Department of
Sustainability and
Environment

index of wetland condition

training, information management and testing

A Victorian Government Initiative

Victoria
The Place To Be

Index of Wetland Condition

training, information management and testing

P. Papas, S. Lyon, J. Holmes and D. Ramsey

November 2009

Authorised by the Victorian Government, 8 Nicholson Street, East Melbourne.

Printed by NMIT Printroom, Preston

ISBN 978-1-74242-326-5 (print)
ISBN 978-1-74242-327-2 (online)

Citation

This report may be cited as: Papas, P., Lyon, S., Holmes, J. and Ramsey, D. (2009) Index of Wetland Condition: training, information management and testing. Department of Sustainability and Environment, East Melbourne, Victoria

Accessibility

If you would like to receive this publication in an accessible format, such as large print or audio, please telephone 136 186, 1800 122 969 (TTY), or email customer.service@dse.vic.gov.au

This document is also available in PDF format on the Internet at www.dse.vic.gov.au/iwc

This report was prepared with the financial support from the Victorian Government and Australian Government under the National Action Plan for Salinity and Water Quality

action
Salinity & Water
AUSTRALIA

Australian Governments and local communities working together to prevent repair and manage rising salinity and declining water quality across Australia.

www.dse.vic.gov.au/iwc

Contents

List of tables and figures

List of tables

List of figures

Acronyms

CDI	Catchment Disturbance Index
CMA	Catchment Management Authority
DSE	Department of Sustainability and Environment
EVC	Ecological Vegetation Class
ISC	Index of Stream Condition
IWC	Index of Wetland Condition
IWCDMS	Index of Wetland Condition Data Management System
LDI	Landscape Disturbance Index
NAP	National Action Plan for Salinity and Water Quality
NHT	Natural Heritage Trust
NRM	Natural Resource Management
RCS	Regional Catchment Strategy
RMP	Regional Management Plan
RCIP	Regional Catchment Investment Plan

Acknowledgements

Funding for the project was provided by the National Action Plan for Salinity and Water Quality. Doug Frood, Pathways Bushland and Environment is thanked for his expertise and assistance with the training program. David Bryant, Department of Sustainability and Environment (DSE) is thanked for assistance in the field. IWC assessments of sites in the Wimmera were undertaken by Ecology Partners Pty. Ltd.

The Information Business Technology group (DSE) and Stock Software provided support for the Information Management component of the IWC.

Yvette Baker (DSE) is thanked for her support for the project whilst acting as project manager.

The implementation and testing of the IWC was undertaken with the guidance and support of a Steering Committee and two panels of wetland ecologists who formed an expert panel for the testing of the IWC method and also the development of a Landscape Disturbance Index (LDI). Steering Committee members were Michelle Dickson (West Gippsland CMA), Bruce Gray (Department of Environment and Heritage), David Parkes, Paul Wilson, Tim O'Brien and Vanessa Stubbs (DSE), Mark Antos (Parks Victoria). Expert panel members (IWC testing) were Dr Paul Boon (Victoria University), Dr Rhonda Butcher, (Waters Edge Consulting), Associate Professor Jenny Davis (now Monash University formerly Murdoch University), Doug Frood (Ecological Consultant, Melbourne), Stephen Perris (formerly of Environment Protection Authority, Victoria), Dr Jane Roberts, (Ecological Consultant, Canberra), Dr Michael Smith (formerly of DSE). Expert panel members (LDI development): Dr Michael Smith, Michele Kohout, Keely Ough (DSE).

An implementation group was formed to initiate discussion on the practical use of the IWC method and recommend improvements to the IWC method. Implementation panel members: Doug Frood (Ecological Consultant, Melbourne), Louise Buckley (Consultant, Kellogg Brown & Root), Luke Hynes (Consultant, Ecology Partners), Fiona Gilbert (Consultant, WBM), Donna Smithyman (Corangamite Catchment Management Authority).

Two separate workshops were conducted to initiate a process for the development of a wetland extent mapping protocol and a wetland EVC mapping protocol for Victoria. Workshop participants were Andrew Corrick (Consultant), Nicholas Cuff and Bruce Wilson (Environment Protection Authority, Queensland), Katherine Williams (Consultant, SKM), Alison Oates and David Parkes (DSE), Doug Frood (Ecological Consultant, Melbourne).

Di Crowther and Adrian Kitchingman (DSE) are thanked for providing comments on the draft. David Meagher is thanked for editing the report.

Summary

The Implementation of the Index of Wetland Condition project, is the second stage of development of the Victorian Index of Wetland Condition (IWC). Commencing in late 2006, the project has included (1) training in the use of the IWC, (2) developing information management protocols and databases, and (3) testing the IWC for consistency in measuring condition against a number of criteria.

Four training sessions have provided over 100 natural resource management practitioners and consultants with experience in the use and application of the IWC. Thus far, approximately 400 wetlands across the state have been provisionally assessed in related regional projects. A number of information management tools have been developed to assist IWC wetland assessors and manage data collected from IWC assessments. The project also scoped protocols for wetland vegetation mapping and wetland extent mapping.

Testing of the IWC was completed in June 2008. Four hypotheses underpinned the testing program: (1) the IWC measures condition consistently across a condition gradient, (2) the IWC measures condition consistently in two hydrological phases (filling and drying) at individual wetlands, (3) the IWC measures condition consistently in different wetland types, and (4) the IWC measures condition consistently between assessors. Approaches adopted for the testing include the development of a method for estimating condition *a priori* from spatial data, analysis of quantitative wetland datasets and an expert opinion assessment of wetland datasets by wetland ecologists.

Testing was undertaken using IWC and quantitative data from 27 wetlands in the Wimmera region of Victoria. Expert opinion was used to derive wetland condition information from this existing independent quantitative data. Fuzzy classification modeling based on the expert opinion data was used to weight the IWC subindices. Biota had the largest weight, followed by water properties, hydrology, wetland catchment, soils and physical form. The IWC total score calculation was modified on basis of these weights.

The IWC and expert opinion scores differed significantly for the physical form subindex, hydrology subindex and unweighted total condition score. There was no significant difference between the weighted IWC total score and expert opinion total score. The untrained assessor group IWC scores differed significantly from the mean expert opinion scores for three subindices and the total unweighted score. However, the trained assessor group IWC scores only differed significantly from the expert opinion scores in two subindices. Training of the first assessor group may explain why their scores were more closely aligned to the expert opinion scores.

The IWC was applied to six wetland types and there did not appear to be any condition bias for any particular type. It was not possible to test whether the IWC measured condition consistently between a drying and filling phase as conditions were very dry throughout Victoria over the period of the testing.

Further development of the IWC is required to improve some measures, enhance the data management system and continue to develop the wetland extent and wetland vegetation mapping protocols.

1 Introduction

1.1 Background

A need for a standard method in Victoria for assessing wetland condition has been driven by international, national and state requirements. These requirements include condition monitoring and evaluation under the Ramsar Convention, the Caring for our Country program, the former National Action Plan for Salinity and Water Quality (NAP) and Natural Heritage Trust (NHT) programs, and State of the Environment and catchment condition reporting in Victoria. In response to this need, a rapid method for assessing the condition of natural, non-marine influenced wetlands in Victoria, the Index of Wetland Condition (IWC) was developed in 2005 by the Biodiversity and Ecosystems Services Division of the Department of Sustainability and Environment in Victoria. Funding assistance was provided by the National Action Plan for Water Quality and Salinity and National Heritage Trust programs. The method was developed with support and expertise from natural resource managers from Victoria and wetland ecologists from around Australia.

Four key outputs were produced from the project: a conceptual framework which detailed the theoretical approach used in the development of the Index (Department of Sustainability and Environment 2005), a literature review detailing wetland condition methods used globally (Department of Sustainability and Environment 2007), a wetland vegetation assessment method (Department of Sustainability and Environment 2006) and a draft manual of IWC methods to be used for undertaking field assessments (Department of Sustainability and Environment unpublished a). All except the methods manual are available for public download on the DSE IWC website: www.dse.vic.gov.au/iwc.

For the IWC, wetland condition is defined as 'the state of the biological, physical, and chemical components of the wetland ecosystem and their interactions' and the reference state against which condition is measured is the condition of the wetland at the time of European settlement (Department of Sustainability and Environment 2005). The IWC is comprised of six subindices: wetland catchment, physical form, hydrology, water properties, soils and biota that reflect key wetland characteristics and measures of wetland components within each subindex (Table 1). Some wetland components in the IWC are measured directly and others indirectly by assessing impacts or threats. The IWC was developed primarily for natural resource managers, including Catchment Management Authorities (CMAs), water authorities and state agencies such as the Victorian Department of Primary Industries and Victorian Department of Sustainability and Environment.

Table 1. Subindices, key ecological components and measures used in the IWC (Department of Sustainability and Environment 2005).

IWC subindex	Key ecological component	Measure	Measure type
Wetland catchment	Wetland catchment	Percentage of land in different land use intensity classes adjacent to the wetland	Threat
	Wetland buffer	Average width of the buffer	Component
		Percentage of wetland perimeter with a buffer	Component
Physical form	Area of the wetland	Percentage reduction in wetland area	Component
	Wetland form	Percentage of wetland where activities (excavation and land forming) have resulted in a change in bathymetry	Threat
Hydrology	Water regime	Severity of activities that change the water regime	Threat
Water properties	Macronutrients (such as nitrogen and phosphorus)	Activities leading to an input of nutrients to the wetland	Threat
	Electrical conductivity (salinity)	Factors likely to lead to wetland salinisation • input of saline water to the wetland • wetland occurs in a salinity risk area	Threat

Table 1. Continued.

IWC subindex	Key ecological component	Measure	Measure type
Soils	Soil physical properties (structure, texture, consistency and profile)	Percentage and severity of wetland soil disturbance	Impact
Biota	Wetland plants	Wetland vegetation quality assessment based on: • critical lifeforms • presence of weeds • indicators of altered processes • vegetation structure and health	 Component Impact Impact Component

It is recommended that the Conceptual Framework and Selection of Measures document (Department of Sustainability and Environment 2005) is read to provide an understanding of the development of the IWC.

1.2 Implementation of the Index of Wetland Condition objectives

The Implementation of the Index of Wetland Condition project has further developed the IWC. The scope of the project included training in the use of the IWC, development of information management protocols and databases and validating the IWC method. The specific objectives of the project were:

- To facilitate the use of the IWC across Victoria by NRM agencies through consultation, training, development of tools to aid field assessment and management of information;
- To coordinate IWC assessments undertaken in this project and in projects by other agencies over the project period;
- To scientifically test the IWC and make recommendations on work required to improve the IWC;
- To provide guidance on the use of IWC results for implementing the assets-based approach to NRM management and assessing wetland condition for State of the Environment and catchment condition reporting; and
- To report results of IWC assessments undertaken in the project period and recommend a program for future monitoring of wetland condition in Victoria.

