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Framework for the assessment of river and wetland health: findings from the trials and options for uptake

Alluvium Consulting

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Waterlines

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Waterlines

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Abbreviations and acronyms

ARC	Assessment of River Condition
AUSRIVAS	Australian River Assessment System
AWR 2005	Australian Water Resources 2005 project
CFEV	Conservation of Freshwater Ecosystem Values
COAG	Council of Australian Governments
CSS	Catchment Simulation Solutions
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DERM	Department of Environment and Resource Management
DPIPWE	Department of Primary Industries, Parks, Water and Environment
DSE	Department of Sustainability and Environment
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EHMP	Ecosystem Health Monitoring Program
FARWH	Framework for the Assessment of River and Wetland Health
FNTSC	FARWH National Technical Steering Committee
GIS	Geographic Information Systems
GRTS	Generalised Random-Tessellation Stratified sampling
HCVAE	High Conservation Value Aquatic Ecosystems
HEVAE	High Ecological Value Aquatic Ecosystems
IQQM	Integrated Quantity and Quality Model
ISC	Index of Stream Condition
LEBRA	Lake Eyre Basin Rivers Assessment
LiDAR	Light Detection and Ranging
MDBC	Murray-Darling Basin Commission
MRHI	Monitoring River Health Initiative
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NWC	National Water Commission
NWI	National Water Initiative
RHAS	River Health Assessment Scheme
RNWS	Raising National Water Standards program
SCORM	Sharable Content Object Reference Model
SEAP	Stream and Estuarine Assessment Program
SED	Standardised Euclidian distance
SoE	State of the Environment
SRA	Sustainable Rivers Audit
SWMA	Surface water management area
SWWA	South-west Western Australia
TRaCK	Tropical Rivers and Coastal Knowledge consortium
TRARC	Tropical Rapid Assessment of Riparian Condition
Water-RAT	Water Dependent Ecosystem Risk Assessment Tool

Foreword

The National Water Initiative (NWI) calls for periodic assessments of the achievements of government efforts to deliver environmental and other public benefit objectives contained in water plans. Australian governments collectively have multi-billion dollar investment programs in water buybacks, water efficiency programs, and improvements to the delivery of environmental water, as well as in riparian and stream restoration. Measuring the environmental condition of rivers and wetlands is essential to assess the effectiveness of these investments.

The Commission's baseline assessment of Australia's water resources (AWR 2005) identified that the absence of a suitable national assessment framework was a barrier to effective decision making in water resource planning. The third biennial assessment of the National Water Initiative, *The National Water Initiative – securing Australia's water future,* goes further to add that '… there has been some progress across jurisdictions in the development of environmental management institutions and their capacity to deliver environmental water. However, accountability for environmental outcomes remains weak. In particular, monitoring capacity is often inadequate, the necessary science to link environmental watering with ecological outcomes is generally weak, and there is a lack of transparent reporting of results.'

Over the past five years the Commission, in cooperation with jurisdictions, has developed a practical, transparent and accountable framework for a national report on river and wetland health. Technical experts in the assessment of rivers and wetlands have trialled the framework and found it applicable to a range of different assessment programs and ecosystem types. The outcome is a refined national reporting model that is achievable and supported by practitioners at a regional level—the Framework for the Assessment of River and Wetland Health.

The Commission urges all parties to the NWI to work together to provide the necessary information to implement the framework and produce the first nationally-consistent reports on the condition of our rivers and wetlands.

Professor Stuart Bunn
Commissioner
National Water Commission

Executive summary

The Framework for the Assessment of River and Wetland Health (FARWH) is a system that should allow comparable reporting of river and wetland health across all parts of Australia. The FARWH builds on more than a decade of river and wetland health assessments that have been conducted at a jurisdictional level.

The need for an effective framework for river and wetland health was identified as part of the National Water Initiative's baseline assessment of water resources (Australian Water Resources 2005). This assessment recognised the absence of a suitable national assessment framework as a barrier to effective decision making in water resource planning.

The initial FARWH was developed based on existing river assessment programs in Victoria, Tasmania and the Murray-Darling Basin. It was based on a hierarchical model of river function and used indicators based on six components: Catchment Disturbance, Hydrological Disturbance, Water Quality and Soils, Physical Form, Fringing Zone and Aquatic Biota.

The initial development was followed by four trials of the FARWH between 2005 and 2011. The trials were designed to test the framework across a variety of wetland and river types, climatic zones and jurisdictions. The trials assessed a number of technical and feasibility questions to guide the national framework's future implementation. The FARWH National Technical Steering Committee – consisting of jurisdictional and Commonwealth representatives – oversaw the development and implementation of the trials.

This synthesis report compiles the main outcomes of the trials and makes recommendations for further refinement and implementation of the FARWH.

Outcomes of the FARWH trials

The FARWH trials demonstrated that an effective national approach to river and wetland assessments was possible (with some modifications) (Table 3). Although the trials identified a range of technical and methodological issues, none were considered insurmountable for reporting at a national level. Many of these issues related to the selection of supporting indicators of health and appropriate reference conditions, and were expected given the variety of river and wetland environments across Australia. The FARWH allows (indeed depends on) knowledge of the specific environment being monitored and the selection of system-appropriate sub-indices. Importantly, the general themes (termed indices) for river and wetland health appear to be relatively consistent across the country for both river and wetland systems.

Table 3: Overall findings and conclusions from the four FARWH trials

Theme	*Findings and conclusions*
Reporting of condition scores	• The trials successfully applied the six key indices identified in the FARWH foundation report and supported their use in future. • The trials found that the 0 to 1 condition rating was achievable and (mostly) meaningful. • The trials identified the need to include an additional measure of wetland extent.
Reference condition	• The trials supported the use of reference condition as a way to identify and report on condition. However, all trials found that further work was required to improve the understanding of reference condition.
Two-tiered approach	• The trials found that a two-tiered approach would be useful to identify specific areas for greater field sampling effort, based on an overall broadscale assessment. The broadscale assessment would be used to target areas for more costly field-based assessments.

The inclusion of wetlands in the assessment framework adds a level of complexity due to the relative lack of experience in wetland condition assessment – compared with river condition assessment – in the jurisdictions. In particular, the development of wetland typology (a description of the way the system functions) for some wetland types is still required. An important conclusion of the wetland trial and the subsequent jurisdictional workshop was that understanding the location and extent of wetlands was necessary to meaningfully inform wetland condition assessment.

All the trials recommended the FARWH be applicable at a variety of spatial scales to efficiently assess river and wetland health. To be truly effective the FARWH must be able to report at a national level, as well as direct monitoring and management effort at a regional scale. This finding was strongly endorsed by the jurisdictional wetlands workshop in February 2011. It has also been a finding of established programs outside of the FARWH such as the Victorian Index of Stream Condition (ISC).

When the FARWH trials and existing jurisdictional programs that follow a similar methodology are considered, the condition of a significant proportion of wetlands and rivers across Australia has been assessed at some level. While some spatial gaps remain (e.g. northern Western Australia, eastern Northern Territory/western Queensland) the progress in assessing wetland and river health since the Australian Water Resources (AWR) 2005 project has been significant. Many of the programs that have achieved this geographical coverage are not directly funded through the FARWH but have used similar methodology and techniques. The presence of the national approach (FARWH) has been seen by all jurisdictions as stimulating and aligning other river and wetland programs.

The trials and associated jurisdictional programs have therefore represented a significant step towards the AWR 2005 goal of implementing the FARWH and in turn being able to improve the management of water resources. While Australia is not yet in a position to provide a baseline assessment of the condition of rivers and wetlands, the framework has been shown to be adaptable across the variety of systems found nationally. The FARWH, together with previous Commonwealth and jurisdictional funding programs, has stimulated comprehensive and ongoing river condition assessment programs for a large proportion of eastern Australia. Where ongoing programs have not been established (e.g. in Western Australia) an assessment methodology and in some cases a baseline condition has been established. Further work is required to develop a baseline for the remaining areas of Australia that have not yet been addressed (e.g. in northern Western Australia).

Recommendations for the FARWH method

The FARWH trials identified a number of changes to incorporate into the framework's formal implementation phase. The two major recommendations will require the technical supporting documents to be updated. Those two recommendations are:

1. The inclusion of Wetland Extent as an index for all wetland assessments

An important outcome from the NSW wetland trial and subsequent jurisdictional workshop was that wetland mapping and estimation of wetland reduction over time was essential to inform wetland health assessments. This is because wetland area is often significantly altered as a result of changes in land use, hydrology or other anthropogenic pressures. The Wetland Extent index will need to allow for the high natural variability of Australian wetland environments and be appropriately linked with other indices of wetland health. The inclusion of this index has implications for the FARWH's implementation given much of the country does not have baseline mapping of wetlands. Wetland mapping therefore becomes a significant pre-requisite for further FARWH reporting.

2. The adoption of a two-tiered approach to the FARWH

Both the FARWH trials and the jurisdictional wetland workshop concluded that the framework needed to operate over a range of spatial scales both to satisfy national reporting needs and provide useful direction for regional monitoring and management actions. These findings are supported by experience from the Victorian ISC, which has been operating for more than 10 years using a similar approach to the FARWH. In this case the broadscale monitoring has been supplemented with more targeted assessments at a finer spatial and temporal scale for detecting change associated with management actions. Another major though not unexpected finding from the trials is that detailed monitoring of condition demands a high level of resourcing. In areas where condition is influenced by uniform and well-understood threats or pressures, the need for detailed monitoring was questioned. An approach that targeted resources to areas of high threat or value was recommended as a more efficient use of resources.

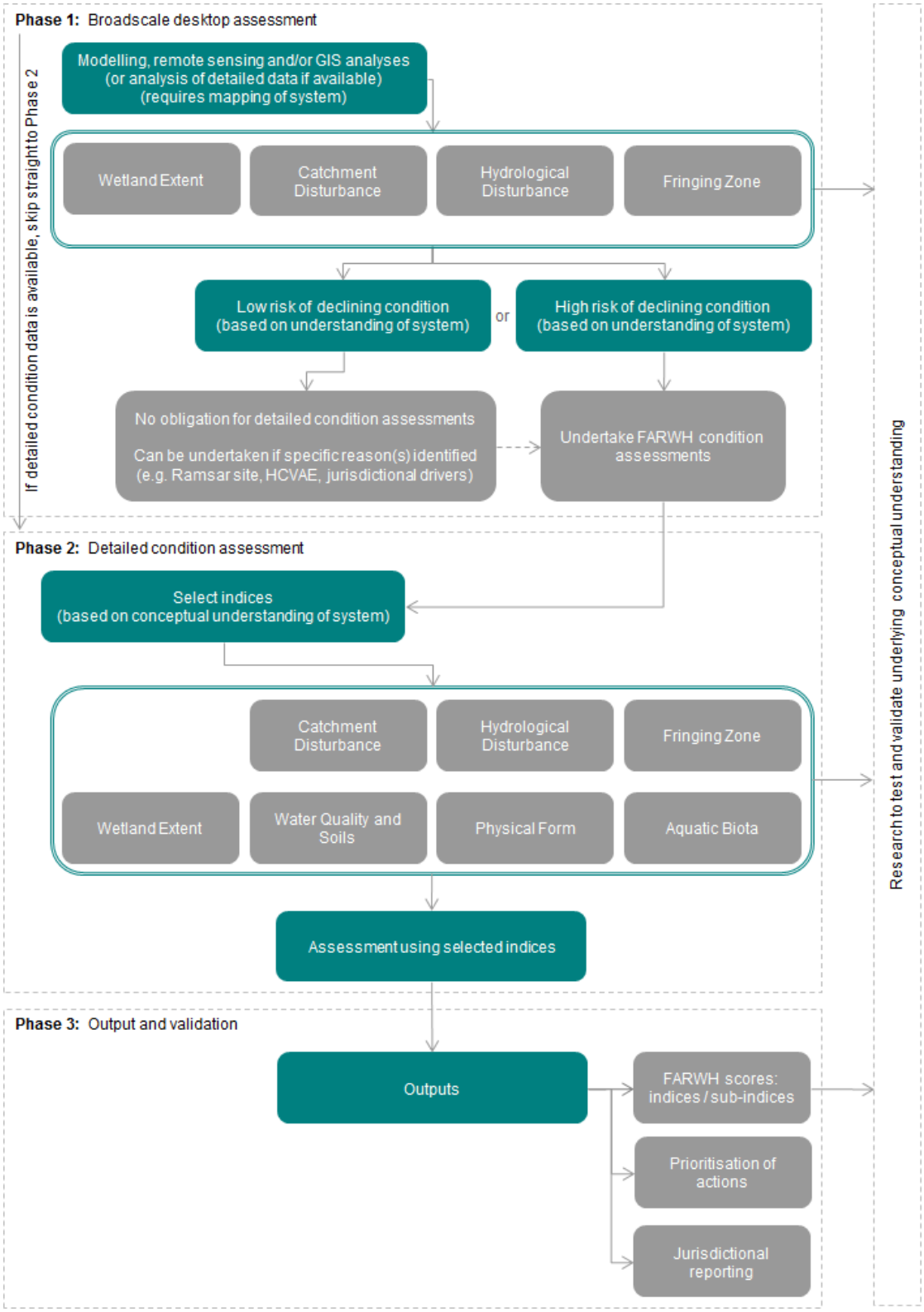
The first tier of the approach (Figure 4) involves a broadscale assessment of the entire region of interest, predominantly using existing datasets and desktop assessment methods, with the estimation of Wetland Extent as an essential component. This approach builds on numerous assessment programs that have used risk factors to infer the ecological condition of rivers and wetlands. These datasets are likely to comprise data that is threat based (e.g. Catchment Disturbance, Hydrological Disturbance) rather than direct measures of condition. If more detailed condition-based data is available (e.g. the Victorian ISC and Sustainable Rivers Audit for the Murray-Darling Basin) this step can be bypassed.

The second tier involves a more detailed assessment at the reach or site scale for systems at a high risk of change or of particularly high conservation value. The full suite of FARWH indices is likely to be used in this assessment, although not all indices are necessarily required in all environments. For example, Wetland Extent may not be required if it has been adequately assessed in the first tier.

Implicit in this approach is that the conceptual models are used to link the chosen indicators with a subsequent change in condition. These models will be fundamentally different for wetlands and rivers. There will also be differences in the chosen indicators for various types of rivers, or rivers in different landscapes. While these models are available (and widely used) for many systems being considered, some systems may require further model development.

It is anticipated that including these two recommendations in the FARWH will result in a method that could provide national reporting and be used at a finer scale for jurisdictional and regional needs. A number of more detailed recommendations are outlined in the report.

Figure 4: The proposed two-tiered FARWH assessment approach



Options for implementing the FARWH

The FARWH trials and other jurisdictional assessment projects demonstrated that an effective national approach to river and wetland assessments was technically feasible. The trials also illustrated various applications of the assessment method. The jurisdictions strongly support the framework's continuation based on the recommendations of the FARWH National Technical Steering Committee (FNTSC).

In addition to the adoption of the FNTSC's recommendations, a number of projects or work packages have been identified to aid the framework's implementation. This report describes these work packages and gives broad costs based on the trials and other jurisdictional programs. The projects are:

- updating the FARWH technical guidelines
- addressing outstanding technical issues from the trials
- continuing support for FARWH governance and coordination
- compiling existing condition/risk assessments
- implementing the training and reporting website
- completing wetland mapping and typology
- supporting the ongoing research program
- implementing the knowledge and adoption program
- supporting broadscale assessments
- supporting detailed condition monitoring.

These projects have been used to outline five options to implement the FARWH (Table 14), The options are differentiated by a varying scope and level and extent of coverage, ranging from a base case to extensive monitoring (Case 5). All options have been costed at a preliminary level, with costs per year ranging from $225 000 (Case 2) to $1 177 000 (Case 5) and the additional up-front costs ranging from $720 000 (Case 2) to $4 840 000 (Case 5) – the base case does not involve any new costs. It should be noted that hybrids of these options involving different work packages are possible and this would require further detailed planning between the parties involved.

Table 14: Options for future operation of the FARWH (all cases assume the recommendations of the FARWH National Technical Steering Committee (FNTSC) regarding a two-tiered approach and wetland extent are adopted)

Option	*Central actions*	*Jurisdictional actions*	*Probable outcomes*
Base case – jurisdictional reporting	• None	• Based on local needs	• Comprehensive reporting will not be possible at a national level • Jurisdictions continue with own programs based on local needs • Based on current levels of effort significant work will still occur in some places, however coordination will be ad hoc • The original FARWH (in terms of indices) will probably still provide some guidance for jurisdictional programs for a short time. This will diminish as methods and technology progress
Case 2 – national reporting at a 10-year interval	• Coordination of the FARWH including the operation of and support for the FNTSC • Publication of FARWH technical guidelines as new methodologies and approaches arise • Resourcing the compilation of jurisdictional data • Maintenance and updating of the website • Compilation of all existing data (FARWH trials and other) into the FARWH	• Based on local needs • Follow broad FARWH framework • Report data at 10-year intervals (via website)	• Reporting at a national level will be patchy, with large parts of the country not being assessed. Few areas will have detailed condition assessments even if considered high risk • Jurisdictions continue with own programs based on local needs • Based on current levels of effort significant work will still occur in some places, though large sections of the country will have little coverage • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources
Case 3 – national reporting at a five-year interval using broadscale desktop assessments	As above plus: • Funding provided for jurisdictions to undertake broadscale assessments based on desktop analysis at five-yearly intervals • Support for jurisdictions to undertake baseline mapping of wetland extent • Funding for compilation of existing data into the FARWH framework (and website)	• Use two-tiered approach to prioritise and report on efforts • Detailed condition assessments based on local needs • Follow broad FARWH framework • Report data at five-yearly intervals (via website)	• National reporting on river and wetland health based on broadscale desktop assessments. However, high-risk areas will have incomplete coverage in terms of detailed condition assessments • Jurisdictions continue with own programs based on local needs. Based on current levels of effort significant detailed work will still occur in some places • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources

Option	*Central actions*	*Jurisdictional actions*	*Probable outcomes*
Case 4 – national reporting at a five-year interval using broadscale desktop assessments and limited field assessments	As above plus: • Funding assistance provided for first two monitoring periods to support jurisdictions that do not currently have monitoring programs	• Follow broad FARWH framework • Use two-tiered approach to prioritise and report on efforts • Undertake monitoring program (funded for some high-risk areas) • Report data at five-yearly intervals (via website)	• National reporting on river and wetland health based on broadscale assessments. High-risk areas will be identified, however there is no specific funding identified to undertake more detailed condition assessments • Jurisdictions continue with own programs based on local needs. Based on current levels of effort significant detailed work will still occur in some places • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources
Case 5 – national reporting at a five-year interval using broadscale desktop assessments and detailed field assessments	As above plus: • Funding for nationwide monitoring at five-yearly intervals	• Follow broad FARWH framework • Use two-tiered approach to prioritise and report on efforts • Undertake monitoring program (funded for all high-risk areas) • Report data at five-yearly intervals (via website)	• National reporting on river and wetland health based on broadscale assessments. All high-risk areas will have detailed condition assessments • Jurisdictions continue with own programs based on local needs. Based on current levels of effort significant detailed work will still occur in some places • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources

1. Background

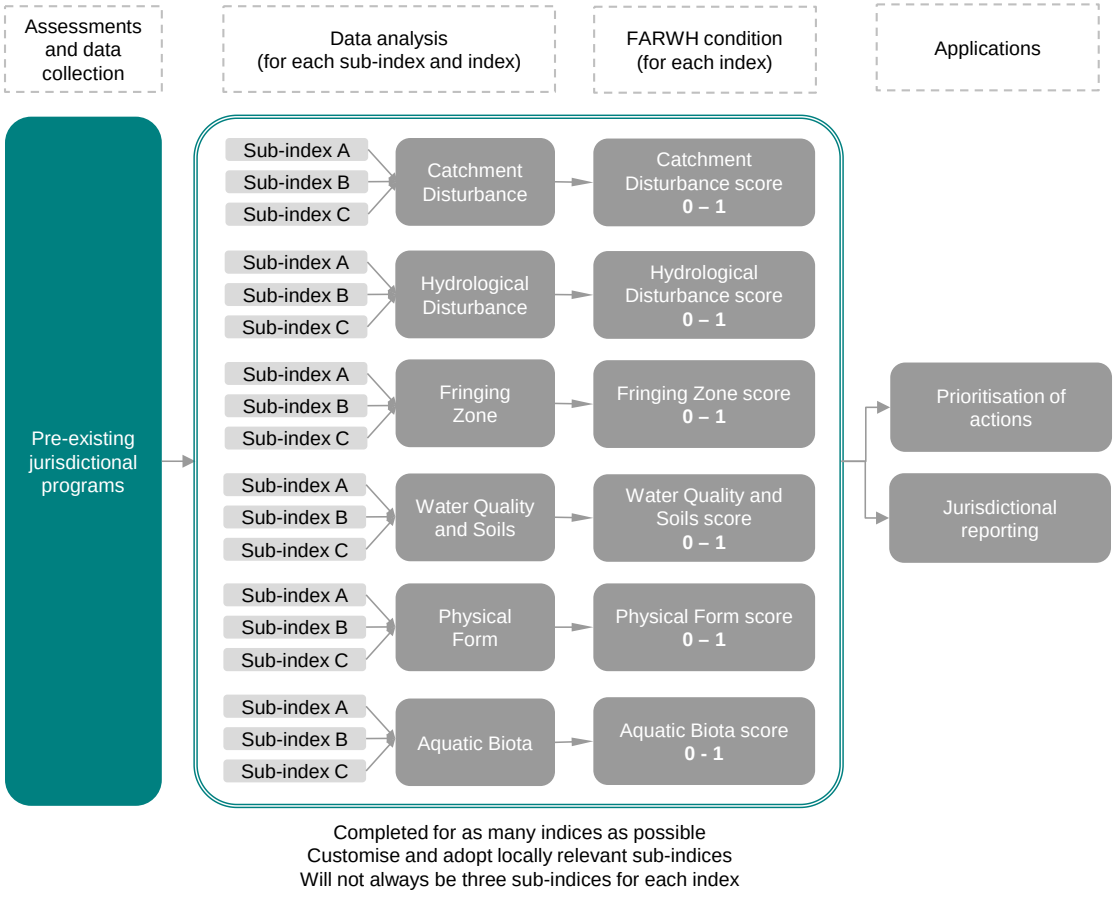
1.1 What is the FARWH?

