimming • Ability of monitoring to detect the impact of land clearing will reduce with distance downstream of the impact area
Reduced dry season flows due to water extraction	Assess impact of reduced dry season flow on river water quality	Douglas Daly and Katherine regions	Temperature pH Water clarity (e.g. turbidity) Dissolved oxygen (DO) Nutrients	• Understanding of relationship of flow through river pools (residence time) and water quality required • Knowledge of impact of extraction on river flow required from Water Allocation Plan (WAP) monitoring • Duration: Several dry seasons • Profiles of temperature, pH and DO in pools • Nutrient and algae (chlorophyll) concentration • Needs to be accompanied by flow data

Issue	Example WQ Monitoring Program Objective(s)	Proposed site location	Water Quality Indicators	Comments
Pollutants from mining activities (past and current)	Assess impact of mining on river water quality	D/s of mines sites	pH Heavy metals Non-metallic inorganic ions	• BACI (before and after control and impact) design • Duration: Wet and dry seasons • Concentrations of heavy metals and non-metallic inorganics, pH in groundwater and rivers
Soil erosion caused by catchment burning	Assess impact of soil erosion from catchment burning on wet season water quality		Suspended sediment Nutrients	• Incorporated into soil erosion from cleared land detailed above • Include impact on surface runoff and nutrients
Pollutants from recreational use	Assess impact of recreational use on dry season water quality	Katherine Gorge, Katherine Hot Springs, Daly River	Hydrocarbons (from outboard motors and sunscreen), Suspended sediment (from wave action caused by boats) Micro-organisms indictors of faecal pollution Litter	• Short-term site-specific studies required to understand the nature and extent of the impact required before any long-term monitoring • BACI (before and after control and impact) design • Conducted during tourist season

6.6 Conceptual Models

As discussed above, the substantial work from this project in developing conceptual models of the key pressures/threats in the catchment (see Section 6.4) is presented in this Section to assist in both designing monitoring programs, as well as assisting water quality management in the catchment.

The section firstly describes the usefulness of conceptual models to inform monitoring programs, then it presents the conceptual models based on the identified pressures/threats to Beneficial Uses in the Katherine and Daly River catchment.

Conceptual models are visual tools useful for displaying a large amount of information and complex interactions. As stated by Gross (2003): *Well constructed conceptual models provide a scientific framework for the monitoring program and justification of the choice of indicators*.

Conceptual models can take a variety of forms and there are numerous methods of displaying conceptual models such as pictorials, tables and matrices, flow diagrams, and box and arrow diagrams.

As indicated in Section 5.4.1, conceptual models serve numerous purposes and can be used to:

- educate and facilitate communication of water quality issues;
- identify important linkages and interactions in catchment and rivers;
- assist in identifying gaps in our current understanding;
- identify priority water quality issues for management and possible solutions;
- identify areas where further research is required to improve our understanding; and
- provide information regarding appropriate pressures and water quality indicators to monitor.

Section 6.1 then showed the role of conceptual models in the establishment of monitoring program objectives by helping understand how a system responds to the specific pressure/threat being examined.

The conceptual models in this Section, developed in the project, are provided to assist implementation of the Monitoring Framework for the Katherine-Daly River catchment. They are intended to be used as a starting point to inform future water quality monitoring programs.

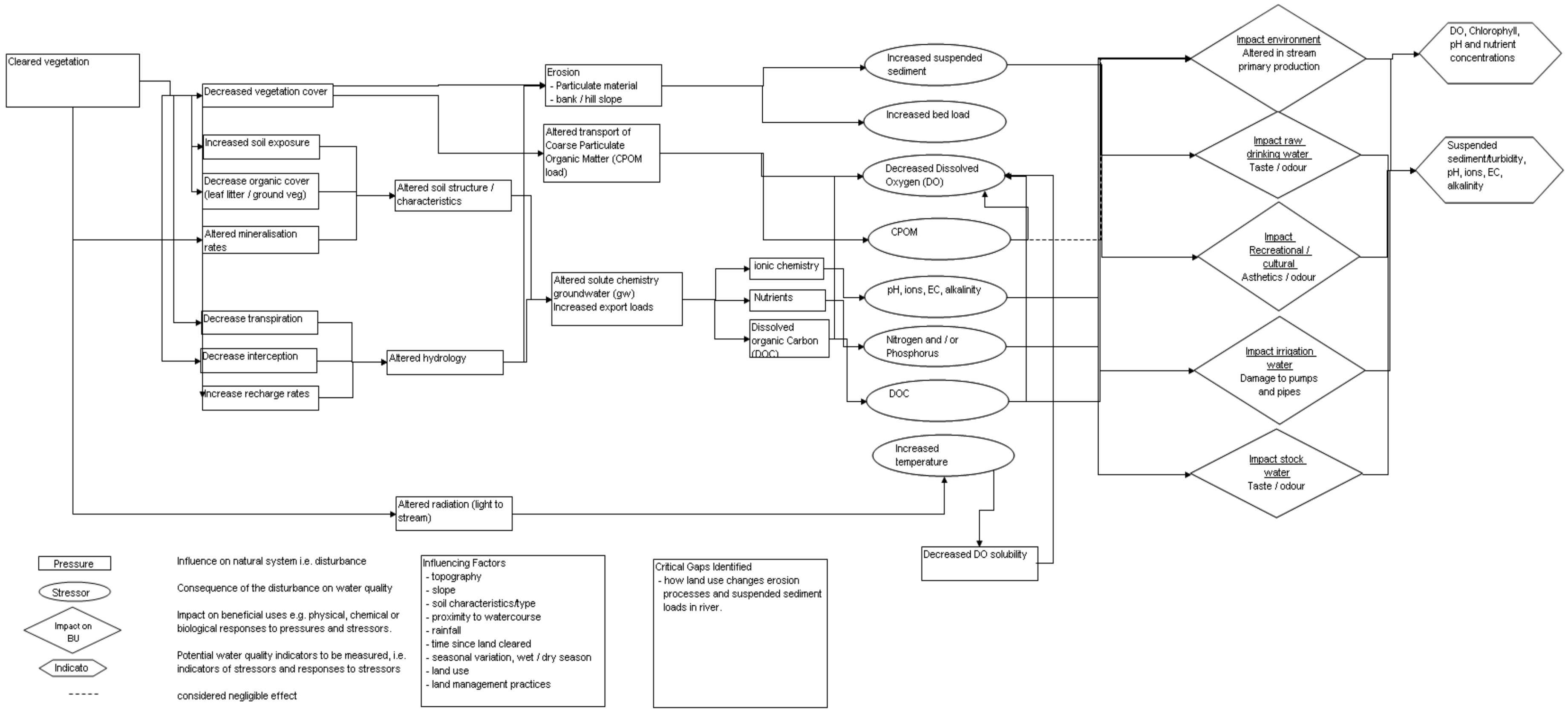
As indicated above, while the Monitoring Framework focuses on water quality, its components are also applicable to the planning and implementation of a broader program of river health monitoring. If river health monitoring is to be undertaken, then additional conceptual models will need to be constructed.

The conceptual models contained within this Section are based on the Pressure-Stressor-Impacts on Beneficial Uses model for environmental monitoring, described in Section 6.3

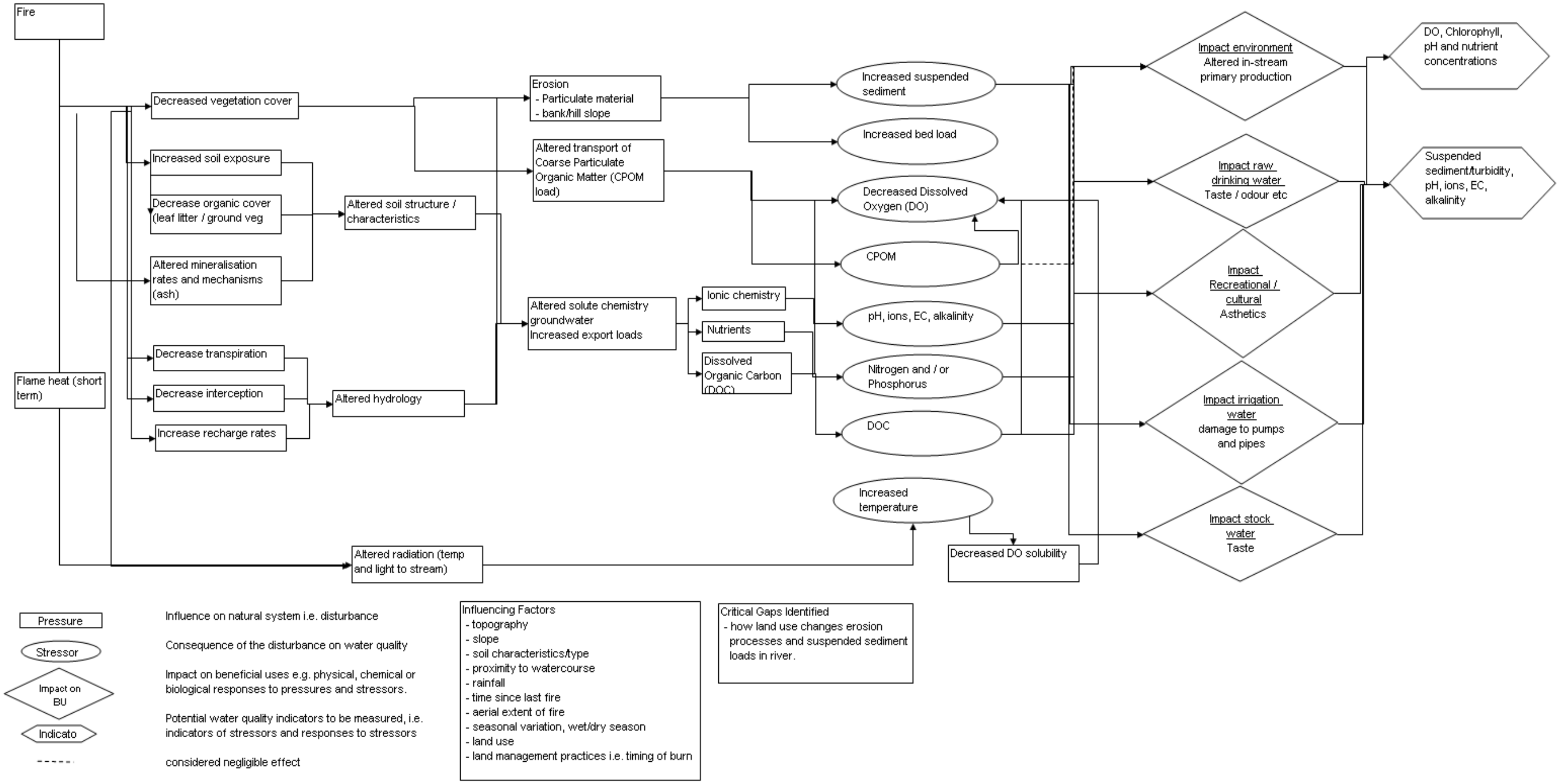
The conceptual models developed are based on the key identified pressures/threats to beneficial water uses (Section 6.4). The models are as follows:

- land clearing (Section 6.6.1);
- fire (Section 6.6.2);
- water extraction (Section 6.6.3);
- application of pesticides (Section 6.6.4);
- application of high nutrient containing materials (Section 6.6.5);
- mining (Section 6.6.6); and
- early wet season runoff events and floods (Section 6.6.7).