2 IWC training program

The objectives of the training program for the IWC were to ensure that NRM practitioners undertaking wetland condition assessments gained an understanding of the IWC and its application, how to assess the condition of a wetland using the IWC, how to manage IWC data and how to interpret the results.

In order to undertake the training there were some prerequisites. These were the ability to identify native plants, a general understanding of wetland ecology, the ability to interpret general NRM information and skills in data collection and notation.

The training program was developed over the course of the project in 2006 and 2007. Initially a one-day training program was delivered in June 2006 in separate training days at Lanigans Swamp and Barmah Forest in northern Victoria. The training involved a brief overview of the IWC project, wetland plant identification skills, wetland ecological vegetation class (EVC) identification activities and a whole-of-wetland assessment demonstration. As a result of an evaluation of these two training days, the program was reviewed and a two-day course was developed.

Two-day training courses were run at Colac (Figure 1a) and Kerang (Figure 1b). The course commenced in an office environment and provided participants with background information on the IWC method and its development. The remaining course components were undertaken at wetlands near Colac and Kerang. A briefing was provided on the IWC method followed by wetland ecological vegetation class (EVC) identification. Wetland EVC assessments were practiced in small groups. Demonstration of the remaining IWC measures was provided by the trainers and practiced by the participants in small groups. An IWC assessment was undertaken on a whole wetland in the small groups and scores were compared between the groups. Participants completed a training program feedback form at the end of the training (Appendix 1).

Sixty people completed the training courses, including staff from eight of ten CMA regions; Corangamite, North Central, Mallee, West Gippsland, Goulburn-Broken, North East, Glenelg-Hopkins and Port Phillip and Westernport.

Comments from the participants were summarised and their responses to the questions on the feedback form were plotted (Figures 2 and 3). Generally the feedback from the training was positive. Most participants felt the length of training was sufficient to cover all aspects of the method. Views differed in the amount of time spent explaining vegetation physiology and lifeforms versus time spent doing a full IWC assessment. Participants found the background presentation helped them understand how the method was developed and provided context for the training. Most participants were confident that they could successfully apply the method in the field after the training. Some participants were concerned that some of the measures were too subjective which could lead to a lack of consistency in the interpretation of the measures and subindices by different field staff. Some participants said they would feel more confident with the method after rigorous testing to see if there are differences between users.

As a result of the feedback, the training program was modified by increasing the length of the program to add a training site and allocate more time for whole IWC assessments.

Figure 1a. Colac region training day October 2006.

Figure 1b. Kerang region training day October 2006.

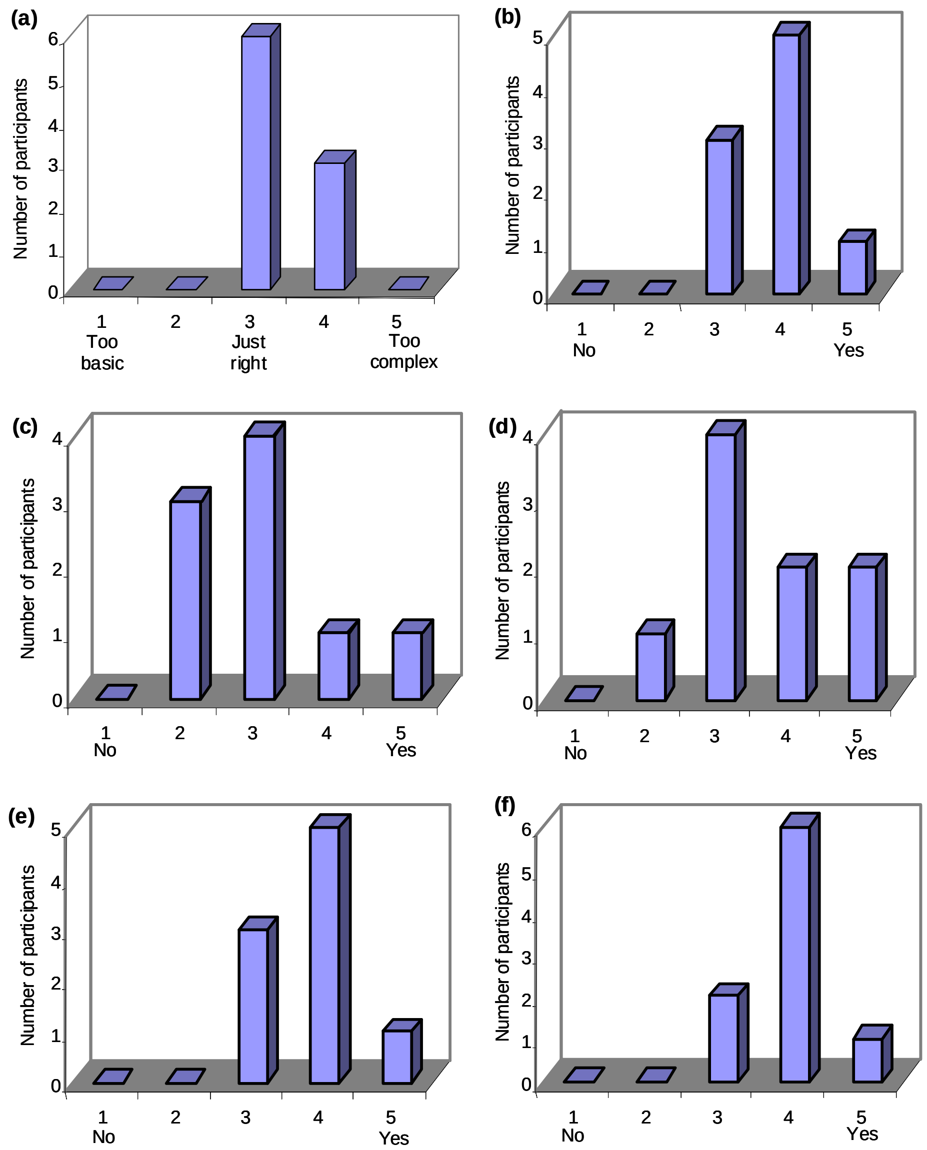

Figure 2. Responses to the Colac training feedback for questions 1-6 as follows:

(a) 1. At what level would you say that the information this course provided is pitched?
(b) 2. Do you think the PowerPoint presentation added value to the training course?
(c) 3. Do you think the length of the training was sufficient to cover all aspects of the IWC method adequately?
(d) 4. As a result of the course information, do you feel you can confidently identify wetland EVCs?
(e) 5. As a result of the course information, do you feel you can confidently assess the non-vegetation measures of the IWC?
(f) 6. As a result of the course information, do you feel confident in using the IWC method?

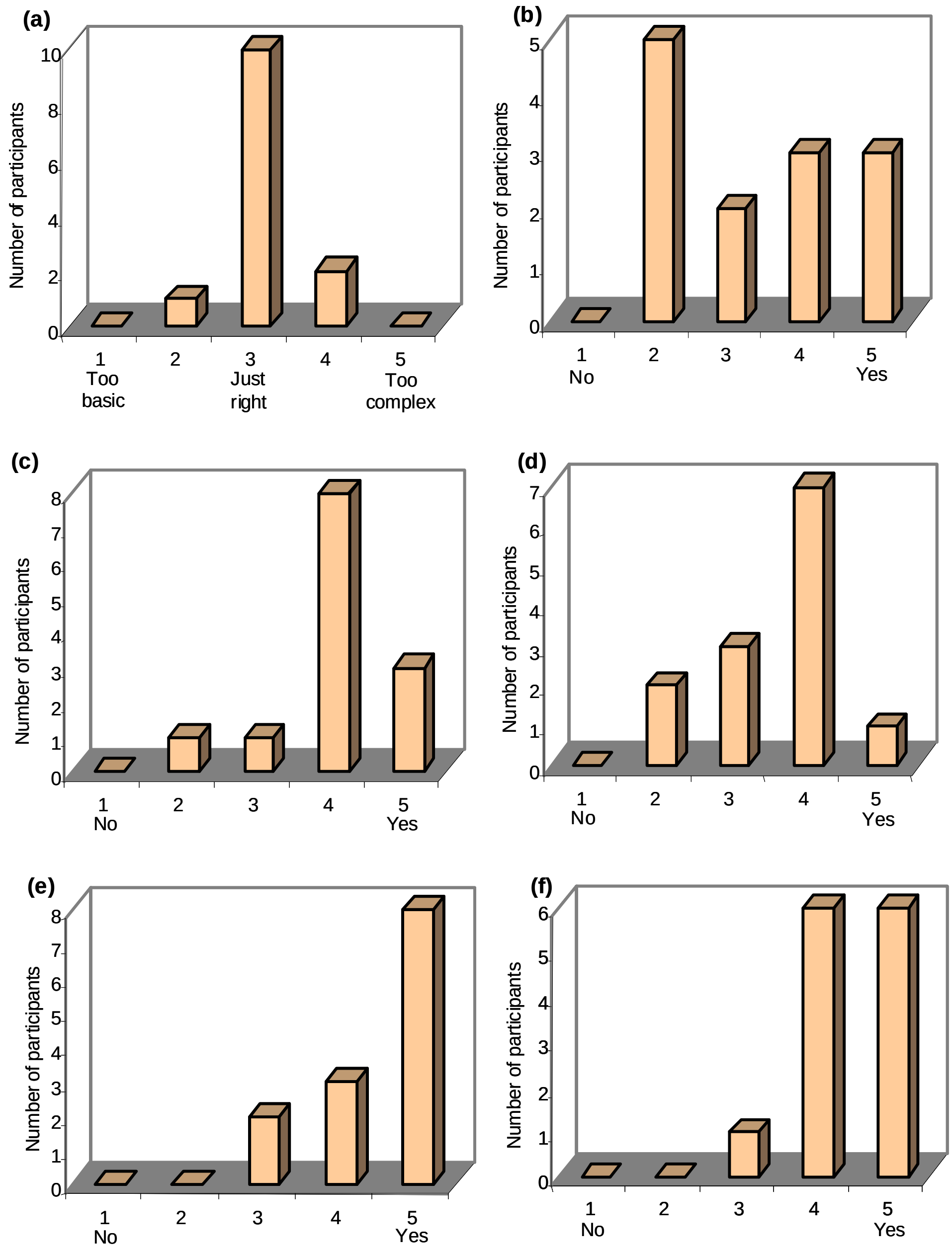

Figure 3. Responses to the Kerang training feedback for questions 1-6 as follows:

(a) 1. At what level would you say that the information this course provided is pitched?
(b) 2. Do you think the PowerPoint presentation added value to the training course?
(c) 3. Do you think the length of the training was sufficient to cover all aspects of the IWC method adequately?
(d) 4. As a result of the course information, do you feel you can confidently identify wetland EVCs?
(e) 5. As a result of the course information, do you feel you can confidently assess the non-vegetation measures of the IWC?
(f) 6. As a result of the course information, do you feel confident in using the IWC method?