The Framework for the Assessment of River and Wetland Health (FARWH) has been developed to allow all Australian states and territories to provide assessments of river and wetland health that are comparable across jurisdictions. The FARWH allows for existing river and wetland condition data from across Australia to be normalised and integrated to allow consistent reporting. It is not intended that the framework replace existing jurisdictional assessment systems.

The FARWH is based on a hierarchical model of river function and was initially designed to use six indices that include Catchment Disturbance, Hydrological Disturbance, Fringing Zone, Water Quality and Soils, Physical Form and Aquatic Biota. The FARWH enables the data collected under pre-existing jurisdictional programs to be used to consistently report on river and wetland condition with the six indices. The FARWH's general structure as initially developed is shown in Figure 1.

The FARWH has been developed by the National Water Commission (NWC) since 2004 and builds on lessons from two decades of jurisdictional and regional assessments of water-dependent ecosystems across Australia.

Figure 1: The initial FARWH assessment approach



1.2 Context

The FARWH was developed as a major component of the baseline assessment of Australia's water resources in 2005. The baseline assessment, called Australian Water Resources 2005 (AWR 2005), identified difficulties in reporting on river and wetland health in a manner that was comparable within and across jurisdictions (NWC 2008a) and developed the FARWH in response. Without a nationally consistent methodology for assessing river and wetland health, decisions on managing water resources are likely to be applied in an ad hoc manner or made without due regard for the health of these water-dependent ecosystems. Indeed, under current arrangements management decisions are being made without adequate measurement, monitoring and reporting systems – which undermines confidence that the desired environmental outcomes are being achieved.

The FARWH was developed to identify long-term changes in condition, including changes resulting from water management regimes, based on existing information and programs (NWC 2007a). The FARWH has been advanced through a number of programs, as summarised in Table 1 and outlined below.

As part of the AWR 2005, the NWC successfully tested the FARWH against two existing jurisdictional river assessment programs: the Victorian Index of Stream Condition (ISC) and the Tasmanian Conservation of Freshwater Ecosystem Values (CFEV). The development of the FARWH during AWR 2005 was also informed by other programs such as the Sustainable Rivers Audit (SRA). The results of this testing phase were published as part of AWR 2005.

Subsequently, the NWC completed four additional trials of the FARWH in New South Wales, Western Australia, Northern Territory and Queensland. The purpose of this synthesis report is to compile the main outcomes from the four recent trials (published at the same time as this report) and provide recommendations for further refinement and implementation of the FARWH. This report is purposely focused on synthesising the FARWH's advances since AWR 2005 and therefore discusses the four recent trials, rather than the initial development and testing. This report draws extensively on the reports from the FARWH trials and recommendations from the FARWH National Technical Steering Committee (FNTSC).

This report is structured to outline the key outcomes of the FARWH trials (Section 2), identify key recommendations from the FARWH trials (Section 3) and recommend options for future implementation of the FARWH (Section 4). The report only considers the technical details of the trials to the level necessary to ensure the FARWH is suitable for its intended future purpose. The report intentionally avoids a detailed description or consolidation of the technical details of the trials, as this information is found within the published trial reports.

Table 1: Overview of the objective(s) of key documents and programs relating to the FARWH

Document/projects	*Objective(s)*	*Period*
Australian Water Resources 2005	Baseline assessment of water resources, leading to creation of the FARWH concept	July 2004 – July 2007
Raising National Water Standards: FARWH trials	Test the FARWH's applicability across a variety of wetland and river types; address technical and feasibility issues; outline recommendations and knowledge gaps to guide future implementation of the national framework	May 2008 – September 2011
FARWH: Lessons from the trials and options for future use	Synthesise key outcomes and recommendations of the trials, present refined FARWH model and options for national rollout	February 2011 – September 2011
Update of technical guidelines	Based on the approved option for the FARWH, develop step-by-step guidelines for its rollout	Post September 2011

1.3 Drivers

A number of drivers have underpinned the FARWH's initiation, development and advancement. The main drivers can be grouped into those resulting from ongoing developments in regional river and wetland health programs during the past two decades, and those associated with the centralised national water reform agenda.

National Water Initiative

In 2004 the National Water Initiative[1] (NWI) was established to build on the national water reform agenda that began in 1994. The NWI provided the principal driver for the FARWH's development via a directive for the NWC to undertake a baseline assessment of water resources (clause 105(i) of the Intergovernmental Agreement on a National Water Initiative).

The NWI objective[2] required the following outcomes for river and wetland health:

- provision for adaptive management of surface and groundwater systems in order to meet productive, environmental and other public benefit outcomes (clause 25 iv)
- identifying and acknowledging surface and groundwater systems of high conservation value, and managing these systems to protect and enhance those values (clause 25 x)
- establishing and equipping accountable environmental water managers with the necessary authority and resources to provide sufficient water at the right times and places to achieve the environmental and other public benefit outcomes (clause 78 ii)
- development and implementation of water resource accounting which provides adequate measurement, monitoring and reporting systems in all jurisdictions, to support public and investor confidence in the amount of water being traded, extracted for consumptive use, and recovered and managed for environmental and other public benefit outcomes (clause 80).

To achieve and measure the success of these outcomes the NWI implemented a baseline national assessment of water resources and governance arrangements. The early stages of

[1] The NWI is Australia's enduring blueprint for water reform. It was initiated through the Intergovernmental Agreement on a National Water Initiative, signed at the Council of Australian Governments meeting in 2004.
[2] The overall objective of the NWI is to achieve a 'nationally compatible market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes' (COAG 2004, p3).

the baseline assessment identified that river and wetland health could not be assessed on a national scale because no suitable framework existed (NWC 2007a). This provided the principal driver for the FARWH's development.

Further reporting commitments

While the NWI was the FARWH's main driver, it was also supported by and linked with a range of other policy and legislative drivers. The most notable and influential drivers are associated with reporting commitments under the Commonwealth's State of the Environment (SoE) program, the National Accounts and Australia's international commitments.

The *Environment Protection and Biodiversity Conservation Act 1999* (the Act) requires that SoE reporting is undertaken every five years to capture and present key information on the condition, pressures and management of the 'environment' at a national scale. The Act does not specify any regulations for the content of SoE reporting (DEWR 2006a). However, river and wetland health is clearly considered an important aspect of SoE reporting, as evidenced by the inland waters theme being included in all national SoE reports (DEWR 2006a).

To date, SoE reporting on river health has been limited to consideration of hydrological disturbance and water quality, and the reporting on wetland health has been limited to the extent of significant wetlands, the number of Ramsar wetlands with management plans, and isolated case studies on the condition of wetland vegetation (DEWR 2006b). The SoE assessments have been limited by a lack of consistent methods and data (Fairweather 1999). This lack of consistency is similar to that identified during the FARWH's initial development (NWC 2007a). The FARWH is seen by the NWC as one mechanism that can improve SoE reporting in the future by supporting a more consistent and representative assessment of river and wetland health across Australia.

The National Water Account is an annual publication delivered by the Bureau of Meteorology as a statutory requirement of the Commonwealth *Water Act 2007*. Its purpose is to provide a national picture of water resources, with the initial focus on identifying the total water resource, the volume of water available for abstraction, the rights to abstract water and the actual abstraction of water for economic, social, cultural and environmental benefit across Australia. To complement the National Water Account the Bureau of Meteorology and Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) have recently established a joint initiative to begin developing National Environmental Accounts, which will involve the creation of National Environmental Information Standards. The FARWH is likely to be an important mechanism to inform the assessment of aquatic ecosystems and water resources in future National Environmental Accounts.

Australia is a member of many international environmental organisations and a signatory to various international agreements concerning the environment, including the:

- United Nations Environment Programme (UNEP)
- Commission on Sustainable Development (CSD)
- Global Environment Facility (GEF)
- South Pacific Regional Environment Programme (SPREP)
- Convention on Biological Diversity
- Convention on Migratory Species
- Ramsar Convention on Wetlands
- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment

- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment
- Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds.

Under many of these (and other) agreements, Australia reports on river and wetland health at a national scale; for example, *Australia's fourth national report to the United Nations Convention on Biological Diversity* (Australian Government 2009). Given the absence of a suitable national framework (NWC 2007a), these international reporting commitments provide another driver for the FARWH's development. The FARWH may provide a mechanism to improve the quality of reporting as well as placing it within a comprehensive national framework.

1.4 River and wetland assessments

Overview of progress

Programs to assess the condition and health of Australia's rivers and wetlands have progressively improved during the past two decades. Australia's first major river health assessment program began in 1992 with the establishment of the Monitoring River Health Initiative (MRHI) under the National River Health Program (NWC 2007c). The MRHI's main objective was to develop a nationally standardised and consistent assessment scheme for evaluating river 'health'.

The Australian River Assessment System (AUSRIVAS) was developed under the MRHI (Schofield et al. 2007). AUSRIVAS is a rapid bioassessment method that uses macroinvertebrates as a sensitivity indicator of in-stream health (Schofield et al. 2007; NWC 2007c). AUSRIVAS was soon widely applied across Australia and informed the *First National Assessment of River Health*, *State of the Environment Report 2001*, the *National Land and Water Resources Audit 2002* and the *Snapshot of the Murray-Darling Basin River Condition* (Schofield et al. 2007; NWC 2007c).

The late 1990s saw the development of more holistic river assessment programs using a wider range of indices to assess multiple facets of river health, beyond macroinvertebrates and water quality (Ladson et al. 1999). Several such programs had been established by the end of the 1990s (e.g. ISC and CFEV). This trend has continued with the development of additional multi-parameter assessment programs, as discussed later in this section.

Health, condition and risk

During the formation of river and wetland assessment programs, practitioners in river and wetland management developed quite distinct notions on the definitions of 'health', 'condition' and 'risk'.

The term 'health' has been widely associated with the early river assessment programs that predominantly used macroinvertebrate assessments to infer health (Norris & Thoms 1999). For example, the AUSRIVAS method formed the foundation of the *First National Assessment of River Health.* The term river 'health' became widely synonymous with assessments limited to macroinvertebrates (and potentially water quality).

The subsequent development of more holistic assessment programs was often associated with the term 'condition'; for example, the ISC and the Index of Wetland Condition (IWC). The

term ‘condition’ became synonymous with programs including assessments of aquatic and fringing vegetation, physical form, catchment disturbance and hydrological pressures.

As actual condition data is often difficult and expensive to obtain over large geographic areas, ‘risk’ factors have also been commonly used to infer the ecological condition of rivers and wetlands. Many risk assessments have adopted a stressor-based framework (or a cause and effect framework) through the use of conceptual models. In these stressors are defined as components of the environment that when changed can affect the condition of the ecosystem; for example, the Queensland Stream and Estuarine Assessment Program (SEAP) and Wetlands Program. In this way, risk assessments can examine the activities influencing each stressor and the observed stressor response to predict the degree of risk to the ecosystem condition. There are four main factors why risk has often been used to infer condition, rather than directly measuring condition:

- complexity in the spatial and temporal variation in riverine and wetland environments makes the collection of pure condition data difficult
- there is often a paucity of available, suitable condition data
- given historical levels of funding, it is unlikely that representative condition data can be collected in all jurisdictions
- the use of risk data in some form potentially makes the assessment useful for both broadscale and finer-scale reporting for prioritisation of works.

Australian Water Resources 2005

The FARWH was developed as part of the baseline assessment of Australia’s water resources in 2005 (AWR 2005). The early stages of the FARWH’s development comprised an assessment of potential comparative indices from existing jurisdictional assessment programs. At that time, the following existing jurisdictional programs were examined for potential comparative indices (NWC 2007c):

- National Land and Water Resources Audit (NLWRA)
- Victorian Index of Stream Condition (ISC)
- Tasmanian Conservation of Freshwater Ecosystem Values framework (CFEV)
- Murray-Darling Basin Sustainable Rivers Audit (SRA).

The FARWH drew heavily on several of these programs for consistency with the existing jurisdictional approaches and to ensure the best thinking was captured in the national approach. These programs are briefly described below.

The NLWRA was established by the Australian Government through the Natural Heritage Trust (NHT) in 1997. Under the NLWRA, the Assessment of River Condition (ARC) approach was developed to assess the aggregate impacts of resource use on waterway condition at a national scale (Norris et al. 2001). The ARC has five basic indices: one for biotic condition (aquatic biota index), one for catchment condition (catchment disturbance index) and three for habitat condition (hydrological disturbance index, habitat index and nutrient and suspended sediment load index) (Norris et al. 2001).

The ISC was established by the Victorian Government in the late 1990s with funding contributions from the MRHI (Paul Wilson, DSE, personal communication). The ISC has five sub-indices to assess river health: hydrology, physical form, streamside zone, water quality and aquatic life. The ISC was applied across Victoria in 1999 and 2004 (with funding assistance from the NHT) and is currently being applied for a third assessment, with the results expected in late 2011 (Paul Wilson, DSE, personal communication). The ISC was one

of the two programs used to develop and test the FARWH as part of AWR 2005 (NWC 2007b).

The CFEV was an initiative of the Tasmanian Department of Primary Industries, Parks, Water and Environment designed to provide a comprehensive audit of the state's freshwater ecosystems (including rivers, wetlands, lakes and waterbodies, estuaries, saltmarshes, karst systems and groundwater-dependent ecosystems) and provided a baseline for the subsequent Tasmanian River Condition Index (TRCI) (DPIW 2008b; NWC 2007b). The CFEV assessment framework is based on three main components: naturalness, representativeness and distinctiveness (DPIW 2008a). The river assessment is based on 20 variables, while the wetland assessment incorporates 10 variables (DPIW 2008a). The river component of CFEV was tested against the FARWH as part of AWR 2005. The testing confirmed that the variables included in CFEV are 'similar to the main components of the environment recommended for assessment in the FARWH' (NWC 2007b, p22) and concluded that 'reasonable inter-jurisdictional comparisons' could be made at the catchment scale by using the CFEV to inform FARWH assessments (NWC 2007b, p31). However, water quality and physical form scores could not be developed and were therefore recommended for further development in the subsequent TRCI.

The SRA was established in 2004 as an initiative of the Murray-Darling Basin Commission (MDBC) to build on the concepts of the NLWRA (NWC 2007c). The SRA combines information about the status and trends of a range of environmental indicators using five themes: hydrology, fish, macroinvertebrates, vegetation and physical form (Davies et al. 2008). The first SRA assessment was conducted between 2004 and 2007 and assessed hydrology, fish and macroinvertebrates (Davies et al. 2008). The second SRA assessment is due in late 2011 and will also include the vegetation and physical form themes (MDBC 2010).

Wetland assessment programs

The FARWH's original design was based on the conceptual understanding of rivers after a decade or more of river assessment programs. While wetlands were intended to be included in the FARWH from the outset, wetlands did not form the focus of the initial FARWH development and trials (e.g. NWC 2007b). At the time of the of initial FARWH development no state-level assessment of wetland health had been undertaken and very few wetland health assessments had been conducted anywhere in Australia.

However all jurisdictions within Australia have applied some form of wetland assessment in recent years. There have been at least 17 significant wetland assessment programs implemented across Queensland, the Northern Territory, Western Australia, South Australia, New South Wales, Tasmania and Victoria. This is in addition to Commonwealth-managed projects such as the National water resource assessment using waterbirds. These assessments have been applied for many reasons, under different organisational contexts, over different scales and on a wide variety of wetlands.

The jurisdictional wetland programs with the greatest level of investment include the:

- Queensland Wetlands Program
- Victorian Index of Wetland Condition
- NSW-FARWH trials
- Tasmanian CFEV framework
- Water Dependent Ecosystem Risk Assessment Tool (Water-RAT)
- Monitoring, Evaluation and Reporting Strategy for NSW Wetlands

- National water resource assessment using waterbirds.

Given the FARWH was initially developed without a strong focus on wetlands, the framework's wetland component has been significantly advanced by the knowledge and findings gained through these jurisdictional wetland programs. As part of the FARWH program a workshop of wetland practitioners from the jurisdictions was held in February 2011. This workshop found broad agreement that the FARWH was a valuable tool for wetland assessment and would complement existing jurisdictional programs.

A number of possible recommendations were discussed in the workshop, two of which were considered critical to the adoption of the framework for wetlands. The two primary recommendations relate to the inclusion of a measure of wetland extent and adoption of a tiered assessment approach that uses desktop assessments to inform where more detailed field assessments should occur.

1.5 FARWH trials

At the completion of AWR 2005, the FARWH had been developed based on the major existing jurisdictional river assessment programs in Australia (NLWRA, ISC, CFEV and SRA) and successfully tested in riverine environments in Victoria and Tasmania.

However the FARWH had not been tested in riverine environments outside south-eastern Australia or in any wetland environments. Consequently, a key recommendation was for further trials of the FARWH to validate and improve its applicability in riverine and wetland environments across the nation.

Funding for four additional FARWH trials was approved under the Raising National Water Standards (RNWS) program. The objective of the four additional trials was to evaluate the FARWH's overall applicability in each area, based on its relationship with existing jurisdictional river and wetland health monitoring and assessment programs.

These trials were conducted between May 2008 and 2011 and included riverine environments in Queensland, Western Australia and northern Australia and wetland environments in New South Wales (Table 2). Together, the FARWH trials have been run as five separate programs undertaken between 2004 and 2011 and represent approximately 10 per cent of the continental land mass (Figure 2; Figure 3):

- Victoria and Tasmania rivers (Vic-FARWH and Tas-FARWH) – final report released July 2007
- Queensland rivers (Qld-FARWH) – final report scheduled for release September 2011
- wet/dry tropical rivers (Tropics-FARWH) – final report scheduled for release September 2011
- south-west Western Australia rivers (SWWA-FARWH) – final report scheduled for release September 2011
- New South Wales wetlands (NSW-FARWH) – final report scheduled for release September 2011.

The extent and distribution of each of the FARWH trials is described in greater detail in Appendix A (Section A3).