6.6.1 Conceptual Model - Land Clearing

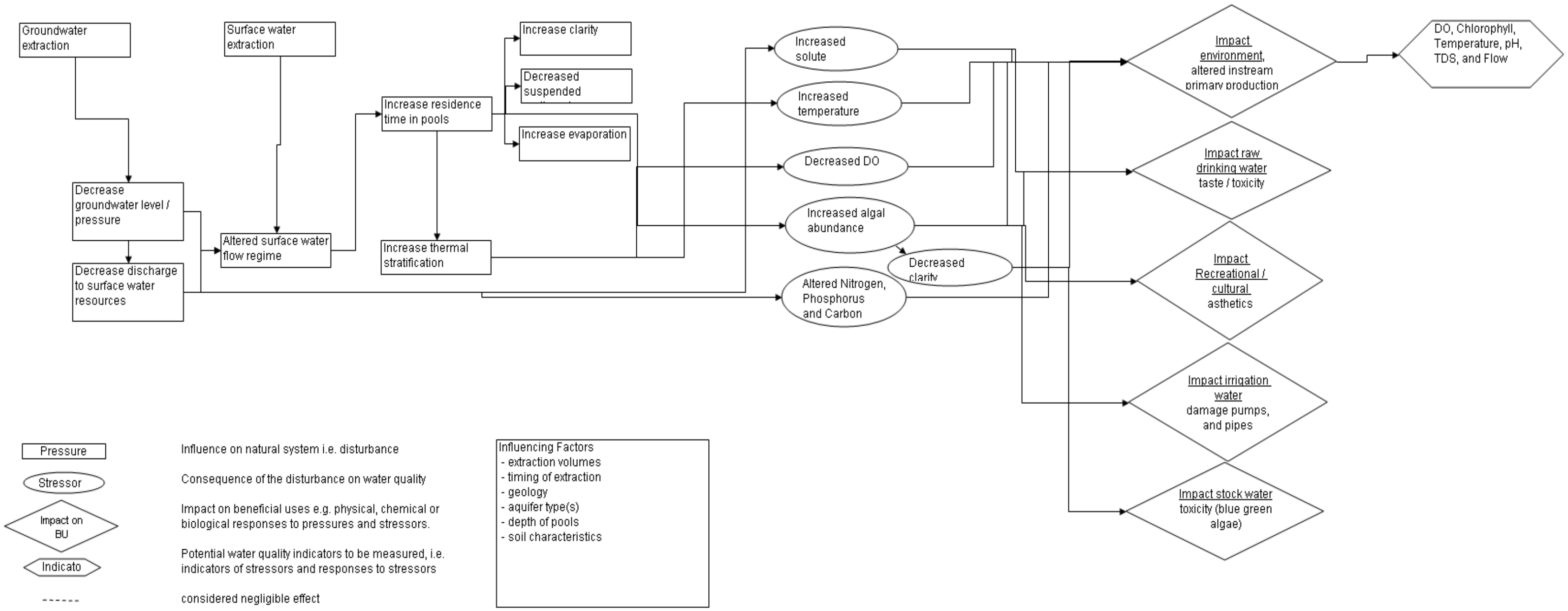


6.6.2 Conceptual Model - Fire

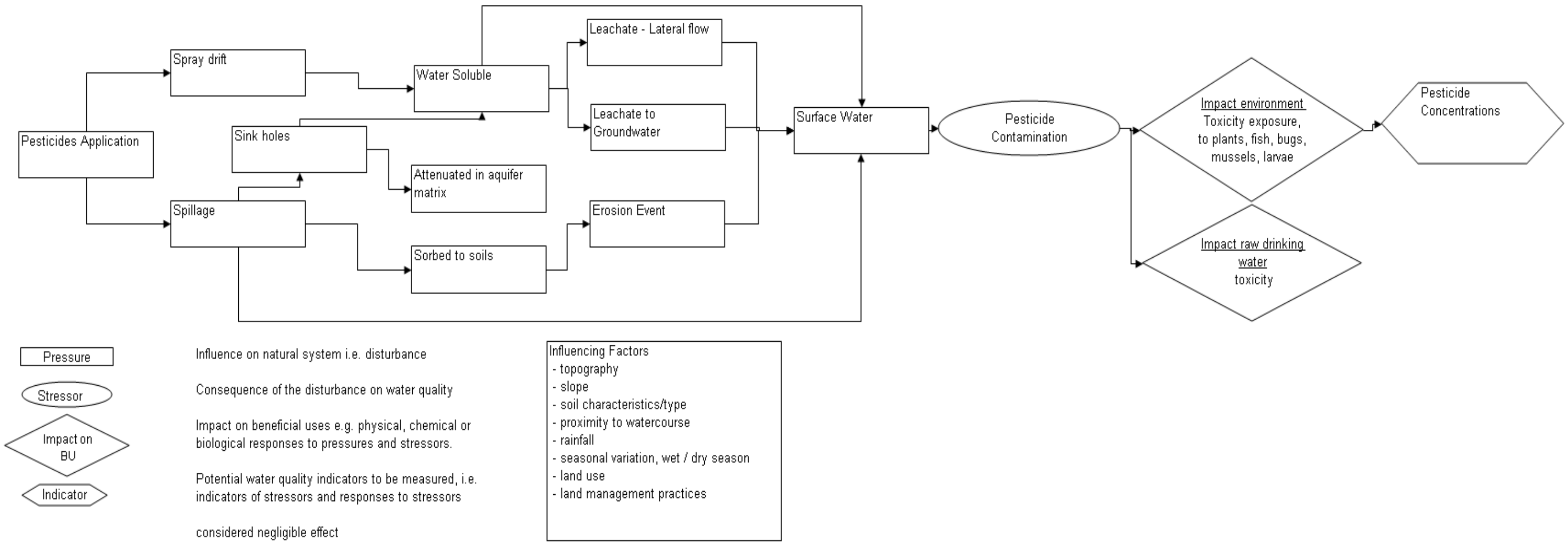


6.6.3 Conceptual Model - Water Extraction

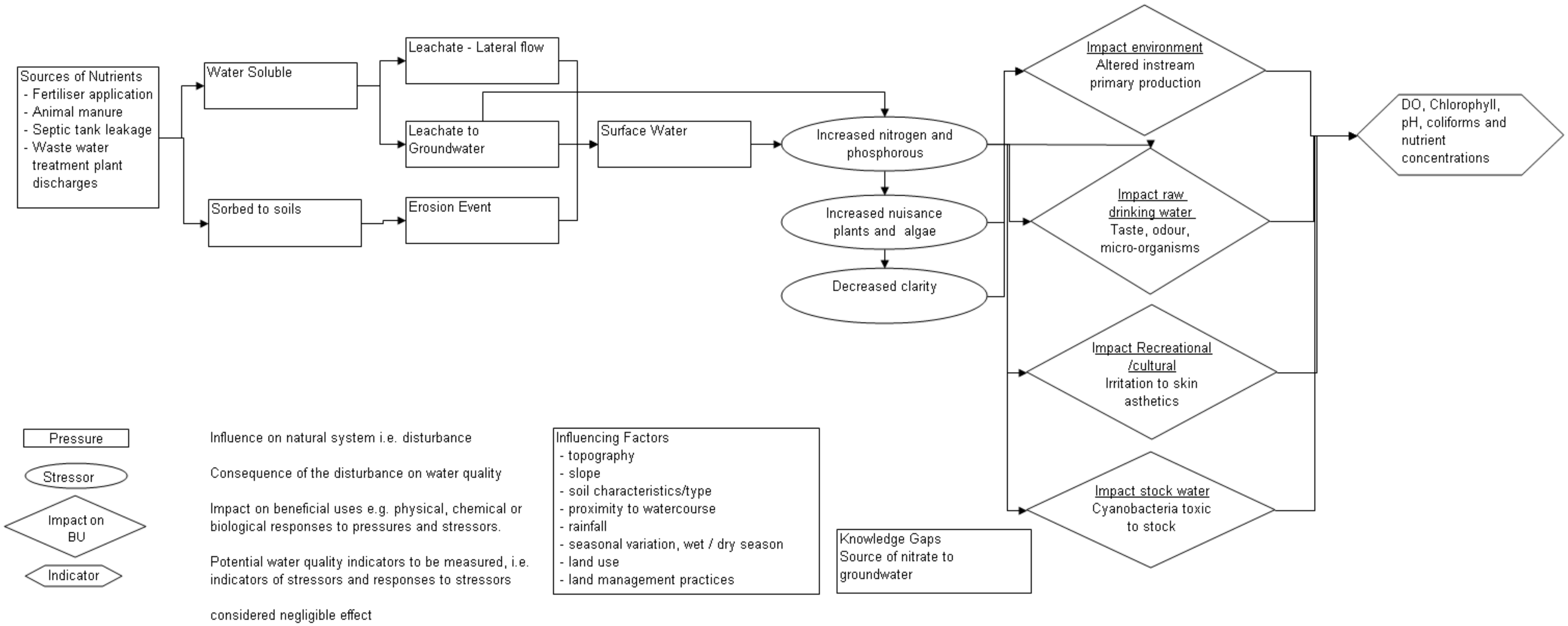
▪



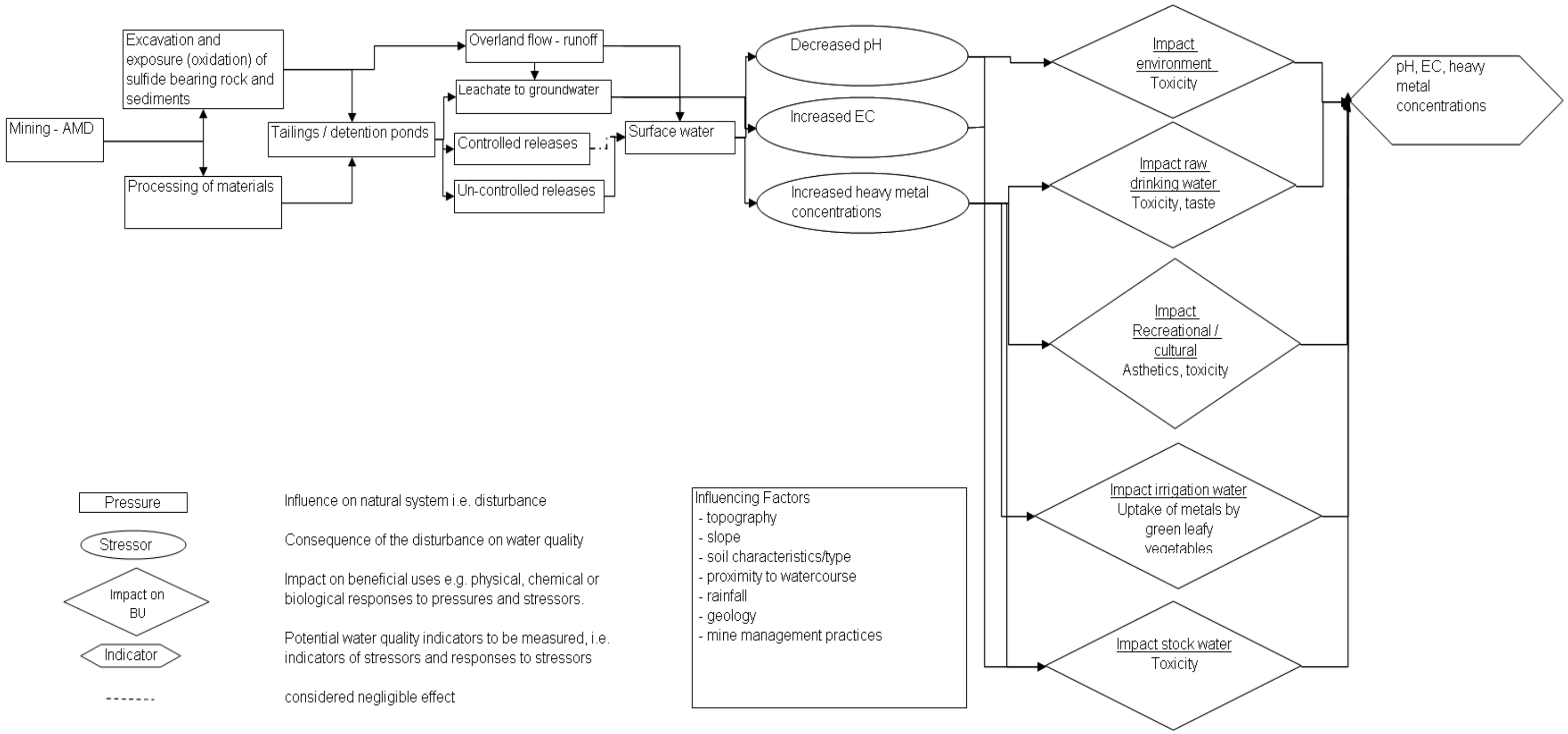
6.6.4 Conceptual Model - Application of Pesticides



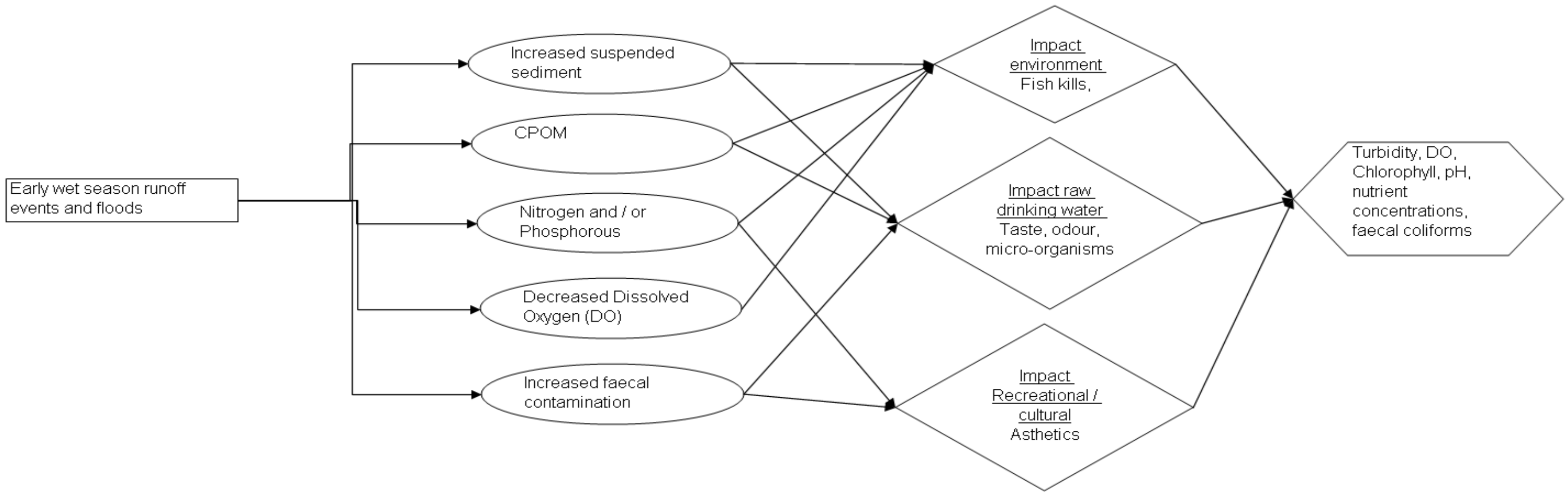
6.6.5 Conceptual Model - Application of High Nutrient Containing Materials



6.6.6 Conceptual Model - Mining



6.6.7 Conceptual Model - Wet Season Runoff/Floods



Pressure	Influence on natural system i.e. disturbance
Stressor	Consequence of the disturbance on water quality
Impact on BU	Impact on beneficial uses e.g. physical, chemical or biological responses to pressures and stressors.
Indicator	Potential water quality indicators to be measured, i.e. indicators of stressors and responses to stressors
-------	considered negligible effect

Influencing Factors
- topography
- slope
- soil characteristics/type
- proximity to watercourse
- rainfall
- time since land cleared
- land use
- land management practices

6.7 *Stakeholder and community involvement in water quality monitoring*

Involving stakeholders and the community in water quality monitoring programs has a number of benefits such as improving knowledge and understanding of water quality issues in the community, and can be a cost effective means of collecting valuable information.

Issues with community involvement in water quality monitoring, as reported by stakeholders and community members in the Katherine and Daly River catchment are:

- A lack of continuity of funding;
- High turnover of project officers, which can be partly contributed to funding uncertainties; and
- Priority given to educational objectives over water quality monitoring.

Willingness was expressed by stakeholders and community members, including indigenous communities, to be involved in water quality monitoring. However, their willingness was dependent on a tangible end use for their efforts, i.e. the data that they collect is actually used and results are reported back to stakeholders and community members.

With adequate communication and collaboration between community groups and government agencies prior to the inception of future community monitoring programs, there is no reason why information collected by the community can not be used for assessing resource condition.

Willing community members and groups are a significant resource. Using community collected water samples and water quality data can be extremely cost effective, provided community members have adequate training, ongoing support and a clear understanding of what information they need to collect. This is a particular advantage in the Katherine and Daly River catchment, given its size, remoteness and inaccessibility.

There are many successful examples throughout Australia of the use of community collected data in both assessing the condition of water resources and informing management decisions. For example, irrigators in the Angas Bremer region of South Australia collect water samples from approximately 200 water bores. The results showed increasing salinity suggesting that the current groundwater extraction limit exceeded the freshwater recharge rate to the aquifer. Allocation reductions are anticipated for the next water allocation plan with support from many of the irrigators.

Indigenous groups expressed a desire to be actively involved in water quality monitoring and, during the public consultation phase, it was suggested that a *Water Ranger* program could be established similar to the existing *Land Management Ranger* programs, but with a focus on water quality. Once again, provided adequate planning prior to adoption of such a program is undertaken, there are considerable economic, social and environmental benefits that could be achieved by such a program.

For summaries documenting the responses of the public consultation phase refer to Appendix 3.

7 Future Directions

7.1 Next Steps

The Monitoring Framework includes the following steps as a foundation for designing WQ monitoring programs for the Katherine and Daly River catchment that can be incorporated into an adaptive management system:

1. Identify and work collaboratively with other groups who may benefit from or require similar information;

2. Clearly define and document agreed objectives;

3. Review and further develop the conceptual models to ensure the most appropriate indicators are selected;

4. Review existing data and current monitoring programs
    a) Is there already adequate information?
    b) Is further information necessary?
    c) Can existing information be built upon?
    d) Are there existing programs that can be incorporated?

5. Document proposed design in consultation with other groups and seek agreement on the proposal. Design consideration should include:
    a) Who is responsible for monitoring what parameters? Will or can it include stakeholders and community groups?
    b) What equipment will be required?
    c) What sites should be monitored? Consideration may include the following questions:
        - Are there suitable control and impact sites?
        - Is the site representative of other sites and is the information transferable?
        - Has the surrounding land use been taken into account?
        - Are there existing monitoring sites for which flow data are available?
        - Are there sites of national, regional or local interest?
    d) What is the duration of the monitoring? For example,
        - Is the objective of the monitoring, long-term trend analysis or short-term compliance or impact assessment monitoring?
    e) What level of impact will monitoring detect (i.e. what is the threshold level of detection)?
    f) What frequency of sampling is required? This will depend on the objectives and corresponding indicators selected.
    g) How will results be collected?
    h) How will results be analysed?
    i) What quality assurances and controls will be put in place?
    j) Where will the data be stored?
    k) What is the most cost-effective monitoring program?

6. Document cost estimates and resourcing requirements and seek agreement on financial and in-kind contributions from program partners.

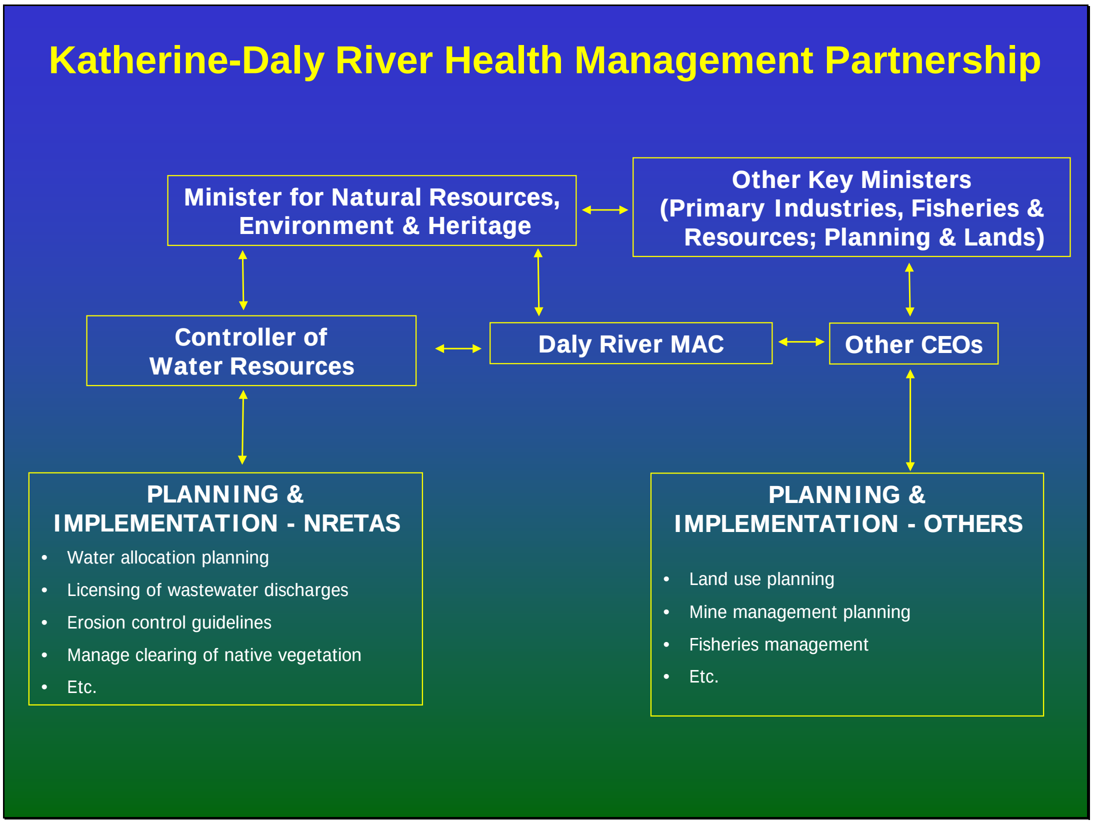
The logical next steps can be simplified into WQ managers agreeing on the priority WQ monitoring objectives (i.e. step 2 above) and then seeking technical input into the design and costing of WQ monitoring programs to achieve those objectives (i.e. steps 5 and 6). This is an iterative process as there is always the budget limitations to be considered and programs may need to be staged (including pilot programs if necessary) to achieve the most cost effective WQ monitoring program(s) for the catchment.

This raises two issues for WQ managers to consider:

I. What is the best process for WQ managers to work together as this iterative WQ monitoring program design is progressed and then implemented and reviewed? and
II. How to best engage the relevant technical experts initially in the design and costing of WQ monitoring programs to meet the priority WQ monitoring objectives that WQ managers determine, then in periodically in evaluating and reporting on the outcomes of the programs and designing subsequent revisions?

Figure 6 shows graphically the current situation for the key WQ managers involved in WQ monitoring in the catchment (as described in Section 5) which could be involved in a partnership to progress WQ monitoring programs in the catchment.

Figure 6 Katherine and Daly Rivers WQ Management Partners



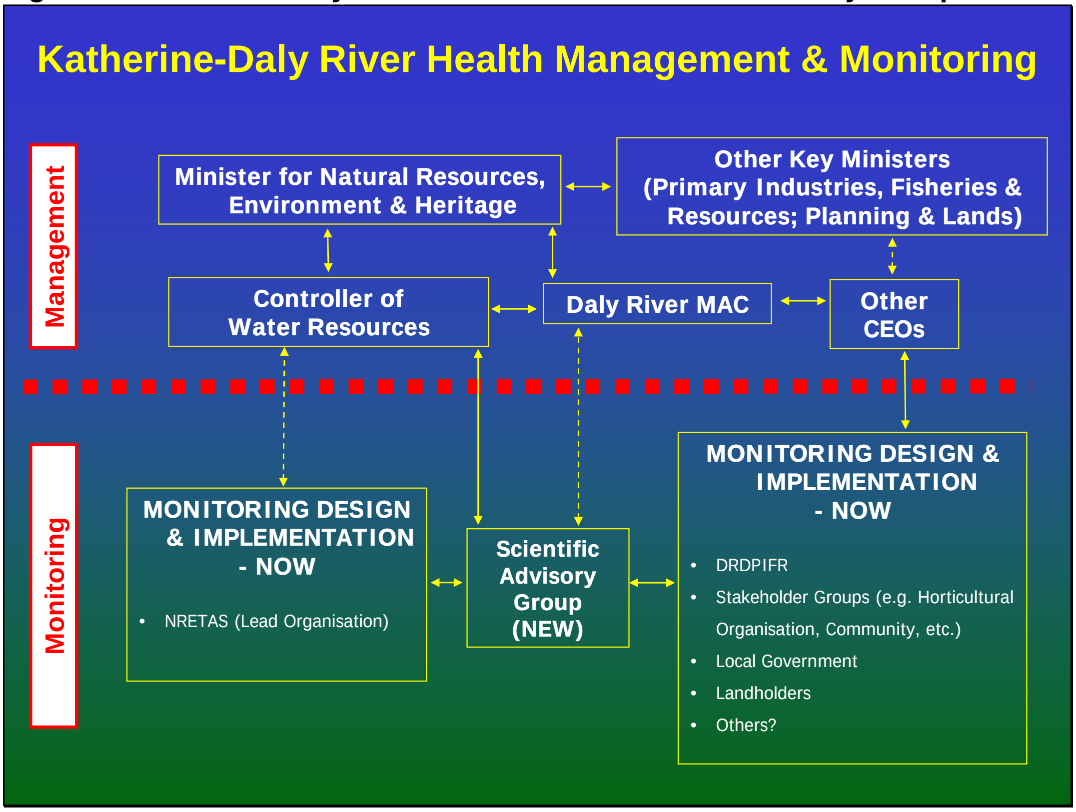
These key WQ managers could meet to discuss the outcomes of this project and agree on:

a) the priority WQ monitoring objectives;
b) the process to set up a technical/scientific WQ Advisory Group to initially assist with the design and costing of WQ monitoring program(s) to address the priority WQ monitoring objectives and then to subsequent provide

scientific advice as needed by the WQ managers. Figure 7 graphically shows the role of this Scientific Advisory Group.

c) Consider declaration of the Beneficial Uses for the Katherine and Daly River Catchment developed in this project. Then set water quality objectives based on the default values of the ANZECC Guidelines, unless water quality objectives are already defined[18].

Figure 7 Katherine-Daly River Catchment Scientific Advisory Group



7.2 *Adaptive Management*

The WQ Management Framework (Figure 3) is an adaptive management process, which is “a systematic process for continually improving management policies and practices by learning from the outcomes of operational practices”. Initial management strategies and processes developed as a result of the first iteration of the process should ideally be subject to ongoing revision, refinement and updating. The review part of the cycle is about gathering up the lessons learnt during each cycle so that they can be fed back into subsequent iterations.