3 Information management

3.1 IWC Data Management System

The Index of Wetland Condition Data Management System (IWCDMS), developed through the life of the project, is a key requirement for the management of IWC data. The process of system development commenced with preparation of an information management scoping paper for the implementation of the IWC. Based on this paper and discussions with DSE information management experts, a business requirements specification was prepared to guide development of the IWCDMS. The functional requirements for the IWCDMS included:

- facilitation of new user access;
- creation of reports and inquiries;
- management of wetland assessment data;
- management of user access;
- management of data for wetland sites assessed using the IWC;
- management of wetland assessors;
- exchange of wetland site data with interfacing systems; and
- management of data for IWC assessment projects.

The IWCDMS is on-line system, that can be accessed through an internet browser. The IWCDMS is currently accessible only by the IWC project team but the design allows for the system to be expanded to allow other users such as CMAs and consultants to access it in the future. Data is stored in a relational database. The data fields are based on those in the IWC field assessment sheet.

The IWCDMS was designed so that data entry from the field assessment sheet was as simple as possible. The order and layout of the screens are similar to the field sheets. Examples are shown in Figures 4 and 5. The system includes features designed to minimise user error and automate calculations for scoring. In addition to the IWC data collected in the field, attachments such as images and documents can be uploaded to the IWCDMS. Both detailed and simple reports can be generated for each IWC assessment.

After development of the system there was a six-month testing period to detect and rectify errors and make minor enhancements. The IWCDMS was upgraded following the development of the new subindex weights (Table 11) and calculation for the total score.

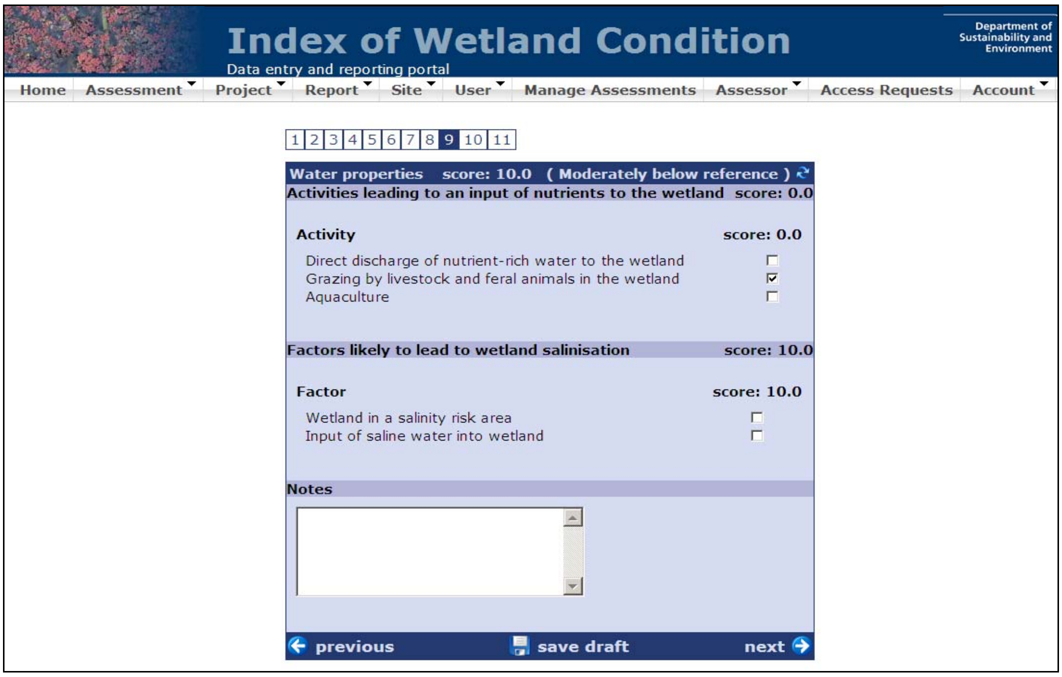

Figure 4. IWCDMS data entry screen for Water Properties measures.

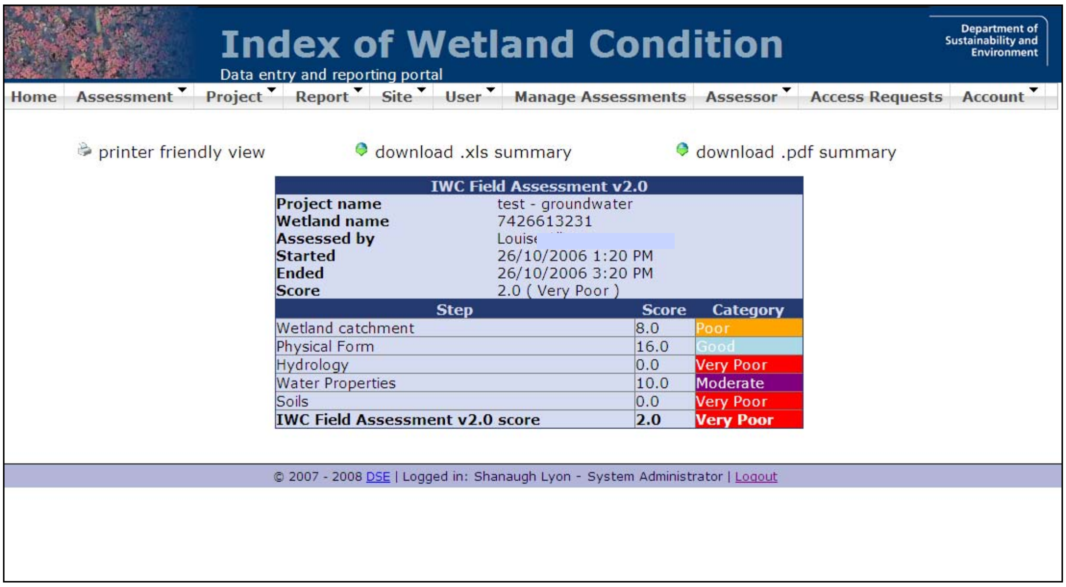

Figure 5. IWCDMS summary report screen.

3.2 Data management protocol

DSE is developing protocols for IWC data management covering IWC data capture, management and reporting, wetland EVC mapping and wetland mapping. Issues associated with the spatial datasets, which include incorrect positioning and the current use of an inadequate wetland identifier, need to be overcome before the protocol can be finalised. These issues are currently being investigated.

The current process of IWC data management includes:

- acquisition of hard copy field sheets from CMAs (originals);
- data entry onto the IWCDMS;
- quality control of data by reviewing 10% of the data;
- review of IWCDMS performance and issues; and
- collation of issues and feedback associated with both IWC method and the IWCDMS.

3.3 Mapping tool

The information management scoping paper for the implementation of the IWC identified the need for a tool to produce wetland base maps, which are required during IWC field assessments. The tool developed as part of the project is web-based and can be accessed through a web browser. The link to the mapping tool is on the DSE website (http://www.dse.vic.gov.au) in the interactive maps page, which can be accessed from a link on the top right hand side of the DSE home page.

The user can search for a wetland using its name or wetland identifier or manually using the interactive map (Figure 6). Once the wetland is located (Figure 7), two types of base maps can be produced — a map of the wetland itself and a map that shows the wetland in the context of the surrounding landscape.

Based on feedback from people undertaking IWC assessments the mapping tool was upgraded to include the addition of land use and salinity discharge spatial datasets (Figures 8 and 9), which will assist IWC assessors in making more informed assessments of the wetland catchment and water properties measures.

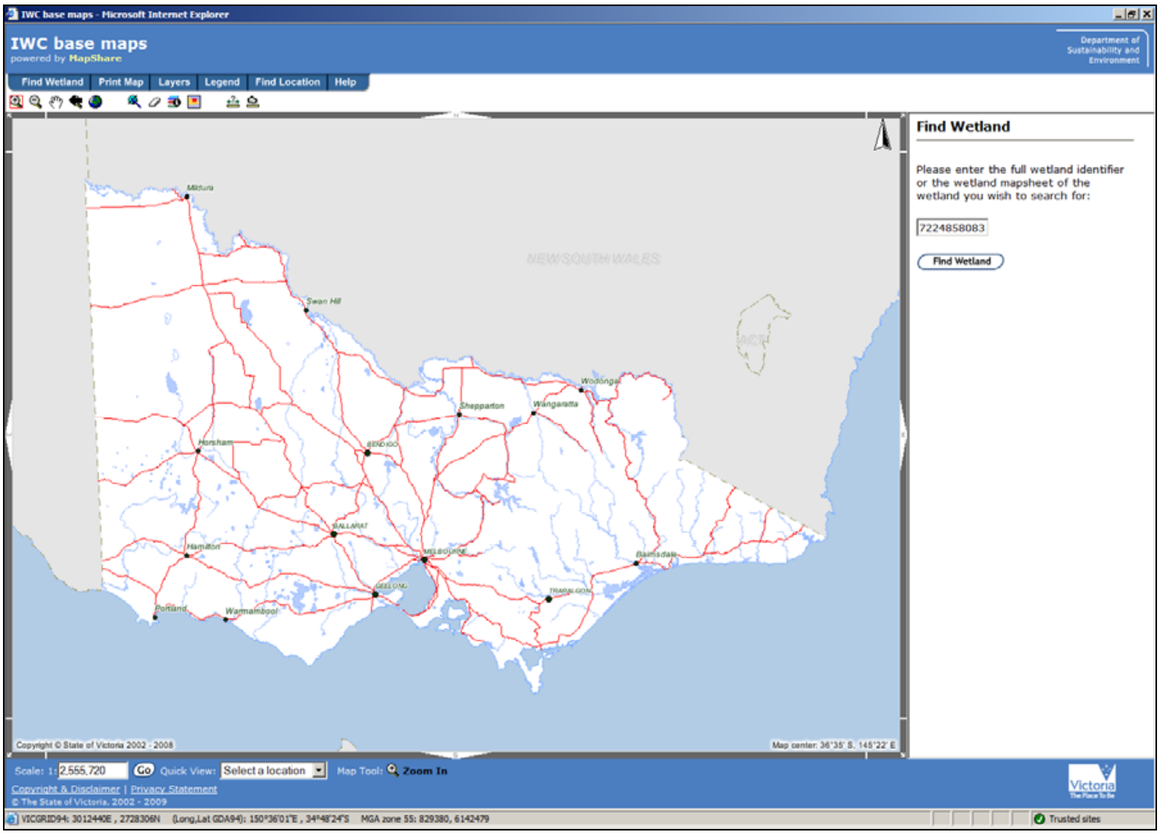

Figure 6. IWC mapping tool: wetland selection screen.