Table 2: Timeline of the FARWH's development and trials

Month	Outcome
June 2004	• NWI signed by all jurisdictions except Tasmania and Western Australia
July 2004 – June 2005	• AWR 2005 river health assessments undertaken
June 2005	• NWI signed by Tasmania
October 2006	• AWR 2005 Level 1 assessment released
April 2006	• NWI signed by Western Australia
July 2007	• AWR 2005 Level 2 assessment released • FARWH foundation report released • Final report from Vic-FARWH and Tas-FARWH released
May 2008	• Next round of FARWH trials begin (Qld, Tropics, SWWA, NSW)
May 2009	• First round report from Tropics-FARWH released (desktop trial)
September 2009	• First round report from SWWA-FARWH released
September 2011	• Final report from Qld-FARWH published by the Department of Environment and Resource Management (DERM) • Final report from Tropics-FARWH (field trial) published by the Tropical Rivers and Coastal Knowledge hub (TRaCK) • Final report from SWWA-FARWH published by the Department of Water (DoW) • Final report from NSW-FARWH published by the Office of Environment and Heritage (OEH), Department of Premier and Cabinet

Figure 2: Study area of the FARWH trials (study areas shown in green)

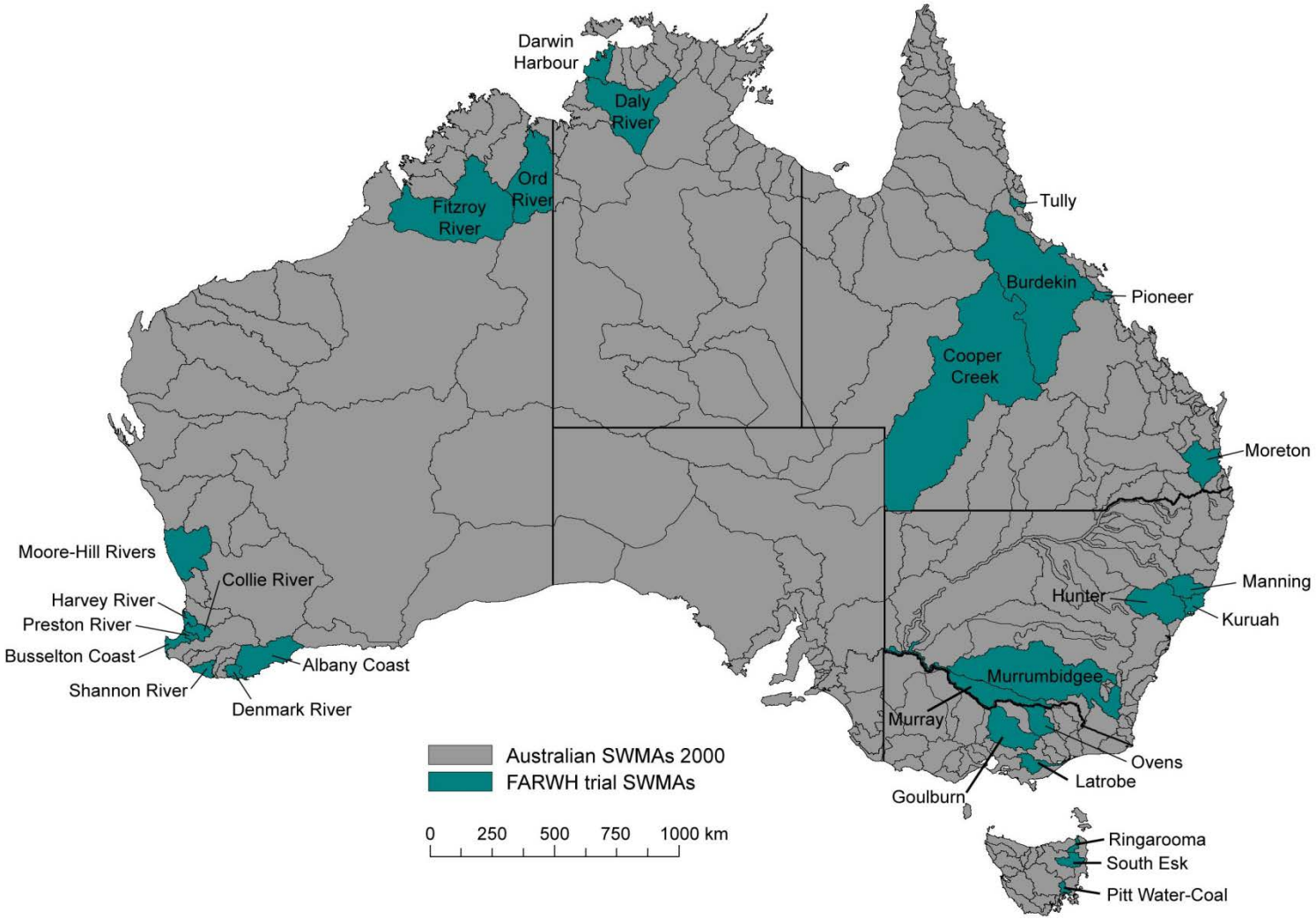
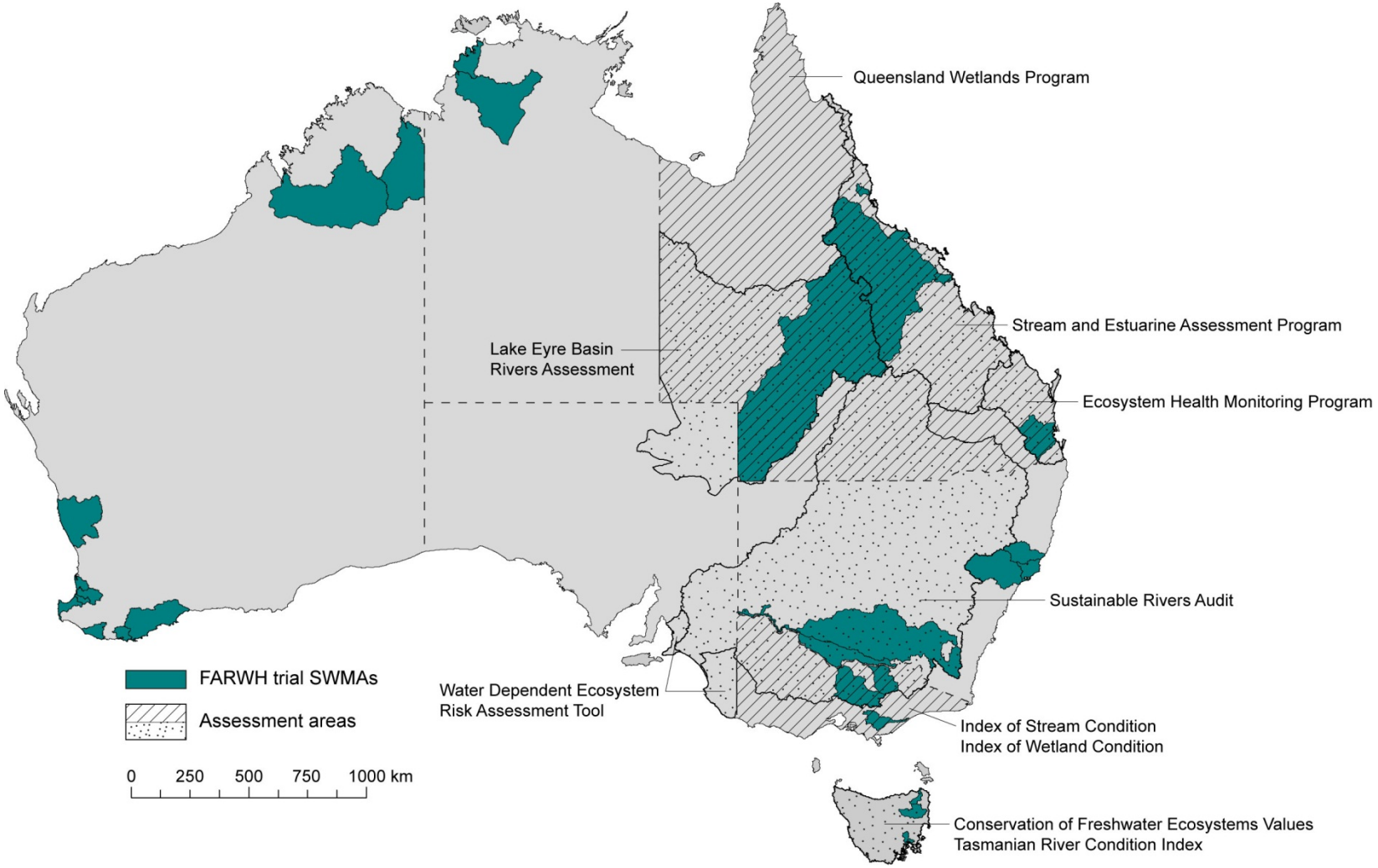


Figure 3: Area covered by the major basin- and state-scale river and wetland health assessment programs (green areas show the study area of the FARWH trials; dotted and striped areas show the assessment program areas)



Note: The implementation of the programs is quite variable and dependent largely on funding availability. For example, the Index of Stream Condition has been applied across Victoria since 1999. Conversely the Stream and Estuarine Assessment Program and Tasmanian River Condition Index methods have both been developed but not implemented statewide.

The focus of this synthesis report is the FARWH trials conducted after the release of AWR 2005; that is, the four between May 2008 and 2011. In particular, this report considers how well the existing jurisdictional river and wetland health monitoring and assessment programs supporting the trials align with the FARWH.

The overall findings and conclusions of the trials are summarised in Table 3 and discussed in detail in the next section (Section 2).

Table 3: Overall findings and conclusions from the four FARWH trials

Theme	*Findings and conclusions*
Reporting of condition scores	• The trials successfully applied the six key indices identified in the FARWH foundation report and supported their use in future • The trials found that the 0 to 1 condition rating was achievable and (mostly) meaningful • The trials identified the need to include an additional measure of wetland extent
Reference condition	• The trials supported the use of reference condition as a way of identifying and reporting on condition. However all trials found further work was required to improve the understanding of reference condition
Two-tiered approach	• The trials found that a two-tiered approach would be useful to identify specific areas for greater field sampling effort, based on an overall broadscale assessment. The broadscale assessment would be used to target areas for more costly field-based assessments

2. Outcomes of the FARWH trials

2.1 Overview

In the period between 2008 and 2011 the FARWH program gathered information from longstanding river and wetland health assessment programs, contributed to new assessment approaches, and has been trialled and tested in areas of Australia that did not have a consistent monitoring or reporting mechanism for assessing river and wetland health.

There have been three key outcomes of the FARWH trials and process so far:

- agreement on the framework for national reporting
- the alignment of assessment methods
- stimulating and assisting jurisdictional programs.

Each of these outcomes is discussed below.

2.2 Agreement on the framework for national reporting

Through AWR 2005 and the four subsequent trials, the FARWH has been developed to provide consistent reporting on river and wetland health at the national scale. The reports that accompany each FARWH trial discuss the technical details and findings from each trial, identify the knowledge gaps affecting the framework's application in each region and make recommendations for future work. The key findings, knowledge gaps and recommendations from the FARWH reports are summarised in Table 3. Recently the NWC published the full reports.

The summary (Table 3) demonstrates that several recurrent issues were identified across the four FARWH trials and these have been grouped into 11 themes. Many of the knowledge gaps (Table 3) are longstanding issues in river and wetland condition assessments. Generally they are related to either:

- a lack of data (spatial and temporal coverage) to inform the understanding of reference condition
- trials not covering all environments in the jurisdiction, but limited to specific areas
- remote sensing and GIS-based technologies having not yet been applied and tested outside of research.

Identification of these knowledge gaps and complementary recommendations has allowed the FNTSC to understand and address these issues in greater detail. Doing so has provided a mechanism to achieve agreement on a national assessment approach across a diverse range of technical issues. The most significant agreements reached through this process concern:

- the reporting and integration of condition scores
- development of indices and sub-indices
- support for a research program.

The agreement on these issues is discussed in the following paragraphs.

Reporting and integration of condition scores

At the broadest level, the FARWH trials supported application of the six key indices considered to represent the ecological integrity of rivers and wetlands. These were outlined in the FARWH foundation report (NWC 2007a) as the following:

- Catchment Disturbance index
- Hydrological Disturbance index
- Water Quality and Soils index
- Physical Form index
- Fringing Zone index
- Aquatic Biota index.

Several FARWH trials identified that further development of specific indicators would be required for future application of the framework (Table 4). Through the NSW wetland trial in particular, it was recognised that further wetland assessments would need to incorporate wetland extent, supported by expanded wetland mapping and classification. It was agreed that the FARWH should include a Wetland Extent index to identify if wetlands had been fundamentally altered in size (or destroyed) – this is discussed in detail in Section 3.1.

The trials have adopted surface water management areas (SWMAs) as their broadest reporting unit as per the FARWH foundation document (NWC 2007a). Australia's SWMAs were defined as part of AWR 2005 based on major river basins and management units previously adopted by the states and territories. The success of index-level integration at the SWMA scale varied among the FARWH trials, although all trials identified this as a problem.

For example, the SWWA-FARWH trials concluded that integration to an overall score was 'meaningless' at the SWMA scale while the Tropics-FARWH trials concluded that integration seemed appropriate, but recommended the integration methods be reconsidered so that they were more intuitive. On balance, integration of index-level scores to an overall health score was considered to provide limited value, as the assessment at the index level is widely considered to be more accurate, representative and informative than a single score.

Development of indices and sub-indices

The riverine FARWH trials all successfully developed locally relevant sub-indices for the six indices[3] and concluded that results for each index were appropriate and representative for that aspect of river health. A unique combination of sub-indices and components were applied for each index, based on the characteristics of the local environment and the available data from existing jurisdictional programs.

The wetland FARWH trial developed sub-indices for three of the six indices: Catchment Disturbance, Water Quality and Soils, and Fringing Zone. This trial demonstrated that broadscale assessments of wetlands could be made using these three indices, although the assessments would be significantly improved with the inclusion of other indices (particularly the Wetland Extent index described above).

The riverine and wetland FARWH trials demonstrated that different indices have different levels of importance in different areas. The relative importance of each index to a condition assessment was found to depend on the characteristics of the local aquatic ecology (i.e.

[3] In the Qld-FARWH trial the Hydrological Disturbance index was developed but not included in all assessments due to inconsistencies in flow records (Cooper Creek) or an absence of an Integrated Quantity and Quality Model (IQQM) model (Tully).

which factors are ecologically important) and the methods/data used to assess each index (i.e. how accurate and representative the results were).

Research program to test conceptual understandings

The FARWH trials confirmed there is also significant regional variability in the sub-indices appropriate for each index (see Section A5 for a review of which sub-indices were used in each trial). For many indices there are commonalities (e.g. turbidity and salinity are included in all water quality indices) but there are also important differences in others (see Section A5). As the identification of the appropriate sub-indices for each index changes considerably between regions, all FARWH trial reports noted that sub-index selection should be underpinned by a relevant conceptual model. In this context the conceptual model is a set of explicit assumptions that outline the relationship between the chosen sub-indices and the index. The conceptual model is therefore likely to be different (and therefore demand different sub-indices) depending on the type of system being assessed. A key outcome of the FARWH trials has been agreement that future FARWH assessments and reporting should be supported by a research program to continually test this underlying conceptual basis.

Table 4: Key findings, knowledge gaps and recommendations from the four FARWH trials

Theme	*Key findings, knowledge gaps and recommendations*
Reporting and integration of condition scores	• The trials supported use of the six key indices identified in the FARWH foundation report, with the addition of a measure of wetland extent. • In general the trials found the index condition scores were an accurate reflection of the observed on-ground conditions. Of course, in isolated cases the final index score was not perceived as reflecting on-ground conditions of an individual reach or SWMA. • Two trials (SWWA and Qld) found that index scores should not be integrated into an overall score. One trial (Tropics) found that index scores could be integrated if need be, but said it was 'critical' to report index scores from a management perspective, as low index scores may be masked by indices that score highly. The Tropics trial recommended any index integration (if adopted) be based on the mean rather than standardised Euclidian distance. In general, no trials strongly advocated for integration to a single score. • Novel presentation and communication approaches were developed through the Tropics and SWWA trials in particular. The Qld trial recommended further exploration and development of options for presentation and reporting of data. All trials supported reporting and communication of data at a range of spatial scales and levels of integration.
SWMA and reach delineation	• All trials reported results at the SWMA scale. • The SWWA trial found that SWMAs should be re-delineated to align more closely with environmental variability, using a standardised method across Australia. The trial identified this as a pre-requisite for national reporting of overall health. • The Tropics trial found a similar issue, concluding that it would not be practical to sample enough sites across a single SWMA to characterise its environmental variability (due to the very large and heterogeneous nature of SWMAs). This trial recommended future FARWH assessments focus on subcatchments of the SWMAs. The subcatchment approach is essentially the same as re-delineating SWMAs to smaller, more homogenous units. • All trials provided in-principle support for the use of SWMAs for reporting, under the proviso that further work is undertaken to re-delineate SWMAs where they are currently too large and too heterogeneous. • The SWWA trial found that reaches were sometimes inaccurately positioned and not always homogeneous, and therefore should be re-defined based on topographic conditions and a fine-scale DEM.
Expand coverage	• All trials found a need to expand the FARWH beyond the trial study area because they believed the study area did not adequately represent all environments within their jurisdiction. For example, NSW and SWWA recommended application across the entire state. This is expected to require validation and further development of the assessment methodology. • The SWWA trial found that expanding the FARWH into other ecosystem types within SWWA would require the protocol to be adapted for dry systems, river pools and the un-trialled SWMAs (i.e. across the Rangelands). Similarly the Tropics trial found adaptation was required for assessments during the wet season.
Improved sampling density and frequency	• All trials found that sampling density and frequency would need to increase above that of the trials to meaningfully account for the natural variability of most sub-indices. The trials did not identify a recommended density and frequency for application across Australia, as this would be a function of the variability of the environment and level of background data. • The Qld trial found that sampling in a single year could not provide a meaningful condition assessment in areas with high temporal variability and a large increase in sample size was required to detect ecologically meaningful changes. • The SWWA trial found that an increase in sampling density and frequency would make assessments sensitive at scales finer than SWMAs. • The NSW trial recommended a monitoring program for aquatic biota and water quality in the trial SWMAs.
Accounting for variable levels of confidence	• The trials found considerable variability in the confidence of scores from each index. • To address this the Tropics trial found that the confidence level should be

	explicitly reported, while the Qld trial found that a sub-index or index level weighting approach should be used to compensate for variable levels of confidence.
Reference condition	• All trials found further work was required to improve the understanding of reference condition. • The QLD trial recommended the development of new modelling techniques and research to establish more ecologically significant bands of condition. The trial also recommended that reference sites from outside the SWMA, but within similar aquatic ecosystems, be used where suitable. • The NSW trial found that further work was required to examine the assumptions used to establish reference condition for the fringing zone. • The SWWA trial found that a river typology assessment would provide a useful tool for establishing reference condition. The NSW trial found that the wetland typology should be replaced with functional, hydro-geomorphic typologies for improved results.
Indicator development	• Most trials found that further development of some indices and sub-indices would be beneficial. • For example, the Tropics trial found that further work was required on indicator responsiveness and thresholds to anthropogenic disturbances, particularly to identify appropriate indicators for detecting low-level disturbance. • The Qld and NSW trials found a significant need for improved hydrological modelling. In NSW the improvement would require combining groundwater, streamflow and runoff, whereas in Qld it would improve the coverage and accuracy and enable potential application of the Flow Stress Ranking (a tool that provides an objective assessment of the potential hydrological stress of a river based on a comparison of two flow records and their associated statistics). • The NSW trial found that an indicator was required to monitor changes in wetland extent. This would require completion of wetland mapping and typing across the remainder of NSW. • The NSW trial also found that further work was required on protocols to assess macroinvertebrates, frogs and water quality.
Site selection	• All the trials adopted a pragmatic approach to sampling design. • In some trials a non-random approach was found to be most appropriate for future application (e.g. Tropics trial). In others a less pragmatic random selection approach was found to be most appropriate (e.g. SWWA trial). • All the trials agreed sampling design should be influenced by pragmatic requirements (e.g. readily accessible sites and safe working environments), as well as statistical requirements for robust sampling design.
Two-tiered approach	• The Qld and Tropics trials found that a two-tiered approach would be useful to identify specific areas for greater field sampling effort, based on an overall broadscale assessment. The broadscale assessment would be used to target areas for more costly field-based assessments, possibly subcatchments within the SWMAs. • The Qld trial identified the pressure-type indicators, Hydrological Disturbance and Catchment Disturbance, as most suitable for a high-level assessment at the first tier. The Qld trial recommended that this should be standardised across all jurisdictions.
Application of remote sensing and GIS analyses	• All trials found that further development of remote sensing and/or GIS-based analyses would be beneficial for a variety of indices and sub-indices. • The NSW trial found that remotely derived data could be integrated with field-surveyed data to extrapolate wetland condition to un-surveyed sites. • The SWWA trial found that GIS-based broadscale assessments would be useful to increase the temporal frequency, but not necessarily used to focus field efforts. • The Qld and Tropics trials explicitly recommended that GIS-based broadscale assessments be used to target field assessments. • However the Qld trial concluded that some remote sensing and GIS technology used in research was not yet available or appropriate for operational monitoring and further work was required to achieve this.
Communication network	• The trials found that the communication networks developed through the FARWH provided an important knowledge transfer mechanism and should be maintained.

2.3 Alignment of assessment methods

The FARWH program has brought together leading practitioners in river and wetland health assessments from around Australia since the establishment of the AWR 2005 project. This has seen a progressive alignment of river and wetland assessment methods across existing and newly established jurisdictional programs.

The first significant examples occurred through AWR 2005 when the Victorian and Tasmanian programs were trialled against the FARWH. At this time the Victorian program was well established and able to provide important lessons for the future Tasmanian assessment programs such as the TRCI. Indeed, the TRCI was developed based on the FARWH (NRM South 2009) and learned from these experiences.

Many jurisdictional river and wetland health assessment programs undertaken throughout Australia since the FARWH's development have adopted a broadly consistent set of indices and similar assessment methods. For example, there are key commonalities among the sub-indices of all the FARWH trials (see Section A5).

Non-FARWH assessments undertaken during and after the trials have also adopted a similar methodology (NWC 2011d). For example, Victoria is developing an Index of Wetland Condition and an Index of Estuary Condition that will both conform with the FARWH (Paul Wilson, DSE; personal communication).

In relation specifically to wetlands, other key commonalities have emerged across the assessment programs undertaken around Australia in recent years. For example, the jurisdictional wetlands workshop in February 2011 identified that all wetland assessment programs had found that estimating the extent and loss of wetland area was essential to informing wetland health assessments. This information has led to the alignment of FARWH wetland assessments, including a measure of wetland extent and a two-tiered assessment approach.

The investigation of GIS-based and remote-sensing applications also identified that several pre-existing national geospatial datasets could be used for FARWH assessments in quite different environments. For example, components of the river disturbance index developed by Stein et al. (2002) were applied successfully to assess Catchment Disturbance in the NSW wetlands and Tropics FARWH trials.

The FARWH training and result publication website (see Section 3.1) provides an important mechanism to guide practitioners in the development and rollout of consistent assessment methods. The website includes an eLearning portal which is a central reference for future training to align the FARWH assessment methods.

2.4 Stimulating and assisting jurisdictional programs

There is a well-established track record of Australian Government investment in river and wetland health – stimulating and assisting jurisdictions to develop and implement their programs. For example, funding to develop the Victorian ISC was provided by the Commonwealth under the Monitoring River Health Initiative and later through the National Heritage Trust (NHT) (Paul Wilson, DSE, personal communication). Similarly, the TRCI was supported with funding contributions from the Commonwealth under the second phase of the NHT (NRM South 2009; Martin Read, DPIPWE, personal communication).

The funding track record has continued under the FARWH program. The most prominent example is the funding contribution to the trials themselves, which has seen approximately $5.3 million provided by the Commonwealth[4] for jurisdictions to build on their programs (NWC 2008c).The trials have brought together leading practitioners from across Australia, which has initiated relationships and knowledge sharing across agency, jurisdictional and disciplinary boundaries. Through the trials, there has been a rapid development of methods (e.g. NWC 2011d) and expanded geographic coverage of existing jurisdictional programs (see sections A3, A4, A6, A7 and A9).