An immediate priority of the “review” process is to determine if the current management strategies are actually achieving the stated WQ objectives or targets[19]. This involves assessment of monitoring information to determine trends in system condition, hence the importance of the Monitoring Framework and the resultant

[18] Water Quality objectives (resource condition targets) for nutrients have been recommended for the Daly River and are detailed in Schult et al. (2007).
[19] Figure 8 is an example of an adaptive management process for this task for WQ managers to consider and further develop as necessary for use in this catchment.

monitoring programs. If the agreed management actions appear to be having little or no effect in improving condition, then there is an obvious need to reassess these actions and the various modelling assumptions that underpin them (as shown in Figure 8)

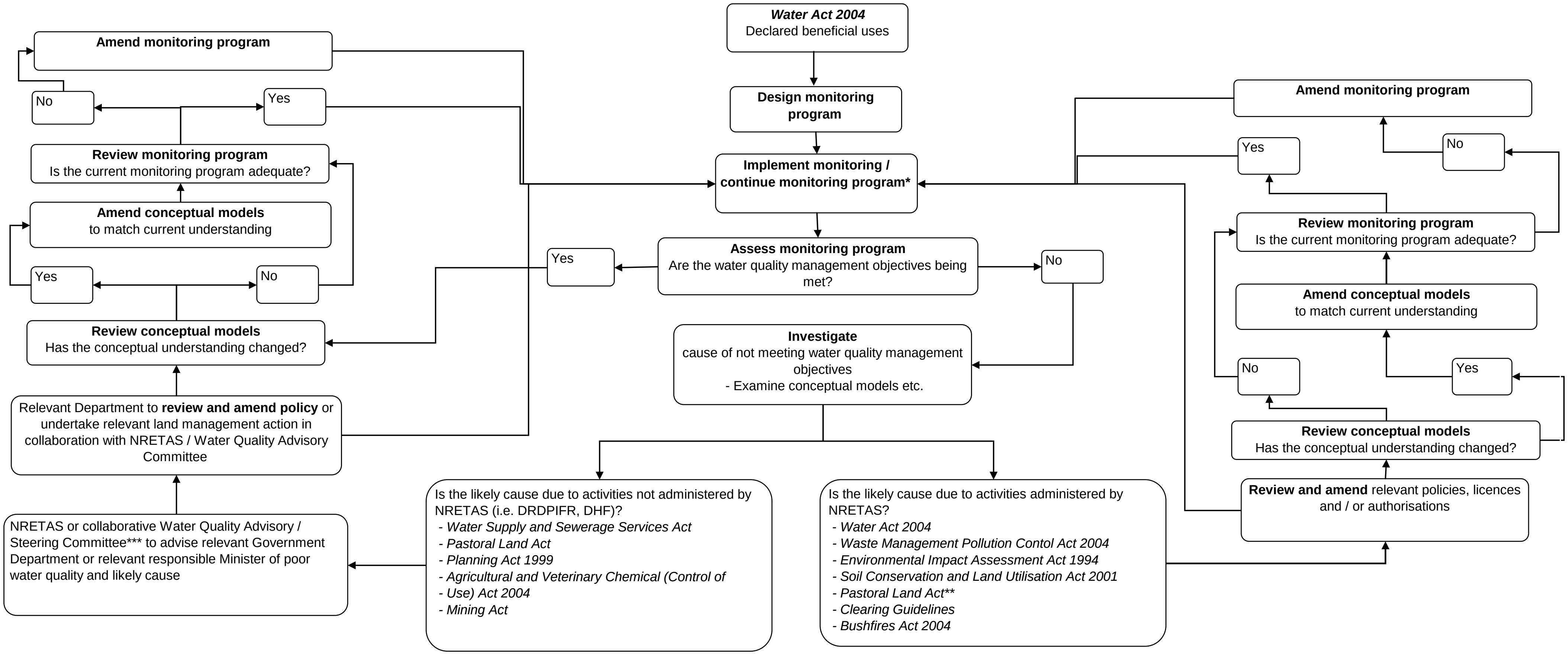
However, the review process is broader than just assessing achievement or otherwise of WQ objectives or targets. Ideally it will cover all aspects of the WQ management cycle, including:

- Current understanding – has our understanding of current condition and system processes improved and if so, how might this influence our indicators, WQOs/targets and management action priorities? Are there new issues that require attention in the strategy?
- Community involvement – were these processes adequate during the first cycle and if not, how can they be improved?
- Beneficial uses / environmental values and management goals – has the communities' current and desired values and uses for the waterways changed?
- WQ Guidelines – are better local guideline numbers available?
- WQ objectives/targets – do these need to be updated based on any changes above?
- Predictive models – have these improved to the point that we can better quantify our management action needs?
- Management actions – have these actually been completed? What changes to actions and processes of efficiently achieving actions are needed?
- Monitoring – are there more cost effective ways of undertaking monitoring?

Information on all these aspects needs to be gathered together in a coherent form and then fed into the revised management strategy. Nonetheless, changes and updates to any/all components can be made at any time (e.g. better processes, actions to address new issues such as new developments in the catchment).

The frequency of major reviews and updates will to some extent be dependent on circumstances in the catchment but they should probably be undertaken at least every 4 years. These reviews should be programmed in as part of the management strategy rather than left to chance. Without a strong review process, there is a significant risk that strategies will lose momentum and eventually become ineffective.

Figure 8 Adaptive Management example – compliance with WQ objectives



* Continued monitoring is essential in order to detect changes over time, determine the effectiveness of different policies and land managment practices and impove conceptual understanding.

** *Pastoral Land Act* - the Minister for Natural Resources, the Pastoral Lands Board and Leesees are responsible to ensure land is managed sustainably.

*** Water Quality Advisory / Steering Committee may be established pursuant to the *Water Act*. It should include representatives from both Government and Non-government Organisations

8 Glossary

Adaptive management – is a structured, iterative process of optimal decision making in the face of uncertainty, with the aim to reduce uncertainty over time via system monitoring.

Anthropogenic – caused or produced by humans

Attenuation - a natural process where concentrations of contaminants are reduced to background levels through physio-chemical and microbiological processes.

Beneficial Uses / Environmental Values - particular values or uses of the environment that contribute to public or private benefit, welfare, safety or health. There may also be particular environmental qualities which the community wishes to preserve.

Diffuse pollution – pollution that can not be directly related to one particular source

Environmental Values / Beneficial Uses - particular values or uses of the environment that contribute to public or private benefit, welfare, safety or health. There may also be particular environmental qualities which the community wishes to preserve.

Groundwater / Underground water – water within aquifers accessed via bores and springs.

Indicators – a descriptor of water quality.

Management objectives – a goal or set of goals that one is trying to achieve.

Non- point source pollution - pollution that can not be directly related to one particular source. It is typically related to urban and agricultural land use where inputs occur over a wide area.

Parameter - measurable or quantifiable characteristic of water

Point-source pollution – pollution that is directly related to one particular source such as discharge from a waste water treatment plant

Policy - a defined course of action to achieve desired outcomes. Policy may or may not be regulatory.

Pollution - An unusually high amount of a chemical in a water body that has the potential to cause an environmental impact.

Riparian vegetation – vegetation occurring on banks and adjacent to streams

Stakeholder - a person or group with an interest in water quality. Examples may include industry representatives, government departments, community groups, environmental groups, research bodies, land owners, indigenous groups and traditional owners.

Surface water – water in rivers, streams, creeks and billabongs

Underground water / groundwater - water within aquifers accessed via bores and springs.

Water quality guidelines - parameters or maximum levels of contamination which can be tolerated based on a combination of scientific evidence and informed judgement.

Water quality objectives - the set of WQ guidelines that satisfy all Beneficial Uses selected for a particular water resource.

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10 Appendices

10.1 Appendix 1 Water Quality Governance Arrangements[20]

AUSTRALIAN WATER GOVERNANCE 2006

WATER QUALITY MANAGEMENT IN THE NORTHERN TERRITORY

- Drinking water management
- Recycled water management
- Environmental health management

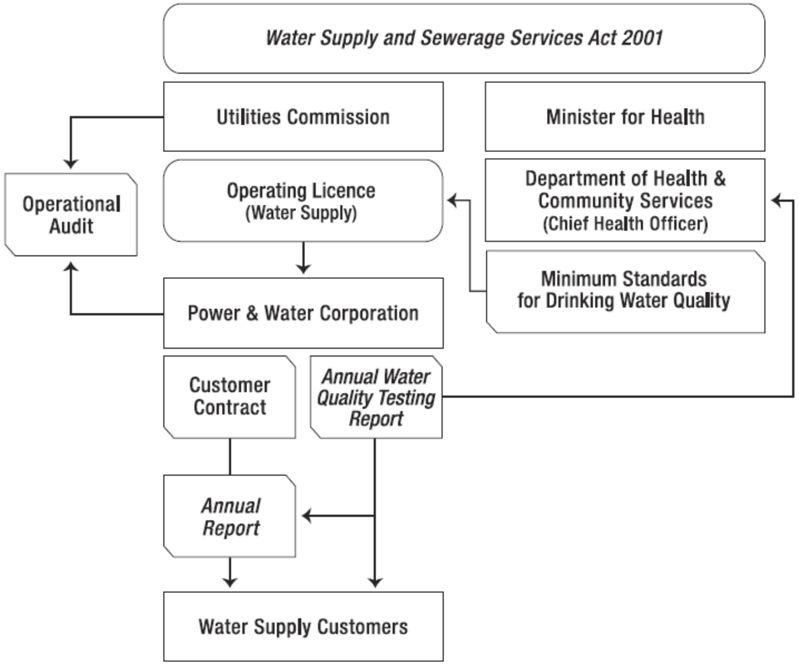
Australian Government

National Water Commission

[20] Source: National Water Commission Australian Water Governance 2006. Australian Government. Accessed on 23 November 2008 http://210.247.163.235/nwi/water_governance/pdfs/NT_WaterQualityManagement.pdf

DRINKING WATER MANAGEMENT

This diagram illustrates how drinking water quality is managed in the Northern Territory.



DRINKING WATER MANAGEMENT

LEGISLATION / REGULATION / STATUTORY INSTRUMENTS / LICENCES

Water Supply and Sewage Services Act 2001

Provides for a system of licensing for water supply services by the Utilities Commission. Under the Act, minimum standards for drinking water quality must be met and may be specified by the Minister for Health. The methods for monitoring compliance with the minimum standards are approved by the Chief Health Officer. **www.nt.gov.au/dcm/legislation/current.html**

Operating Licence (Water Supply)

Power and Water requires a licence to supply water under the *Water Supply and Sewerage Services Act 2001*. The Corporation is required to meet minimum standards for drinking water quality that may be specified by the Minister for Health. These currently refer to the *Australian Drinking Water Guidelines (2004).*

GUIDELINE / REPORT / REVIEW / AUDIT / PROGRAM

Customer Contract

Under the *Water Supply and Sewerage Services Act 2001*, Power and Water is required to develop a customer contract that sets out the rights and responsibilities of customers regarding the provision of water supply services. A summary of the contract, in a form approved by the Utilities Commission, must be distributed to each customer.

Operational Audit

Under its licence, Power and Water is required to undertake an annual operational audit, including their compliance to specified drinking water quality standards.

Annual Water Quality Testing Report

Power and Water routinely tests water quality by taking samples and testing for microbiological, physical and chemical contamination, to ensure drinking water complies with standards in the *Australian Drinking Water Guidelines (2004).*

Based on this water quality testing, Power and Water is required to report to the Utilities Commission, the Chief Health Officer and customers and other parties on their compliance with minimum standards for drinking water quality standards specified in their licence.

Annual Report

Under their Customer Contract, Power and Water is required to produce an annual report on the operations and performance, which may include drinking water quality performance.

Operational Audit

Under its licence, Power and Water is required to undertake an annual operational audit including their compliance to specified drinking water quality standards.

MINISTER / DEPARTMENT / AUTHORITY / ORGANISATION / INDIVIDUAL

Minister for Health

Responsible for the provision of health-related services in the Northern Territory. The Minister is supported by the Department of Health. The Minister may specify minimum standards for drinking water quality to which water supply licence holders must comply under the *Water Supply and Sewage Services Act 2001.*

Department of Health and Community Services (Chief Health Officer)

State government agency responsible for the provision of services to maintain and improve the health of constituents and communities of the Northern Territory. In consultation with Power and Water, the Department of Health and Community Services has set the standards for drinking water quality under the *Water Services and Sewerage Supply Act 2001,* as per the *Australian Drinking Water Guidelines (2004).*

DRINKING WATER MANAGEMENT

The Chief Health Officer is a position within the Department of Health and Community Services with regulatory responsibilities under the *Public Health Act 2005*. The Chief Health Officer approves the methods to monitor compliance with minimum drinking water standards and receives compliance reports from water supply licence holders and performs other statutory functions under the *Water Supply and Sewerage Services Act 2001*.

Power and Water Corporation

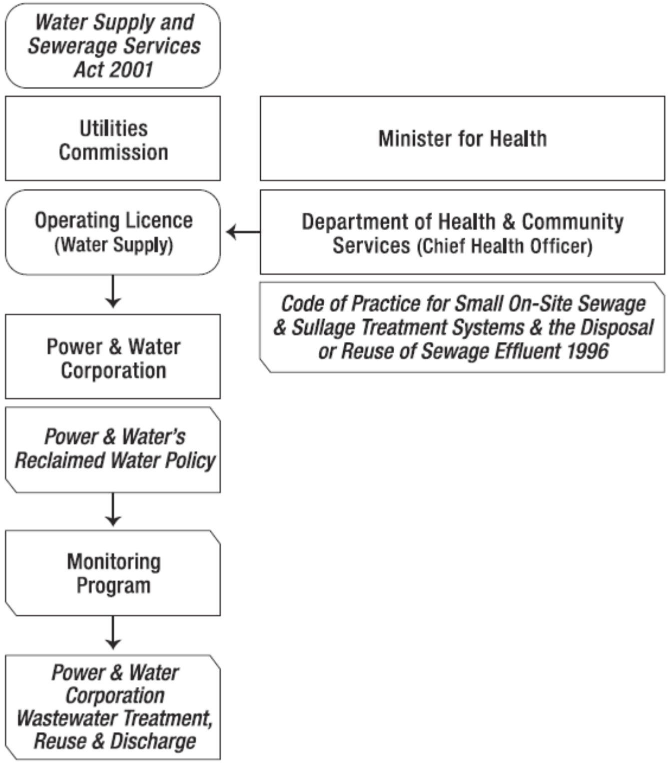
Statutory state-owned corporation that provides water supply, sewerage services and electricity to customers throughout the Northern Territory. **www.nt.gov.au/powerwater**

Utilities Commission

Independent industry regulator that has responsibility for the regulation of water supply services including licensing, and monitoring the performance of operators against licence conditions.
www.utilicom.nt.gov.au

RECYCLED WATER MANAGEMENT

This diagram illustrates the governance arrangements for recycled water use in the Northern Territory.



RECYCLED WATER MANAGEMENT

LEGISLATION / REGULATION / STATUTORY INSTRUMENTS / LICENCES

Water Supply and Sewage Services Act 2001

Provides for a system of licensing for water supply and sewerage services by the Utilities Commission. **www.nt.gov.au/dcm/legislation/current.html**

Operating Licence

Power and Water requires a licence to supply water and sewage services under the *Water Supply and Sewerage Services Act 2000*. Power and Water is required to meet minimum standards for quality of recycled water, which may be specified by the Minister for Health.

NON-STATUTORY DOCUMENTS AND ACTIVITIES

Power and Water's Reclaimed Water Policy

A non-statutory document developed by Power and Water in conjunction with the Department of Health and Community Services, to promote use of reclaimed water, but includes provisions to ensure that public health is protected. The policy states that reclaimed water quality and monitoring will be consistent with the *National Water Quality Management Strategy Guidelines for Sewerage Systems – Use of Reclaimed Water 2000.*

Monitoring Program

In conjunction with the Department of Health and Community Services, Power and Water will continue to monitor the health risks associated with the use of reclaimed water, in particular the results of research associated with unrestricted and indirect potable reuse.

The level of treatment, reclaimed water quality and monitoring program will be in line with the *National Water Quality Management Strategy Guidelines for Sewerage Systems – Use of Reclaimed Water (2000).*

Power and Water Corporation Wastewater Treatment, Reuse and Discharge

This is an annual report produced by Power and Water, as required by their Waste Discharge Licence. It details the quality of reclaimed water supplies.

Code of Practice for Small On-Site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent 1996

A non-statutory document produced by the Department of Health and Community Services that provides guidelines and options for on-site effluent reuse for septic tanks and the conditions imposed on each reuse option. The document is consistent with the *Draft Guidelines for Sewerage Systems – Use of Reclaimed Water 1996.*

MINISTER / DEPARTMENT / AUTHORITY / ORGANISATION / INDIVIDUAL

Utilities Commission

Independent industry regulator set up as an administrative unit of Northern Territory Treasury. The Commission is responsible for the regulation of water supply and sewage services, including licensing, and monitoring the performance of operators against licence conditions. **www.utilicom.nt.gov.au**

Minister for Health

Responsible for the provision of health related services in Northern Territory. The Minister is supported by the Department of Health and Community Services.

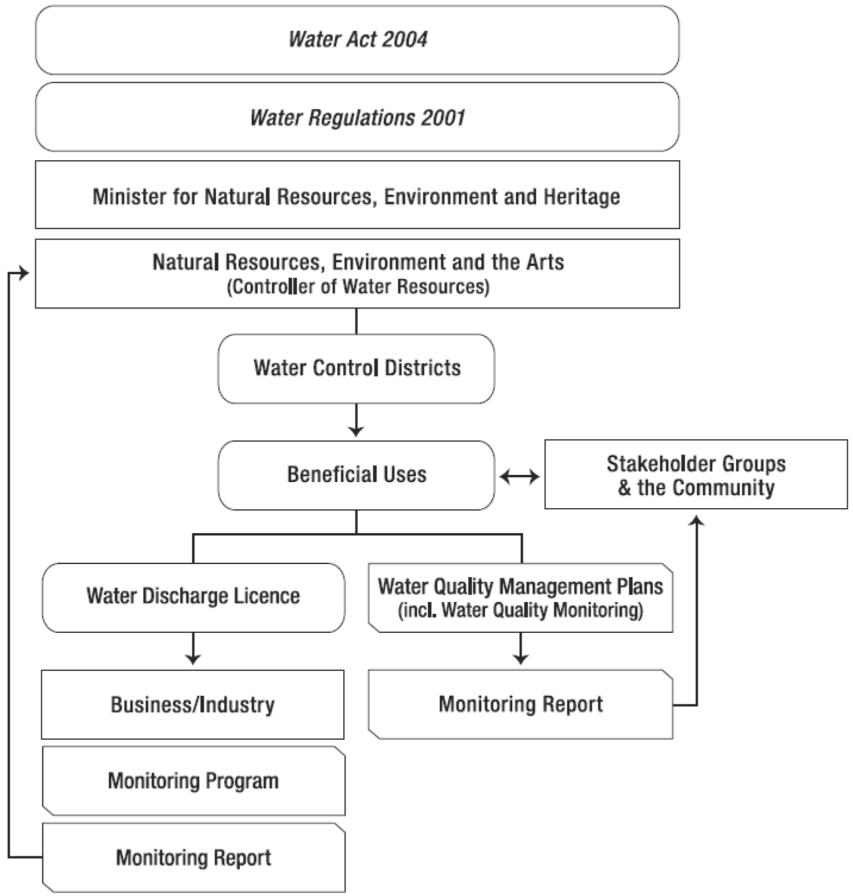
RECYCLED WATER MANAGEMENT

Department of Health and Community Services (Chief Health Officer)
State government agency responsible for the provision of services to maintain and improve the health of constituents and communities of the Northern Territory. The Department has a key role in providing direction and safeguards for wastewater quality for reclaimed water schemes. All reclaimed water proposals are subject to the approval of the Chief Health Officer.
In consultation with Power and Water Corporation, the Chief Health Officer has set the standards for the quality of recycled water licensed under the *Water Services and Sewerage Supply Act 2001*.
www.health.nt.gov.au

Power and Water Corporation
Statutory state-owned corporation under the *Government Owned Corporations Act* that provides water supply, sewerage services and electricity to customers across the Northern Territory.
www.nt.gov.au/powerwater

ENVIRONMENTAL HEALTH MANAGEMENT

This diagram illustrates the governance arrangements for protecting water quality in the Northern Territory.