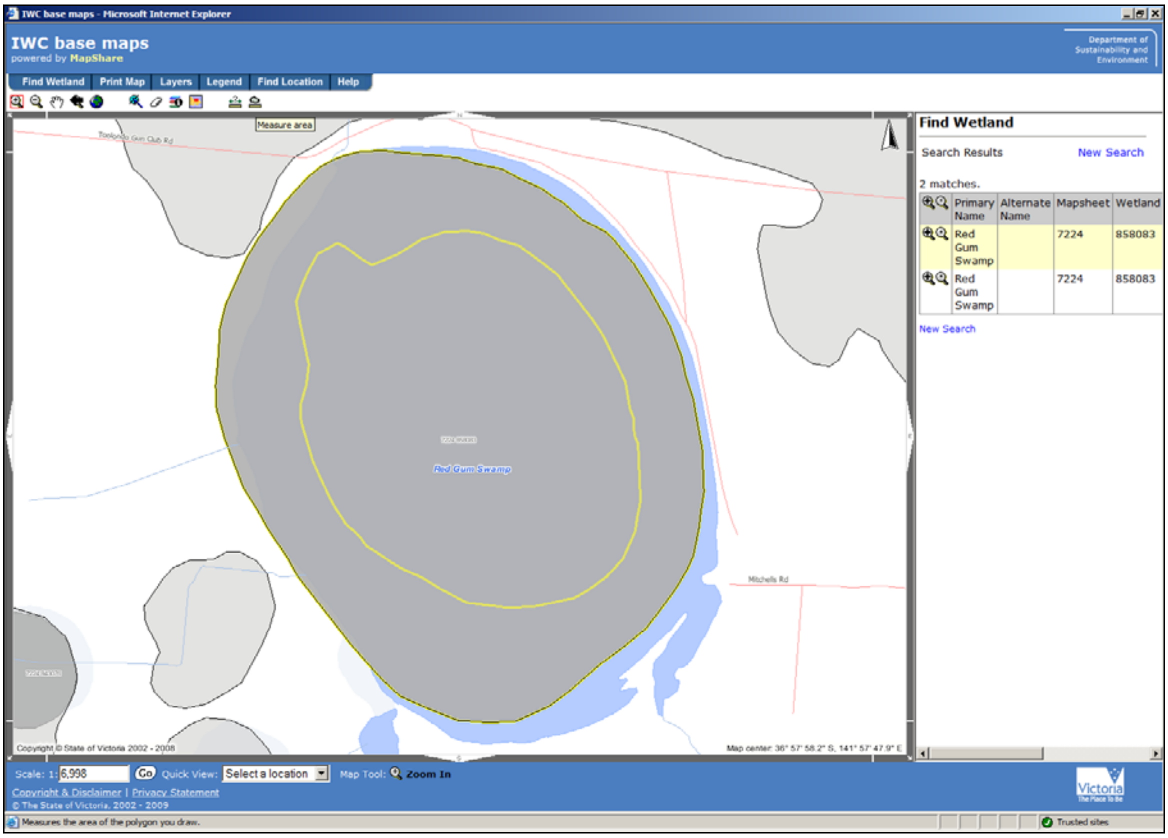

Figure 7. IWC wetland mapping tool: wetland result from the search (Figure 6).

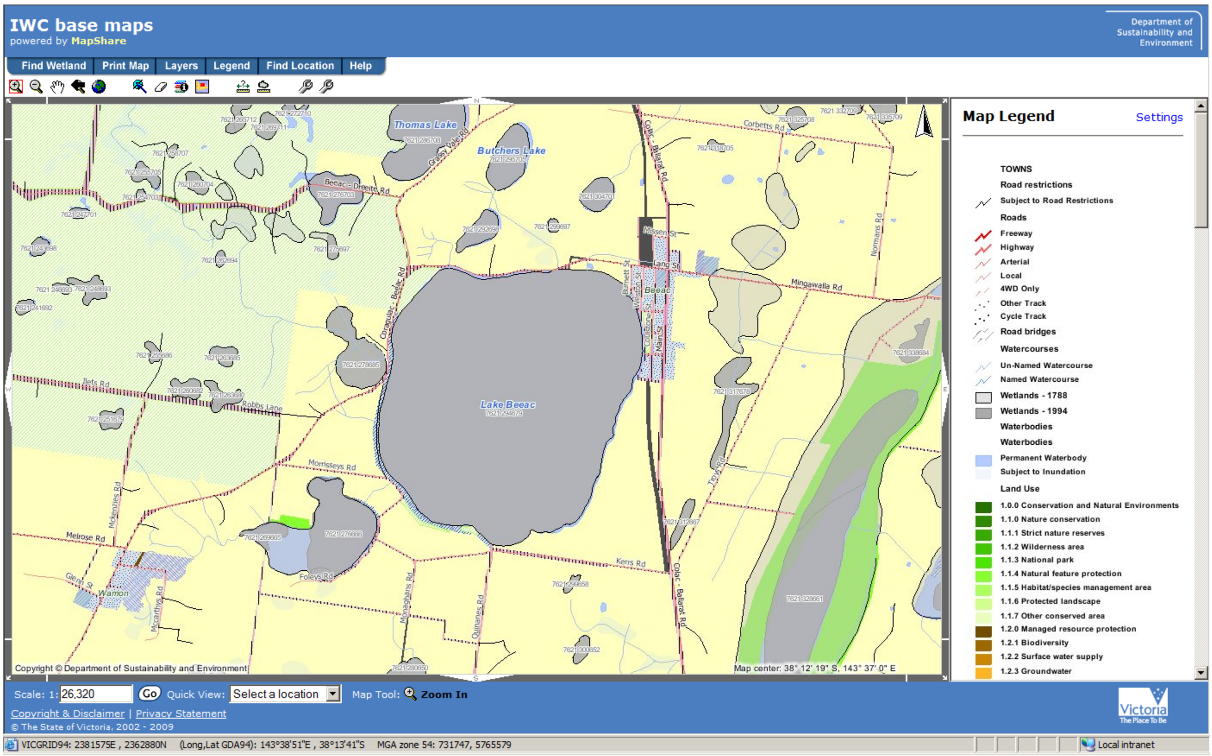

Figure 8. Wetland mapping tool: land use data (zoomed to Lake Beeac in the Corangamite CMA region).

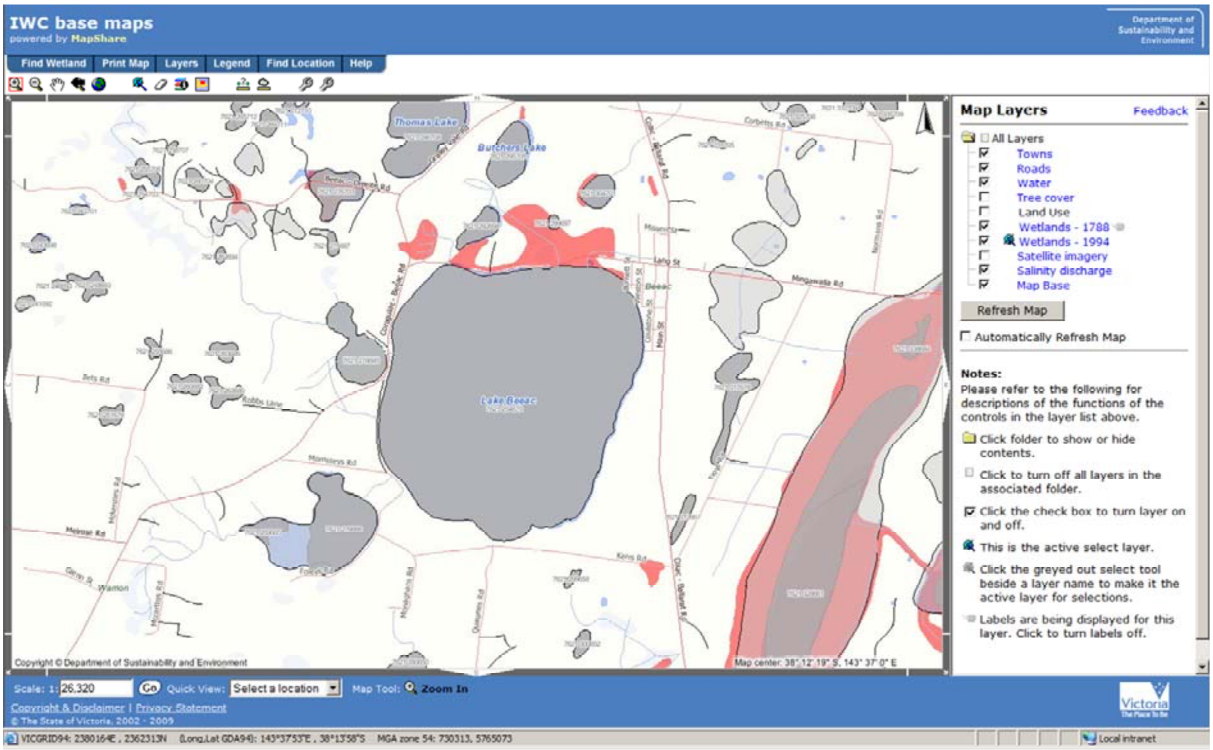

Figure 9. Wetland mapping tool: salinity discharge data (zoomed to Lake Beeac in the Corangamite CMA region).

3.4 Protocols for wetland EVC and wetland extent mapping

3.4.1 Wetland EVC mapping protocol

DSE manages a series of native vegetation datasets describing the spatial extent of native vegetation types before clearing (i.e. pre-1750) and extant (i.e. current extent of EVCs). Further information on these datasets are available on the DSE website via the following links: http://www.dse.vic.gov.au > Conservation & Environment > Native Vegetation Information for Victoria > Accessing Native Vegetation Data

As part of the earlier development of the IWC, EVCs that occur in non-flowing inland wetlands in Victoria were described, and an approach was developed to assess wetland vegetation quality in wetlands covered by the IWC (Department of Sustainability and Environment 2006). While the mapping of terrestrial EVCs in Victoria is complete, prior to the development of wetland EVC descriptions (Department of Sustainability and Environment 2006), wetland EVCs were not mapped in sufficient detail or were recorded using general and less accurate EVC descriptions.

More recently, there have been mapping projects using the wetland EVC typology and descriptions developed for the IWC. These include mapping wetland EVCs in the Barmah Forest, on the Mornington Peninsula and in River Red Gum forests along the Murray River. These projects have provided data that have been or will be incorporated into the DSE EVC spatial datasets. However, wetland vegetation has not been mapped in accordance with the new wetland vegetation typology for the majority of wetlands in Victoria.