There are several specific examples where jurisdictional practitioners reported the FARWH trials stimulated or helped their programs, including:

- In Queensland the FARWH trial ran concurrently with the SEAP's implementation and provided support and collaboration on a number of operational and technical issues. For example, SEAP and Qld-FARWH entered into a collaborative research agreement with the CSIRO Mathematics, Informatics and Statistics Division to develop sampling design protocols, which were trialled, tested and refined during the sampling phases of both SEAP and FARWH (Bill Senior, DERM, personal communication).
- In SWWA the FARWH trials developed an entire method for river assessment that previously did not exist. The new method is now being applied (provisionally called the South West Index of River Condition) for a range of other uses including an update of the River Health Assessment Scheme, assessing the effects of environmental flow releases, monitoring the impact of on-ground remediation activities and determining environmental flow requirements (NWC 2011d).
- The Catchment Disturbance index developed through the Tropics-FARWH has been adopted for reporting on the Darwin Harbour region's ecological health.
- Jurisdictional wetland assessments have been the focus of recent national forums instigated through the FARWH and now cover a wide variety of wetland types. For example the Water-RAT in South Australia – which has been informed by the jurisdictional collaboration – assesses a range of wetland-dependent ecosystems including permanent freshwater lakes, saline lakes, saline swamps and freshwater meadows.

[4] This was complemented by a further $2.6 million provided by the jurisdictions themselves (NWC 2008b).

In addition, there are several examples where the trials have contributed to a general improvement in technical capability and capacity within the jurisdictions, including:

- In Queensland the application of remote sensing and GIS-based desktop analyses during the FARWH trials led to a greatly increased capacity and usage of these techniques within DERM's Water Planning Ecology unit. The work conducted during the trials also led to a better relationship and understanding between ecological scientists and remote-sensing specialists within the Queensland government (Bill Senior, DERM, personal communication).
- Wetland practitioners in Victoria and Queensland reported that wetland programs have benefited from stimulation and assistance through the FARWH (Phil Pappas, DSE; Mike Ronan, DERM, personal communications). Wetlands have not had as strong a history of condition assessments as rivers and, as a result, the conceptual underpinnings for wetlands have required more extensive work, which has been assisted by the FARWH.

2.5 Conclusions

The outcomes from the FARWH trials have demonstrated that a national approach to river and wetland assessments is possible under the proposed broad framework. Although the FARWH trials identified a series of technical and methodological issues when applying the framework to systems across the country, none are considered insurmountable obstacles to reporting at a national level. Indeed many of these issues relate to the selection of indicators that support each index, and are to be expected given the variety of river and wetland systems across Australia. The FARWH allows (indeed depends on) the development of an understanding of the specific systems being monitored and the selection of appropriate indicators to represent each system. Importantly the six indices for rivers and seven indices for wetlands appear to be applicable across the country.

The inclusion of wetlands adds a level of complexity to the FARWH because of the lack of experience with wetland condition assessments when compared with rivers. Further work is required on wetland typology in many areas of Australia to refine indicator selection. An important conclusion of the wetland trial and subsequent jurisdictional workshop was that understanding wetland extent, and therefore wetland mapping, is necessary to meaningfully inform wetland condition assessments.

All trials recommended the FARWH needed to be applicable at a variety of spatial scales to efficiently assess river and wetland health. To be truly effective the FARWH must be able to report at a national level, as well as direct monitoring and management effort at a regional scale. This finding was strongly endorsed by the jurisdictional wetlands workshop in February 2011. It has also been a finding of established programs outside of the FARWH such as the Victorian ISC.

When the FARWH trials and existing jurisdictional programs that follow a similar methodology are considered, the condition of a significant proportion of wetlands and rivers across Australia has been assessed at some level. While some spatial gaps remain (e.g. northern Western Australia, eastern Northern Territory/western Queensland) the progress in assessing wetland and river health since the AWR 2005 project has been significant. Many of the programs that have achieved this coverage are not directly funded through the FARWH but have used similar methodology and techniques. The presence of the national approach has been seen by all jurisdictions as stimulating and aligning other river and wetland programs.

The trials and associated jurisdictional programs have therefore represented a significant step towards the NWI goal of implementing the FARWH and in turn being able to improve the management of water resources. While Australia is not yet in a position to provide a baseline

assessment of the condition of rivers and wetlands, the framework has been shown to be adaptable across the variety of systems found nationally. The FARWH and previous Commonwealth and jurisdictional funding programs have stimulated comprehensive and ongoing river condition assessment programs for a large proportion of eastern Australia. Where ongoing programs have not been established, an assessment methodology and in some cases a baseline condition has been established. Further work is required, particularly in the case of wetland mapping and typology, to develop a baseline for much of the west and north of Australia.

As a result of the trials the FNTSC has made a number of recommendations considered necessary to implement the FARWH. These are outlined and discussed in Section 3 of this report.

3. Recommendations from the trials

The trials identified a range of recommendations (Table 3) that need to be addressed over a range of scales (i.e. from national to local/regional) and involve a range of effort and complexity. Most of the recommendations can be addressed without significant further effort, but two require considerable changes to the FARWH method: the Wetland Extent index and the two-tiered assessment approach. These recommendations are discussed below.

3.1 Wetland Extent index

The NSW wetland trial and the subsequent jurisdictional workshop identified that the mapping of wetlands and estimation of wetland loss was essential to inform wetland health assessments. This is due to the fact that wetlands are often significantly changed in area or even completely lost as a result of changes to land use, hydrology or other factors. Based on this advice, in March 2011 the FNTSC recommended that an additional 'Wetland Extent index' be included as the seventh index when applying the FARWH to wetlands.

The Wetland Extent index will need to allow for the high natural variability of Australian wetland environments and focus on identifying changes beyond that expected under natural conditions (i.e. that due to anthropogenic pressures). It will also be important to ensure the Wetland Extent index and other indices are appropriately linked. For example, the interaction of the indices will need to allow for a scenario where an individual wetland has reduced in extent (beyond natural rates of variability) but still exhibits healthy characteristics (for a wetland of that size, location and character) and is therefore in good condition, albeit of lesser extent.

The inclusion of a Wetland Extent index has implications for the FARWH's operation, as much of Australia does not have baseline mapping of wetlands. Wetland mapping therefore becomes a significant pre-requisite for further FARWH reporting. Anticipated costs for wetland mapping are presented in Section 4.

3.2 Two-tiered assessment approach

Both the FARWH trials and the jurisdictional wetland workshop held in February 2011 concluded the framework needed to operate over a range of spatial scales to satisfy national reporting needs and be useful to direct monitoring and management actions (see recommendations from the Qld-FARWH and Tropics-FARWH in particular).

This conclusion is supported by experience from the Victorian ISC program, which has been operating for more than 10 years using a similar approach to the FARWH. In Victoria the broadscale assessment program continues and is used for high-level reporting, but it was found that supplementation at a finer scale was required to verify the conceptual understanding and to detect change associated with management actions over a shorter time period (Paul Wilson, DSE, personal communication).

Another major though not unexpected finding from the trials was that detailed monitoring of condition demands a high level of resourcing. In areas where condition is influenced by uniform and well-understood threats or pressures, the need for detailed monitoring was questioned.

To address these findings the FNTSC agreed in March 2011 to adopt a two-tiered assessment approach (Figure 4). The two-tiered assessment approach is a refinement of the initial FARWH assessment approach illustrated in Figure 1. The first tier of the approach

involves a broadscale assessment of the entire region, predominantly using desktop assessment methods and existing geospatial datasets. An estimation of wetland extent is an essential component of the first tier.

This approach is developed from numerous programs that have used risk factors to infer the ecological condition of rivers and wetlands (see Section 1.4). These datasets are likely to comprise data that is threat based (e.g. Catchment Disturbance, Hydrological Disturbance) rather that direct measures of condition. If more detailed condition-based data is available (e.g. ISC in Victoria, SRA for rivers in the Murray-Darling Basin) this step can be bypassed.

The second tier involves a more detailed assessment at the reach and site scales for systems at high risk of change or of particularly high conservation value. The full suite of FARWH indices are likely to be used in this assessment, although not all indices are necessarily required in all environments. For example, Wetland Extent may not be required if it has been adequately assessed in the first tier. Implicit in this approach is that conceptual models are used to link the indicators selected and a subsequent change in condition. These models will be fundamentally different for wetlands and rivers. There will also be differences in the chosen indicators for various types of rivers, or rivers in different landscapes. While these models are available (and widely used) for many systems being considered, some systems may require further model development. Systems that require further development of conceptual models are likely to include local or uncommon systems (e.g. groundwater-dependent mound springs).

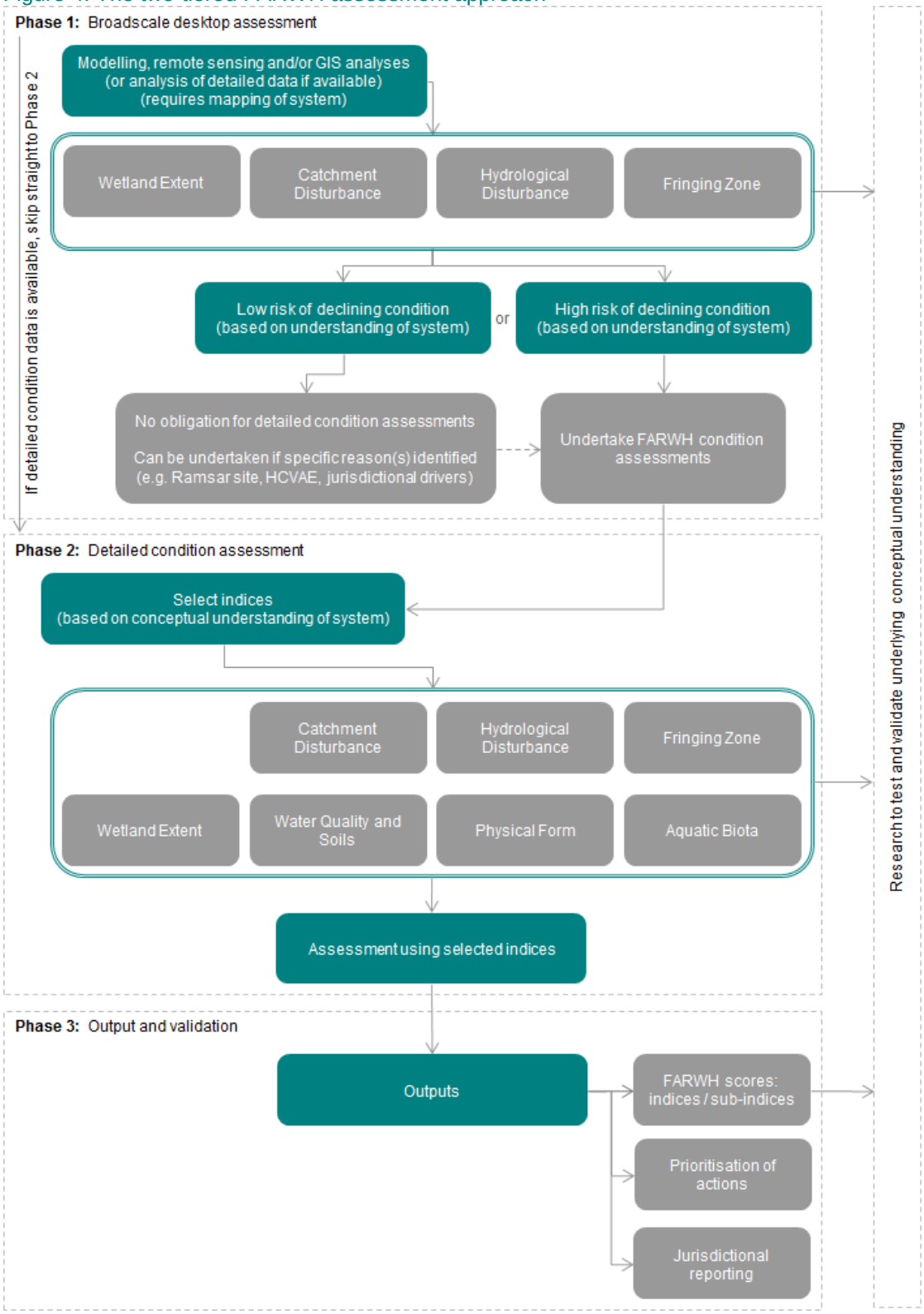
The second tier also requires a systematic method to test and verify the conceptual underpinnings of the monitoring program. This is likely to involve two elements:

- selected monitoring of systems considered in ‘good’ condition to establish a reference condition for assessment
- an associated research program (or a method to assess and integrate other research) to test and improve the monitoring program.

Through such an approach it is anticipated that resources could be effectively used to deliver a broadscale assessment, while providing the flexibility to adapt the FARWH for different types of systems. It is also designed to allow the data generated to be used at a range of spatial and temporal scales.

Further development of the two-tiered assessment approach should consider the recommendations of some trials to use a nationally consistent geospatial dataset for the Catchment Disturbance index. The further work should also place considerable emphasis on improving the understanding of reference condition and developing techniques to establish reference condition using locally relevant indicators.

Figure 4: The two-tiered FARWH assessment approach



3.3 Other recommendations

In addition to the two major recommendations discussed above, the FARWH trials raised a number of more detailed technical issues concerning the framework's implementation (Section 2.2). The FNTSC has already reached agreement on several issues during recent meetings. Further work to formally document and publish these agreements needs to be undertaken.

Proposed approaches to addressing the key findings and recommendations from the four FARWH trials are summarised in Table 5. The summary in Table 5 is supported by the following considerations:

- The FNTSC has already considered the merits of integrating scores from each index and agreed in March 2011 that the FARWH should not encourage index-level integration to a single overall score.
- The FNTSC has also considered the merits of integrating scores from rivers and wetlands within a single SWMA. Wetland assessment programs across the country have often found that even though river and wetland systems interact (particularly floodplain wetlands), assessments of condition are generally not comparable. For example, initial results from the Victorian Index of Wetland Condition program identified floodplain wetlands in good condition where the adjacent river was in poor condition. On this basis, in March 2011 the FNTSC also resolved that FARWH river and wetland condition assessment scores should not be combined into a single score.
- The re-delineation of SWMAs will need discussion through the FNTSC and with national organisations (e.g. Geoscience Australia), particularly given the NWC is not the custodian of this geospatial dataset.
- The FTNSC should discuss the mechanism to communicate FARWH results and the future of the communication network.

Table 5: Strategies to address the trials' key findings and recommendations

Theme	*Strategy*
Reporting and integration of condition scores	• Requires FNTSC agreement (with documentation) on adopting six indices for rivers and seven indices for wetlands (recommended by the FNTSC in March 2011) • Requires FNTSC agreement (with documentation) that index scores will not be integrated to an overall score (recommended by the FNTSC in March 2011) • Requires FNTSC agreement (with documentation) on the mechanism to communicate results (to be developed as part of the knowledge and adoption plan)
SWMA and reach delineation	• Requires FNTSC agreement (with documentation) on a SWMA re-delineation approach (likely to be an issue wider than the FARWH and should be raised as part of the on-going FARWH governance process) • Requires further work at a local/regional scale to revise the reach re-delineation approach (should be included in program development at a local level)
Expand coverage	• Requires further work at a local/regional scale to develop methods and conceptual models for application of the FARWH in un-trialled areas (see Section 4.1)
Improved sampling density and frequency	• Requires FNTSC agreement (with documentation) on the two-tiered approach (recommended by the FNTSC in March 2011) • Requires further work at a local/regional scale to identify regions requiring increased sampling density (should be included in program development at a local level)
Accounting for variable levels of confidence	• Requires FNTSC agreement (with documentation) on strategies to explicitly account for variable confidence levels between indices/sub-indices (not yet achieved – should be raised as part of the on-going FARWH governance process)
Reference condition	• Requires further work at a local/regional scale to improve the understanding of reference condition and reference-site selection strategies (should be included in program development at a local level)
Indicator development	• Requires FNTSC agreement (with documentation) on adopting the Wetland Extent index (recommended by the FNTSC in March 2011) • Requires FNTSC agreement (with documentation) on the specific approach to assess Wetland Extent (see Section 4.1: Updating of the FARWH technical guidelines) • Requires further work at a local/regional scale to improve the understanding of methods to assess each indicator; for example, hydrologic modelling (should be included in program development at a local level)
Site selection	• Requires further work at a local/regional scale to select the most appropriate strategy based on available data and constraints (should be included in program development at a local level)
Two-tiered approach	• Requires FNTSC agreement (with documentation) on the two-tiered approach (recommended by the FNTSC in March 2011)
Application of remote sensing and GIS analyses	• Requires FNTSC agreement (with documentation) on the possible application of nationally-consistent geospatial datasets for the broadscale assessment in the two-tiered approach (likely to be an area of continual improvement over time – should be raised as part of the on-going FARWH governance process) • Requires further work at a local/regional scale to improve remote-sensing methods (likely to be an area of continual improvement over time – should be raised as part of the on-going FARWH governance process)
Communication network	• Requires FNTSC agreement (with documentation) to continue the communication network (should be raised as part of the on-going FARWH governance process)

4. Future work

4.1 Overview of projects

A variety of programs and tasks have the potential to contribute to the FARWH's further implementation and development. This section describes each of these as a standalone project. It is acknowledged that each project will not be completely independent, but they have been described separately to help identify options for future stages of the FARWH process.

For each project, a preliminary estimate of the cost required is given. These costs are largely based on the cost estimates provided in the FARWH trial reports, as well as those provided for several established river and wetland assessment programs. Details on how these cost estimates have been calculated are provided in Appendix B.

Updating of the FARWH technical guidelines

The FTNSC's recommendations involve several changes to the FARWH that have arisen from the trials undertaken between 2007 and 2011. To formalise these changes, and to enable FARWH users to make the most efficient use of the program, the current technical guidelines will require updating. The recommendations requiring the most significant changes to the FARWH technical guidelines are the inclusion of:

- wetland extent and loss, which requires the completion of wetland mapping guidelines beforehand
- the two-tiered approach to assessment.

In addition to the FNTSC's recommendations, the trials have identified a range outstanding technical issues that should be addressed in the updated technical guidelines (see Section 3.3). The update of the technical guidelines should also consider the requirement to complete the wetland mapping and typology (discussed as a separate project below).

It is assumed the technical guidelines would require two workshops with jurisdictional representatives to finalise the recommendations (in particular the two-tiered approach). The technical guidelines would also require the FNTSC's approval. A technical specification for this work would be developed by the FNTSC.

The estimated costs for this activity are outlined in Table 6.

Table 6: Estimated costs for updating of guidelines

Tasks	*Once-off cost*	*Assumptions*
Jurisdictional representatives attendance at two workshops	–	• No cost recovery from jurisdictions
Updating of technical documentation	$70 000	• Estimated • Wetland mapping guidelines completed

Continued governance and coordination

One of the FARWH program's identified benefits to date has been the coordination of existing jurisdictional and other regional programs. Under a future FARWH program a governance structure should be set up to enable and assist coordination of jurisdictional effort. The coordinating body's responsibilities should include:

- technical assessment and recommendations regarding new methods or approaches
- coordination of the FARWH with associated river and wetland scientific programs
- commissioning and implementing future work to assist the FARWH
- expanding knowledge and adoption of the FARWH by engaging across industry.

The importance of the governance and coordination role is highlighted when considering technological advancements. The history of river health and condition assessments within Australia and internationally has shown that new monitoring and analytical methods (e.g. remote sensing or ecological monitoring) have the ability to rapidly change the way data is obtained, used and reported. For the FARWH to remain relevant it needs to retain the ability to adapt to such changes over time.

The national coordination of the FARWH trials between May 2008 and June 2011 was undertaken for a total of $210 000 (NWC 2008b) or $70 000 a year. Continued governance and coordination of the FARWH is expected to require a similar level of ongoing investment. An estimated breakdown of this allowance is provided in Table 7.

Table 7: Estimated costs for governance and coordination

Tasks	*Annual cost*	*Assumptions*
Jurisdictional representatives attendance at four steering committee meetings a year	–	• No cost recovery from jurisdictions
Administrative support	$30 000	• Requires 0.3 FTE • $100 000 FTE salary package
Operating expenses (travel, accommodation, small investigations and reports)	$40 000	• Estimated

Compilation of existing condition/risk assessments

Although only four official trials have been conducted under the FARWH (in addition to the Victorian and Tasmanian programs) there have been many jurisdictional programs looking at river and wetland health across the country.

At the jurisdictional wetlands workshop in February 2011, representatives reported on 17 programs that considered wetland condition, health or extent. The vast majority of these were assessed as being at least partially consistent with the FARWH. For those that were not consistent, the program scope was generally not related to a pure risk or condition assessment (e.g. the scope may have involved only wetland boundary delineation), indicating that consistency with the FARWH's methods would not be expected in any case.

For riverine environments, similar or greater amounts of condition and health data exist outside of the official FARWH trials. A notable example is the Murray-Darling Basin Authority's SRA program.

The last national compilation of condition and health data occurred as part of AWR 2005. It is recommended that an updated report be developed. This would provide a baseline report on river and wetland health across Australia. The dissemination and publication of its results would also help to further stimulate a coordinated national approach to river and wetland condition assessments.

The estimated costs for this activity are outlined in Table 8.

Table 8: Estimated costs for compilation of existing assessments

Tasks	*Once-off cost*	*Assumptions*
Administrative support	$50 000	• Requires 0.5 FTE for one year • $100 000 FTE salary package
Funding to seven jurisdictions (Tas, Vic, SA, NSW, Qld, WA, NT) to prepare existing data so it becomes suitable for compilation	$350 000	• Estimated consultancy fee of $50 000 per jurisdiction • Internal project management
Project to compile and analyse data using the FARWH to provide FARWH-compliant scores for publication on the website	$150 000	• Estimated consultancy fee • Internal project management

Implement training and reporting website

As part of the Tropics and SWWA trials a training and result publication website was developed by the eWater CRC with the Institute of Applied Ecology, University of Canberra and Catchment Simulation Solutions. The website was designed not only to demonstrate how the FARWH could be communicated but also how training could be managed. More specifically, the website was designed to allow jurisdictions to upload data to serve three main objectives (CSS 2011):

- educating the general public about the FARWH
- providing training materials for agency staff and volunteers
- reporting on FARWH results and delivering mapping products.