ENVIRONMENTAL HEALTH MANAGEMENT

LEGISLATION / REGULATION / STATUTORY INSTRUMENTS / LICENCES

Water Act 2004

Regulates the management and protection of water resources in the Northern Territory. Under the Act, pollution of water is prohibited unless licensed under the Act. The Act also provides for the declaration of water control areas and beneficial uses of waterways. Definitions of beneficial use categories are specified in the Act. **www.nt.gov.au/dcm/legislation/current.html**

Water Regulations 2001

Provides further detail relevant to the administration of licences issued under the *Water Act 2004*. **www.nt.gov.au/dcm/legislation/current.html**

Water Control Districts

Under the *Water Act 2004*, the Minister for Natural Resources, Environment and Heritage may declare parts of the Northern Territory as water control districts and give them a name. Districts are declared for specified purposes such as water allocation.

Beneficial Uses

A legislated process under the *Water Act 2004* that identifies the values and uses of a water control district to assist in its protection and management. Seven categories of beneficial uses are listed in the *Water Act 2004,* and include agricultural, cultural, aquaculture, public water supply, environment, riparian and manufacturing industry.

Waste Discharge Licence

Regulatory instruments issued by the Controller of Water Resources under the *Water Act 2004* in areas where beneficial uses have been declared. Licences specify the quality and quantity of wastewater discharged to natural waters by industrial and commercial operations in the Northern Territory.

NON-STATUTORY DOCUMENTS AND ACTIVITIES

Monitoring Program

Waste discharge licences specify environmental monitoring programs that a licence holder must implement to verify that discharge limits are being met.

Monitoring Report

Under the *Water Act 2004*, holders of waste discharge licences are required to provide the results of monitoring specified in the licence to the Controller of Water Resources, in a form and at intervals specified in the licence.

Water Quality Management Plan (incl. Water Quality Monitoring)

The Department of Natural Resources, Environment and the Arts implements water quality management plans for areas with declared beneficial uses.

MINISTER / DEPARTMENT / AUTHORITY / ORGANISATION / INDIVIDUAL

Minister for Natural Resources, Environment and Heritage

Responsible for the protection of the environment in the Northern Territory. The Minister is supported by the Department of Natural Resources, Environment and the Arts. In this role, the Minister is responsible for implementation of the *Water Act 2004* including appointment of the Controller of Water Resources and the declaration of water control districts.

ENVIRONMENTAL HEALTH MANAGEMENT

Department of Natural Resources, Environment and the Arts (Controller of Water Resources)

State government department responsible for ensuring sustainable use of natural resources through the regulation of appropriate land and water management practices and provision of advice and information. The Department also supports the declaration of beneficial uses for water control districts by characterising the waterway and its uses, facilitating community input, and managing and monitoring water quality.

The Controller of Water Resources is appointed by the Minister for the Natural Resources, Environment and Heritage to administer the *Water Act 2004* and its Regulations, including issuing of licences and intervening in cases of pollution. **www.nt.gov.au/nreta**

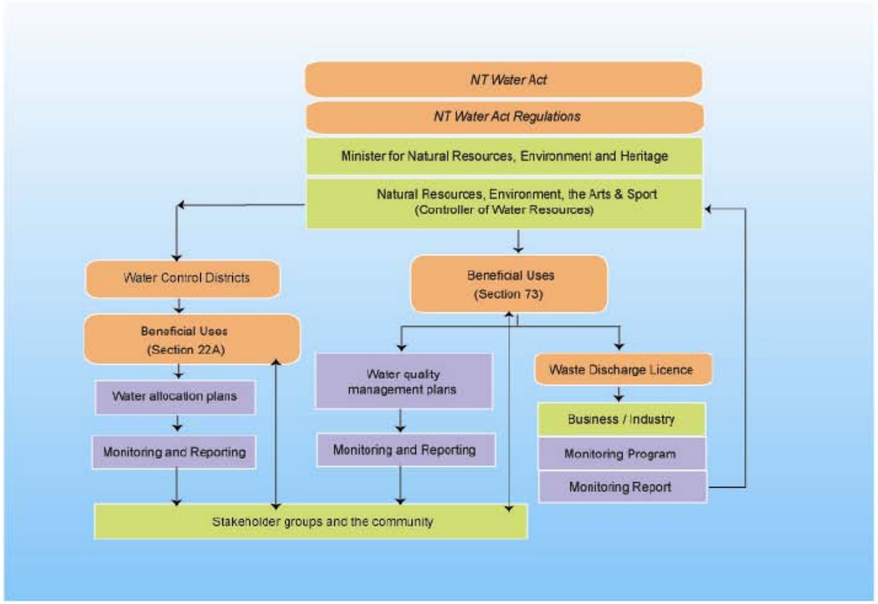
Stakeholder Groups and the Community

The community participates in the process to decide the beneficial use categories that should apply to a water control district.

Relevant Recent Updates on Water Quality Governance - NT Extracts from Bennett (2008)[21]

Final Discussion Paper on Implementation of NWQMS

Northern Territory



Prepared by John Bennett in consultation with NWQMS Contact Group – December 2008

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[21] Source: *Final Discussion Paper on Implementation of the National Water Quality Management Strategy* (Bennett 2008) http://www.environment.gov.au/water/publications/quality/nwqms-discussion-paper.html

Northern Territory

Legislation / Regulation / Statutory Instruments / Licences	
Water Act	Regulates the management and protection of water resources in the Northern Territory. Under the Act, pollution of water is prohibited unless licensed under the Act. The Act also provides for the declaration of water control areas and beneficial uses of waterways. Definitions of beneficial use categories are specified in the Act. www.nt.gov.au/dcm/legislation/current.html
Water Regulations	Provide further detail relevant to the administration of licences issued under the *Water Act*. www.nt.gov.au/dcm/legislation/current.html
Water Control Districts	Under the *Water Act 2004*, the Minister for Natural Resources, Environment and Heritage may declare parts of the Northern Territory as water control districts and give them a name. Districts are declared for specified purposes such as water allocation.
Beneficial Uses	A legislated process under the *Water Act* that identifies the values and uses of a water control district, or other area where potential impact to ambient waters may occur, to assist in its protection and management. Seven categories of beneficial uses are listed in the *Water Act 2004* and include agricultural, cultural, aquaculture, public water supply, environment, riparian and manufacturing industry.
Water Quality Objectives	Can be declared under s 73 and can specify the WQOs that need to be met to sustain range of beneficial uses in ambient waters.
Water Allocation Plans	Declared under s 22b of the Act – Plan incorporates allocation of water quantities to beneficial uses and can specify monitoring of ecological flow and water quality parameters.
Waste Discharge Licence	Regulatory instruments issued by the Controller of Water Resources under the *Water Act 2004* in areas where beneficial uses have been declared. Licences specify the quality and quantity of wastewater discharged to natural waters by industrial and commercial operations in the Northern Territory.
Non-statutory documents and activities	
Monitoring Program	Waste discharge licences specify environmental monitoring programs that a licence holder must implement to verify that discharge limits and ambient WQOs are being met. Research work may be called up to close knowledge gaps. Water Allocation Plans likewise call up monitoring requirements.
Monitoring Report	Under the *Water Act* holders of waste discharge licences are required to provide the results of monitoring specified in the licence to the Controller of Water Resources in a form and at intervals specified in the licence. Reports called up in the licence are public documents.
Water quality management and water allocation plans (incl. water quality monitoring)	The Department of Natural Resources, Environment the Arts and Sport implements water allocation and quality management plans for areas with declared beneficial uses.
Minister / Department / Authority / Organisation / Individual	
Minister for Natural Resources, Environment and Heritage	Responsible for the protection of the environment in the Northern Territory. The Minister is supported by the Department of Natural Resources, Environment and the Arts. In this role, the Minister is responsible for implementation of the *Water Act* including appointment of the Controller of Water Resources and the declaration of water control districts.
Department of Natural Resources, Environment, the Arts and Sport (Controller of Water Resources)	Territory government department responsible for ensuring sustainable use of natural resources through the regulation of appropriate land and water management practices and provision of advice and information. The Department also supports the declaration of beneficial uses for water control districts by characterising the waterway and its uses, facilitating community input, and managing and monitoring water quality. The Controller of Water Resources is appointed by the Minister for the Natural Resources, Environment and Heritage to administer the *Water Act* and its Regulations including issuing of licences and intervening in cases of pollution. www.nt.gov.au/nretas
Stakeholder groups and the community	The community participates in the process to decide the beneficial use categories that should apply to a water control district. A Water Advisory Committee can be appointed under s 23 to advise the Minister on the effectiveness of the Plan.

<u>Northern Territory</u> - WQ Management Roles & Responsibilities, including relevant legislation, policies, regulations, plans, monitoring and reporting

		WQ Planning	Point source management	Urban stormwater management	Rural land use and land management	Flow management	Riparian & in-stream management	Protection & Conservation	Ambient WQ Monitoring	Reporting
General Comments										
'Partners' in Waterway Management	Environmental Protection Agency	Policy only (Environment Protection Authority Act)			Policy only		Policy only	Policy only		Annual report to Leg. Assembly
	Dept. Natural Resources Environment The Arts and Sport	Water Control Districts, Water allocation Plans, Declarations of Beneficial Uses, Policy development (Water Act), Environmental Impact Assessments under Environmental Assessment Act (and Admin Procedures).	Licences via Water Act & Waste Management & Pollution Control Act (for scheduled activities)	Erosion and sediment control guidance, Codes of Conduct for urban stormwater mgt. General environmental duties under WMPCA	Pastoral Land Act - best pastoral practice guidance, Vegetation mgt (Weeds Mgt. Act) Veg. clearance permits (under Planning Act) Soil Con. and Land Utilisation Act	Water allocation planning with environmental flow provisions (Water Act) Bore licensing and metering	Parks & Wildlife Conservation Act + regs	Territory wide policy Parks & Wildlife conservation planning Biodiversity mgt., Bushfires mgt (Bushfires Act + regs)	All waters – ground marine surface waters. HYDSTRA database management and custodian-ship for WQ, hydrology (gw, sw).	Licence reports annually from licensees
	Dept. Regional Development, Primary Industry, Fisheries and Resources	Activity approval require environmentally sustainable practices, demonstration of industry best practice (eg in Mine Management Plans)	Issue activity approvals to extractives, mining and aquaculture under Mine Management Act and Fisheries Act		Agricultural and Veterinary Chemicals (Control of Use) Act. Best irrigation and fertiliser management practices		Stock exclusion zones, off-stream watering, Fisheries Act			Annual reports on mining activities
	Dept. Planning & Infrastructure	Planning Schemes – Land Use Objectives	Marine Pollution Act for ship discharges (ballast water, bilge etc)	Development approvals and permits under Planning Act, subdivision approvals, WSUD policy, Development Consent Authority (DCA) conditions for developments.	Planning Schemes – Land Use Objectives for rural districts					
	NT NRM Board, DHAC, DRMAC, DRWAP, Greening Australia (GA).	Strategic Plans (incl. WQPP) – Matters for Target NT-wide Planning for whole of NT (INRM) and Daly River, Darwin Region							Water for Life program (GA) associated with priority catchments	
	Dept. Health & Community Services	Water recycling guidance Potable water supply approvals, endorsement of Drinking Water Guidelines.			Re-use schemes, Septic Tank- on-site disposal approvals under Public Health Act					

		WQ Planning	Point source management	Urban stormwater management	Rural land use and land management	Flow management	Riparian & in-stream management	Protection & Conservation	Ambient WQ Monitoring	Reporting
	Local Government	Local environmental management plans incorporate aspects of good water resource mgt.		By-laws under Local Government Act Design specs requirements for urban drainage. Maintenance of stormwater systems				Urban streams and wetlands subject to by-laws		
	Power Water Corporation	Potable water supply and catchment management plans' Sewage treatment and disposal both under Water Supply and Sewerage Services Act (and Regs)							Source water incl. ground & surface water (rivers, reservoirs) Receiving waters wq monitoring as part of licence conditions.	Annual performance reports to public

10.2 Appendix 2 Acts and Objectives

The Water Act, 2008.

The Act provides for the investigation, allocation, use, control, protection, management and administration of water resources, and for related purposes. Part 2 of the Act relates to general provisions relating to natural water and pollution. Other parts refer to administration, water resource investigation, surface water, groundwater, water extraction licence decisions, water resource development, general provisions and miscellaneous items.

The Minister may, in writing, appoints a person to be the Controller of Water Resources. Further powers may be further delegated.

The following are the beneficial uses of water are defined by the Act:

(a) agriculture – to provide irrigation water for primary production including related research;

(b) aquaculture – to provide water for commercial production of aquatic animals including related research;

(c) public water supply – to provide source water for drinking purposes delivered through community water supply systems;

(d) environment – to provide water to maintain the health of aquatic ecosystems;

(e) cultural – to provide water to meet aesthetic, recreational and cultural needs;

(f) industry – to provide water for industry, including secondary industry and a mining or petroleum activity, and for other industry uses not referred to elsewhere in this subsection;

(g) rural stock and domestic – to provide water for the purposes permitted under sections 10, 11 and 14.

The Act defines *pollute*, in relation to water, means directly or indirectly to alter the physical, thermal, chemical, biological or radioactive properties of the water so as to render it less fit for a prescribed beneficial use for which it is or may reasonably be used, or to cause a condition which is hazardous or potentially hazardous to: (a) public health, safety or welfare; (b) animals, birds, fish or aquatic life or other organisms; or (c) plants.

Part 7 of the Act, Water Quality, provides for water quality standards, whereby the Administrator may, by notice in the *Gazette*, declare, either generally or for an area specified in the notice, the beneficial uses, quality standards, criteria or objectives which apply to or in relation to any: (a) waste or class of waste; or (b) water or class of water. It also provides for the granting of waste discharge licences, which can require monitoring at the licensee’s own expense and which shall be supplied to the Controller of Water Resources.

Waste Management and Pollution Control Act 2004

Pursuant to section 5 of this Act, *the objectives of this Act are -*

> *(a) to protect, and where practicable to restore and enhance the quality of, the Territory environment by -*
>
> > *(i) preventing pollution;*
> > *(ii) reducing the likelihood of pollution occurring;*
> > *(iii) effectively responding to pollution;*
> > *(iv) avoiding and reducing the generation of waste;*
> > *(v) increasing the re-use and re-cycling of waste; and*
> > *(vi) effectively managing waste disposal;*
> > *(b) to encourage ecologically sustainable development; and*
> > *(c) to facilitate the implementation of national environment protection measures made under the National Environment Protection Council (Northern Territory) Act .*

Environmental Impact Assessment Act 1994

Pursuant to section 4 of this Act, *the object of this Act is to ensure, to the greatest extent practicable, that each matter affecting the environment which is, in the opinion of the Minister, a matter which could reasonably be considered to be capable of having a significant effect on the environment, is fully examined and taken into account in, and in relation to –*

> *(a) the formulation of proposals;*
> *(b) the carrying out of works and other projects;*
> *(c) the negotiation, operation and enforcement of agreements and arrangements (including agreements and arrangements with, and with authorities of, the Commonwealth, the States and other Territories);*
> *(d) the making of, or the participation in the making of, decisions and recommendations; and*
> *(e) the incurring of expenditure,*

by, or on behalf of, a person, either alone or in association with another person.

Soil Conservation and Land Utilisation Act 2001

The purpose of the Act is to prevent erosion and conserve soil. In accordance with the long title of the Act, the purpose is *to make provision for the prevention of soil erosion and for the conservation and reclamation of soil.*
Pastoral Land Act

Pursuant to section 4 the objects of this Act include, but are not limited to the following –

- *a) to provide a form of tenure of Crown land that facilitates the sustainable use of land for pastoral purposes and the economic viability of the pastoral industry;*
- *b) to provide for –*
  - *i) the monitoring of pastoral land so as to detect and assess any change in its condition;*
  - *ii) the prevention or minimisation of degradation of or other damage to the land and its indigenous plant and animal life; and*
  - *iii) the rehabilitation of the land in cases of degradation and other damage;*

Bushfire Act 2004

The *Bushfire Act 2004*, establishes the legal framework and responsibilities for bushfire management[22]. This is *an Act relating to the prevention and suppression of bushfires.*

In addition to the above-mentioned Acts, there are a number of other Acts that relate to water resources directly or indirectly through provision relating to sustainable development. These Acts are not administered or implemented by NRETAS and include:

Water Supply and Sewerage Services Act

pursuant to section 3, *the objects of the Act are –*

- *b) to promote the safe and efficient provision of water supply and sewerage services;*
- *c) to establish an enforce standards of service in water supply and sewerage services;*
- *d) to facilitate the provision of financially viable water supply and sewerage services; and*
- *e) to protect the interests of customers.*

The *Water Supply and Sewerage Services Act* provides a system of licensing for water supply services by the Utilities Commission (an independent industry regulator). Under the Act, Power and Water requires a licence to supply water, and is also required to meet minimum standards for drinking water quality specified by the Minister for Health. These standards currently refer to the *Australian Drinking Water Guidelines (*National Health and Medical Research Council and Natural Resource Management Ministerial Council, *2004)*[23]*.*

Planning Act

Pursuant to section 2A;

1) *The objects of this Act are to plan for, and provide a framework of controls for, the orderly use and development of land.*
2) *The objects are to be achieved by –*
    - *a) strategic planning of land use and development and for the sustainable use of resources;*
    - *d) control of development to provide protection of the natural environment, including by sustainable use of land and water resources;*

Agricultural and Veterinary Chemical (Control of Use) Act 2004

Pursuant to section 3

1) *The purpose of this Act is –*

[22] http://www.nt.gov.au/nreta/nretas/bushfires/index.html accessed on 23 November 2008.