Accurate mapping of wetland EVCs will assist wetland EVC identification for IWC assessments. It is likely that such mapping will be undertaken by different agencies as a series of discrete projects for different parts of Victoria. There is currently no guidance for mapping wetland EVCs with respect to methods and metadata standards and there is no process for acquiring wetland EVC data from external agencies. The objectives of the wetland EVC mapping protocol are to provide guidance on wetland EVC mapping to ensure that:

- data is stored in an appropriate repository (such as the existing EVC dataset);
- appropriate metatdata is collected;
- data collection meets required standards of accuracy; and
- wetland EVCs are mapped as consistently as possible.

A draft EVC mapping protocol has been developed in consultation with representatives of DSE. After being reviewed within DSE it will be circulated for external consultation.

3.4.2 Wetland mapping protocol

The majority of wetland extent mapping in Victoria has been undertaken since 1975, commencing with statewide mapping from 1975to 1994 (Corrick and Norman 1980, Corrick 1981, Corrick 1982, Norman and Corrick 1988). Project outputs included spatial datasets that are curated by DSE. Since then, mapping has been on a project basis, managed by some of Victoria's Catchment Management Authorities (Figure 10) and DSE. The Wimmera CMA undertook wetland extent mapping in 2004 in the Wimmera CMA region (Sinclair Knight Mertz unpublished a). The Mallee CMA corrected errors in the DSE dataset for their region in 2005 (Sinclair Knight Mertz unpublished b). Wetland extent mapping in part of the West Gippsland CMA region was undertaken by the West Gippsland CMA in 2005 and 2006 (Ecosystem Management Australia unpublished). The Goulburn-Broken CMA mapped peatlands, springs and soaks in 2005 and the lower Broken River floodplain wetlands in 2007 (Ecology Australia unpublished a, b). The North Central CMA undertook an audit of the Wetland

1994 dataset and created a new wetlands spatial dataset for the region in 2008 (Alluvium unpublished). DSE (Arthur Rylah Institute) has mapped alpine bogs and wet heathlands (Figure 10).

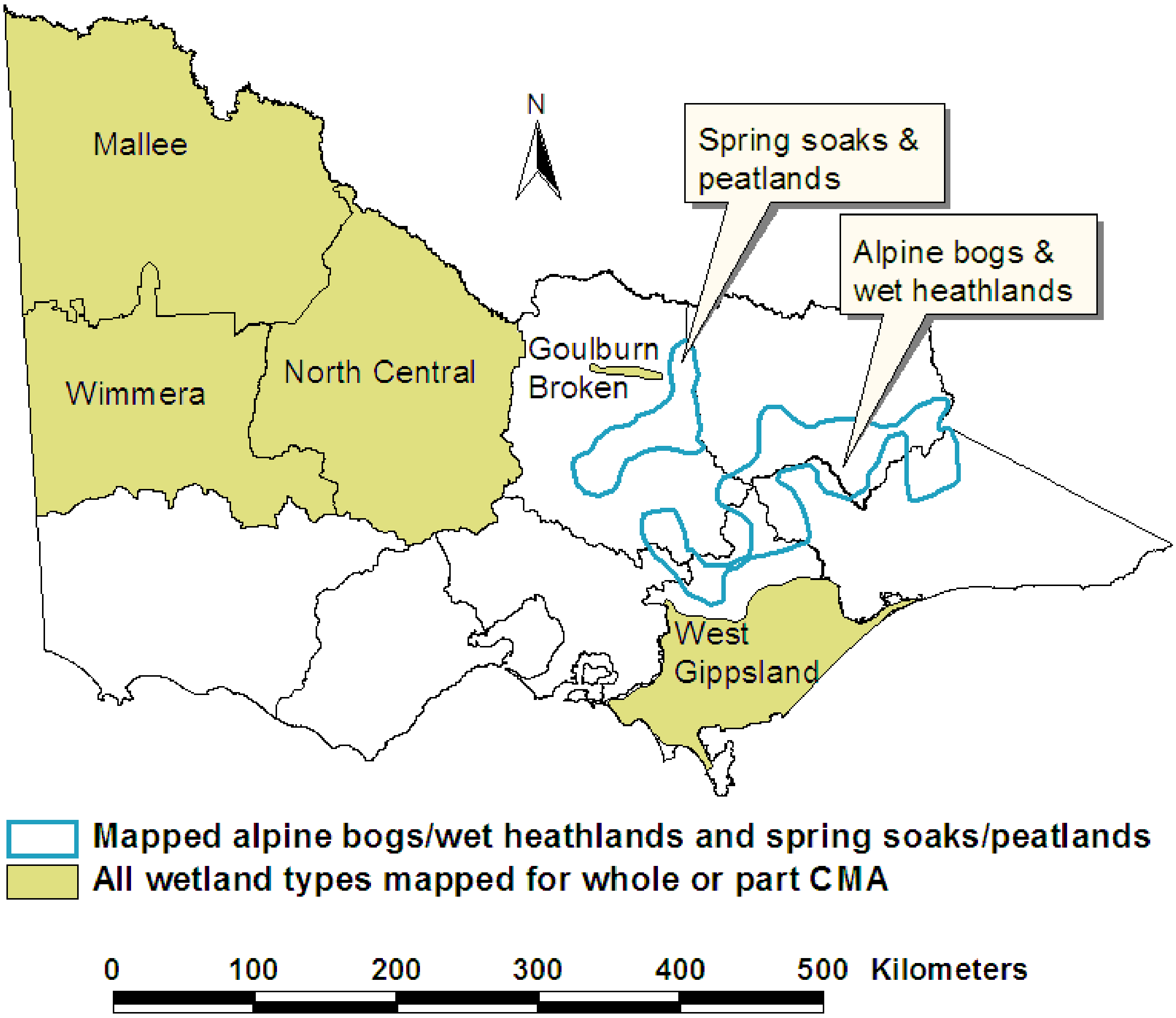

Figure 10. Status of wetland extent mapping in Victoria.

In Victoria there is currently no guidance on mapping wetland extent with respect to methods and metadata standards. Mapping methods are inconsistent across the state and spatial datasets lie within CMAs. DSE has no systematic process for acquiring wetland mapping data from external agencies that have undertaken the work that has not been part of a DSE project. A wetland mapping protocol would help ensure that these issues are rectified.

In order to initiate a process for the development of a wetland extent mapping protocol in Victoria, a workshop was held on 24 April 2008 which drew together experts in wetland mapping in Victoria and Queensland. A wetland mapping protocol document structure has been proposed and is currently being reviewed within DSE. A national wetland mapping protocol is also under development. Further consultation is required, which will be undertaken in a future stage of the IWC (Section 7).

4 IWC assessments and improvements to the method

4.1 IWC assessments

The use of the IWC by CMAs was supported by the IWC project team in providing a data management and training program. Results from regional IWC assessments were used to assess the practical application of the method across a wider range of users and identify areas for improvement, as only limited practical testing of the IWC method was performed during the development phase (Department of Sustainability and Environment 2005).

The IWC method was used provisionally across five CMA regions in Victoria (North East, Goulburn-Broken, Mallee, Corangamite and West Gippsland) and across two DSE/DPI regions (North East and North West) to report on wetland condition for a number of projects. Two hundred and fifty-six wetlands were assessed in these regions between 2006 and 2008, however data for only 228 wetlands were entered into the IWCDMS because the remaining wetlands did not have a unique wetland identifier. In order to enter new unmapped wetlands into the IWCDMS, a unique wetland identifier is required. The new wetland identifier will be developed in late 2009.

4.1.1 Provisional IWC results

The majority of wetlands were assessed using the provisional IWC method between 2006 and 2008. These were rated as 'slightly below reference' using the provisional condition categories assigned to wetland scores in the development stage of the IWC (Department of Sustainability and Environment 2005) (Table 2). The scoring system and score categories were modified following testing of the IWC (Section 5).

IWC assessment projects performed during the IWC project period were not part of a statewide assessment of wetland condition, however they were used provisionally for the 2007 Victorian catchment condition report (Victorian Catchment Management Council 2007).

Table 2. Provisional results from IWC assessments between 2006 and 2008.

Lead agency	Project	Number of wetlands	Condition category			
			Well below reference	Moderately below reference	Slightly below reference	Reference
North East CMA	Wetlands strategy	**42**	0	8	29	5
Goulburn-Broken CMA	Broken, Boosey, Nine Mile creeks	**10**	0	2	6	2
	Lower Broken	**29**	0	3	22	4
Mallee CMA	2006 IWC assessments	**27**	0	8	13	6
	2007 IWC assessments	**17**	0	0	11	6
Corangamite CMA	Wetlands tender	**26**	1	10	9	6
North West DPI	Gunbower	NA	NA	NA	NA	NA
DSE Arthur Rylah Institute	IWC Round 1 testing	**22**	0	1	12	9
	IWC Round 2 testing	**26**	0	1	12	13
	Total	**199**	**1**	**33**	**114**	**51**
	Percentage of wetlands		**<1%**	**17%**	**57%**	**26%**

4.2 Improvements to the method

The project team sought to identify and address issues with the practical application of the IWC by seeking feedback from assessors and reviewing completed field assessment sheets.

The project team sought regular feedback throughout the project on the practical issues associated with the application of the IWC from CMA staff and consultants who used the method in 2006–2008. In addition, a workshop to review the implementation of the IWC was held in May 2008. The workshop participants (four consultants, one CMA wetlands officer and two IWC project team members) had all been trained in the IWC method and had undertaken IWC assessments. The project team collated and reviewed all completed IWC assessment sheets and entered the data in the IWCDMS. This also assisted in identifying potential issues with the practical application of the method which were also discussed at the workshop. The issues could be classified into six broad areas, as follows:

1. Clearer guidance was required on:
   - the expertise and time required to undertake IWC assessments;
   - assessing large wetlands;
   - assessing wetlands that have been dry for an extended period;
   - assessing wetlands not recorded on the State wetland layer;
   - setting up photopoints and taking photographs;
   - defining and identifying the wetland buffer;
   - assessing catchment land use;
   - defining and recording the wetland boundary;
   - assessing soil disturbance due to pugging;
   - using landscape diagrams to aid in identifying EVCs;
   - on-ground identification and assessment of EVCs; and
   - recording EVC scores on field assessment sheets.
2. Access to better information was required to improve the assessment of catchment land use and salinity risk measures.
3. Provision was requested for recording notes on the field assessment sheet.
4. Improvements to the IWC measures in the hydrology, water properties and soils subindices were suggested.
5. Clarification was sought for the rationale for not including biota measures other than for vegetation.
6. Concerns were expressed regarding the IWC scoring system, which included equal weights of the sub-indices and a limited number of scoring bands for the hydrology and water properties subindex. Feedback suggested that the IWC scoring system over-estimated the condition of wetlands compared to subjective observations in the field.