The website's landing page provides links to pages on 'what is FARWH', 'why FARWH', 'FARWH interpretation', as well as maps, results and training (Figure 5). For new users it also provides an overview video to introduce the layout of the site (Figure 5).

A major component of the website is the training portal, which is an eLearning module compliant with the Sharable Content Object Reference Model (SCORM) industry standard (Figure 6). The training material currently covers nine topics and is designed to teach the recommended methods for future FARWH assessments (CSS 2011).

The result mapping and publication application allows users to interactively examine FARWH scores across Australia for all six indices, and even scores for sub-indices (Figure 7). This information is obtainable in tabular and graphic formats. Users can zoom into the reach scale to obtain detailed condition information for a particular area of interest (Figure 8).

The website is well established and currently hosts results from the Tropics and SWWA FARWH trials. The website also has nine online training modules which have been developed to teach practitioners how to apply the FARWH methods from these trials.

However, changes to the website will be necessary to support the FNTSC's recommendations on the addition of a Wetland Extent index and the adoption of a hierarchical two-tiered assessment approach. Further work will also be required to integrate the other trial results and methods onto the website. This work should occur simultaneously with the compilation of existing condition/risk assessments so that data can be reported using a widely available and user-friendly online tool.

The estimated costs for this activity are outlined in Table 9. These costs include an initial once-off cost for website changes and the ongoing costs associated with hosting and maintaining the website.

Table 9: Estimated costs for website maintenance

Tasks	Annual/once-off cost	Assumptions
Website changes to incorporate FNTSC recommendations	$50 000 – once off	• 1 FTE for six months • $100 000 FTE salary package for maintenance
Website hosting	$9600 – annual	• Costs sourced from CSS 2011 • $100 000 FTE salary package for maintenance
Data/content maintenance	$120 000 – annual	
Software maintenance	$7500 – annual	
Hardware maintenance	$2500 – annual	

Figure 5: Screenshot of the landing page for the FARWH website

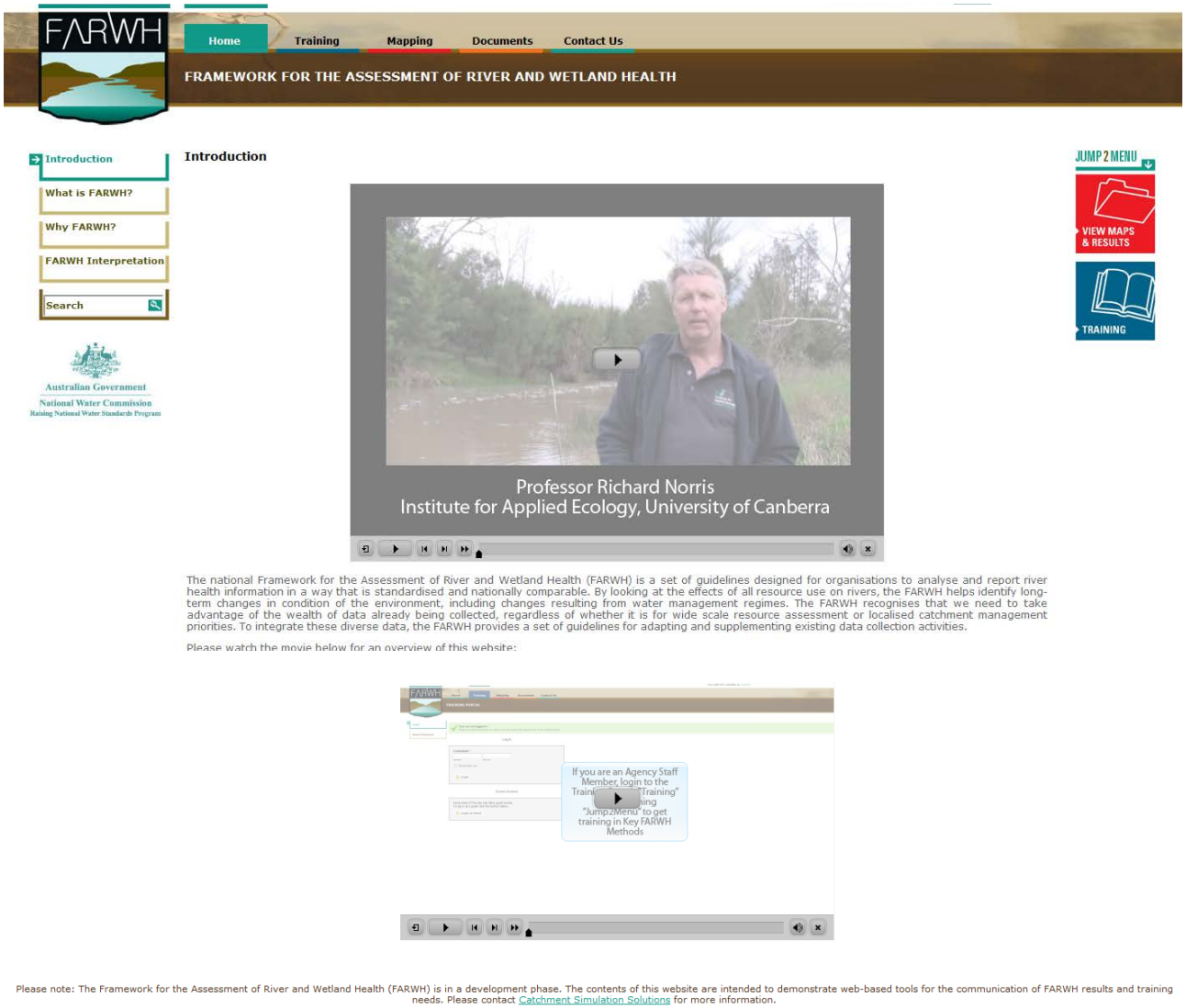


Figure 6: Example screenshot from the training portal

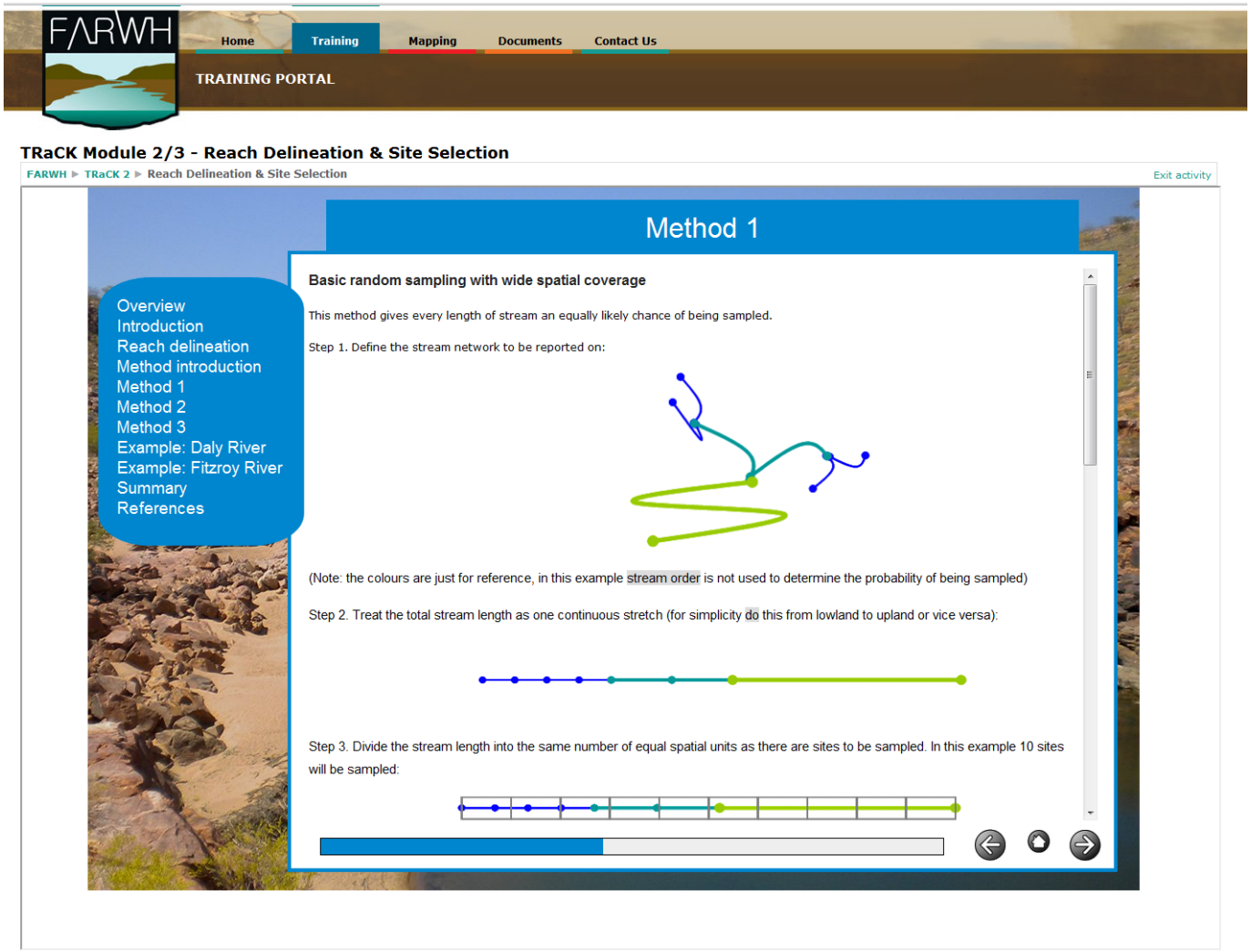


Figure 7: Screenshot of the result mapping and publication page

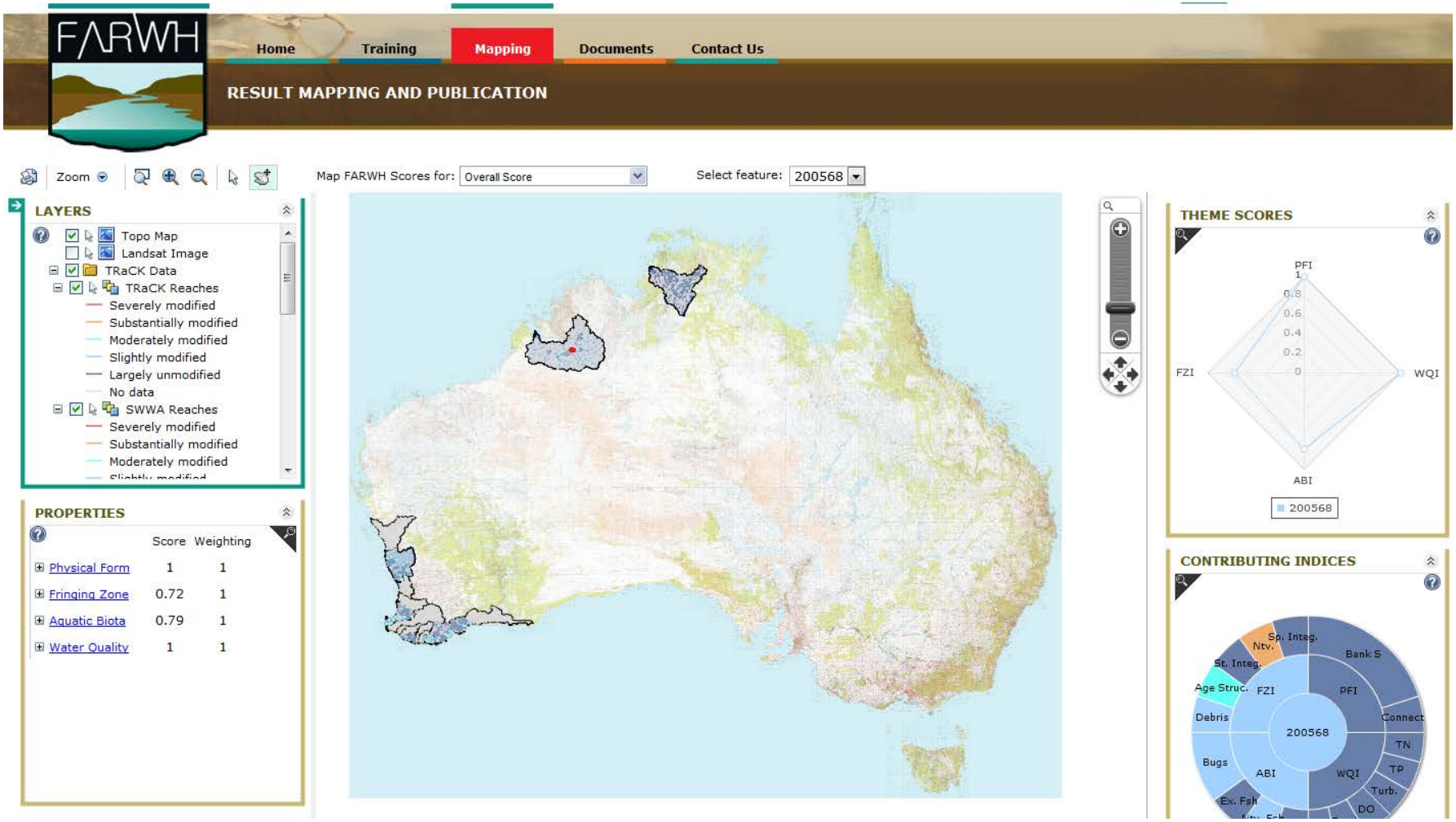
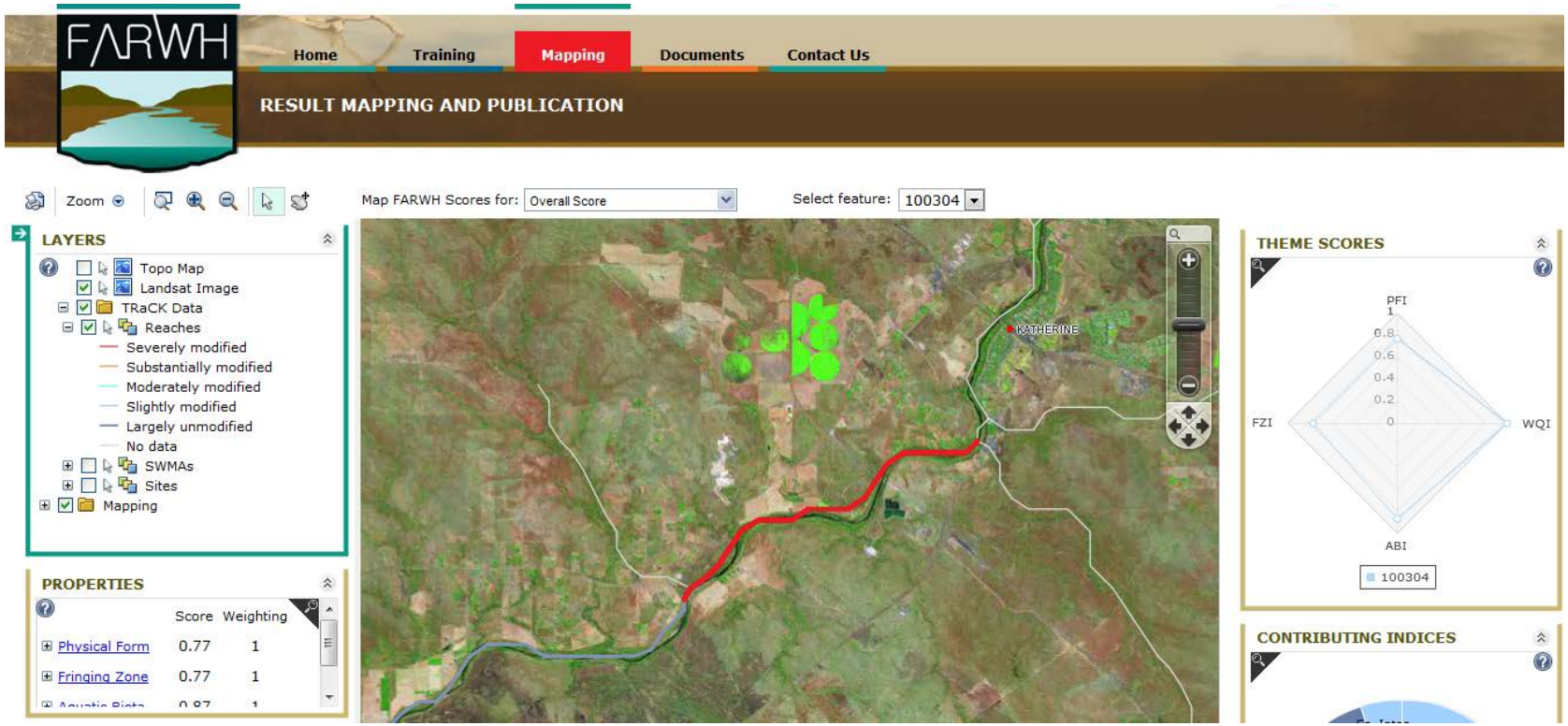


Figure 8: Screenshot of the result mapping zoomed into Katherine in the Northern Territory



Complete wetland mapping and typology

As the extent of wetlands and therefore wetland loss is considered an essential element to inform wetland health assessments, the mapping of wetlands is essential.

In jurisdictions that have done the most extensive assessments there was a common lesson: that the mapping component of wetlands was an extensive task and that sufficient resources were required to ensure success. In the largest wetland programs (Queensland and Victoria) good quality mapping of baseline extent was seen to be fundamental. The initial mapping in a sense becomes a capital investment in the program's future success.

Wetland typology systems and the associated conceptual models are less developed than equivalent systems for rivers. This is particularly the case for environments such as groundwater-dependent ecosystems. In theory, the same FARWH indices could be used for wetlands as has been used for rivers. However the specific conceptual models needed to identify the sub-indices relevant for each index require further development.

Three key pieces of work are required under the general topic of wetland mapping and typology. They are:

- finalisation of the National Wetlands Mapping Guideline (currently being developed by DSEWPaC)
- further development of wetland typology and associated conceptual models, much of which is already believed to be occurring within jurisdictions
- mapping and typing of wetlands for areas where this information is not currently available.

The estimated costs for this activity are outlined in Table 7.

Table 10: Estimated costs for wetland mapping and typology

Tasks	*Once-off cost*	*Assumptions*
Finalisation of National Wetlands Mapping Guideline	–	• Program already funded
Development of typology and conceptual models	Included below	• Typology development included in costs for undertaking mapping and typology • Issue already partially funded under existing programs
Undertake wetland mapping and typing across the remainder of Australia	$4 120 000	• No further mapping/typology required in Qld or Victoria • Mapping/typology required throughout all Australia's non-arid region (excluding Qld and Victoria) – estimated at approx. 1.3 million km^2 • Mapping/typology required in Australia's arid region is limited to areas of habitat availability for waterbirds in Roshier et al. 2001 (fig 3.9b) (excluding Qld and Victoria) – estimated at approx. 1.0 million km^2 • Cost of mapping /typology per unit area in non-arid region is greater than in arid region • Cost of mapping/typology in non-arid region is $\$2.90/km^2$, the higher of the Qld and NSW cost estimates • Cost of mapping/typology in arid region is $\$0.35/km^2$, the lower of the Qld and NSW cost estimates

Support for research program

The two-tiered approach to the FARWH is based on the assumption that by using available datasets, a broadscale assessment will be able to identify areas that are at risk of declining condition (at least at a large scale). The assessment will use a conceptual understanding of the system to inform what data is necessary.

To validate this conceptual understanding the FARWH will require inputs from relevant scientific programs. These programs should be used to continuously test the assumptions linking a particular indicator with its condition outcome for particular types of rivers and wetlands.

It is envisaged that much of the scientific work required will take place through already existing academic or government institutions (e.g. eWater CRC, universities or jurisdictional agencies). The recommended role of the FARWH in the process is to provide governance functions that enable the relevant science from Australia and internationally to be applied.

Implement knowledge and adoption program

The FARWH program is relatively well known within the jurisdictional agencies that deal with river and wetland assessments. However knowledge of the FARWH is lower at a regional level (e.g. in regional natural resource boards, catchment management authorities, academic institutions, the resource industry etc.). This is the level where most management actions are undertaken, and for many programs it is the level where data is collected. This factor is particularly important given the recommended two-tiered approach for the FARWH – which aims to allow the tool to be used at a variety of levels.

Understanding and accepting the FARWH at each of the various levels associated with river and wetland management (i.e. from national to regional) is therefore an important ingredient

for its success. Any further implementation of the FARWH should be accompanied by activities designed to educate practitioners at national, state/territory and regional levels about the FARWH to increase its adoption.

The FARWH website is seen as a key mechanism to assist in the knowledge and adoption program.

The estimated costs for this activity are outlined in Table 11.

Table 11: Estimated costs for knowledge and adoption

Tasks	*Annual/once-off cost*	*Assumptions*
Presentation of FARWH results, methods and updates at relevant forums (two a year)	$15 000 a year	• Estimated • Two presentations a year
National road show to launch the FARWH to targeted practitioners	$50 000 – once-off	• Estimated
Development and maintenance of the website	Included in previous	• Refer previous

Support for broadscale desktop assessments

The FNTSC's recommendation for a hierarchical approach using desktop assessment data at the highest level is aimed at allowing the FARWH to be implemented in areas with data gaps or limited resources. In general the jurisdictions (except for possibly Victoria) have at best incomplete temporal and spatial coverage of risk and condition assessments. Indeed most jurisdictions have very limited funding for even a broadscale assessment.