[23] http://svc044.wic032p.server-web.com/nwi/water_governance/pdfs/NT_WaterQualityManagement.pdf accessed on 24 November 2008.

a) *to impose controls relating to the possession, sale, use and application of chemical products, and the manufacture, sale and use of fertilisers and stockfoods, that ensure sustainable agriculture by protecting –*
    ii) *the environment*

Mining Act 1997
Pursuant to section 3A
1) *The objects of this Act are –*
    a) *to provide a framework within which persons may undertake activities to explore for and mine mineral resources; and*
    b) *to enable the value of the mineral resources in the Territory to be maximised.*
2) *The objects are to be achieved by –*
    d) *reducing risks of damage to the environment caused by mining to an optimal level taking into account the full cost and benefits of doing so;*

10.3 Appendix 3 Spatial Data Sources for Pressures and Threats

Pressure/Threat	Unit	GIS Representation	Source of Data
Land Uses: 1. Cropping 2. Grazing Modified Pastures 3. Grazing Natural Vegetation 4. Intensive Animal Production 5. Intensive Horticulture 6. Irrigated Agriculture 7. Manufacturing & Industrial 8. Other Minimal Uses 9. Production Forestry 10. Residential 11. Services 12. Transport & Communications 13. Utilities	Hectares	Polygon	Extract of Land Use Mapping of the Northern Territory (2002). This dataset contains land use classes allocated in accordance with the "Australian Land Use and Management Classification (ALUMC Version 5)". Source: NT Department of Natural Resources Environment and the Arts
Fire	Frequency	Raster	Fire frequency data derived from MODIS satellite imagery. The fire frequency data are a composite of fire mapping for the years 2003 to 2006. Fire Affected Areas (FAAs) for each calendar year are attributed with a value of 1 (i.e. for this analysis they are not separated by month nor season) and all layers summed, creating a layer with values from 0 to 4. Source: Tropical Savannas CRC and Bushfires NT.
Land clearing	Hectares	Polygon	Extract of the NT Native Vegetation Clearing Dataset (2005). Source: Natural Resource Management Division, NT Department of Natural Resources Environment and the Arts.
Mining	Frequency	Point	Mineral Occurrence Database (MODAT) 2005. Includes abandoned mine, mineral occurrence and prospect status. Source: Northern Territory Geological Survey
Sea Level Rise	Hectares	Polygon	Dataset derived from Shuttle Radar Topography Mission (SRTM) 3 arc-seconds elevation data and GEODATA TOPO 250K Series 3 wetland data. Source: Geoscience Australia

Pressure/Threats and Habitat and Sources of Spatial Data

Pressure/Threat	Unit	GIS Representation	Source of Data
Habitat			
Riparian Vegetation Communities	Hectares	Polygon	Extract of Northern Territory National Vegetation Information System (NVIS) 2005.
			Source: NT Department of Natural Resources Environment and the Arts
Wetlands	Hectares	Polygon	GEODATA TOPO 250K Series 3 (the following feature classes: flats, lake, watercourse, reservoirs, rapid areas, pondage areas and native vegetation areas).
			Source: Geoscience Australia
Waterways	Km^2	Line	GEODATA TOPO 250K Series 3
			Source: Geoscience Australia

Source: Bartolo R, Bayliss P & van Dam R (2008) Chapter 3 Semi-quantitative risk assessments – Relative Risk Model, pg 180 – 181.

10.4 Appendix 4 Summary of responses from community workshops

Aboriginal Reference Group Meeting
Nauiyu, Monday, 13 October 2008 1.15 pm – 2.00 pm

Question	Response
What are the Beneficial Uses of both surface water and underground water that you want to protect? (For areas not previously declared under the Water Act)	• Aquatic Ecosystem Protection • Raw Drinking Water • Cultural • Recreational – Primary contact i.e. swimming
What are the issues that may harm water quality (health)?	• Affect of limestone on human health (high incidence of kidney problems in some areas) and damage to infrastructure i.e. pipe work. • Mining and impact to Edith River, potential leakage from tailings dams • Potential mining of uranium, Tipperary Station • Underground water input to rivers and the impact on water quality, i.e. the water is a milky colour. • Salt water intrusion, salt water coming further up the Daly River • Gas pipeline construction and impact on the aquifers and river bed • Lack of integration of water quantity and quality, identified a need to work together as extraction may lead to reduced flows and this has an impact on water quality. • Large debris – blocking flow and causing erosion • Land management issues such as weeds, feral animals • Erosion as a direct result of the wave action caused by boats on the rivers.
What places do you want monitored? (i.e. related to the locations you are concerned about)	• Edith / Fergusson / Daly (Mining impact) • Below Oolloo crossing (Underground water input – milky blue colour) • Proposed mine sites - obtain data now so can get a picture of water quality before mine is developed and after. • Douglas and Daly confluence (where the two rivers meet) • Mouth of the Daly • Tjuwaliyn (Douglas Hot Springs) • Claravale, Dorisvale and Daly River crossings • Florina Station (Yuwaiyunn Creek)
Who should monitor water quality?	• NT Government responsibility • Opportunity for industry and Indigenous partnerships e.g. mining companies could contribute funding to support "River Rangers" program. • Federal Government funding through Caring for Country to support full time "River Rangers".
How do you want results to be reported?	• Preferred option is for the relevant person to give a presentation to the Aboriginal Reference Group. • Any mining activities should have mandatory reporting to the Aboriginal Reference Group and local communities.

Katherine Meeting
Civic Centre - Council Chambers, Tuesday, 14 October 2008, 6.00 pm – 7.30 pm

Question	Response
What are the Beneficial Uses of both surface water and underground water that you want to protect? (For areas not previously declared under the Water Act)	• Aquatic Ecosystem Protection • Raw Drinking Water (public and private) • Cultural • Recreational – primary contact swimming, secondary contact boating • Stock water • Irrigation (Industry)[24]
What are the issues that may harm water quality (health)?	• Agricultural chemicals, pesticides (i.e. herbicides, insecticides, fungicides) and fertilisers. • Water Quantity – low levels and flows in the dry season may impact water quality • Erosion, naturally occurring and also due to the influence of stock • Feral animals • Mining – Mt Todd and Maud Creek • Runoff to sink holes – little or no attenuation if poor water enters sinks holes, potential to impact groundwater quality. • Radium and other naturally occurring minerals and metal (metals may be mobilised if pH of water is altered, this may be a risk associated with acid leachate from mines) • General condition of catchment / ground cover • Future agricultural development estimated at three times current levels. This has potential to increase water demand by three times the current rate. Over-extraction of water can impact water quality. • Litter
What places do you want monitored? (i.e. related to the locations you are concerned about or general places of interest)	• Flora River and Falls • Noon Springs (Flora River) • Katherine Springs • Edith Falls • Spring Creek and Stray Creek • Tindall aquifer discharge to Katherine River (Knotts Crossing) • Railway bridge downstream of Katherine Township (paired site with water quality and water levels/discharge) • Oolloo aquifer / Daly River (Taylors Park / Florina Road) Southern end of Oolloo • Pristine area.

[24] Watering of lawns and golf clubs is classed as industrial use of water under the *Water Act* for the purpose of issuing licences (pers comm. Lachlan Kellsall). This is not consistent with the *National Water Quality Management Strategy* (NWQMS) where industrial uses are categorised as activities such as mining and power stations. The use of water for the irrigation is classified under the NWQMS as irrigated horticulture and has a corresponding beneficial use as Agriculture. For the purpose of the Framework, the use of water for irrigation will be identified as irrigated horticulture.

Question	Response
Who should monitor water quality?	• NT Government primary responsibility • Support should be provided (i.e. funding) to train community groups e.g. schools and indigenous groups, community members. This will help raise awareness, build capacity in the community and provided useful information.
How do you want results to be reported?	• Annual reports with advertisements in newspapers directing people to website. • Online newsletters • Links on website for full reports.
How should monitoring be integrated into the current management systems?	• Currently not well done • NRETAS, PowerWater and Fisheries should discuss and clearly identify responsibilities • Available resources and lack of commitment are current issues impacting better integration of water quality monitoring in the region.

Darwin Public Meeting
Museum and Art Gallery, Wednesday, 29 October 2008, 7.00 pm – 8.30 pm

Question	Response
What are the Beneficial Uses of both surface water and underground water that you want to protect? (For areas not previously declared under the Water Act)	• Aquatic Ecosystem Protection both surface water and underground water • Raw Drinking Water – surface water and groundwater • Cultural – surface water and groundwater • Recreational – primary contact i.e. swimming both surface water and underground water (Tjuwaliyn) and secondary contact i.e. boating and recreational fishing for surface water resources • Agricultural – underground water • Rural stock – underground water • Industrial i.e. mining – surface water resources.
What are the issues that may harm water quality (health)? And what indicators could be monitored?	• Fire regime. Indicators - suspended sediment, nutrients, temperature • Extraction. Indicators – salinity, water levels, flow regime / environmental flows • Clearing/Erosion. Indicators suspended sediment • Mining. Indicators pH, metals, TDS • Agriculture. Indicators – nutrients, pesticides and sediments • Large scale land change, altered flow regime, altered infiltration / recharge. Indicators – nutrients, pesticides, sediments, water levels • Weed control i.e. mimosa – and use of pesticides • Stock - bank side erosion. Indicators - suspended sediment, nutrients, coliforms • Urban runoff- Indicators - hydrocarbons, metals, asbestos • Urban Development – Indicators - sediment • Sewerage Discharge(Katherine) -micro-organisms • Septic leakage SW & GW issue - organic loading • Tourism, Camping grounds. Indicators litter/rubbish, nutrients, sediment, micro-organisms
What places do you want monitored? (i.e. related to the locations you are concerned about)	• Strategic to monitor • Control points • Where issue identified • Pre-disturbance • Reference site-outside of Katherine & Daly • Head waters to mouth regular intervals
What frequency should monitoring occur?	• Need to consider when to monitoring i.e. o Every three months for 15 months i.e. to detected changes in turbidity o Event-based monitoring

Question	Response

	• Other considerations
	    o When is the best time - beginning of the wet/wet/dry
	    o Cover all seasons. Including big floods.
	    o Consider grab stations – or telemetered sites as high OH&S risks during wet season Flow/turbidity/conductivity/pH
	    o Linked to purpose e.g. pesticides-initially after rainfall event
	    o Include variety of conditions
	    o Representative

Who should monitor water quality?	• NRETAS - legislative responsibility • Resourced Advisory committees (sitting fees, secretarial support) i.e. DRMAC/ARG • On ground Water Rangers • Community Groups (Adopt a River scheme), complex and needs to be carefully managed and scientific limitations data need some form of validation • Industry i.e. Mining Co
How do you want results to be reported?	• Depends on audience i.e. scientific, Traditional owners, general public • Victoria – *Water Data Warehouse* is a web- based example however its limitation is how the data is interpreted. • The data should be stored in a central location and should be consistent and comparable across the entire NT • *Report Card* system-QLD. Applies a simple grade A – E for water quality it is very easy to tell if water quality has improved or deteriorated. Generally gets reported by media. • Other issues- Costing and resource implications

Woolianna Public Meeting
Woolianna School, Thursday, 30 October 2008, 6.00 pm – 7.30 pm

Question	Response
What are the Beneficial Uses of both surface water and underground water that you want to protect? (For areas not previously declared under the Water Act)	• Aquatic Ecosystem Protection • Raw Drinking Water • Cultural • Recreational – Primary contact i.e. swimming
What are the issues that may harm water quality (health)?	• Large number of pumps in watercourse • Bore levels dropping • Irrigation extractions leading to declining water levels • Illegal Clearing - Sediment • Lack of compliance • Moratorium on clearing does not exclude Katherine area • Flow alteration • Stock in watercourse • Framework should include the Estuary – Sediment may create island this will impact water quality of the Daly River • Climate change • Weeds i.e. *Salvinia* affects pH • Development pressure
What places do you want monitored? (i.e. related to the locations you are concerned about)	• Bamboo Creek • B/W Browns creek & Crossing • Flood plain (mimosa) • Coppermine Billabong (u/s) - Concern aboriginal community
Who should monitor water quality?	• Community monitoring - to feed into scientifically creditable work- needs to be used/end use. • Issue “Water for Life” program no continuity • NT Government • Resourcing for community & groups i.e. Equipment and maintenance of equipment and training
How do you want results to be reported?	• Newsletters (not everyone has internet)

Edith Farms Fire Brigade Community Meeting
Lot 2329 Edith Farms Road
Tuesday, 4 November 2008, 7.00 pm – 8.30 pm

Question	Response
What are the Beneficial Uses of both surface water and underground water that you want to protect?	• Raw Drinking Water (surface water and groundwater) • Recreational – Primary contact i.e. swimming and tourism (Edith Falls) • Irrigated horticulture (groundwater) • Fire fighting (groundwater) • Stock water (groundwater)
What are the issues that may harm water quality (health)?	• Large impact to water quality due to rainfall in the wet season • Sedimentation is an issue however this is natural and is due to the tidal influence in the estuary (not due to land clearing) • Mining and leachate and seepage from holding ponds – arsenic and other metals • Dewatering of mines • Effluent discharge (Katherine township) • Stormwater discharge (Katherine township) • Leachate from Katherine rubbish dump to underlying aquifer • Debris from rubbish dump (large amounts of waste including tractor tyres, pesticide containers etc washed downstream during floods, no effort to recover debris was reported) • Land clearing – In particular in the Daly region • Forestry / Mahogany plantations • Bat excrement on rooves and possible impact on human health • Weeds clogging waterways
What places do you want monitored? (i.e. related to the locations you are concerned about)	• Katherine at effluent and stormwater outflows • Katherine River • Cullen River • Edith (including downstream of mine) and groundwater as concerns related to impacts caused by dewatering • Fergusson • Flat rocks (confluence Edith and Fergusson) • Bores • Rainwater tanks (bats) impact human health Landcare has undertaken monitoring in region with local community member speak to Caroline Green or Sharon Hillian (Natural Resources Department)
Who should monitor water quality?	• Not the NT Government, but an independent body i.e. ERISS • Landcare and Greening Australia with community groups should collect water quality information provided there is an end use for the data. • Adequate resources need to be provided to train community members, provide equipment and ensure ongoing equipment maintenance.

Question	Response
How do you want results to be reported?	• Rural communities have limited to no access to internet. Preferred method or results reporting is via newsletter to established community groups such as the Edith Farms Fire Brigade. Identification of all stakeholders would be required.
Other issues	• Too many restrictions impact investment, investment is necessary for growth of communities – Community concern that future monitoring may lead to future restrictions on water use • Fear of metering and user pays systems being implemented • Concern that Murray Darling Basin rules and regulations are being transferred to the Northern Territory and those rules are not applicable because of the difference in rainfall • Distrust of government

Douglas Daly Community Centre Public Meeting
Wednesday, 5 November 2008, 7:00 pm – 8:30 pm.

Question	Response
What are the Beneficial Uses of both surface water and underground water that you want to protect? NB: Beneficial Uses form the basis of our future management objectives.	• Ecosystem protection (surface water and groundwater) • Raw Drinking Water (surface water and groundwater) • Cultural and Recreational – Primary and secondary contact (surface water and groundwater (Hot springs) • Irrigated horticulture (surface water and groundwater) • Stock water (Surface water and groundwater)
What are the issues that may harm water quality (health)?	• Wet season runoff • Seasonal variation i.e. consecutive low rainfall during wet season results in increase calcium carbonate ($CaCO_3$) and salinity concentrations. • Climate change • Mining and agricultural production and potential for mobilisation / leaching of chemicals into the groundwater system (or aquifers). • Tourism – litter, increase nutrients • Recreational Fishing – wave action causing bank erosion, altering geomorphology of watercourse, increasing channel depth, input of petrochemicals. • Forestry – soil disturbance and once trees established interception of water may reduce runoff. Increase demand on groundwater systems • Reduce quantity of water • Feral animals – over-grazing and impact to river banks and bank stability (including wallabies) • Weeds and the use of pesticides to control them (particularly along the flood plain) • Issues within the estuary include tourism, recreational fishing and the introduction of weeds, litter and speed of boats causing bank erosion.
What places do you want monitored? (i.e. related to the locations you are concerned about) Douglas Daly region	• Routine monitoring of observation bores and also to include routine monitoring of production bores (due to continually drawing water they provide a better representative sample of the quality of water with in the aquifer). • Tourist locations – Tjuwaliyn (Douglas Hot Springs) • Downstream of The Arches (Douglas River) • Small tributaries to detect what is being picked up in runoff as it travels over land • Black Bull Run (Daly River near Stray Creek) • Green Ant Creek – representative of a cleared catchment • Stray Creek – representative of forestry development • Fish River – representative of pristine catchment (i.e. low level of development, very few weeds etc) • Permanent billabongs e.g. Ruby Billabong (back of the Douglas Daly Research Farm)

Question	Response
Who should monitor water quality?	• Joint responsibility of NT Government i.e. NRETAS, Parks and Wildlife and Power and Water • NRETAS should be undertaking permanent (long-term) water quality monitoring at catchment scale • Land holders could be involved in water quality monitoring at a smaller scale • Issues with Greening Australia Water Quality Monitoring Projects – i.e. no continuity, not adequately resourced • Suggestion that EPA could require monitoring and report of industry groups if their proposed development is likely to pose a significant (needs to be defined, not intended for small scale irrigators) risk to water quality
How do you want results to be reported? (Douglas Daly region)	• Web-based however sometimes results can be miss interpreted. • Preferred method is a public meeting where results and what they mean or are telling us can be explained. Comments: • A lot of data is collected by Government however there is a significant lack of resourcing for the analysing, interpreting and reporting results back to the community. Results are generally only reported internally. • There is a large gap between research and people who actually manage the land

Katherine Meeting
Civic Centre - Council Chambers, Wednesday, 12 November 2008, 6.00 pm – 7.30 pm

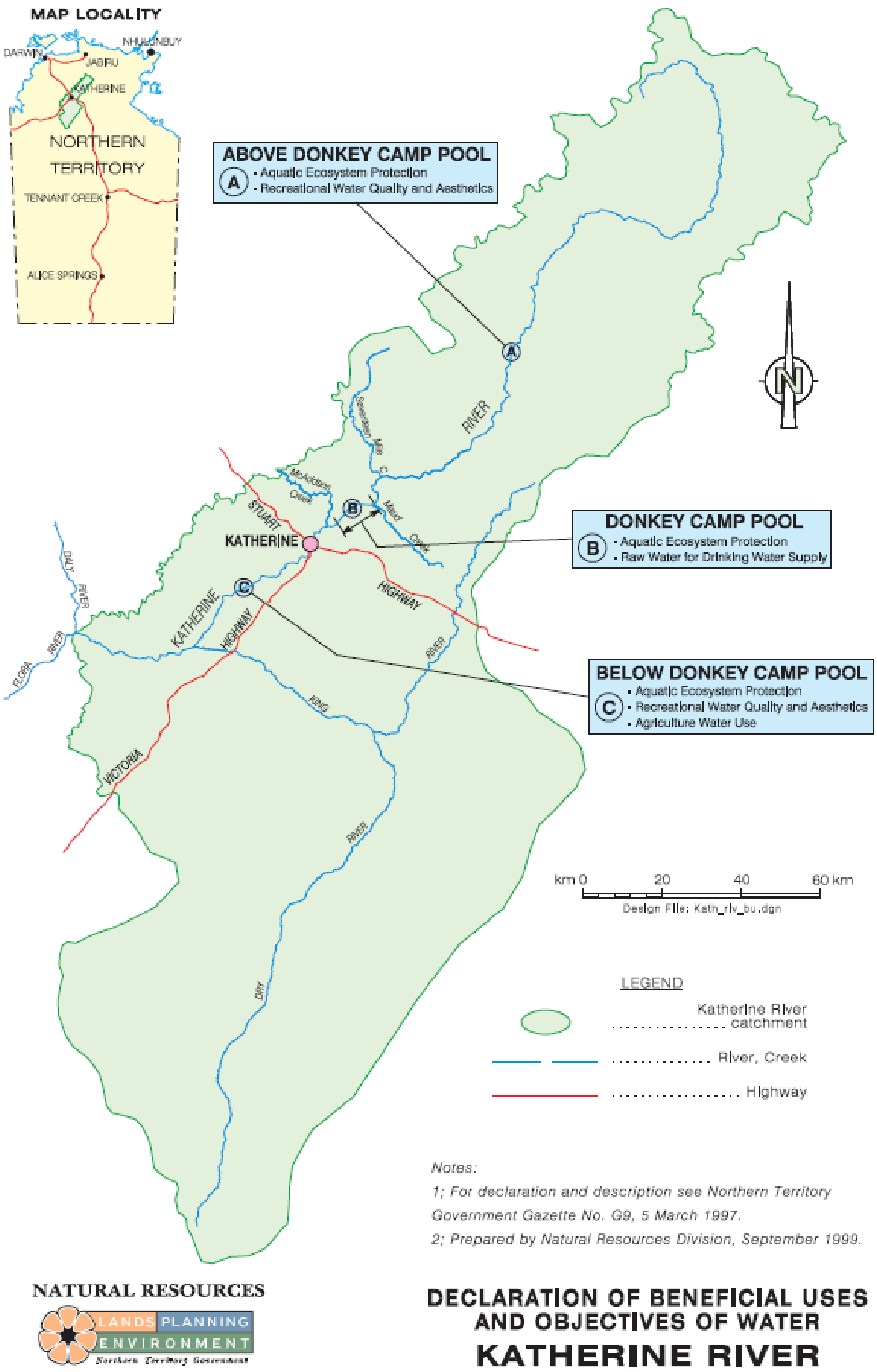
Question	Response
What are the Beneficial Uses of both surface water and underground water that you want to protect?	• Aquatic Ecosystem Protection (surface water and groundwater) • Raw Drinking Water (public and private) – (surface water and groundwater) • Cultural and recreational – primary contact swimming, secondary contact boating and visual amenity (includes groundwater as groundwater is used to irrigate ovals for sporting activities and recreational use areas. Groundwater is also used for filling swimming pools and Katherine Hot Springs are used for swimming) • Irrigation • Aquaculture (Groundwater only at Mataranka, while outside of Katherine Daly River Catchment, the Katherine Tindall aquifer extends to Mataranka) • Stock water (surface and groundwater) • Industrial Mining (surface water and groundwater)
What are the issues that may harm water quality (health)?	• Government and lack of continuity of projects and funding. Need long-term commitment • Erosion due to changes in land use and clearing of native vegetation • Use of fertilisers and pesticides for agricultural production • Glass and cans i.e. litter • Waste from cattle and feedlots • Feral animals in particular pigs, as well as stock and wallabies • Lack of natural predators i.e. due to culling of dingos there are no predators for the wallabies which can cause impacts to the stream banks if the wallabies are in large numbers. • Seasonal change i.e. dry season to wet season • Urban runoff from Katherine Township including fertilisers, pesticides, micro-organisms, petroleum products and metals • Septic and sewerage waste during flood times • Tourism and human waste (approx 250 000 people visit the Gorge annually)
What places do you want monitored and why? (i.e. related to the locations you are concerned about or general places of interest)	• Katherine Hot Springs – tourism impact • Donkey Camp Pool – town supply • Below Gorge – tourist impact • After Katherine Township – urban impact • Control site above Gorge – perhaps in vicinity of community so the area is accessible • Groundwater bores • Flora River – Pristine in comparison to Katherine • Upstream river confluences to identify the difference in water quality between major tributaries • Galloping Jacks – seepage from Tindall aquifer to river • Old water watch sites – could build on existing data.