At the completion of the workshop the issues and recommended changes were compiled and reviewed by the project team. This resulted in a number of actions (Appendix 2), which involved:

- changes to the way some measures are to be assessed;
- changes to the IWC base maps;
- changes to the IWC field assessment sheets;
- revision of the draft IWC methods manual (Department of Sustainability and Environment unpublished a); and
- changes to the IWCDMS.

The IWC scoring system was reviewed as part of the testing program (Section 5).

5 Testing program

5.1 Introduction

Recommendations on the implementation and future development of the IWC were documented (Department of Sustainability and Environment 2005). Future testing and periodic revision of the IWC were recommended to continue to develop the IWC as a robust and credible method for the rapid assessment of wetlands. It was recommended that the IWC should be used in a provisional sense as part of an implementation program that incorporates use and testing. There was provisional use of the IWC by several CMAs from 2006 to 2008 as outlined in Section 4.1. The purpose of the testing program was to assess the IWC scoring system and subindex weights, and determine whether the method measures wetland condition consistently. Ideally validation and calibration of the method would have taken place prior to the CMA IWC assessments; but this was not possible due to CMA project timing constraints.

A literature review (Appendix 4) was conducted to gain an understanding of the approaches used for testing rapid assessment methods (similar to the IWC). The review informed the testing objectives used for this project. Topics covered were:

- validating using existing data;
- establishing an a priori condition gradient using direct measures of wetland components;
- establishing an a priori condition gradient using remote-sensed data and human disturbance measures;
- determining relationships between the rapid assessment method and direct measures of wetland components;
- determining relationships between two different wetland condition assessment methods;
- accounting for seasonal and inter-annual variability;
- ensuring the method is applied consistently by different assessors and that assessors have different skill bases;
- analysing data; and
- calibrating: refining index scoring and weight.

5.2 Objectives for testing the IWC

The objectives for testing the IWC were established in consultation with the project steering committee and an expert panel based on consideration of the literature review and the objectives of the project (Section 1.2). The specific objectives of the testing program were to:

1. test that the IWC measures condition consistently across a condition gradient;
2. test that the IWC measures condition consistently in two hydrological phases (filling and drying) at individual wetlands;
3. test that the IWC measures condition consistently in different wetland types; and
4. test that the IWC measures condition consistently between the IWC project team, NRM consultants and CMA staff.

5.3 Testing sites

Sites for the IWC testing program were selected in the Wimmera Catchment Management Region because of the availability of detailed quantitative physico-chemical, environmental and biotic datasets available from two projects undertaken independently in 2004 and 2005: (i) Wetlands, Biodiversity and Salt (Smith et al. 2008) and (ii) Wimmera Wetland Condition Assessment (Butcher unpublished) (Table 3).

Fifty-eight sites were sampled in 2004 during the wet phase for the Wetlands, Biodiversity and Salt project. Of these, 12 were sampled four times in 2005 during a wet phase. Seventy-six sites were sampled once in Spring 2004 for the Wimmera Wetland Condition Assessment project. Fourteen sites were sampled in both projects.

Sites for IWC testing were prioritised according to the amount and type of data available for each site. Sites were selected where the most comprehensive data has been collected. These included (i) 14 sites where multiple datasets existed for the Wetlands, Biodiversity and Salt project, (ii) Wetlands, Biodiversity and Salt sites visited on more than one occasion (11 sites), and (iii) sites that were sampled once during both projects (2 sites). Twenty-seven sites in total were considered suitable for testing (Figure 11, Table 4). When the quantitative data was collated, three sites were found to have data missing and were removed when testing objective 1. Twenty-seven sites were used for all other objectives of the testing program.

Table 3. Data collected for the Wetlands, Biodiversity and Salt and Wimmera Wetland Condition Assessment projects.

Project	Objective	Project measures/components	Number of sites	Year sampled	Sampling frequency
Wetlands, Biodiversity and Salt	Measure wetland biodiversity across a salinity gradient	• Diatoms • Zooplankton • Fish • Frogs • Crayfish • Birds • Macrophytes • Wetland vegetation • Riparian vegetation • Water chemistry	58	2004	All sites – once (wet phase) Fish and water chemistry -twice 12 sites – 4 times (wet phase)
Wimmera Wetland Condition Assessment	Develop a method for measuring wetland condition for the Wimmera CMA	• Climate • Hydrology • Geomorphology • Land use • Hydrogeology • Salinity • pH • Dissolved Oxygen • Electrical conductivity • Turbidity • Surface water temperature • Nutrients in water column • Amphibians and reptiles • Waterbirds • Wetland vegetation condition • Riparian vegetation condition	76	2004	All sites once

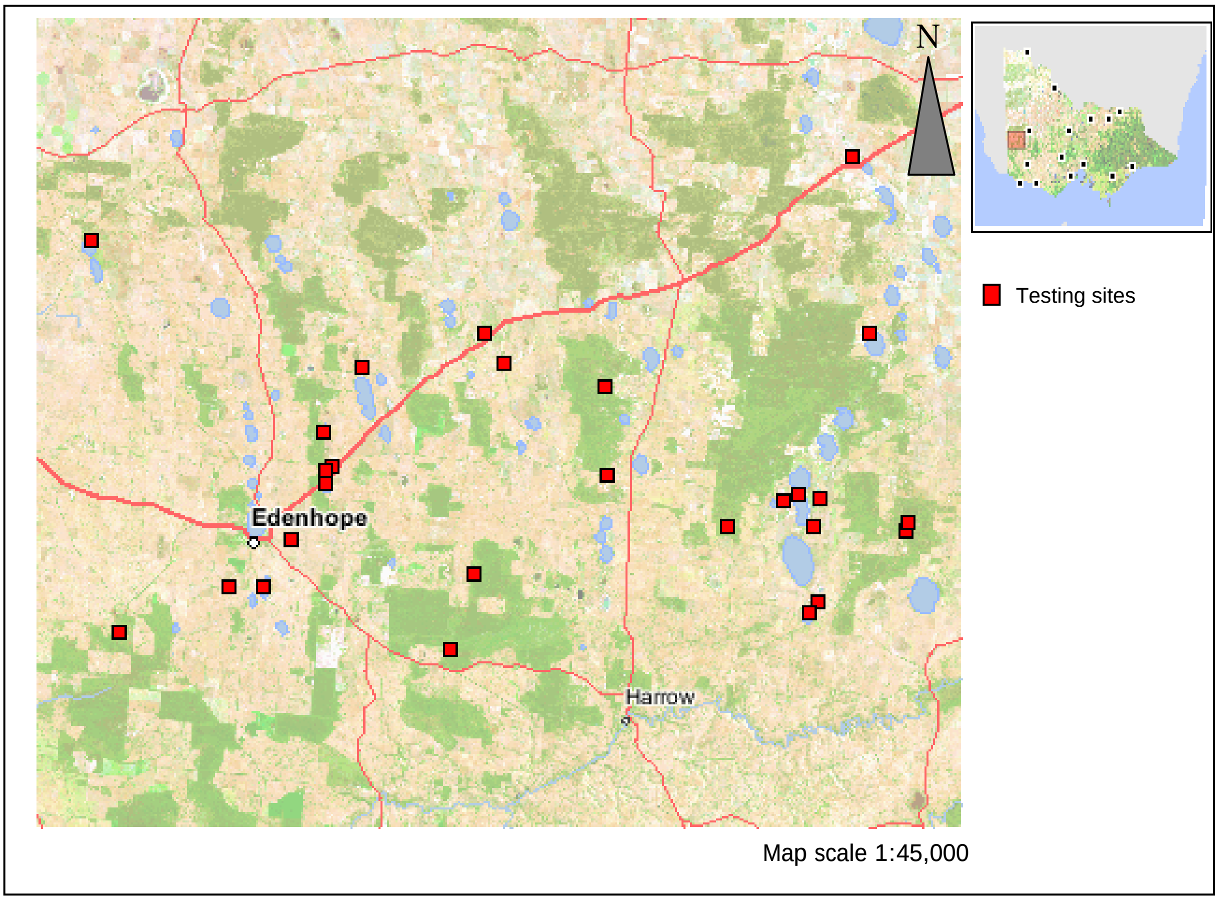

Figure 11. Location of wetlands used in the testing program in the Wimmera region of Victoria.

Table 4. Wetlands selected for the IWC testing program.

Wetland identifier	Wetland name	Area (ha)
7223519043	Unnamed	23.68
7223606002	Unnamed	3.86
7124144230	Lake Bringalbert	90.27
7124338136	Alakilu Swamp	54.09
7123264972	Lake Kemi Kemi	69.87
7124313086	Champion Swamp	35.6
7124318058	Caldows Lake (North)	18.41
7124313055	Caldows Lake (South)	12.07
7123238974	Unknown	3.4
7123283008	Hurleys Bank	18.5
7123399921	Unnamed	8.83
7224710271	Unnamed	7.27
7223671945	McGlashins Swamp	21.04
7224447130	Little Donkey Woman	4.39
7223673020	Unnamed	17.67
7224521111	White Lake	7.86
7223738993	Unnamed	8.77
7223742000	Unnamed	5.57
7223670999	Unnamed	4.05
7123313043	Collins Lake	41.15
7223662012	Centre Lake	220.2
7224722135	Bow Lake	168.4
7123418977	Unnamed	2.2
7124432154	Sheepwash Swamp	39.10
7223650020	Unnamed	15.77
7123158943	Unnamed	16.72
7223663933	Stinky Swamp (Ti Tree Lake)	51.47

5.4 Objective 1: Testing the IWC across a condition gradient

Hypothesis

Condition measured by the IWC is strongly positively correlated with condition across a condition gradient as determined by expert opinion from comprehensive datasets.

Testing approach

The approach to testing this hypothesis consisted of three steps:

1. using an index based on wetland catchment land use as a surrogate for wetland condition, to ensure the wetlands selected for the IWC testing program cover a range of condition;
2. weighting IWC subindex scores; and
3. comparing weighted IWC scores with independently determined condition scores.

Step 1: Determining the condition gradient using the Landscape Disturbance Index

A Landscape Disturbance Index (LDI) was developed as a means of estimating wetland condition from land use data to ensure that the wetlands selected for testing the IWC reflected a condition gradient. The use of the LDI for this purpose was based on the assumption that disturbance in the landscape surrounding the wetland is an important factor in determining wetland condition. However, it is recognised that other factors, including activities within the wetland, can also cause changes in wetland condition.