It is unlikely that a comprehensive national broadscale assessment will be achieved without support to the jurisdictions. A first step in providing support to the jurisdictions would be to provide resources for a broadscale assessment based on the protocols agreed under the FARWH. This assessment would allow a comprehensive and consistent assessment of rivers and wetlands (based largely on risk, not condition) and also allow jurisdictions to prioritise their limited funding.

It is important to note that these broadscale assessments will need to be accompanied by at least some focused detailed monitoring to ensure the validity of the process and underlying conceptual models (i.e. that the broadscale assessment is appropriate to infer the condition of various wetland and river types). Under this option the level of detailed monitoring could be fairly modest. The next option involves additional monitoring to go beyond a broadscale assessment.

The estimated costs for this activity are outlined in Table 12.

Table 12: Estimated costs for supporting broadscale assessments

Tasks	*Cost per assessment*	*Assumptions*
Undertake broadscale assessment for rivers and wetlands	$340 000	• Based on cost estimates for Qld-wide broadscale assessment for rivers and wetlands ($0.10/km^2) • Required throughout all Australia's non-arid region and all arid region with habitat availability for waterbirds in Roshier et al. 2001 (fig 3.9b), excluding all of Victoria – estimated at approx. 3.4 million km^2
Incorporate detailed condition information from Victoria (rivers and wetlands)	$30 000	• Estimated consultancy fee of $30 000
Undertake limited validation monitoring	$200 000	• Two FTEs for each of eight jurisdictions for 1.5 months • $100 000 FTE salary package

Support for detailed condition assessment

A long-term goal of the FARWH should be to achieve a consistent and comprehensive assessment of river and wetland health across the country. The FNTSC has recommended that a broadscale desktop analysis be used for the first tier, based on indices that can be monitored through desktop studies using remote sensing, modelling and GIS analysis. The second tier would involve detailed condition monitoring.

In addition to the limited monitoring required to test and improve the broadscale assessment process, additional monitoring would allow for detailed condition assessments to be undertaken in focus areas. The hierarchical approach recommends that detailed monitoring is undertaken for all systems with a high risk of change. It is envisaged that some of the high-risk (or high-value) systems will covered by programs such as Ramsar or the High Ecological Value Aquatic Ecosystems[5] (HEVAE) and thus may receive monitoring funding through other sources. Despite this, the current level of resourcing in most jurisdictions will not support condition monitoring of all high-risk systems and therefore the goal of a comprehensive condition assessment will not be achieved.

Funding, at the very least for a limited period, is likely to be required to achieve a national condition assessment. This could be undertaken in a targeted manner with areas identified through the broadscale assessment process being targeted with 'trials' similar to the initial FARWH trials.

The estimated costs for this activity are outlined in Table 13.

[5] The High Conservation Value Aquatic Ecosystems (HCVAE) project was renamed to the High Ecological Value Aquatic Ecosystems (HEVAE) project in November 2010 with the support of the multi-jurisdictional Aquatic Ecosystems Task Group and endorsement of the NRM Ministerial Councils' Natural Resources Policies & Programs Committee.

Table 13: Estimated costs for supporting detailed assessments

Tasks	*Cost per assessment*	*Assumptions*
Undertake extended detailed assessment of rivers	$3 842 000 for all high-risk areas $960 500 for selected risk areas	• Based on the unit cost per area of SRA, which approximates the median of the river condition assessment cost estimates – i.e. $5.65/km^2 • Total study area is all Australia's non-arid region and all arid region with habitat availability for waterbirds in Roshier et al. 2001 (fig 3.9b), excluding all of Victoria – estimated at approx. 3.4 million km^2 • Study area for option 5 (all high-risk areas) assumed to comprise 20% of total study area – i.e. approximately 680 000 km^2 • Study area for option 4 (some high-risk areas) assumed to comprise 5% of total study area – i.e. approximately 170 000 km^2
Undertake detailed assessment of wetlands	$300 000 for all high-risk areas $74 800 for selected risk areas	• Based on NSW-FARWH cost estimate of $0.65/km^2 • Total study area is all Australia's non-arid region and all arid region with habitat availability for waterbirds in Roshier et al. 2001 (fig 3.9b), excluding all of Victoria and Queensland – estimated at approx. 2.3 million km^2 • Study area for option 5 (all high-risk areas) assumed to comprise 20% of total study area – i.e. approximately 680 000 km^2 • Study area for option 4 (some high-risk areas) assumed to comprise 5% of total study area – i.e. approximately 170 000 km^2
Incorporate detailed condition information from Victoria (rivers and wetlands) and Queensland (wetlands)	$50 000	• Estimated consultancy fee of $50 000

4.2 Options for implementation of the FARWH

The outcomes from the FARWH's trial phase have demonstrated the technical feasibility and various applications of nationally consistent reporting on river and wetland health. There is strong support at a technical level for the FARWH's continuation based on the recommendations of the FNTSC.

Five options for the FARWH's future operation are presented (Table 14). The options are differentiated by a varying scope and level and extent of coverage, ranging from a base case to extensive monitoring (Case 5). The condition data will vary in its type, resolution and quality between each option. Therefore under all options some consideration of the most appropriate way to analyse, communicate and use the resulting condition data will be required once the assessments have taken place.

The five options are presented in a cumulative manner: each option includes the actions and costs in the preceding option. It should be noted that hybrids of these options are possible, and that further detailed planning should be undertaken when a specific approach is recommended.

In terms of costs, estimates have been made by drawing on the FARWH trials and other appropriate jurisdictional information (Appendix B). The cost estimates presented in Table 14 should be regarded as indicative. Reported costs for past monitoring programs have varied considerably due to different program objectives, the physical nature of the systems being monitored and the trial nature of some of the programs. Uncertainty regarding costs is increased by the recommended two-tiered approach which has not been used extensively in many of the current trials (although this is expected to reduce overall costs).

At a preliminary level, the cost estimates indicate that costs per year range from $225 000 under Case 2 to $1 177 000 under Case 5 (Table 15). The additional up-front cost across these options ranges from $720 000 for Case 2 to $4 840 000 for Case 5 (Table 15). These cost estimates should be refined as part of detailed planning following specific recommendations.

This level of funding ensures a progression of the FARWH's current achievements. Funding of Case 5 would be likely to provide a significant improvement in the efficiency of expenditure on river and wetland health programs across Australia. For example, a national reporting approach would see unit-cost reductions through bulk purchasing and reduce overlaps in existing assessment and reporting programs. In some cases, a national approach could partially, or even fully, replace money currently spent on state and Murray-Darling Basin assessments and national reporting requirements (e.g. State of the Environment).

Adoption of Case 3 would ensure the completion of broadscale assessments nationally, although it is likely that more detailed assessments would not achieve comprehensive coverage even for systems identified as under threat.

Jurisdictional representatives on the FNTSC expressed broad support for Case 4 or above. Case 4 or above would ensure not only a national assessment at a broad scale, but some areas that currently have limited or no monitoring coverage would receive detailed assessments (providing more confidence in the outcomes for high-risk areas in particular).

Table 14: Options for future operation of the FARWH (all cases assume the recommendations of the FNTSC regarding a two-tiered approach and wetland extent are adopted)

Option	*Central actions*	*Jurisdictional actions*	*Probable outcomes*
Base case – jurisdictional reporting	• None	• Based on local needs	• Comprehensive reporting will not be possible at a national level • Jurisdictions continue with own programs based on local needs • Based on current levels of effort significant work will still occur in some places, however coordination will be ad hoc • The original FARWH (in terms of indices) will probably still provide some guidance for jurisdictional programs for a short time. This will diminish as methods and technology progress
Case 2 – national reporting at a 10-year interval	• Coordination of the FARWH including the operation of and support for the FNTSC • Publication of FARWH technical guidelines as new methodologies and approaches arise • Resourcing the compilation of jurisdictional data • Maintenance and updating of the website • Compilation of all existing data (FARWH trials and other) into the FARWH	• Based on local needs • Follow broad FARWH framework • Report data at 10-year intervals (via website)	• Reporting at a national level will be patchy, with large parts of the country not being assessed. Few areas will have detailed condition assessments even if considered high risk • Jurisdictions continue with own programs based on local needs • Based on current levels of effort significant work will still occur in some places, though large sections of the country will have little coverage • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources
Case 3 – national reporting at a five-year interval using broadscale desktop assessments	As above plus: • Funding provided for jurisdictions to undertake broadscale assessments based on desktop analysis at five-yearly intervals • Support for jurisdictions to undertake baseline mapping of wetland extent • Funding for compilation of existing data into the FARWH framework (and website)	• Use two-tiered approach to prioritise and report on efforts • Detailed condition assessments based on local needs • Follow broad FARWH framework • Report data at five-yearly intervals (via website)	• National reporting on river and wetland health based on broadscale desktop assessments. However, high-risk areas will have incomplete coverage in terms of detailed condition assessments • Jurisdictions continue with own programs based on local needs. Based on current levels of effort significant detailed work will still occur in some places • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources

Option	*Central actions*	*Jurisdictional actions*	*Probable outcomes*
Case 4 – national reporting at a five-year interval using broadscale desktop assessments and limited field assessments	As above plus: • Funding assistance provided for first two monitoring periods to support jurisdictions that do not currently have monitoring programs	• Follow broad FARWH framework • Use two-tiered approach to prioritise and report on efforts • Undertake monitoring program (funded for some high-risk areas) • Report data at five-yearly intervals (via website)	• National reporting on river and wetland health based on broadscale assessments. High-risk areas will be identified, however there is no specific funding identified to undertake more detailed condition assessments • Jurisdictions continue with own programs based on local needs. Based on current levels of effort significant detailed work will still occur in some places • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources
Case 5 – national reporting at a five-year interval using broadscale desktop assessments and detailed field assessments	As above plus: • Funding for nationwide monitoring at five-yearly intervals	• Follow broad FARWH framework • Use two-tiered approach to prioritise and report on efforts • Undertake monitoring program (funded for all high-risk areas) • Report data at five-yearly intervals (via website)	• National reporting on river and wetland health based on broadscale assessments. All high-risk areas will have detailed condition assessments • Jurisdictions continue with own programs based on local needs. Based on current levels of effort significant detailed work will still occur in some places • The FARWH will provide guidance for jurisdictional programs in terms of new science, methods and resources

Table 15: Estimated costs to implement each option ($'000s) as at 2011

Costs – ($'000s)	*Updating technical guidelines*	*Continued governance and coordination*	*Data compilation*	*Implement website*	*Wetland mapping and typology*	*Knowledge and adoption*	*Broadscale assessments*	*Detailed assessments*	*Total*
Base case – jurisdictional reporting	-	-	-	-	-	-	-	-	-
Case 2 – national reporting at a 10-year interval	$70 once-off	$70 a year	$550 once-off	$50 once-off + $140 a year	-	$50 once-off + $15 a year	-	-	$720 once-off + $225 a year
Case 3 – national reporting at a five-year interval using broadscale desktop assessments	As above	As above	As above	As above	$4120 once-off	As above	$114 a year ($570 per assessment)	-	$4840 once-off + $339 a year
Case 4 – national reporting at a five-year interval using broadscale desktop assessments and limited field assessments	As above	As above	As above	As above	As above	As above	As above	$217 a year ($1085 per assessment)	$4840 once-off + $556 a year
Case 5 – national reporting at a five-year interval using broadscale desktop assessments and detailed field assessments	As above	As above	As above	As above	As above	As above	As above	$838 a year ($4192 per assessment)	$4840 once-off + $1177 a year

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Appendix A—Summary of approaches applied in the FARWH trials

A1. Introduction

This appendix summarises and compares the approaches of the various FARWH trials to identify broad consistencies and differences in the framework's application and implementation across Australia.

The primary focus of this review is the FARWH trials that have been undertaken since the release of AWR 2005, which have been run through four programs:

- Queensland rivers (Qld-FARWH)
- wet/dry tropical rivers (Tropics-FARWH)
- south-west Western Australia rivers (SWWA-FARWH)
- New South Wales wetlands (NSW-FARWH).

Where appropriate, the review also discusses the FARWH trials which were undertaken during the AWR 2005 development phase, which included two additional programs:

- Victorian rivers (Vic-FARWH)
- Tasmanian rivers (Tas-FARWH).

The review firstly outlines the existing jurisdictional programs which have supported the FARWH trials and then examines specific aspects of each trial in the following sections.

A2. Alignment with existing programs

The FARWH was designed to be used with existing jurisdictional programs so that data currently generated for state or regional management needs could provide an assessment that was comparable and applicable at a national level.

The FARWH trials demonstrated a wide range in the coverage and sophistication of existing jurisdictional river and wetland health assessment programs. In some trials the FARWH could be tested against existing data from a single program whereas in other trials there was no suitable existing program at all.

Table 16 summarises the key existing jurisdictional programs that supported the FARWH trials and each of these programs is outlined below in brief.

Table 16: Existing jurisdictional programs supporting the FARWH trials

Trial	Program
QLD	• Stream and Estuarine Assessment Program (SEAP) • Ecosystem Health Monitoring Program (EHMP) • Lake Eyre Basin Rivers Assessment (LEBRA)
Tropics	• Tropical Rapid Assessment of Riparian Condition (TRARC)
SWWA	• River Health Assessment Scheme (RHAS) • Ecological Values of Waterways in the South Coast Region
NSW	• None
Vic	• Index of Stream Condition (ISC)
Tas	• Conservation of Freshwater Ecosystem Values (CFEV)

QLD-FARWH

There were two existing river health assessment programs applicable for testing in the Qld-FARWH trials and another program that informed the Qld-FARWH approach.

The Stream and Estuarine Assessment Program (SEAP) is the statewide program for assessing and reporting on aquatic ecological conditions in Queensland. One province is assessed with the SEAP each year (DERM 2010). SEAP implementation began in the Central Province in 2007–08 and continued in the Wet Tropics Province during 2008–09. SEAP program data from these areas has been tested against the FARWH, without the inclusion of any supplementary field-based data collected as part of the FARWH trials (NWC 2011a).

The Ecosystem Health Monitoring Program (EHMP) provides a multi-parameter assessment of waterway health across South East Queensland's 19 major catchments, 18 river estuaries and Moreton Bay. The EHMP sampling covers 135 freshwater sites twice a year and 254 estuarine and marine sites that are monitored monthly. Data from the EHMP in South East Queensland has been tested against the FARWH.

The Lake Eyre Basin Rivers Assessment (LEBRA) is a monitoring program designed to assess the condition of the Lake Eyre Basin's watercourses and catchments. LEBRA was being developed during the Qld-FARWH trials and is scheduled to complete its 'establishment phase' in 2012–13 for a full trial assessment to be conducted in 2013–14 (Price et al. 2009). The developing LEBRA was used to guide the selection of appropriate indicators for the FARWH trial, but the program was not tested against the FARWH.

Tropics-FARWH

There was no holistic river health assessment methodology adopted in the wet/dry tropics before the Tropics-FARWH trials. The Tropical Rapid Assessment of Riparian Condition (TRARC) technique had been developed to provide a multi-parameter riparian condition assessment (Dixon et al. 2006) and was implemented in parts of the wet/dry tropics including the 'Top End' of the Northern Territory and the Ord River catchment in Western Australia (Dixon & Douglas 2007). Data from the TRARC program was tested against the FARWH and used to develop a new more holistic river health assessment method.

SWWA-FARWH

Only one applicable program exists in SWWA: the River Health Assessment Scheme (RHAS). The RHAS was developed to provide a multi-parameter river health assessment scheme for the rivers and drains of the Swan-Canning catchment. To date, four years of data

has been collected (2007–10) across 12 of the 31 subcatchments in the Swan-Canning catchment. Data from the RHAS program has been tested against the FARWH.

The Ecological Values of Waterways in the South Coast Region program set out to provide an ecological snapshot of fauna, flora, habitat and water quality at one point in time (2008). The program was not intended to provide a holistic assessment of river health and repeat surveys were not intended. Where applicable, data from this program was used to help inform site selection and provide interpretive data for the FARWH trial, but the program was not tested against the FARWH.

NSW-FARWH

There was no single existing jurisdictional wetland condition assessment program which could be tested against the FARWH in New South Wales. Instead, the NSW-FARWH incorporated existing data from a variety of sources, which avoided the need for catchment-scale collection of field data. The existing data sources helped to inform the methods used to delineate wetlands and assess their condition.

Vic-FARWH

In Victoria, the established Index of Stream Condition (ISC) program was used to test the FARWH during its development for AWR 2005. The ISC is a multi-parameter assessment technique for waterway health which is intended to be undertaken across the state every five years. The ISC assessment method has been refined over time and has now had three iterations: the original 1999 method, a revised 2004 method and a method in the final stages of development scheduled for completion in 2011. Data from the 2004 ISC program was tested against the FARWH.

Aside from the ISC, there are other existing assessment programs that could support further application of the FARWH across Victoria. These programs, which have not been tested to date, include the Index of Wetland Condition and Index of Estuary Condition.

Tas-FARWH

In Tasmania, the established Conservation of Freshwater Ecosystem Values (CFEV) framework was used to test the FARWH during its development for AWR 2005. The CFEV project involved a statewide audit and conversation evaluation of rivers, wetlands, lakes and waterbodies, saltmarshes, estuaries, karst systems and groundwater-dependent ecosystems.

Since the Tas-FARWH trials a new approach to the assessment of river condition has been developed for Tasmanian catchments – the Tasmanian River Condition Index (TRCI). This approach is consistent with the FARWH and will allow compatible reporting of river condition at the state and national scale (NRM South 2009).

A3. Extent and distribution of assessment

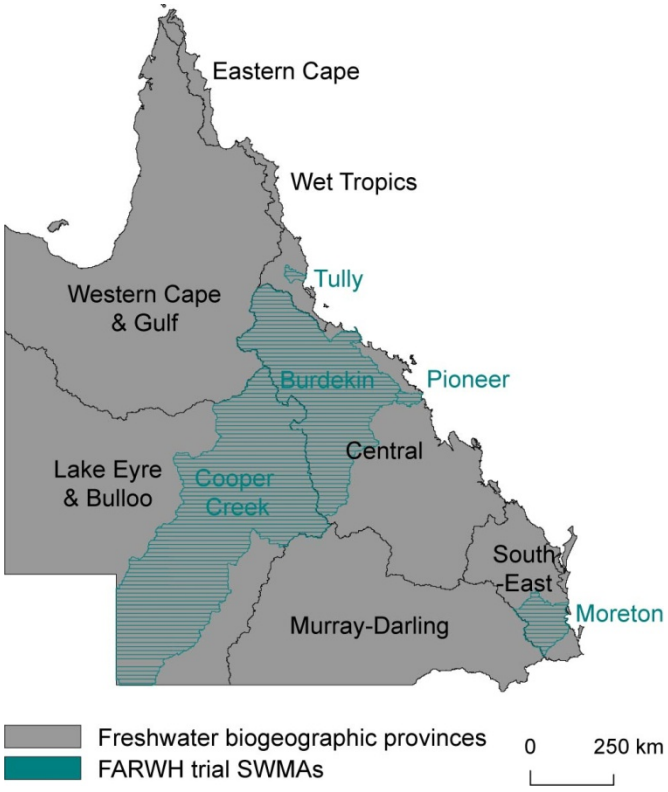
The FARWH foundation report recommended that Australia's surface water management areas (SWMAs) be used to define the extent and distribution of the FARWH assessments (NWC 2007a). Australia's 340 SWMAs were defined as part of AWR 2005 based on management units previously adopted by the states and territories (NWC 2006). Together the FARWH trials have covered 28 of the 340 SWMAs, covering approximately 10 per cent of Australia. The following section outlines the extent and distribution of each trial in greater

detail, focusing on the number and coverage of SWMAs and how this relates to the environmental variability in each of the trial regions.

The Qld-FARWH trials included four different regions in Queensland: Central Queensland, South East Queensland, the Wet Tropics, and Lake Eyre Basin (Figure 9). This encompassed four of the nine major freshwater ecosystem types (termed 'freshwater biogeographic provinces') across Queensland. The FARWH trial authors considered the study area was a representative sample of the different types of freshwater ecosystems found within Queensland and Northern Australia (NWC 2011a). The study area was chosen on the basis of jurisdictional programs and also to provide a contrast between SWMAs with a significant variation in size, climate, geomorphology and other ecological attributes (NWC 2011a). The FARWH trials excluded the three biogeographic provinces in north Queensland (Eastern Cape, Jardine, Western Cape and Gulf), the province of the Fraser Coast (Wallum) and the Murray-Darling Basin province.

The Qld-FARWH trials included five SWMAs within the four biogeographic provinces (Figure 9). The riverine environments in the trials included well-defined perennial and ephemeral systems, as well as systems with poorly defined channels that were typically dominated by isolated waterholes (NWC 2011a).