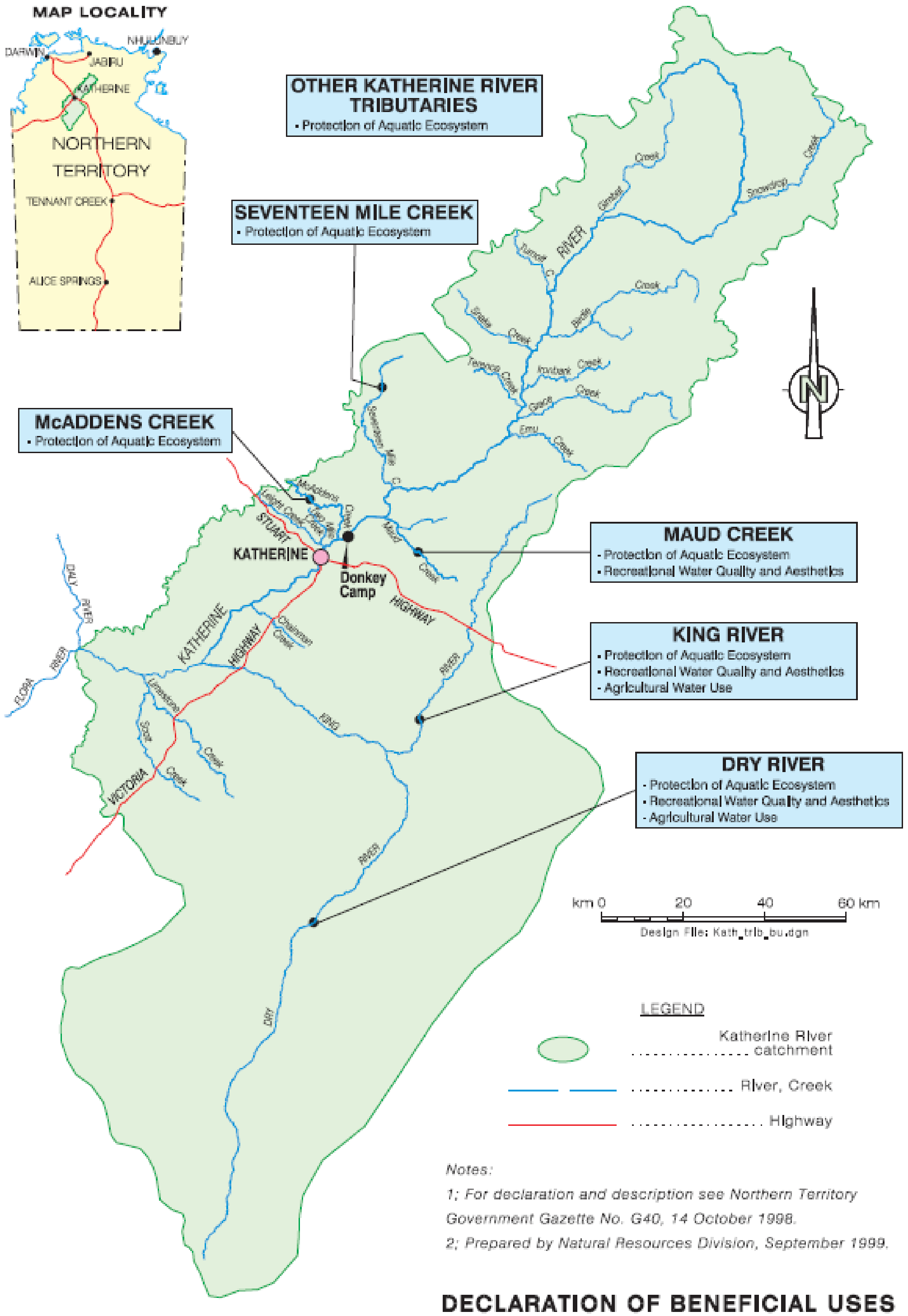
Question	Response

Who should monitor water quality?	• NT Government NRETAS, DRDPIFR and Power and Water – (note Power and Water may not be ideal as they are not bound by Freedom of Information Legislation)
	• If NT Government, i.e. NRETAS, there need to be clear terms of reference, adequate resourcing, central repository for all data collected (similar to BOM weather data) and full disclosure of results.
	• The EPA could require large industries to monitor water quality if their developments were thought to pose a significant risk to water quality.
	• Community, Katherine Landcare and interest groups should also monitor water quality however, there needs to be;
	  o continuity, i.e. appropriate funding and training
	  o an adequate end use of the data collected, and
	  o a central repository for data storage.

How do you want results to be reported?	• Annual report summaries compiled into newsletters (kept simple with not to much detail) distributed to key stakeholder (i.e. Cattlemen's Association, etc) for further dissemination. • Website should be included on the newsletter where interested people can access raw data. • Displayed alongside raw data should be acceptable levels/range of each parameter measured i.e. pH acceptable range = X to Z , last sample pH = Y • Reporting should display raw data and have a simple score card or traffic light system that is easy for everyone to understand
Data acquisition	• There should be a co-ordinated approach to data collection so as to avoid wasting resources. For example the Water Allocation Plan will require monitoring and the person who is currently going to sites collecting data should also collect water quality data at the same time.
Data storage	• Need dissemination database (oracle database) similar to the NRETAS maps website or the CDU/CRC Info Net which is a free public site and is frequently updated.
When should monitoring occur?	• Monitoring frequency needs to be higher during the beginning of the wet season
Key Issues	• Adequate resourcing needs to be provided for data acquisition, storage and dissemination

10.5 Appendix 5   Beneficial Use Declared Areas





NATURAL RESOURCES

LANDS PLANNING ENVIRONMENT

Northern Territory Government

DECLARATION OF BENEFICIAL USES AND QUALITY STANDARDS OF WATER

KATHERINE RIVER TRIBUTARIES

Notes:

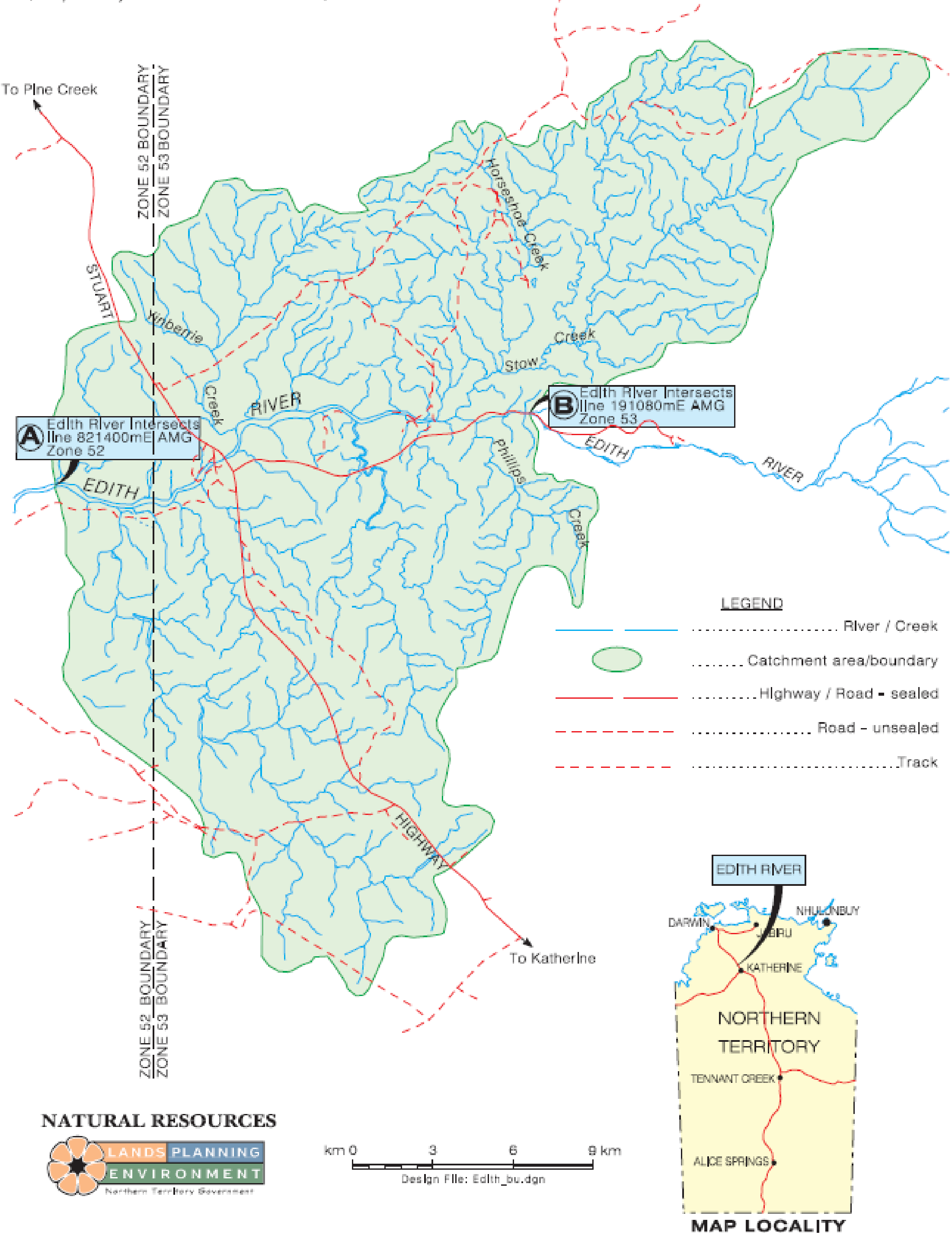
1; Beneficial Use is aquatic ecosystem protection for the portion of the waterway known as Edith River and the tributaries that enter that waterway between the points marked (A) and (B) on the plan.

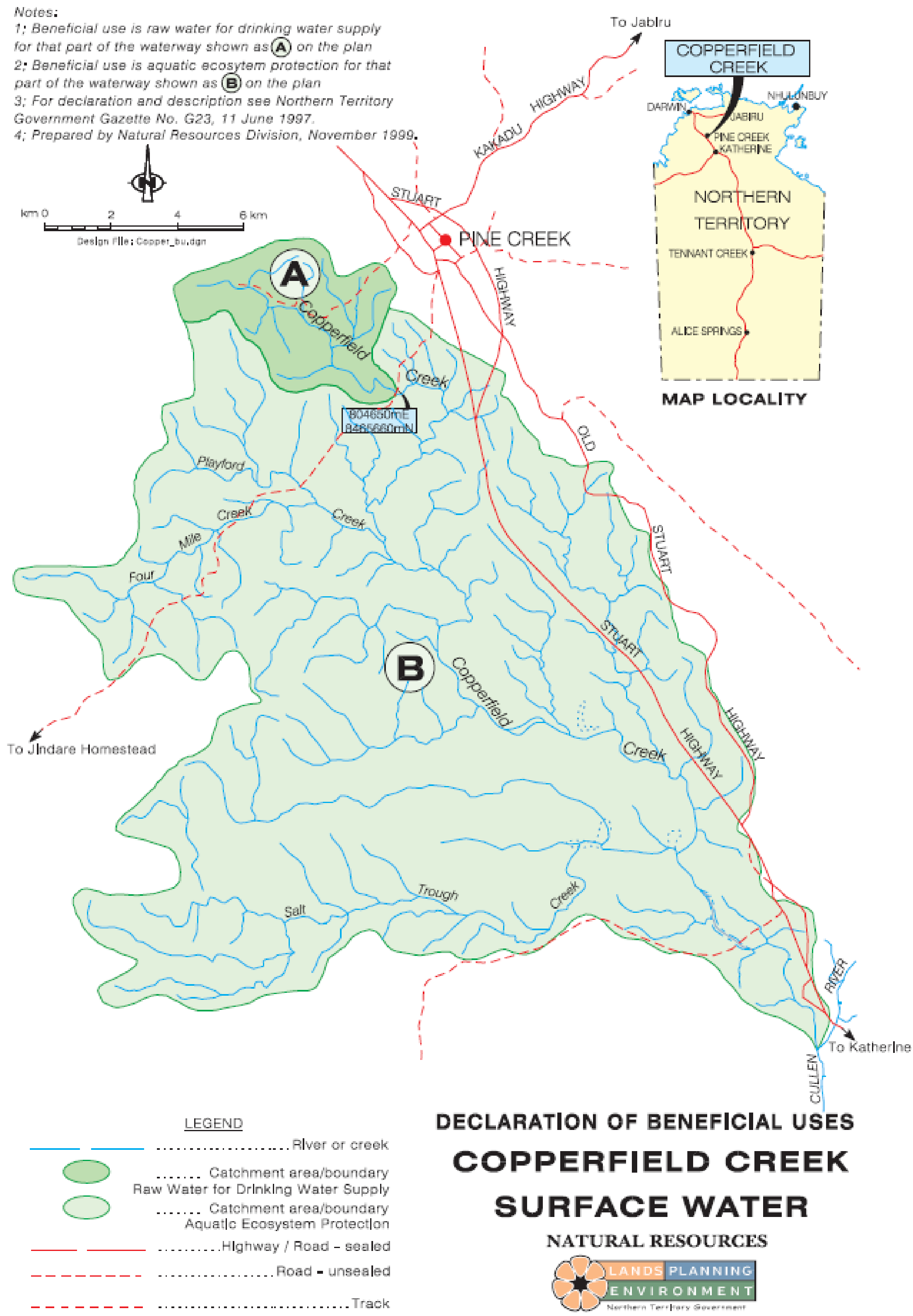
2; For declaration and description see Northern Territory Government Gazette No. G23, 11 June 1997.

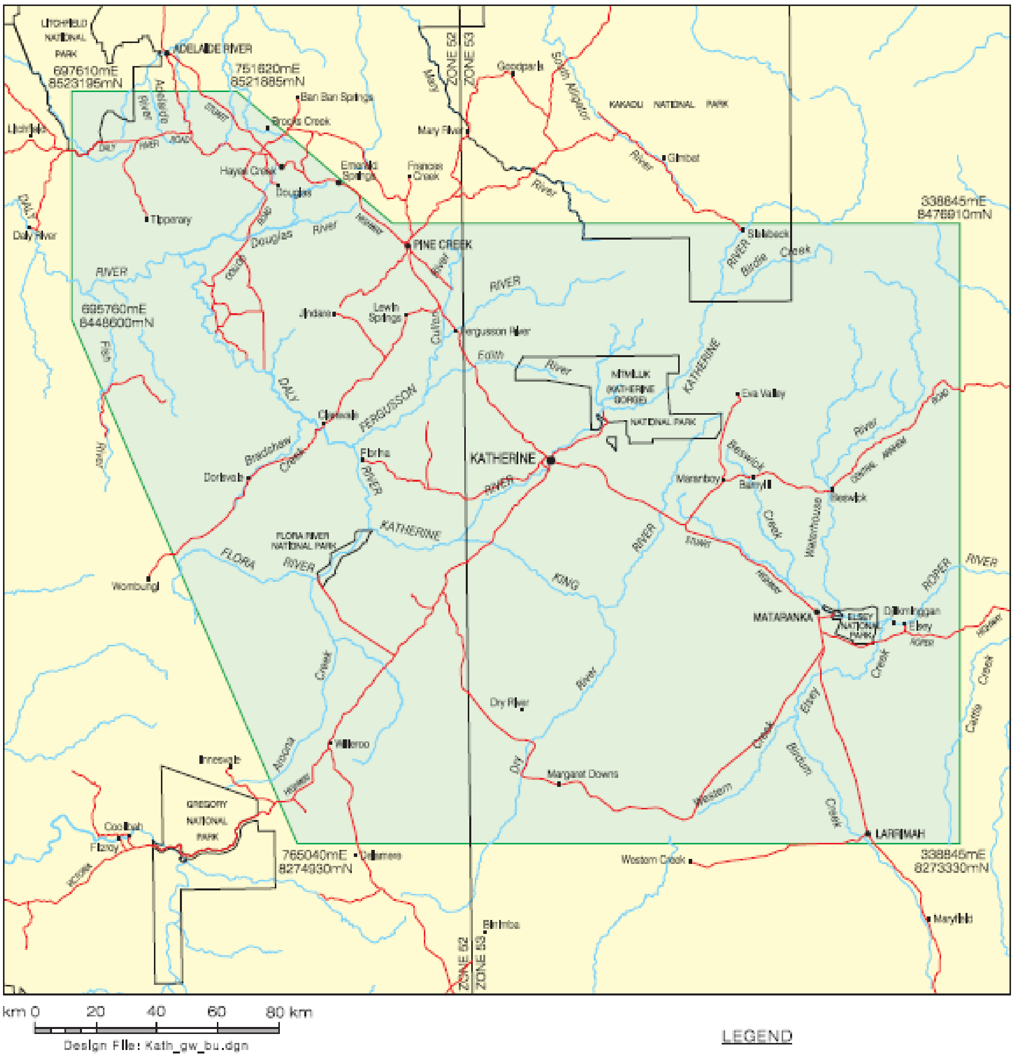
3; Prepared by Natural Resources Division, November 1999.