The LDI is based on a Catchment Disturbance Index (CDI) described in the National Framework for the Assessment of River and Wetland Health (FARWH) (National Water Commission 2007). The CDI estimates the effects that land use, change in vegetation cover and infrastructure (e.g. roads, rail lines) are likely to have on the run-off of sediments, nutrients and other contaminants to rivers (National Water Commission 2007). In developing the stream-based CDI, the literature was reviewed to identify a set of land use categories associated with changes to water quality and aquatic biota in rivers (National Water Commission 2007).

Design of the LDI

The LDI was designed to estimate the impacts of land use and infrastructure on wetland condition. Land use and infrastructure categories were derived from a land use spatial dataset (Department of Sustainability and Environment 2009). The index is similar to other wetland disturbance indexes (e.g. Lopez and Fennessy 2002, Brown and Vivas 2005). A panel of five wetland ecologists reviewed the categories of impacts used by the stream CDI and derived a set of impacts applicable to wetlands (Table 5).

Table 5. Potential impacts of land use and infrastructure on wetland condition.

Type of impact	Produced by land use and/or infrastructure
Augmentation of the nutrient supply to a wetland	Both
Increase in salinity	Land use only
Release of biocides (pesticides, herbicides and fungicides)	Both
Change to the hydrological regime	Both
Augmentation of the sediment supply to a wetland	Both
Loss of native buffer vegetation	Both
Acidification of soil or water	Both

Values representing the probability of impact from each land use category on the wetland specifically, its nutrients, salinity, biocides, toxicants, hydrological change, sediment supply and riparian change were assigned to each land use type by the panel.

For each land use type the probability of impact values for each impact were averaged to produce an overall score (Table 6). Weights were derived from the average scores by scaling them between 0 and 0.7. Note that the scores were not scaled between 0 and 1 because a value of 1 implies that the impact cannot increase in magnitude (National Water Commission 2007). Weights were compared with the outcomes of studies on the impact of catchment land uses on components of the wetland condition (Boulton and Brock 1999, Batzer and Sharitz 2006, National Water Commission 2007).

Wetland catchments were derived using mapped wetland catchments from a Wimmera CMA project (Sinclair Knight Mertz unpublished a). Land use and infrastructure categories were derived from land use mapping undertaken in Victorian between 1994 and 2005.

Table 6. Land use categories and associated impacts used in the LDI. Impact scores range from 0-6 where 0= minimum impact and 6 = maximum impact (adapted from National Water Commission 2007).

Land use category	Nutrients	Salinity	Biocides	Toxicants	Hydrological change	Sediment supply	Riparian change	Mean score	Weight
1.0.0 Conservation and natural environments	0	0	0	0	0	0	0	0.00	0.00
1.1.0 Nature conservation	0	0	0	0	0	0	0	0.00	0.00
1.1.1 Strict nature reserves	0	0	0	0	0	0	0	0.00	0.00
1.1.3 National park	0	0	0	0	0	0	0	0.00	0.00
1.1.4 Natural feature protection	0	0	0	0	0	0	0	0.00	0.00
1.1.5 Habitat/species management area	0	0	0	0	0	0	0	0.00	0.00
1.2.1 Biodiversity	0	0	0	0	0	0	0	0.00	0.00
1.2.2 Surface water supply	0	0	0	0	0	0	0	0.00	0.00
1.2.4 Landscape	0	0	0	0	0	0	0	0.00	0.00
1.3.0 Other minimal use	0	0	0	0	0	0	0	0.00	0.00
2.0.0 Production from relatively natural environments	0	0	0	0	0	0	0	0.00	0.00
2.1.0 Grazing natural vegetation	1	0	0	0	0	0	3	0.57	0.09
2.2.0 Production forestry	2	2	3	3	2	2	2	2.29	0.35
3.0.0 Production from dryland agriculture and plantations	4	4	4	3	3	4	2	3.43	0.53

Table 6. (Continued)

Land use category	Nutrients	Salinity	Biocides	Toxicants	Hydrological change	Sediment supply	Riparian change	Mean score	Weight
3.1.1 Hardwood production	2	2	3	3	2	2	2	2.29	0.35
3.1.2 Softwood production	2	2	3	2	2	2	2	2.14	0.33
3.2.0 Grazing modified pastures	3	3	3	2	2	2	3	2.57	0.39
3.3.0 Cropping	4	4	4	3	3	3	2	3.29	0.50
3.5.0 Seasonal horticulture	6	4	3	1	2	2	2	2.86	0.44
4.0.0 Production from irrigated agriculture and plantations	6	6	6	2	5	4	3	4.57	0.70
4.2.0 Irrigated modified pastures	6	6	6	2	5	4	3	4.57	0.70
4.4.0 Irrigated perennial horticulture	6	6	6	2	5	4	3	4.57	0.70
4.5.0 Irrigated seasonal horticulture	6	5	6	2	5	4	2	4.29	0.66
5.4.1 Urban residential	5	2	3	6	6	3	6	4.43	0.68
5.5.0 Services	1	1	1	1	1	1	1	1.00	0.15
5.5.2 Public services	1	1	1	1	1	1	1	1.00	0.15
5.5.3 Recreation and culture	1	1	1	1	1	1	1	1.00	0.15
5.8.1 Mines	5	6	1	3	4	3	2	3.43	0.53
5.8.2 Quarries	5	6	1	3	4	3	2	3.43	0.53
5.9.0 Waste treatment and disposal	6	4	1	2	5	1	1	2.86	0.44
5.7.2 Roads	3	n/a	1	6	6	3	n/a	3.80	0.70

To calculate the LDI score for the wetland, the proportion of each land use type in the wetland catchment was first determined and represented as decimal (e.g. 0.4 representing 40% of the wetland catchment). The proportion value was then multiplied by the weight (Table 6). This was repeated for each land use type and all values were summed to give the final score. The final score range is between 0.3 and 1 with increments of 0.07. The stream-based CDI has five condition categories. We have adopted the same categories and descriptors for the LDI (Table 7).

Table 7. LDI scores and linguistic descriptors for the LDI, adapted from the CDI.

LDI score range	LDI descriptor
0.86 - 1	Largely unmodified
0.72 – 0.86	Slightly modified
0.58 – 0.72	Moderately modified
0.44 – 0.58	Substantially modified
0.3 – 0.44	Severely modified

LDI scores were calculated for 27 wetlands in the Wimmera region that were selected for the testing program (Section 5.3). A clear condition gradient was evident (Table 8).

Consultants were engaged to undertake IWC assessments at the 27 sites (Figure 11) in October 2007 after receiving training in the IWC assessment method.

Table 8. Preliminary LDI scores and LDI descriptors for 27 wetlands in the Wimmera region of Victoria used for the testing program.

Wetland Identifier	Area (ha)	LDI Score	LDI descriptor
7223671945	21.04	0.31	Severely modified
7224710271	7.27	0.53	Substantially modified
7223606002	3.86	0.66	Moderately modified
7124144230	90.27	0.60	Moderately modified
7124338136	54.09	0.59	Moderately modified
7123264972	69.87	0.65	Moderately modified
7124318058	18.41	0.69	Moderately modified
7124313055	12.07	0.59	Moderately modified
7123238974	3.4	0.61	Moderately modified
7123283008	18.5	0.65	Moderately modified
7223673020	17.67	0.66	Moderately modified
7223670999	4.05	0.71	Moderately modified
7223662012	220.2	0.70	Moderately modified
7124432154	39.10	0.60	Moderately modified
7223650020	15.77	0.60	Moderately modified
7123158943	16.72	0.62	Moderately modified
7223663933	51.47	0.61	Moderately modified
7223519043	23.68	0.74	Slightly modified
7124313086	35.6	0.80	Slightly modified
7224447130	4.39	0.74	Slightly modified
7123313043	41.15	0.85	Slightly modified
7224722135	168.4	0.75	Slightly modified
7123418977	2.2	0.76	Slightly modified
7123399921	8.83	1.00	Largely unmodified
7224521111	7.86	0.99	Largely unmodified
7223738993	8.77	0.95	Largely unmodified
7223742000	5.57	0.95	Largely unmodified

Step 2: Weighting IWC subindices scores

In the provisional IWC method, a pragmatic decision was made to weight the six subindices equally as there was no data to suggest otherwise (Department of Sustainability and Environment 2005). Feedback from IWC assessors on this provisional method indicated that wetlands were generally scored too high compared to their professional judgement and that some subindices were biasing the results. To determine appropriate weights for the subindices, an expert opinion exercise was undertaken and a predictive model of wetland condition was developed. The model produced weights for the subindices and was also used as a benchmark to test the relationships between unweighted IWC results and with IWC data that was independently collected from the same sites used to construct the model.

Expert opinion exercise

No wetland condition data available in Victoria has been tested for their accuracy and consistency. In order to provide a standard for comparing IWC scores, we were limited to determining wetland condition from quantitative data (Section 5.3). An expert opinion process was followed, whereby a group of wetland ecologists assessed wetland datasets and imagery and estimated the condition of wetlands. Expert opinion has been a suitable way of interpreting comprehensive data to develop condition categories (Spencer et al. 1998, Sutula et al. 2006). The expert opinion scores were treated as an independent measure of condition, and were also used to derived the weights for the IWC subindices and to test the ability of the IWC to consistently measure wetland condition according to the objectives outlined in Section 5.2. The process is however limited by the different ways that each expert interprets the wetland data provided to them.

Nine wetland experts with a range of wetland ecology backgrounds (invertebrates, water chemistry, wetland vegetation and amphibians) participated in the process. The expert opinion process was initiated through a workshop to guide experts through the expert assessment process which involved review of quantitative datasets in the Wimmera region (Figure 11) to determine wetland condition scores for 24 of the 27 wetland sites selected for testing. Three wetland sites were not included in the expert panel assessment because they had missing data.

Experts were assigned 12 wetlands each to assess. The data and information was presented in a standard fashion for each wetland and consisted of the following:

- information on the wetland type and area (as determined by Corrick and Norman (1980);
- imagery of the wetland and its catchment (air photos taken in 2005, site photos and land use map); and
- quantitative datasets (geomorphology/soils, electrical conductivity, pH, nutrients, turbidity, cations, wetland plants, birds, frogs, diatoms, rotifers, zooplankton, macroinvertebrates and wetland plants).

The quantitative data was sourced from the two wetland projects that captured data from multiple wetland components (Table 3, Section 5.3). Each wetland expert was asked to assign both an overall score and score for each IWC subindex score for each wetland. The scores were recorded on an assessment sheet that also included information on scoring weighting and rationale, confidence score and rationale and the tools/datasets used to determine wetland condition (Appendix 3).