Figure 9: Queensland's freshwater biogeographic provinces, showing the extent of the FARWH trials

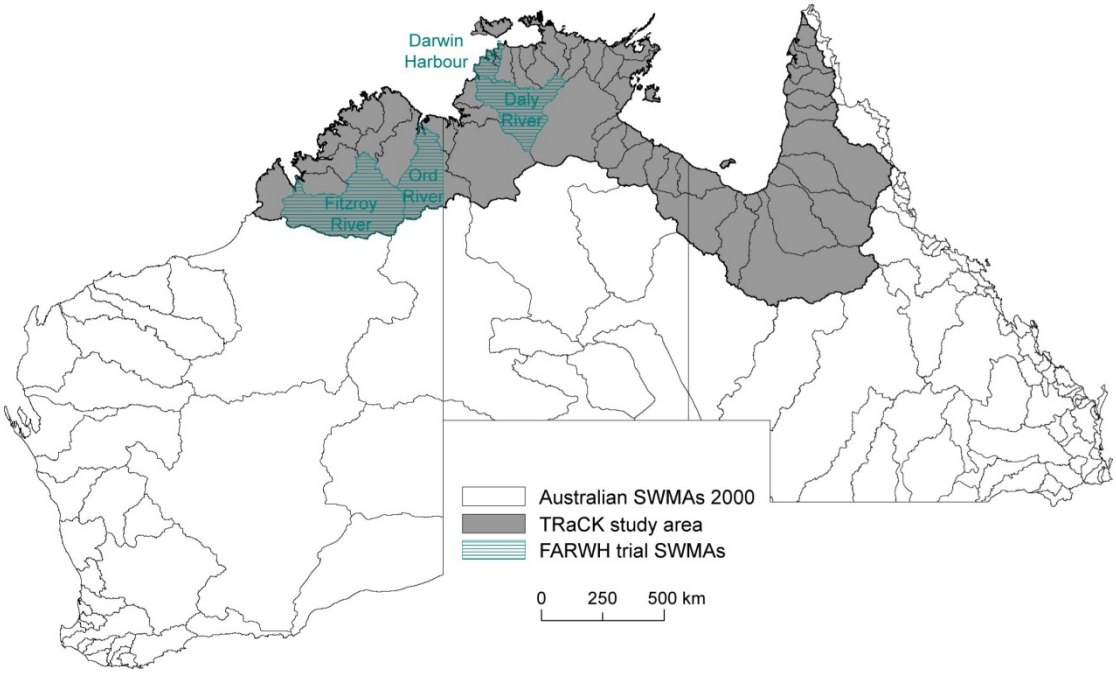


The Tropics-FARWH trials were undertaken on behalf of the Tropical Rivers and Coastal Knowledge (TRaCK) research consortium. The TRaCK research program relates to the entire tropical rivers region of Australia, which stretches from Broome in Western Australia to Cape York in Queensland (Figure 10). The Tropics-FARWH trials focused on the wet/dry tropics of northern Australia. The wet tropics of eastern Australia and the arid tropics of inland Australia were not part of the trials (NWC 2011b).

The Tropics-FARWH trials were undertaken in two stages: a desktop trial (Dixon et al. 2009) and then a field trial (NWC 2011b). The desktop trial included the Darwin Harbour (NT) and Ord River (WA) catchments and the field trial included the Daly River and Fitzroy River catchments (Figure 10). The field trial catchments are two of the four focus catchments of the TRaCK research program (the others being the Flinders River and Mitchell River SWMAs).

The riverine environments included were limited to perennially flowing rivers (i.e. those flowing throughout the late dry season) for the most part. In general ephemeral and seasonal rivers were excluded.

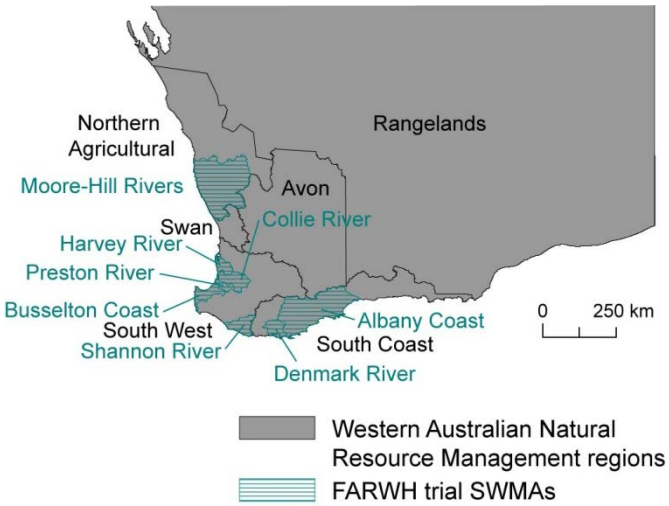
Figure 10: The tropical rivers region of northern Australia, showing the extent of the FARWH trials



The SWWA-FARWH trials focused on developing and implementing the FARWH for rivers in south-west Western Australia. South-west Western Australia includes five of the six natural resource management (NRM) regions in Western Australia (i.e. all except the Rangelands). The AWR 2005 baseline assessment sampled four of these five NRM regions (the Avon was excluded) and the subsequent FARWH field trials sampled three of these five NRM regions (the Avon and Swan were excluded) (Figure 11).

The riverine environments included in the trials were limited to flowing rivers (non-flowing rivers and wetlands were excluded). There are 17 SWMAs with perennially flowing rivers in the five NRM regions of SWWA. The SWWA-FARWH trials covered eight of these 17 SWMAs.

Figure 11: The natural resource management regions of south-west Western Australia, showing the extent of the FARWH trials



The NSW-FARWH trials addressed a range of large inland wetland complexes in central NSW, incorporating many of the most significant wetlands of the Murray-Darling Basin (Figure 12). Five SWMAs were chosen to provide a range of ecosystem conditions (e.g. climate, catchment size, wetland types) and pressures (e.g. extent of water resource development, agriculture, urban).

Figure 12: Extent of the FARWH trials in New South Wales

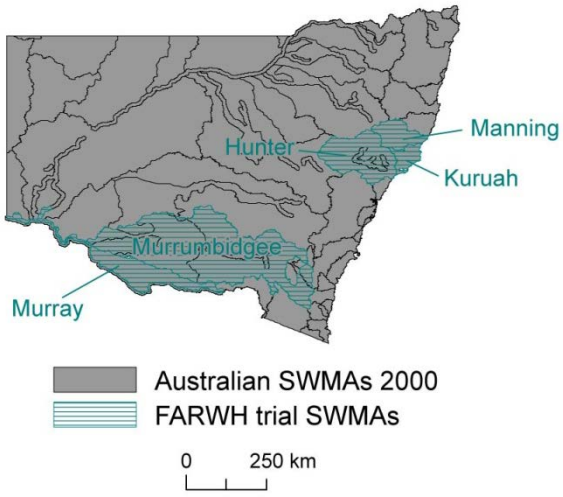
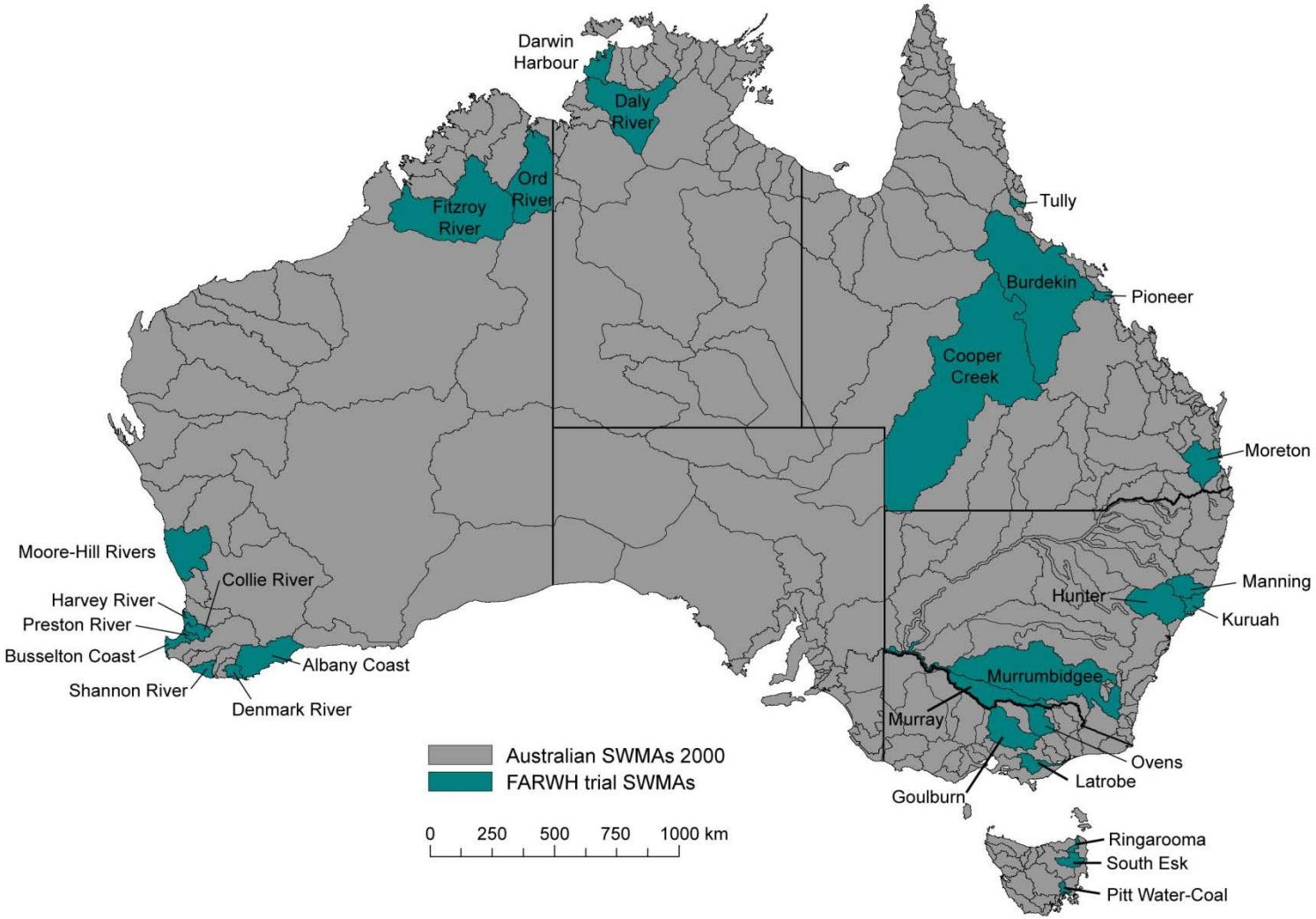


Figure 13: Study area of the FARWH trials



A4. Sampling design

Sampling is a statistical technique used to select a subset of individual observations from within a population of individuals, for the purposes of making predictions across the entire population based on statistical inference. The three main advantages of sampling are that the cost is lower, data collection is faster, and since the dataset is smaller it is possible to ensure homogeneity and to improve the accuracy and quality of the data.

For the FARWH, sampling is used to select features at two spatial hierarchies: river reaches/individual wetlands and assessment sites. The intent of the river reach/individual wetland sampling is to provide sufficient coverage to provide a realistic representation of health across each SWMA. The intent of the site sampling is to provide enough samples to categorise the health of each river reach/individual wetland.

In an ideal world, a randomised sampling design would be used to provide the best-possible statistical power for assessing and monitoring river and wetland health. Unfortunately completely randomised sampling is often unachievable due to constraints imposed by site access and limited resourcing. In this case, stratified sampling is a useful tool to help enforce a spatial representation of samples across the study area.

The FARWH is purposely designed not to prescribe data collection (but instead to use existing data from existing programs) and so the trials each adopted slightly different approaches based on their existing programs and jurisdictional policy drivers. All the FARWH trials adopted a pragmatic approach to sampling design. All the trials outlined a preference for randomised sampling, but used systematic (i.e. non-random) sampling to varying degrees. In many cases this was combined with stratified sampling to ensure a representative sample of environments was chosen.

The QLD-FARWH appeared to use the most randomised approach by adopting a generalised random-tessellation stratified sampling (GRTS) design. An exclusion criteria based on site access was applied to the GRTS design (i.e. sites greater than 500 m from roads were excluded).

The Tropics-FARWH and SWWA-FARWH trials both adopted a systematic block design. The sample reaches and sample sites were selected by analysing the variation across the study area in a set of key stratification criteria to identify sites that provided a representable sample. Again an exclusion criterion was used to exclude sites with poor access.

The NSW-FARWH trials of wetlands adopted a different approach, as all the wetlands within the study area were assessed for each indicator if possible with the available data. Hence no sampling design was adopted for the trial. However, for wider application the NSW-FARWH trials recommended a stratified random sampling design where stratification is based on wetland types and random selection of sampling sites is based on validated wetland maps.

A5. Indicator selection

The FARWH foundation report identified six key indices considered to represent the ecological integrity of rivers and wetlands:

- Catchment Disturbance index
- Hydrological Disturbance index
- Water Quality and Soils index
- Physical Form index

- Fringing zone index
- Aquatic biota index.

A seventh index for wetlands has since been recommended for inclusion by the FARWH National Technical Steering Committee (FNTSC): the Wetland Extent index.

The FARWH foundation report did not prescribe the sub-indices and components (i.e. the parts making up each sub-index) used to calculate each index.

The four trials have each used a unique combination of sub-indices and components to assess the six key indices. The selection of sub-indices and components was heavily based on the data collected under the existing jurisdictional programs for each of the assessment areas. In some areas, the existing jurisdictional programs provided an extensive platform to build on (e.g. Central and Wet Tropics bioprovinces of Queensland), whereas in other areas there was no suitable existing wide-scale assessment program (e.g. outside the Swan Coast SWMA in SWWA).

Figure 14 illustrates the sub-indices and components used across the FARWH trials. There are key similarities in many of the indices (e.g. turbidity and salinity are included in all water quality indices) and key differences in others (e.g. longitudinal connectivity was not included in the Physical Form assessment for the Qld-FARWH).

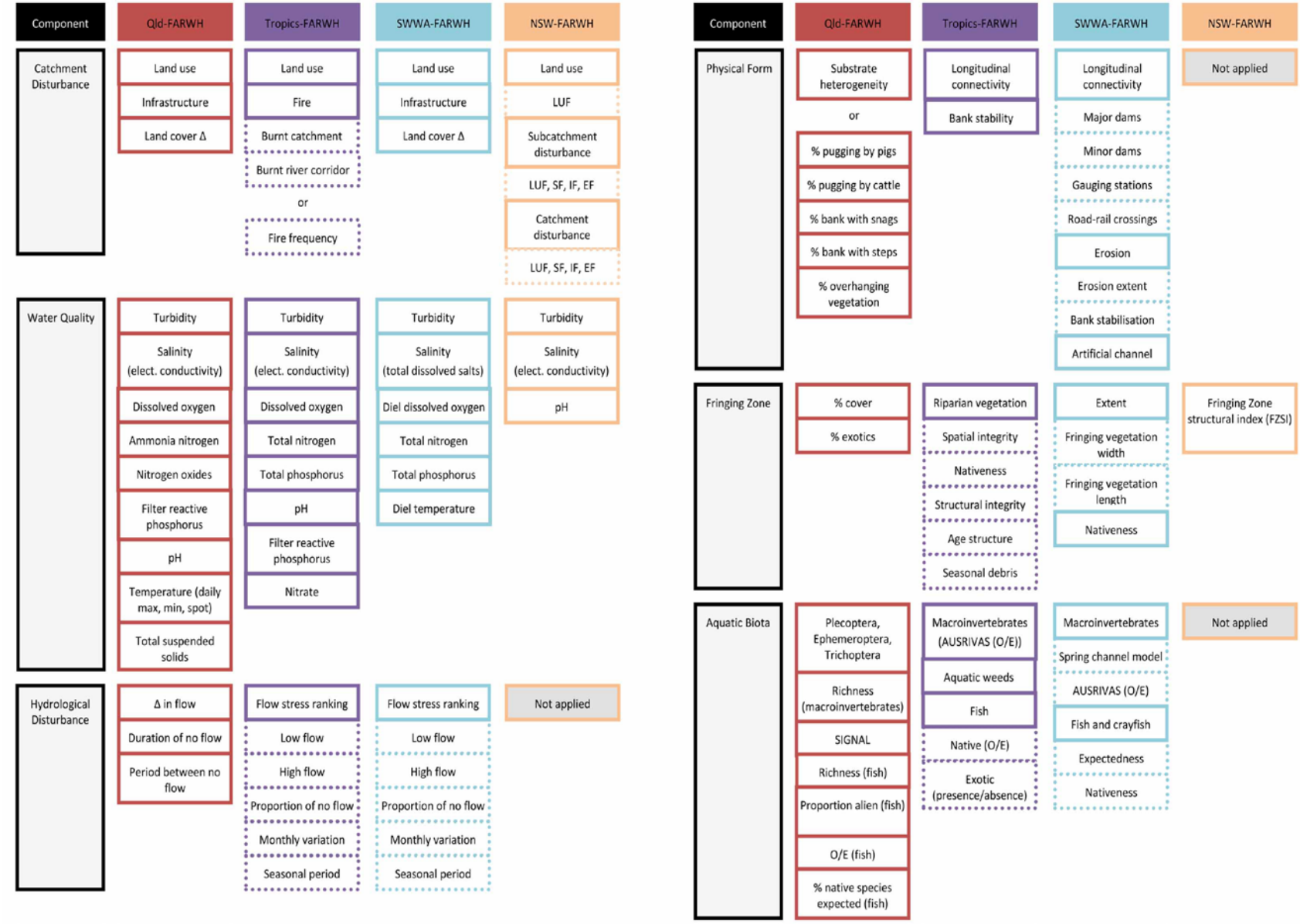


Figure 14: Selection of sub-indices (coloured solid borders) and components (coloured dashed borders) for each index under each of the four FARWH trials

Note: The Hydrological Disturbance index was developed for the Qld-FARWH trial, but not included in all assessments due to inconsistencies in flow records (Cooper Creek) or an absence of an Integrated Quantity and Quality Model (IQQM) model (Tully)

Abbreviations: O/E = observed/expected; LUF = land use factor; SF = settlement factor; IF = infrastructure factor; EF = extractive indices factor.

A6. Reference condition

The FARWH is built on scoring indicators of a range of ecological conditions based on departure from reference condition. The reference condition is usually defined as the presumed natural state of a site (NWC 2007a). Even so, how reference is defined is somewhat dependent on data availability and therefore a variety of approaches have been used across the FARWH trials.

The ideal approach for establishing reference condition is to select reference sites that meet a set of criteria that define a 'minimally disturbed' system. Reference condition indicators can then be established from measurements at the reference sites. Unfortunately the identification of reference sites is often not possible because most sites generally contain some degree of catchment modification: this trend has been observed in many parts of the world (NWC 2011d) and was a common theme in the FARWH trials.

The FARWH trials used a range of mechanisms to identify reference condition that included a combination of the following:

- selecting 'minimally disturbed' sites for field survey of reference condition
- literature review
- expert opinion/best professional judgement
- distribution modelling.

The mechanisms used to identify reference condition in each of the FARWH trials are summarised in Table 17 below. The key points of this table are the high proportion of trials where reference sites could not be identified and the variable nature in the definition of reference condition used to accommodate for this.

The most consistently applied measure of reference condition related to the macroinvertebrate assessment for the Aquatic Biota index. This index generally used an observed/expected approach based on distribution modelling undertaken through the Australian River Assessment System (AUSRIVAS) program.

Table 17: Mechanisms used to identify reference condition in each of the FARWH trials

	Catchment Disturbance				Water Quality				Hydrological Disturbance					Physical Form					Fringing Zone				Aquatic Biota				
	RS	LR	EO	DM	RS	LR	EO	DM	RS	LR	EO	DM		RS	LR	EO	DM		RS	LR	EO	DM	RS	LR	EO	DM	
QLD	×	×	✓	✓	✓	×	×	×	×	×	×	✓		×	×	✓	×		×	×	✓	✓	✓	×	×	✓		
Tropics	×	✓	✓	×	×	✓	✓	×	×	✓	✓	×		✓	×	×	×		✓	×	×	×	✓	✓	✓	✓		
SWWA	×	×	✓	×	×	✓	×	×	✓	×	×	✓		×	×	✓	×		×	✓	✓	×	✓	✓	✓	✓		
NSW	✓	×	×	×	✓	×	×	×	index not used					index not used					✓	×	×	×	index not used					

- RS: Reference sites
- LR: Literature review
- EO: Expert opinion
- DM: Distribution modelling

✓: Mechanism was used in the trial
×: Mechanism not used in the trial

All trials reported significant concerns with the identification of reference sites and condition. These issues were generally associated with the limited number, consistency and coverage of existing ecological monitoring and research programs.

A7. Integration and aggregation

The term ‘integration’ denotes the process of combining scores from several indices, sub-indices or components to provide a single score at the same spatial scale. ‘Aggregation’ denotes the process of combining scores from the same index (or sub-index) in different locations to provide a single score at a larger spatial scale.

Integration and aggregation are applied at a number of levels in generating the FARWH scores. For example, integration can be applied to integrate several components to a single sub-index score at the reach/site scale, or could also potentially be applied to integrate several index scores into a single overall score at a SWMA scale. Integration and aggregation can therefore operate across many spatial scales and different levels of indicator specificity. Accordingly, a wide range of approaches to integration and aggregation was adopted in the FARWH trials.

In general, the trials adopted either a standardised Euclidian distance (SED) or an unweighted mean approach for integrating scores at the river reach and SWMA spatial scale. While the SED approach was favoured in the FARWH foundation document (NWC 2007a), simpler measures were found to provide a similarly beneficial result in some trials (e.g. NWC 2011b).

Regardless of the specific method used, practically all trials identified major issues in integrating indices to a single overall score at the SWMA scale. The primary issue of concern related to data smoothing; that is, trends in the data are smoothed out due to averaging and are no longer detectable. The SWWA trial concluded that integrating index scores to an overall SWMA health score was ‘meaningless’ (NWC 2011d, p68) and the Queensland trial concluded that individual index scores were a ‘more useful assessment tool than the integrated overall score’ (NWC 2011a).

For aggregation, the trials typically adopted an area or length weighted mean calculation to combine information from the river reach or site scale to the SWMA scale.

A8. Sensitivity of indices

The trials examined the sensitivity of indices and sub-indices in several ways. For example, in the Qld-FARWH and SWWA-FARWH trials a statistical analysis was undertaken to examine the impact of each index on the overall condition score (analogous to the ‘jack-knife’ method). However in the Tropics-FARWH trial the analysis focused on testing the sensitivity of each index to a gradient of local pressures. The NSW-FARWH trial report did not report specifically on the sensitivity analysis approach or its results.