DECLARATION OF BENEFICIAL USES

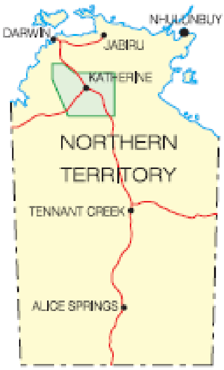
EDITH RIVER SURFACE WATER




Notes:
1; Beneficial use is raw water for drinking water supply for that part of the waterway shown as A on the plan
2; Beneficial use is aquatic ecosytem protection for that part of the waterway shown as B on the plan
3; For declaration and description see Northern Territory Government Gazette No. G23, 11 June 1997.
4; Prepared by Natural Resources Division, November 1999.
km 0 2 4 6 km
Design File: Copper_bu.dgn
To Jabiru
KAKADU HIGHWAY
STUART
PINE CREEK
HIGHWAY
A
Copperfield
Creek
804650mE
8465660mN
Playford
Creek
Four
Mile
Creek
Creek
OLD
STUART
STUART
HIGHWAY
HIGHWAY
B
Copperfield
Creek
To Jindare Homestead
Salt
Trough
Creek
RIVER
CULLEN
To Katherine
COPPERFIELD CREEK
DARWIN
JABIRU
NHULUNBUY
PINE CREEK
KATHERINE
NORTHERN TERRITORY
TENNANT CREEK
ALICE SPRINGS
MAP LOCALITY
LEGEND
River or creek
Catchment area/boundary Raw Water for Drinking Water Supply
Catchment area/boundary Aquatic Ecosystem Protection
Highway / Road - sealed
Road - unsealed
Track
DECLARATION OF BENEFICIAL USES
COPPERFIELD CREEK
SURFACE WATER
NATURAL RESOURCES
LANDS PLANNING
ENVIRONMENT
Northern Territory Government



MAP LOCALITY



LEGEND

- Declared area
- Highway
- Road
- River or creek

Notes:

1; Beneficial Uses are raw water for drinking water, raw water for agriculture, and raw water for industrial purposes.

2; For declaration and description see Northern Territory Government Gazette No. G22, 9 June 1999.

3; Prepared by Natural Resources Division, September 1999.

NATURAL RESOURCES

LANDS PLANNING ENVIRONMENT

Northern Territory Government

DECLARATION OF BENEFICIAL USES AND QUALITY STANDARDS OF GROUNDWATER

KATHERINE AREA

10.6

Appendix 6 Water Quality Monitoring and Reporting Guidelines

Effective water quality investigations systematically collect physical, chemical and biological information, and analyse, interpret and report those measurements, all according to a carefully pre-planned design which follows a basic structure.

This NWQMS Monitoring Guidelines document (ANZECC and ARMCANZ 2000) sets out a standard structure (i.e. framework) for the design of a monitoring program (see Figure 1.1). The chapters in the Guidelines lead the monitoring team through the necessary stages in Figure 1.1. Each chapter contains a summary flowchart and checklist (copied in subsequent sections below and referred to with the links shown on Figure 1.1), and these chapters discuss how to:

- define information requirements and objectives for monitoring programs (Chapter 2);
- design a study, including its type, scale, measurement parameters and sampling programs, and preferred methods for sampling (Chapters 3 and 4);
- design a laboratory program including preferred methods for laboratory and field analysis (Chapters 4 and 5);
- set up quality assurance and quality control procedures (Chapters 4 and 5);
- be aware of occupational health and safety concerns (Chapters 4 and 5);
- statistically analyse and interpret the data (Chapter 6 and Appendix 5);
- report and disseminate information to various audiences, and collate feedback (Chapter 7).

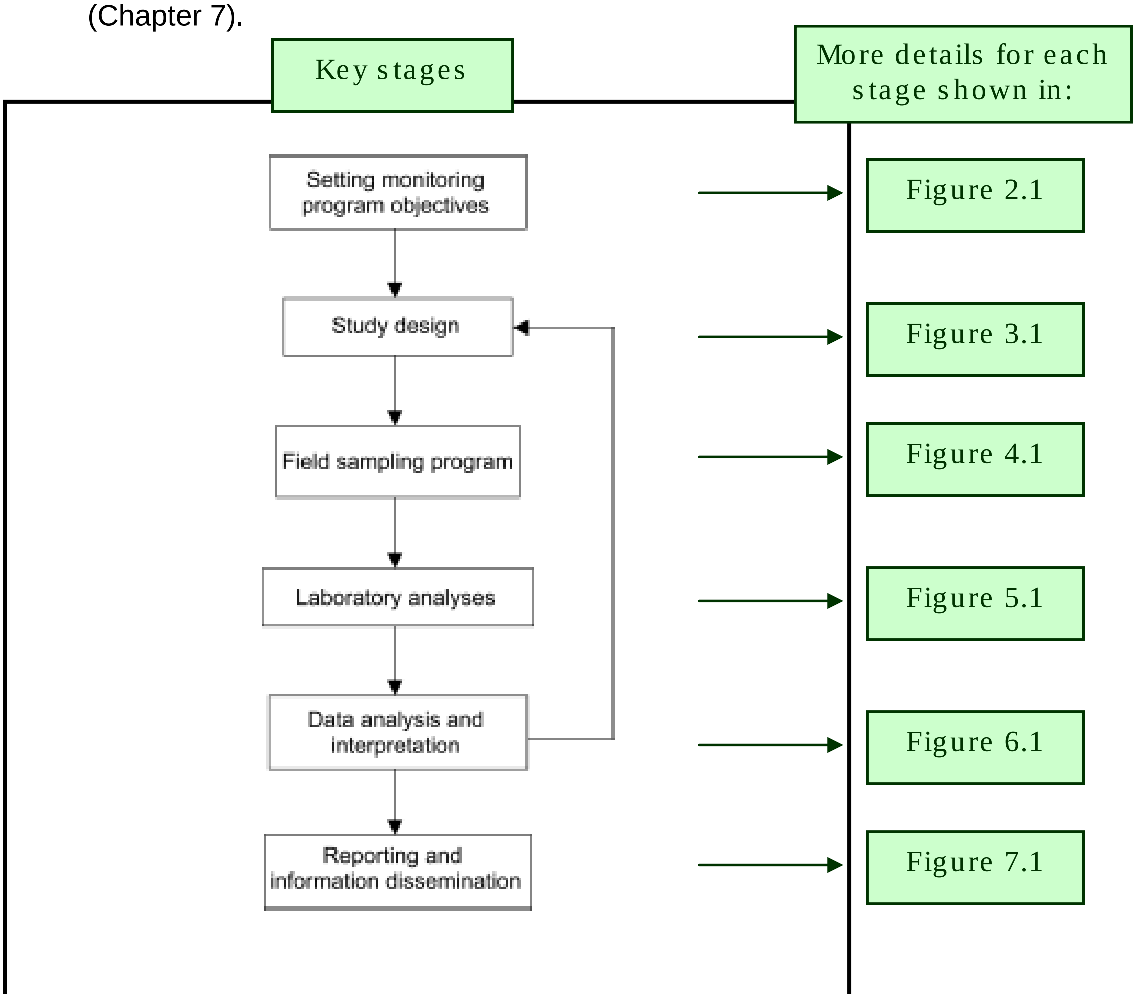


Figure 1.1. Framework for a water quality monitoring program. Each box is dealt with by one chapter of the Monitoring Guidelines, from Chapter 2 to Chapter 7.

Sometimes, more detailed advice will be required and this can either be found in the appendices to the Guidelines or in references or other listed sources.

It is important to remember that the design of a monitoring program is an iterative process, as indicated in Figure 1.1, and that earlier components in the structure should be refined on the basis of findings in later stages. The Monitoring Guidelines is intended for use by water quality personnel with basic technical training, involved in environmental monitoring throughout Australia, working in agencies, water authorities, catchment management authorities, councils, industry, consulting companies and tertiary institutions. It should also be helpful for community groups.

Setting Monitoring Program Objectives

The most important component of a monitoring program is to define its objectives clearly; otherwise it will not be able to fully address the more detailed questions of how to undertake the required investigation. The objective of an effective monitoring program is to provide information and knowledge about a particular issue, preferably for the least cost, to inform those who have commissioned it and will use the data. Good monitoring programs are not just exercises in data collection.

Before defining the objectives and information requirements, the first step is to identify the issues that are to be addressed. After a comprehensive analysis of the issues, the monitoring team should understand what information is needed, and be able to formulate the specific objectives for the monitoring program.

Water quality management issues in Australia typically fall into four categories:

- the long-term management, protection and restoration of aquatic ecosystems so they can fulfil their beneficial uses / environmental values;
- contaminants, their sources and fates in aquatic ecosystems, the magnitude of the problem and the actions that need to be taken to protect the beneficial uses / environmental values;
- the performance of management strategies; and
- conformity with water quality guidelines.

These sorts of issues have driven many monitoring programs in the past. Many monitoring programs have set out to collect information relevant to the environmental values (called ‘beneficial uses’ in NT) of a water body. Beneficial uses / environmental values reflect the uses that can be made of the water body, perhaps by aquatic ecosystems, or as water supply for primary industries (irrigation, stock drinking water, agriculture and aquaculture), or for recreational use and aesthetics, or for drinking water. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000), from now on termed the Water Quality Guidelines, has been developed so that these values can be protected.

Monitoring of waters is commonly undertaken to meet one of the following general objectives:

- to measure the quality of ambient freshwater or marine water;
- to provide assurance that the water meets appropriate guidelines for its designated use;
- to investigate why the water may not be meeting such guidelines;
- to assess the loads of materials entering the water body from the catchment (export studies);
- to assess the loads of materials carried past various points, the transformations of materials and the rates of loss in-stream or over-bank, so that streamflow mass balances can be calculated;

- • to characterise the biota within a river, estuary or coastal marine water body;
- to assess biological productivity;
- to assess the state of the resource as defined by a variety of measurement indicators (State of the Environment reporting, and National Audit reporting);
- to assess the effectiveness of actions for contaminant control, or restoration or rehabilitation of waters; and
- to identify trends in the condition of the water body.

Figure 2.1 outlines the process for translating issues into monitoring program objectives.

A key component of the objective-setting exercise is making a preliminary assessment of the issue and then developing a conceptual model (see dotted red box in Figure 2.1) that can form the basis of the proposed monitoring study. The conceptual models developed as part of this project will greatly assist managers with setting monitoring program objectives.

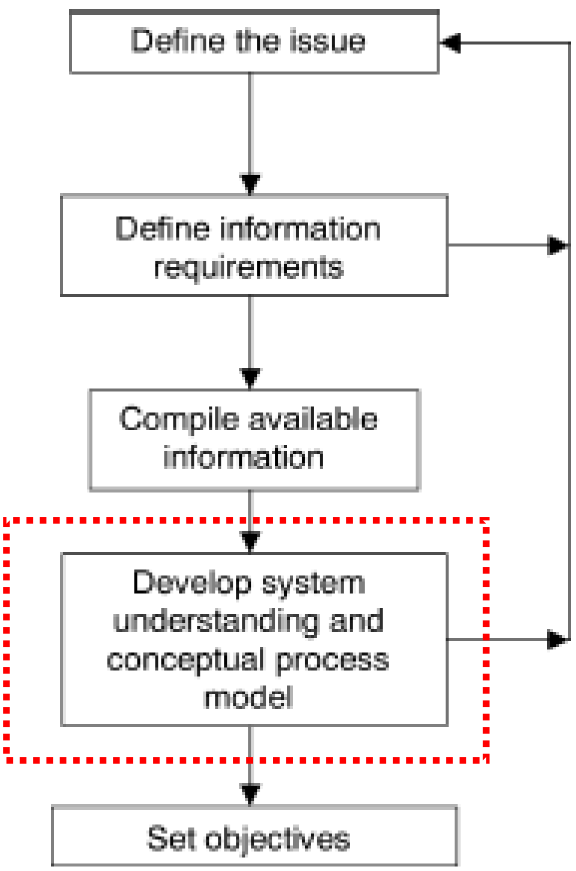


Figure 2.1. Framework for setting monitoring program objectives

Study Design
Once the conceptual model is agreed and the objectives of the monitoring program defined, the next stage involves general decisions about a more detailed design that also specifies data requirements. This is a fundamental stage that ensures that the sampling and analysis programs are cost-effective. It takes place before sample collection starts, and again involves interaction with the end-users of the information.

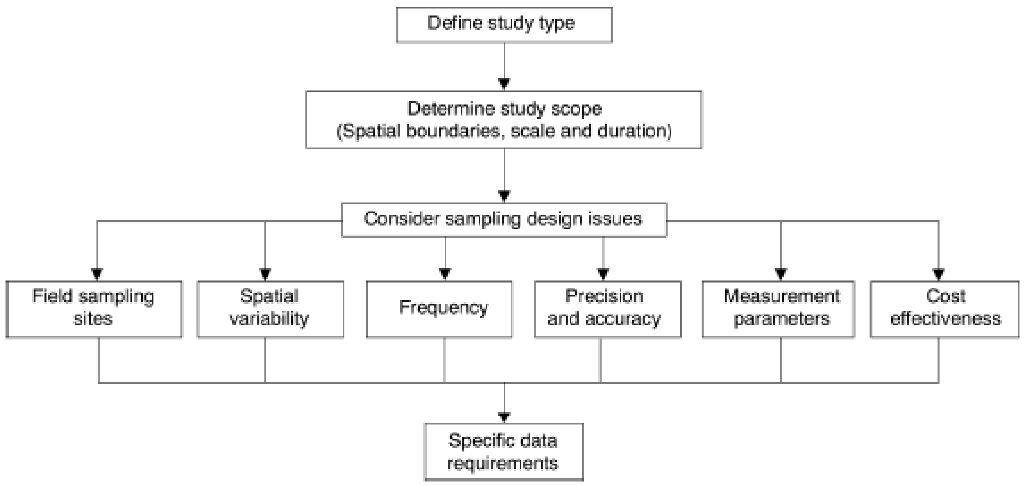


Figure 3.1. Framework for designing a monitoring study

A key component of the study design involves assessing sites for suitability, before subsequently installing equipment, and collecting data.

The monitoring program must be designed to meet the needs for data analysis and interpretation. Water quality monitoring should be linked to monitoring the pressures/threats to assist in the interpretation of the results and also provide managers with evidence of the cause(s) of water quality degradation.

The simplest data analysis would be to compare water quality concentrations with a guideline value and conclude that the sample or samples pass or fail the criterion. A fail infers that there has been an impact, with the most probable cause or causes identifiable from the conceptual model. When water quality monitoring is accompanied by monitoring of drivers, the causes of a failed sample may be apparent. When multiple causes for water quality degradation are present, the design of the monitoring program would ideally permit an assessment of each potential threat's impact independently, though this cannot always be achieved.

The inference that water quality is degraded through human activities, based on one or more sample concentrations that exceed a criterion, may however be false. It is possible that the concentration that exceeds a water quality objective is caused by natural variability. This is likely to occur if measured water qualities did vary only slightly from the water quality criterion, and if the criterion was based on a data set that did not account for inter-annual variability.

To overcome the issue of natural variability, a reference site can be monitored, where catchment drivers are unlikely to impact on water quality. Such an approach lends itself to statistical analysis to infer whether an impact has degraded water quality. The underlying assumption is that natural variability in water quality will occur equally at both the potentially impacted and the reference site.

One of the most powerful designs for data collection and analysis is the Before-After-Control-Impact (BACI) design. This design provides for the sampling of one or more potentially impacted sites both before and after the time of impact, and is compared to control sites that are not impacted and monitored over the same period. There are several types of BACI designs that address different questions and have different data requirements and analyses. The choice of sites, however, can be problematic when catchment land-use is diverse. Despite this, because much of the Katherine and Daly River catchment is not fully developed, this design may be applicable and provides a powerful method to infer impact. There are many texts on the design of monitoring programs for statistical analyses. A recent text, directed to water scientists, planners, engineers and managers, is Downes et al. (2002).

An advantage of the statistical approaches is that the risk of making an error in decision-making can be assessed. There are two types of error:

1. Concluding there is an impact, when in fact, none exists (Type 1 Error)
2. Concluding there is no impact when one exists (Type 2 Error)

Site Selection

Prior to installing equipment or collecting water samples, selected sites should be checked for accessibility:

- Is the site easily accessed?
- Are there safety concerns regarding the site e.g. crocodiles?
- Is the site likely to provide the anticipated results?
- Are there alternative sites?
- Is permission required from land holders to access sites?
- If undertaking work on Aboriginal lands, have the necessary permits and/or land use agreements been obtained from the Northern Land Council (NLC)? Information to undertake work or research on Aboriginal land can be accessed from the Northern Land Council's website at: http://www.nlc.org.au/html/visit_general.html

Commonly, sites are selected with the use of maps, and upon inspection of the site, there may be factors which make the site unsuitable. For example, sites downstream of river tributaries are often selected to monitor the effect of a tributary on a larger river. This assumes the tributary water is well mixed with the larger river and this should be tested, as it can take several kilometres for tributary waters to become fully mixed with river water. Tributary water can flow along a bank or indeed flow under or on top of the river it is entering. Careful and informed site selection is crucial to a robust monitoring program. Field visits will be necessary to ensure that sites selected are suitable to measure the required indicators.

Where access through private property is required, it is recommended that agreements are put in place with land holders and indigenous groups (through the NLC as listed above). Those responsible for monitoring should provide regular results to the land holders and traditional owners and provide copies of any related reports.

Equipment

When considering deploying equipment, site accessibility and the cost of servicing the equipment need to be taken into account. Telemetry could be considered where frequent access is difficult or costly.

If equipment is to be installed, consider the location of the installation, is it likely to be damaged or vandalised? Can the equipment be relocated so it is less likely to be damaged?

Prior to purchase of water quality monitoring equipment, investigations as to the most appropriate and reliable equipment should be undertaken. The cheapest option is not always reliable and could result in higher costs over the long term.

Equipment maintenance and calibration needs to be scheduled into the monitoring program in accordance with manufacturer recommendations, as should training in the use and maintenance of equipment.

Implementation

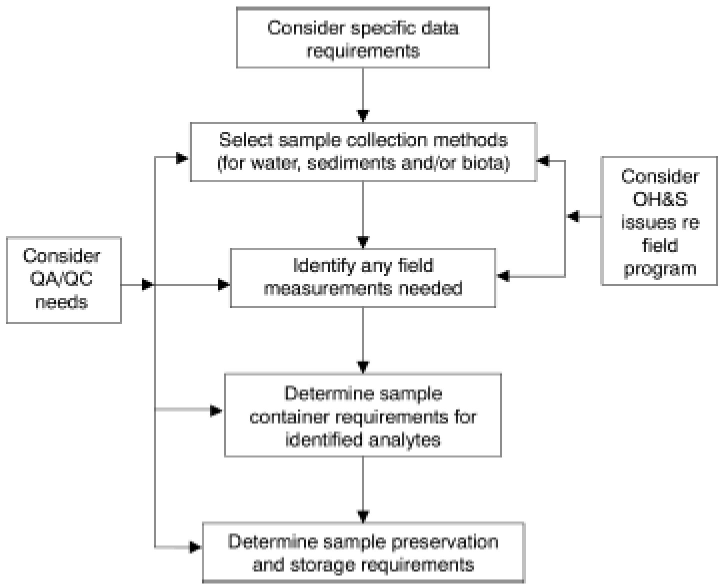


Figure 4.1. A framework for designing sampling programs

Once sites have been selected, measurements of water quality can commence. This can be done by:

- installing instruments long-term, e.g. a turbidity meter linked to a data logger and telemetry;
- measuring water quality in the field; or
- collecting water samples for laboratory analysis.