While the observed differences in sensitivity vary both within and between each trial (NWC 2011a, p81), some consistent trends have emerged across the trials. For example, the Qld-FARWH and SWWA-FARWH both identified that the Catchment Disturbance index was very influential on the overall condition score. In particular, the Qld-FARWH trial found that ‘Catchment Disturbance had the greatest influence on final trial scores’ (NWC 2011a, p81) (as shown in Table 18) and the SWWA-FARWH trial found it was ‘critical as it differentiates the broad pressures influencing the environment’ (NWC 2011d, p48). Similarly both trials also found that Water Quality had a relatively limited influence. It had the least influence in Qld-FARWH and the SWWA-FARWH considered that ‘most health issues that water quality data indicate would be detected in biota or be related to Catchment Disturbance and Fringing Zone’ (NWC 2011d, p48).

Table 18: Average change to overall scores resulting from the removal of each index, averaged across the four Qld-FARWH trials (NWC 2011a, Table 32)

	Average change in overall score	Overall sensitivity ranking
Physical Form	0.09	2
Fringing Zone	0.06	3
Water Quality and Soils	0.04	4

The sensitivity analysis in the Tropics-FARWH found considerable variability in how sub-indices responded to disturbance pressure (e.g. the sensitivity of riparian and aquatic biota sub-indices to cattle disturbance was quite variable). That trial concluded that the variable sensitivity of indicators 'emphasises that indicator sensitivity needs to be understood' and therefore future FARWH assessments needed to select indicators with low detection thresholds to 'permit early detection of river health degradation' (NWC 2011b, s12.1).

A9. Remote sensing and GIS potential

Remote sensing and Geographic Information System (GIS) technologies were examined and applied in all of the FARWH trials, with varying degrees of success (Table 19).

In general, the trials confirmed that Catchment Disturbance and Hydrological Disturbance can be assessed with desktop methods using remote sensing, GIS and modelling of existing geospatial and hydrologic datasets. Catchment Disturbance was the most readily and successfully applied desktop assessment approach; Hydrological Disturbance was often restricted by limited coverage of existing gauging stations.

Desktop assessments of Fringing Zone were successful for all sub-indices in the NSW wetlands. However, they were only successful for a small subset of sub-indices in the Queensland and SWWA trials and not suitable at all in the Tropics trial.

The Water Quality, Physical Form and Aquatic Biota indices were generally found to be unsuitable for remote sensing or GIS-based desktop assessments. However, the Tropics and SWWA trials did suggest that Physical Form (in particular) might be able to be assessed if further development of remote sensing and GIS technologies is undertaken (LiDAR in particular). As an example of such an application, a LiDAR-based approach has recently been adopted by Victoria for the physical form and vegetation assessments for the 2011 statewide ISC (Paul Wilson, DSE, personal communication).

Table 19: Summary of remote sensing and GIS applications and outcomes

	Remote sensing/GIS applications	Outcome
QLD	• Trials assessed two indices (Fringing Zone and Catchment Disturbance) using remote sensing and GIS analysis • Within Fringing Zone, one sub-index was assessed with remote sensing and GIS analysis: per cent cover of riparian vegetation • Remote sensing and GIS analysis for other Fringing Zone sub-indices was reviewed but not applied • Catchment Disturbance index was applied using remote sensing and GIS analysis	• Remote sensing and GIS analysis is seen as a key component of future Qld FARWH assessments • Trials validated the accuracy of remote sensing and GIS analysis of Fringing Zone index across all SWMAs/programs • Future development and assessment of remote sensing and GIS analysis to other indices is essential • Riparian assessment methodology has been improved through the trials • In SEAP trials, Fringing Zone, Catchment Disturbance and Hydrological Disturbance indices can be assessed with a desktop approach
Tropics	• Catchment Disturbance and Hydrological Disturbance indices were assessed using GIS analysis of existing spatial datasets • Remote sensing was examined but not used for Fringing Zone index due to limited riparian vegetation clearance • GIS analysis of Physical Form index was examined but found to be too course at this stage	• Remote sensing is not suitable for Fringing Zone of the wet/dry tropics due to limited riparian vegetation clearance • Remote sensing of Physical Form index should be considered for future FARWH assessments if technology improves • Remote sensing and GIS analysis of Catchment Disturbance and Hydrological Disturbance should be continued
SWWA	• Catchment Disturbance and Hydrological Disturbance indices calculated using modelling, remote sensing and GIS analysis • Some sub-indices of Fringing Zone were calculated using remote sensing and GIS analysis	• Catchment Disturbance and Hydrological Disturbance can generally be successfully assessed remotely • Other indices (e.g. Aquatic Biota) cannot yet be assessed remotely, but are critical indices • Further development of remote sensing is required (e.g. LiDAR technologies)
NSW	• Integrate existing wetland/vegetation spatial datasets and filter out lotic environments • Wetland delineation using automated classification with aerial photograph interpretation • Wetland typology using semi-automated classification and fuzzy cluster analysis • Catchment Disturbance and Fringing Zone assessed using existing geospatial datasets	• Wetland mapping and delineation using remote sensing and GIS analysis was successful and should be applied elsewhere • Catchment Disturbance and Fringing Zone can be assessed remotely

Appendix B—Implementation costs

B1. Overview

Further implementation of the FARWH will require ongoing investment to continue developing the method (particularly in un-trialled environments) and rollout the assessment programs across Australia. A wide range of activities and processes will be required for successful implementation of the FARWH which include, but are not limited to:

- research and development to validate and finalise the FARWH in un-trialled environments
- baseline mapping of wetland extent
- site selection and sample design
- data collation and analysis for a desktop-based assessment
- data collection for a field condition-based assessment
- data collation and analysis for a desktop-based assessment
- synthesis of data analysis and compilation/reporting on results
- governance of the FARWH program
- maintenance of the FARWH results website, and potentially
- research and development of remote sensing and GIS technologies.

The FARWH trial reports outlined the costs associated with finalisation of the FARWH and implementation of the assessment methods within their jurisdiction. Cost information has also been provided for the application of the Victorian ISC, Tasmanian RCI, Murray-Darling SRA and Queensland Wetlands Program.

The detailed cost information from these sources has been extrapolated to estimate the cost per SWMA, per site and per unit area for each method. The detailed costs and the assumptions used for this process are described in Section B3. Section B2 provides a summary of this information, to estimate the cost for implementing the two-tiered FARWH assessment approach across Australia.

B2. Summary

The cost estimates to undertake broadscale and detailed assessments are outlined in Table 20 to Table 22. Before considering the costs, it is essential to stress the high degree of variability in the level of service provided under each program. Some programs involve field- and desktop-based condition assessments of all FARWH indices at a detailed spatial resolution (e.g. ISC and TRCI), whereas others provide broadscale-based assessments.

There is therefore enormous variability in the estimated cost per km^2, per site and per SWMA. This variability is a function of the sampling density (mostly impacting $/km^2), number of indices/sub-indices assessed (mostly impacting $/site), SWMA size (mostly impacting $/SWMA) and coverage.

The cost estimates in Table 20 to Table 22 have been used to guide the costs for each option in the main body. At this stage these estimates are still precursory and highly variable. Once the scope and requirements of the FARWH have been agreed to, the costs for a relatively consistent level of service across jurisdictions could be more reliably estimated.

The estimated costs for implementing one round of a broad-based assessment, similar to the first tier of the FARWH, is estimated in Table 20. The cost estimates per unit area vary by a factor of 10, from approximately $0.20 to $2.00 per km^2.

The estimated costs for implementing one round of wetland mapping and classification are estimated in Table 21. The cost estimates per unit area are also highly variable for this component, varying by a factor of 8, from approximately $0.35 to $2.90 per km^2.

The estimated costs for implementing one round of detailed condition assessment are estimated in Table 22. The cost estimates for rivers per unit area are hugely variable, varying by a factor of over 150, from approximately $0.65 to $109 per km^2. The cost required for wetlands is generally lower than the cost required for rivers (Table 22).

Table 20: Cost for an assessment similar to the broadscale tier 1 FARWH assessment

Source	Cost / SWMA	Cost / km^2	Comment	More detail
Qld-FARWH	$100 000	$2.00	Desktop assessment only of rivers Based on trials in limited number of SWMAs	Table 25, row 2
Qld DERM	$2300 to $3500	$0.10 to $0.30	Desktop assessment only of rivers and wetlands Based on statewide projects to assess river and wetland risks	Table 30, rows 2 & 3

Table 21: Cost for wetland mapping and classification

Source	Cost / SWMA	Cost / km^2	Comment	More detail
NSW-FARWH	$5700	$0.35	Based on estimate from trials in five SWMAs	Table 29, row 2
Qld DERM	$78 000	$2.90	Based on real cost from statewide application	Table 30, row 4

Table 22: Cost for an assessment similar to the detailed tier 2 FARWH condition assessment

Source	Cost / SWMA	Cost / site	Cost / km^2	Comment	More detail
Qld-FARWH	$111 000	$4200	$1.40	Field and desktop assessment of rivers	Table 23, row 6
Tropics-FARWH	$650 000	$32 500	$13.00	Field and desktop assessment of rivers	Table 25, rows 3 & 4
SWWA-FARWH	$23 800	$1600	$1.25	Field and desktop assessment of rivers	Table 26, row 2
ISC	$579 000	$16 100	$73.70	Field and desktop assessment of rivers (excluding gauging station costs)	Table 31, row 2
TRCI	$43 640	$2200	$109.10	Field and desktop assessment of rivers (Tasmanian SWMAs are typically much smaller than those on mainland Australia)	Table 32, row 2
SRA	$315 800	$3000 to $4000	$5.65	Field and desktop assessment of rivers	Table 33, row 2
NSW-FARWH	$10 200	n/a	$0.65	Field and desktop assessment of wetlands	Table 28, row 2

B3. Detailed cost information

QLD-FARWH

The actual costs for implementing a field-based condition assessment program were assessed from a post-trip analysis of the Qld-FARWH trials (NWC 2011a). The costs included all aspects associated with fieldwork such as staff costs, travel allowances, accommodation, vehicle hire, vehicle maintenance and repair, equipment purchase and pre-field training. It did not include allowances for data analysis, handling or reporting.

The actual costs are summarised in Table 23 and compared relative to the cost per SWMA, per site and per unit area. These costs assume that the Central, South East, Wet Tropics and Lake Eyre regions included 26, 44, 30 and 32 sites respectively. These site numbers have been inferred from tables 3, 4, 7, 8, 9, 10, 12 and 14 in NWC 2011a.

Overall, the fieldwork cost was approximately $110 000 per SWMA, $4200 per site or $1.40/km^2 (Table 23).

Table 23: Fieldwork costs from the Qld-FARWH trials based on NWC 2011a (p89)

Region	Total cost	No. SWMAs	Cost / SWMA	No. sites	Cost / site	Area (km^2)	Cost / km^2
Central	$161 144	2	$80 572	26	$6198	136 467	$1.18
South East	$83 037	1	$83 037	44	$1887	15 707	$5.29
Wet Tropics	$38 593	1	$38 593	30	$1286	1683	$22.93
Lake Eyre	$272 640	1	$272 640	32	$8520	244 102	$1.12
Overall mean	**n/a**	**n/a**	**$111 083**	**n/a**	**$4208**	**n/a**	**$1.40**

Tropics-FARWH

The estimated cost for undertaking a FARWH assessment in the wet/dry tropics was assessed assuming that a two-tiered assessment approach was adopted (NWC 2011b). The first tier would involve an assessment of pressures across the entire catchment, primarily using the Hydrological Disturbance and Catchment Disturbance indices. The second tier would involve an assessment of other FARWH indices to detect impact from anthropogenic non-point-source disturbances.

The estimated cost for the two-tiered assessment is $750 000 per SWMA (NWC 2011b). This assumes there would be approximately 20 sites per SWMA, sampled twice in the dry season. This does not include allowances for the research required to improve the FARWH metrics, site selection, sample design or administrative support.

The cost estimates from the Tropics-FARWH have been used to estimate the fieldwork and desktop costs for each tier of the FARWH (Table 24). This has required some assumptions on the distribution of effort across the two tiers.

Based on these assumptions and assuming the four trial SWMAs total 200 547 km^2, the typical cost per SWMA, per site and per unit area for each component is provided in Table 25.

Table 24: Desktop and fieldwork costs for a two-tiered approach based on NWC 2011b (s12.3)

Task	Tier	Cost per SWMA	Assumptions
Office support	1	$100 000	• Tier 1 requires 100 days of the 250 total days of office support
Field labour	2	$400 000	• All field costs allocated to tier 2
Field operational costs	2	$100 000	• All field costs allocated to tier 2
Office support	2	$150 000	• Tier 2 requires 150 days of the 250 total days of office support

Table 25: Estimated costs for each tier of a FARWH assessment

Component	Cost / SWMA	No. sites	Cost / site	Area (km^2)	Cost / km^2
Tier 1	$100 000	n/a	n/a	200 547	$1.99
Tier 2 field	$500 000	20	$25 000	200 547	$9.97
Tier 2 desktop	$150 000	20	$7500	200 547	$2.99

SWWA-FARWH

The estimated cost for undertaking a FARWH assessment in SWWA was made assuming a three year rolling assessment program (NWC 2011d).

The estimated cost of $500 000 a year (NWC 2011d) includes all costs for data collection and analysis (e.g. analysis of water quality, identification of invertebrates, travel and equipment maintenance). It does not include costs for scoring and reporting, although this is not expected to be a significant cost.

The application of the FARWH across SWWA would include a significant portion of 21 SWMAs and cover approximately 400 000 km^2 (based on the study area identified in Figure 4 of the SWWA-FARWH report). The SWWA-FARWH report identifies that 117 sites were assessed through the trials across eight SWMAs (NWC 2011d), averaging approximately 15 sites per SWMA. On this basis a FARWH assessment across SWWA may cover approximately 315 sites.

Based on these assumptions, the typical cost per SWMA, per site and per unit area is provided in Table 26.

Table 26: Estimated fieldwork and data analysis costs based on NWC 2011d

Component	Total cost	No. SWMAs	Cost / SWMA	No. sites	Cost / site	Area (km^2)	Cost / km^2
Fieldwork and data analysis	$500 000	21	$23 810	315	$1,587	400,000	$1.25

NSW-FARWH

The NSW-FARWH outlined the cost of undertaking eight tasks to implement the FARWH across wetlands in New South Wales (NWC 2011c). These eight tasks relate to those required to finalise the FARWH method and those to undertake one round of broadscale statewide wetland monitoring (Table 27).

Table 27: Desktop and fieldwork costs for a two-tiered approach based on NWC 2011c (p52)

Task	Purpose	Total cost
1. Extend wetland mapping procedure across NSW	Finalise FARWH	$100 000
2. Ground validation and refinement of mapping	Finalise FARWH	$100 000
3. Refinement of typology	Finalise FARWH	$30 000
4. Typing of wetlands across NSW	Finalise FARWH	$20 000
5. Develop rapid biological assessment protocols	Finalise FARWH	$240 000
6. Collect reference condition data	Finalise FARWH	Included in 5
7. Develop new Water Quality and Aquatic Biota indices	Finalise FARWH	$100 000
8. Develop statewide monitoring program	Undertake assessment	$300 000 to $500 000

The estimated cost of $300 000 to $500 000 to develop the broadscale statewide monitoring program was based on a three-year sampling cycle. Table 28 provides an estimated cost per SWMA and per unit area based on the upper cost estimate and assuming that all 49 SWMAs across NSW are included (totalling 799 464 km^2). The inclusion of all 49 SWMAs is supported by Kingsford et al. 2003 (p15) which indicated wetlands occur throughout all the SWMAs in NSW.

Table 28: Estimated fieldwork and data analysis costs for condition monitoring based on NWC 2011c

Component	Total cost	No. SWMAs	Cost / SWMA	Area (km^2)	Cost / km^2
Fieldwork and data analysis	$500 000	49	$10 200	799 464	$0.63

The estimated cost for extending the wetland mapping and classification across the remainder of NSW is $250 000 (tasks 1 to 4 in Table 27). There are a further 44 SWMAs to apply the wetland mapping and classification, equating to an average cost of $5700 per SWMA or $0.34 per km^2 (Table 29).

Table 29: Estimated costs for wetland mapping and classification based on NWC 2011c

Component	Total cost	No. SWMAs	Cost / SWMA	Area (km^2)	Cost / km^2
Fieldwork and data analysis	$250 000	44	$5700	~725 400	$0.34

QLD Department of Environment and Resource Management

Cost estimates for applying a FARWH assessment across Queensland have also been provided by the Department of Environment and Resource Management (DERM), independently of the Qld-FARWH report. Cost estimates were provided for three tasks:

- undertaking a broadscale risk assessment for rivers and wetlands
- undertaking a fine-scale risk assessment for wetlands
- undertaking wetland mapping and classification.

A Queensland-wide broadscale risk assessment for rivers is estimated to be approximately $100 000 per assessment round. This allowance includes approximately 30 weeks of a GIS operator, oversight from a project leader and the expenses associated with one multi-jurisdictional expert workshop. It was estimated that wetlands could be included in the broadscale risk assessment for a further $50 000. The total cost of $150 000 for application across Queensland's 64 SWMAs equates to an average cost of approximately $2300 per SWMA or $0.09 per km^2 (Table 30).

Queensland has another project underway which is assessing the risk for all freshwater wetlands in the Great Barrier Reef catchment. Based on this project, the estimated cost for a fine-scale risk assessment of wetlands only is approximately $3500 per SWMA or $0.31 per km^2 (Table 30).

The Queensland Wetlands Program involved the development of wetland mapping and classification protocols, development of an inventory database and web servers and the application of the mapping and classification across the state. The mapping and classification component was estimated to cost approximately $5 million (personal communication Mike Ronan, DERM).

Table 30: Cost estimates for applying a FARWH assessment across Queensland based on personal communication with Mike Ronan, DERM

Component	Total cost	No. SWMAs	Cost / SWMA	Area (km^2)	Cost / km^2
Broadscale risk assessment (rivers and wetlands)	$150 000	64	$2300	1 730 648	$0.09
Fine-scale risk assessment (wetlands only)	$120 000	34	$3500	385 000	$0.31
Wetland mapping and classification	$5 000 000	64	$78 000	1 730 648	$2.89

Victorian Index of Stream Condition

Informal cost estimates for applying the Victorian ISC's 2011 method have been provided by the Department of Sustainability and Environment (DSE). The ISC is a relatively intense (i.e. dense sampling), extensive (i.e. statewide coverage) and holistic (i.e. five indices) assessment method and therefore the cost for implementation is considerably higher than other programs. The 2011 ISC method also relies heavily on remote sensing and GIS-based analysis which involves statewide capture of LiDAR and aerial photography (Paul Wilson, DSE, personal communication).

The cost estimates have been provided at the site scale for some indices (e.g. water quality, aquatic life) and at the reach scale for others (e.g. vegetation and physical form). These costs have been extrapolated into SWMA-scale costs based on the following assumptions:

- there are 1040 ISC sites, covering 28 500 km of rivers across 29 SWMAs
- LiDAR and aerial photography costs are based on statewide capture (and therefore heavily discounted) and are repeated for each assessment round (approximately $150 per km per assessment)
- water quality lab analysis is undertaken once per assessment, for four metrics (approximately $4000 per assessment)
- fish sampling is undertaken once per assessment (approximately $5000 per assessment)
- macroinvertebrate sampling is undertaken twice per assessment (approximately $1500 per assessment)
- approximately 685 water quality and flow stations across the state require continuous operation (at approximately $8000 per station per year).

Based on these assumptions a complete assessment is estimated to cost $44.2 million. However, if the costs for water quality and flow stations are excluded (note these costs are not included in the cost estimates for other programs) then the total assessment cost drops to $16.8 million. Based on the overall $16.8 million estimate the costs per SWMA, per unit area and per site are provided in Table 29.

Table 31: Estimated fieldwork and data analysis costs for the ISC

Component	Total cost	No. SWMAs	Cost / SWMA	No. sites	Cost / site	Area (km^2)	Cost / km^2
Fieldwork and data analysis	$16 800 000	29	$579 000	1,040	$16 100	227 416	$73.68

Tasmania River Condition Index

Informal cost estimates for the application of the TRCI have been provided by Martin Read of DPIPWE. Like the ISC, the TRCI is a relatively intense, extensive and holistic assessment method and therefore the cost for implementation is considerably higher than other programs.

The TRCI cost estimates were provided based on a rollout across the Huon subcatchment. The site-based costs have been extrapolated based on the assumption that the Huon subcatchment is approximately 400 km^2 and has 20 sampling sites.

Table 32: Estimated fieldwork and data analysis costs for the TRCI

Component	Cost / SWMA	No. sites	Cost / site	Area (km^2)	Cost / km^2
Fieldwork and data analysis	$43 640	20	$2200	400	$109.10

Murray-Darling Sustainable Rivers Audit

Michael Wilson of the MDBA has provided informal cost estimates for applying the SRA (at the basin and site scale). At a basin scale, the SRA costs approximately $1 million per theme per assessment. With a three-year reporting period and six themes this averages out to $6 million per assessment or $2 million per year.

These costs have been extrapolated to costs per SWMA, per site and per unit area (Table 33) based on the following assumptions:

- there are 19 SWMAs in the Murray-Darling Basin

- there are between 80 and 100 sites in the average SWMA across all themes.

Table 33: Estimated fieldwork and data analysis costs for the SRA

Component	Total cost	No. SWMAs	Cost / SWMA	No. sites	Cost / site	Area (km^2)	Cost / km^2
Fieldwork and data analysis	$6 000 000	19	$315 800	1520 to 1900	$3000 to $4000	1 061 469	$5.65