Regardless of the method employed, personnel taking water samples or measuring water quality need to be suitably trained in occupational health and safety standards and procedures and instrument use and water sample collection procedures.

Occupational health and safety considerations specific to the Katherine and Daly River catchment include sunburn, dehydration, biting insects, crocodiles and boating safety. In the wet season, there is risk of flooding and cutting of roads, additional supplies should be carried. Due to the remoteness of much of the catchment, telephone coverage will not always be available. Detailed travel itineraries and scheduled check-in times should be arranged prior to conducting any field work.

There are national standards for the collection of water quality samples, including storage and transportation. These standards are described in the Australian and New Zealand Standards (AS/NZS 1998) and can be purchased online at: http://www.saiglobal.com/shop/script/search.asp

Examples of relevant standards include:

- AS/NZS 5667.1:1998 : *Water quality - Sampling - Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*
- AS/NZS 5667.6:1998: *Water quality - Sampling - Guidance on sampling of rivers and streams*
- SA/NZS 5667.11:1998: *Water quality - Sampling - Guidance on sampling of groundwaters*
- AS/NZS 5667.4:1998: *Water quality - Sampling - Guidance on sampling from lakes, natural and man-made*
- AS/NZS 5667.10.1998: *Water quality – Sampling – Guidance on sampling of waste waters*
- AS/NZS 5667.12:1999: *Water quality - Sampling - Guidance on sampling of bottom sediments*

It is particularly important that consistent methods are used for collection of data as this ensures results are comparable. For quality assurance purposes, the relevant standards should be followed at all times, regardless of who is collecting the data.

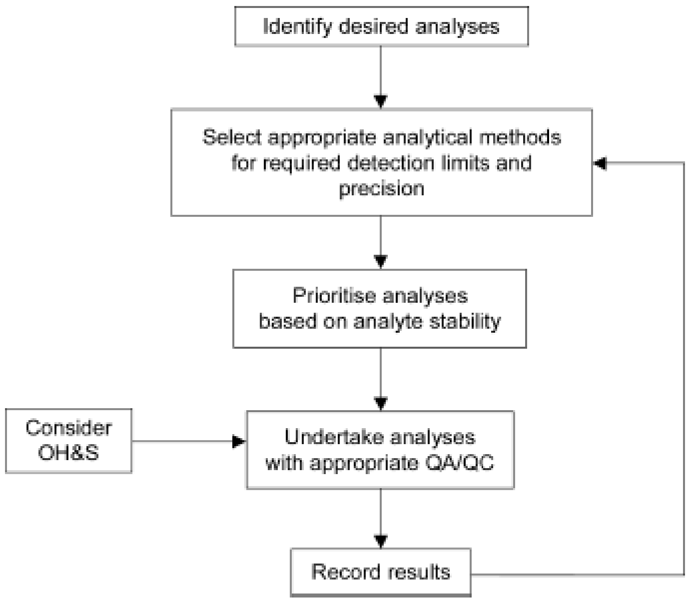


Figure 5.1. A framework for designing an analysis program

If samples are collected for laboratory analysis, laboratories that are certified with the National Association of Testing Authorities (NATA) are preferable. NATA is Australia's national laboratory accreditation authority. NATA accreditation ensures a high level of quality assurance and control. Laboratories will also give advice on how to preserve and store samples and often provide containers for collecting water samples.

Data analysis and interpretation

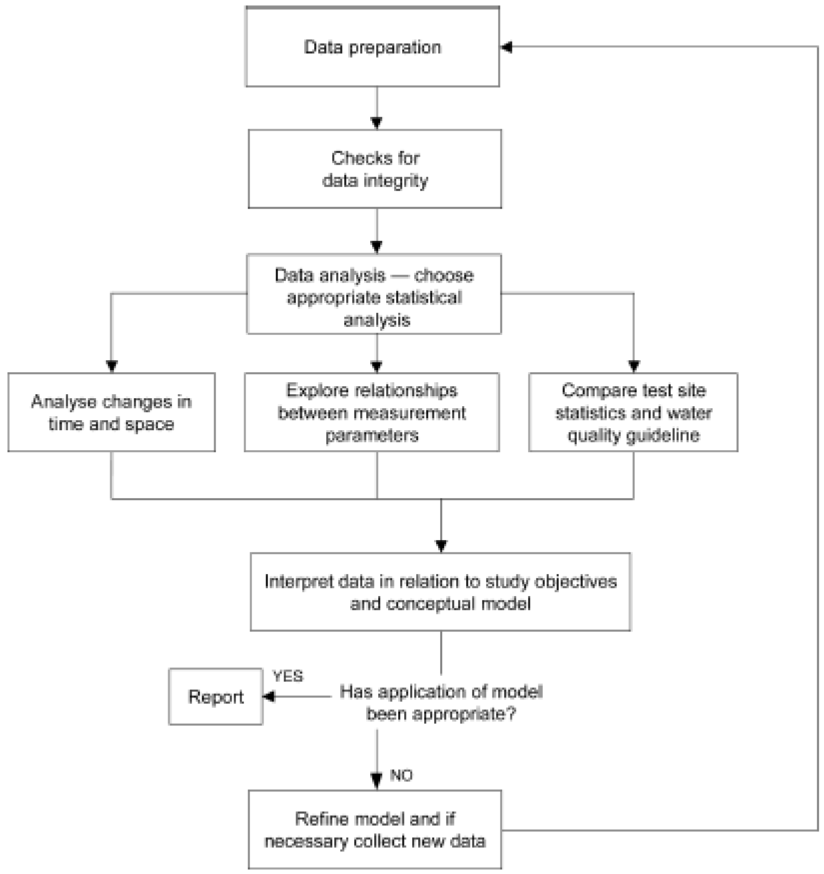


Figure 6.1. Framework for data analysis and interpretation

This section of the Monitoring Framework relates to the evaluation and assessment of the effectiveness of the monitoring program against the defined objectives and importantly, provides recommended courses of action depending on results.

Adaptive management, which assumes incomplete knowledge of system responses, requires continuous review and improvement and will often necessitate modification of our conceptual understanding, monitoring objectives and/or management responses.

Considerations in the evaluation and assessment of monitoring programs should include:

- Have the objectives of the program been achieved?
- Has the monitoring program been adequate? e.g. were the right indicators selected?
- Has the information gained led to a change in the conceptual understanding?
- Were issues identified that were not anticipated? e.g. presence/absence of contaminate(s)?
- Were the desired outcomes achieved through the implementation of the management actions or policies?

In relation to the Integrated Natural Resource Management Plan (INRM Plan) for the Northern Territory (Northern Territory Natural Resource Management Board, 2005), consideration should also be given to the relevant management actions, management action targets and resource condition targets identified in the INRM Plan. In short, the resource condition targets (RCT) for water quality should the same as the water quality objectives (WQO) for each river and stream (see Appendix 7 for a comparison of the terminology used for the INRM Plan under the former NHT2 program [e.g. RCT] and that used for the NWQMS [e.g. WQO]).

The INRM Plan's management actions are short-term actions (i.e. generally less than 5 years) that lead to the achievement of defined management action targets. In turn, management action targets are designed to lead to the achievement of the broader long-term goals (10-20 years). These long-term goals are referred to as resource condition targets. The INRM Plan identifies a number of management actions, management action targets and resource condition targets that relate specifically to water quality (i.e. the WQOs). Examples are displayed in Figure 9 below. Progress towards achieving these targets should also be assessed and integrated into the review phase.

It is important that it is clear who is responsible for taking remedial action if necessary. Collecting and analysing data is only one part of a monitoring program. Taking action in relation to results is another.

Figure 9 Management Action Targets and Resource Condition Targets

Management Actions: MA5-16 and MA5-17

Monitor, report and regulate discharges to inland waters in line with the NWQMS and the thresholds defined in above mentioned action.

Implement industry monitoring and reporting programs for discharge waters

Management Actions: MA5-44

Develop data sharing arrangements between government agencies, resource users, landholders, and local communities to ensure water quality data etc. are available for all regional and property-based planning

Management Action Target: MAT5-3

By 2010, water quality standards for sediment and nutrients in waste water discharges into developed catchments and groundwater systems will be set, incorporated into integrated catchment management plans and considered in waste water discharge licensing.

Management Action Target: MAT5-9

Improved networks, partnerships and processes are developed across state boundaries, between sectors and communities, and within government agencies to improve understanding, planning for and management of inland water resources by 2008

Resource Condition Targets: RCT5-3 and RCT 5-4

By 2020, surface and groundwater quality is maintained in all undeveloped catchments.

By 2020, surface and groundwater quality is improved in degraded and developed catchments.

Source: Extracts from the Northern Territory Natural Resource Management Board (2005) Integrated Natural Resource Management Plan for the Northern Territory.

Reporting

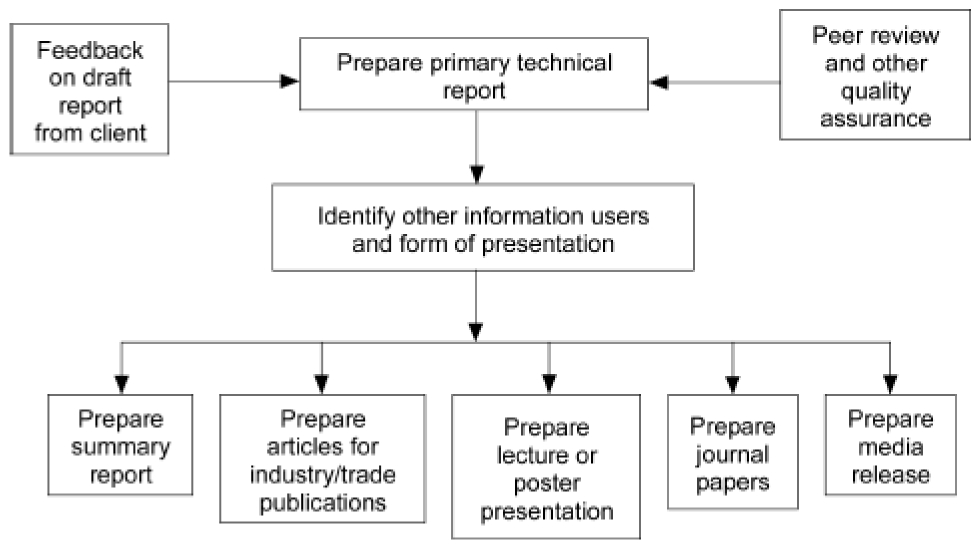


Figure 7.1. A framework for designing a reporting system

Reporting water quality data is an integral component of water quality monitoring and management. The results from water quality monitoring need to be reported to several audiences or bodies, depending on the objectives of the monitoring program. These include:

- Controller of Water Resources to assess whether water quality objectives are being met;
- Controller of Water Resources to assess whether licence conditions for water quality monitoring are being met;
- Scientists for peer review; and
- Stakeholders and the community for public information.

Reporting to the Controller of Water Resources initiates a management response, whilst reporting to other scientists underpins the credibility of water quality monitoring. Reporting to the community and stakeholders seeks to inform and educate the public about water quality, the effectiveness of water quality management, and water quality issues that need to be addressed.

A range of communication media and products are used to ensure stakeholders and the community are informed of water quality monitoring results. This acknowledges their wide range of needs and preferences for communication. Community and stakeholder consultation for this project identified face-to-face presentations, newsletters available in hardcopy or from a web page, and water quality data sheets as the three forms of recommended communication. Newsletters were the preferred format.

The newsletter should display the results of the water quality monitoring as well as the thresholds (i.e. water quality guidelines) for the identified Beneficial Uses e.g. Ecosystems, Raw Drinking Water and Stock. A simple report card or traffic light system could be used to display whether the water quality was acceptable for the Beneficial Uses. An example of a newsletter is displayed in Table 14, and provides a clear, easy to interpret colour chart. Web links should also be provided on the newsletter directing people to further water quality information including:

- the location of the database or web-based interface that can access database information;
- the significance of each water quality parameter measured; and
- past annual report summaries.

It has been suggested that the NRETAS Maps website would be a useful tool to display water quality data and related reports. As the site is already established, incorporating water quality information should be relatively cost effective, particular considering NRETAS also hold the HYDSTRA database capable of housing water quality data.

Table 14 Example of Reporting of Water Quality to Stakeholders

SITE	Sample Date (Previous / Latest)	Test Results (previous / latest)	What does this mean for:-		
		EC (µS /cm)	Stock	Agriculture	Environment
Weirs					
Bedford Weir (200m upstream near surface)	17 Dec / 21 Dec	210 / 222			
Bingegang Weir (Town Water Supply offtake near surface)	03 Dec / 09 Dec	360 / 350			
Tartrus Weir (100m upstream near surface)	27 Nov / 04 Dec	1108 / 363			
Eden Bann Weir (200m upstream near surface)	03 Dec / 10 Dec	755 / 910			
Fitzroy Barrage (Town Water Supply intake near surface)	15 Dec / 22 Dec	801 / 694			
NRW Gauging Stations					
Yatton (Isaacs R)	13 Dec / 22 Dec	263 / 226			
Coolmaringa (Mackenzie R)	15 Dec / 22 Dec	348 / 394			
The Gap-Eden Bann Weir (Fitzroy R)	15 Dec / 22 Dec	843 / 617			

DARK GREEN	LIGHT GREEN	YELLOW	ORANGE	RED
Normal levels	Above normal but not exceeding any alert threshold levels	Early Alert for a particular reason	Approaching guideline or threshold levels	Guideline or threshold levels exceeded

Source: Extract from the Fitzroy River System Water Quality Management Weekly Update 22 December 2008. http://www.epa.qld.gov.au/register/p02701ak.pdf accessed on 15 January 2009

Table 14 above clearly shows where the water quality is adequate for the identified beneficial use and where the levels are approaching (yellow and orange) or exceeding (red) the relevant threshold/WQ guideline values. At a glance, it is clearly evident that the beneficial use for ecosystem protection is not met at 3 of the monitored sites and 2 sites are assigned alert status.

Other methods of displaying data may include report card systems, i.e. A = good water quality, F = fail or poor water quality. The report card system is used in the Healthy Waterways Partnership Program in Queensland at:
www.healthywaterways.org .

Results displayed on maps are another effective method of reporting. Again a colour can be used to represent whether or not the water quality is acceptable or poor. An example of this can be accessed online at:
http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/current_water_quality_in_queensland/

Simple tables can also be used to display results with highlights or colour systems indicating results that have exceeded the water quality objectives.

Whatever method is employed, it should clearly indicate where water quality thresholds/guidelines are exceeded, or approaching these limits. Any signs of poor or deteriorating water quality should stimulate investigations of the likely cause, and be followed up with appropriate management actions.

Data Storage
Once data is collected it needs to be stored. Adequate storage of data is essential for records management and particularly important to support the analysis and reporting on it e.g. detecting long-term trends in water quality.

Ideally, all data that relates to water quality should be stored in a central repository. Having a central data repository provides a one stop shop for people seeking water quality data and significantly reduces the resources required to obtain existing data. To date, water quality data has been collected by NRETAS, DRDPIFM, Power and Water Corporation, Greening Australia, Landcare Groups[25] and numerous research organisations. As part of the consultation phase of this project, surveys identified that most often water quality data was stored on individuals' computers. A central repository for data would benefit all those involved in, or with an interest in, water quality and would significantly reduce duplication.

A central repository also provides a degree of consistency as quality codes assigned to data inform the user of the accuracy of the data. Accurate and consistent data quality coding is an essential and necessary task, as the codes assigned to the data will determine the suitability of the data for analysis and decision making. Quality coding is a necessary requirement for all those wanting to use the data. It is then up to the discretion of the user to determine what data to include or exclude when analysing or interpreting results.

The repository should also contain site summary information such as site establishment and closure details, length of record, quality of record and who manages the site (e.g. community group, NRM Board, NRETAS, Power and Water).

Standard data collection sheets should be provided to all those involved in collecting water quality data, that capture the information required by the database. If data is subject to restricted use, at the very least, metadata should be collected and stored within the database.

While a HYDSTRA database, capable of storing water quality data currently resides with NRETAS, there is a lack of resources to adequately manage the database beyond

[25] Katherine Landcare Group was responsible for running past Waterwatch programs.

its current capacity. This is a significant impediment to the future water quality monitoring and reporting, as efficient storage and retrieval of data is essential for records management and reporting purposes.

Ideally, there should be a web-based interface to provide access to the database so that anyone wishing to view the data and download files can do so at their own convenience. This would also save considerable resources as it means that individuals can source their own data rather than relying on agencies or departments.

The Victorian Water Resources Data Warehouse provides an excellent example of readily accessible water and water quality data. It can be accessed on-line at: http://www.vicwaterdata.net/vicwaterdata/home.aspx

10.7 Appendix 7 Comparison of NWQMS and NHT Terms

The NWQMS originated in the early 1990s and there has been a steady roll out of its guideline documents since then. This was accompanied by initial Australian government publicity campaigns during the release of the guideline documents with some follow-up after the release.

At a State/Territory level, the detail of the NWQMS is well known to key people in relevant agencies. However outside of this group, while people may know that the NWQMS and its key guideline documents exist, they generally do not have a detailed knowledge of it. Similarly, while key elements of the NWQMS have been incorporated into environmental legislation in most Australian jurisdictions, the application of these elements has varied. In the NT, a key focus has been the declaration of beneficial uses (i.e. environmental values) in the *Water Act*.

The lack of ongoing publicity has meant that detailed knowledge of the strategy has been confined to a few experts in the field. The advent of regional NRM bodies has seen the recruitment of a whole new generation of NRM practitioners who, given the context described above, are largely unaware of the NWQMS.

This situation has been significantly compounded by the National Action Plan for Salinity and Water Quality (NAP) and NHT programs that, while attempting to achieve the same outcomes as the NWQMS with respect to water quality, have introduced superficially different management frameworks and a new set of terminology. Table 15 below attempts to demonstrate how the NWQMS and NHT terms complement each other and should be seen as one and the same for each river and stream.

Table 15 Comparison of NWQMS and NAP/NHT frameworks

	NWQMS framework	**NAP & NHT program frameworks (i) Standards and Targets, and (ii) Monitoring and Evaluation**
Objective of strategy / programs	Sustainable use of the nation's water resources	Achieve desired national natural resource outcomes
Purpose of frameworks	Show how the NWQMS guidelines can be applied	(i) establish the principles and requirements for NRM standards and targets, and guide investment through national NRM programs (ii) assess progress towards improved natural resource condition
What is it trying to protect?	'**Environmental values**' – that is social, economic and ecological values and uses of waters	'**Critical assets**' – e.g. ecosystem and habitat 'matters for targets' below
What does it call the 'levels of quality' of the water resource that it is aiming to achieve?	**Water quality objectives** (which includes ecosystem health objectives)	**Resource condition targets** for relevant matters for targets, including: - Inland aquatic ecosystems integrity - Estuarine, coastal and marine habitats integrity - Nutrients in aquatic environments - Turbidity / suspended particulate matter - Surface water salinity (freshwater)