Development of a model to predict wetland condition

A model was developed that takes the individual component scores and applies appropriate weights to predict the overall score. As the assessment of component scores is necessarily subjective, the model must be able to incorporate this subjectivity and propagate the resulting uncertainty into the predicted index.

A fuzzy cognitive map (FCM) model was constructed to represent the IWC (Figure 12). The IWC model consisted of a single output (IWC) and six inputs representing each of the individual components. Each of the edges connecting each component and the IWC node represents the (weighted) influence of that component on the IWC node.

In order to use the model it is necessary to estimate the appropriate values for the edge weights. This was undertaken by fitting the model to actual data to learn the appropriate weights. This process is called training and the data used to train the model is called training data. Training data was obtained from 24 wetlands independently assessed by nine experts. Each expert scored a value for each of the wetland components represented in the model on a scale between 1 and 10 and then independently scored the overall IWC again on a value between 1 and 10. Individual components and the IWC were also scored using a linguistic assessment using the classifications poor, good, very good and excellent. The resulting training data consisted of 111 observations for each of the 27 wetlands.

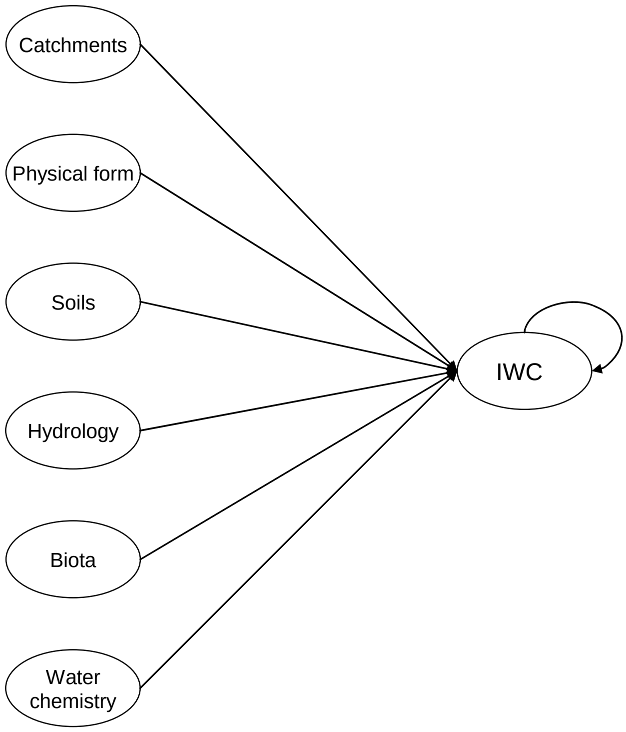

Figure 12. A fuzzy cognitive map (FCM) model of the IWC. Each of the concepts represent a component in the model. The arrows (edges) connecting the concepts represents a weight.

Accounting for uncertainty

Because the scoring of each component and the overall IWC is a subjective exercise, there is some uncertainty or 'vagueness' in the assessment. Vagueness results when the score for a component, for example the value 'good', is interpreted slightly differently by different experts. To handle this vagueness we used fuzzy logic, the mathematics behind computing with language (Zimmermann 1996)

Fuzzy sets explicitly model the relationship between the vague linguistic descriptors used to describe the 'state' of a component and the resulting score assigned to that component. This process, known as fuzzification, takes values (e.g. scores) and classifies them into an arbitrary number of categories or sets (e.g., 'low', 'high'). Unlike ordinary sets that have 'hard' boundaries, fuzzy set boundaries are 'soft', reflecting uncertainty in the boundary of the set. This means a score can belong to more than one set.

Fuzzy sets were constructed to represent each of the four linguistic classifications of condition ('poor', 'good', 'very good', 'excellent') (Figure 13). The upper and lower boundaries of each set were elicited by expert opinion and represent an estimate of the 'vagueness' around each linguistic classification for a given score. Hence, based on expert opinion, wetlands with an IWC score of 9 or 10 definitely represent wetlands in 'excellent' condition but if the score was less than 7 it was considered that the wetland was definitely not 'excellent'. Thus scores between 7 and 9 represent wetlands that are 'somewhat' or 'partially' excellent. As each fuzzy set has overlapping boundaries, scores of 7 and 9 also partially belong to the fuzzy set 'very good'. Hence any score can be represented by a membership function representing the vector of membership values of each set for that score. Another feature of the fuzzy set procedure used here is that these fuzzy-set membership values can be integrated to calculate a single (fuzzy) output value (called 'defuzzification'). This value is called a 'fuzzy score' and is an approximate number. Hence a fuzzy score of 5 is interpreted vaguely (e.g. 'about 5'). Both the 'fuzzy set' (linguistic approximations of 'poor', 'good', etc.) and 'defuzzified' scores were produced from our model to predict the IWC.

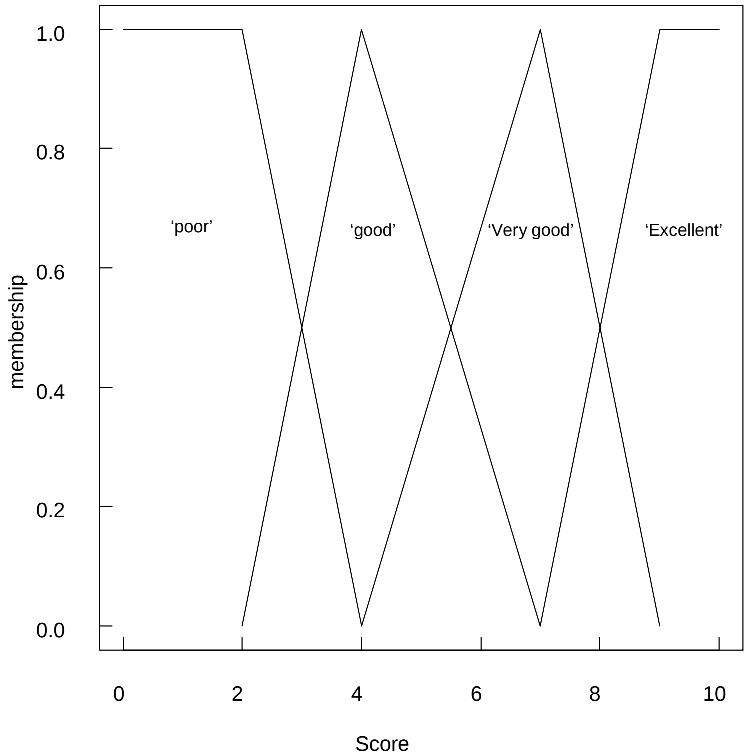

Figure 13. Fuzzy sets classifications used to classify scores from each of the wetland components and the overall IWC.

Training the model

To train the model, single observations from the training data consisting of scores for each of the six individual components were 'fuzzified' and entered into the model. The overall IWC fuzzy score was predicted by 'defuzzification' again using the fuzzy sets. This was repeated for each of the observations in the training data set. For a training data set consisting of *n* observations, the predicted fuzzy IWC scores were compared to the observed fuzzy score by calculating the 'fitness'. The model was then use to predict both the IWC score and the linguistic category for each of the prediction sets.

Measure of accuracy

Overall linguistic accuracy was 72%, meaning the model predicted the correct linguistic category 72% of the time on average. However there was much discrepancy among the prediction sets with prediction set 1 having the highest linguistic accuracy (95.7%) and prediction set 5 the lowest (56.5). Estimates of relative bias were fairly low, with a mean error of 11%. (That is, the predicted IWC fuzzy score differed by an average of 11% from the observed IWC fuzzy score). A more complete picture of the relationship between the predicted and observed fuzzy scores is given in Figure 14.

The overall best-fit estimates of the edge weights for each component in the model, averaged over the 5 training sets, is given in Table 9. Most weight is given to the biota component and least to the soils and physical form component.

Table 9. Best-fit estimates of the edge weights for the model.

IWC subindex	Weight
Catchment	0.26
Physical form	0.08
Soils	0.07
Hydrology	0.31
Biota	0.73
Water properties	0.47
Entropy	-0.81

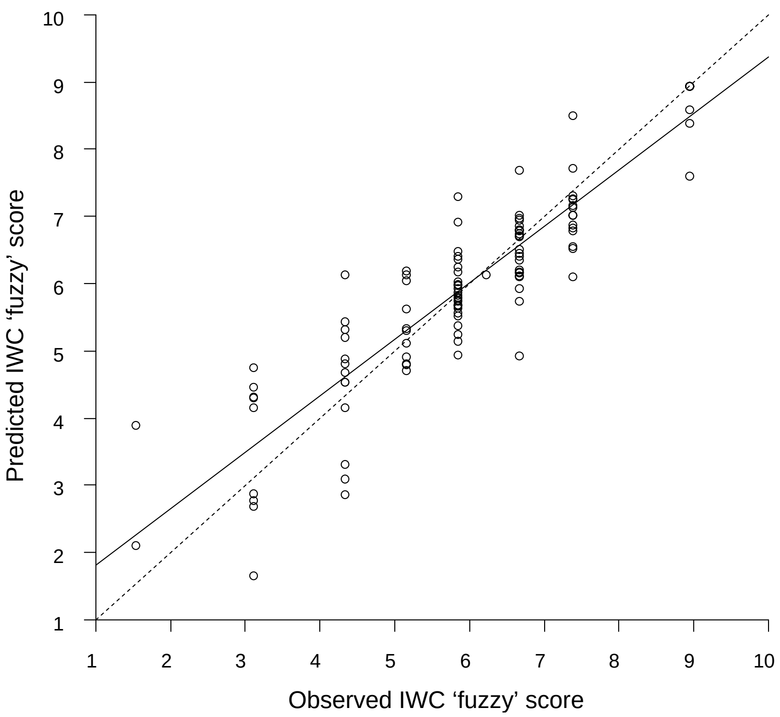

Figure 14. Plot of the observed fuzzy IWC score vs the predicted IWC fuzzy score for each observation from the prediction sets.

Step 3: Comparing weighted IWC scores with independently determined condition scores

The mean of the wetland condition scores from the expert opinion exercise were compared to IWC total scores for each wetland. Only 22 wetlands were used in the analysis because five wetlands were too dry to assess for the Biota subindex, and therefore a total IWC score was not available for these sites.

As the expert opinion and total IWC score data were normally distributed, a paired *t*-test was applied to test whether the two datasets were significantly different to each other, and a simple linear regression was performed to determine the relationship between the two datasets. Analysis was performed with both the original IWC scores and the IWC scores modified using the weights in Table 9. The IWC subindex score data was not normally distributed, so a non-parametric Wilcoxon matched paired test was applied to test whether the expert opinion and IWC subindex data were significantly different from each other.

Results from the paired *t*-test indicated there was a significant difference between the mean expert opinion total scores and the unweighted IWC total scores and no significant difference between the mean expert opinion total scores and the weighted IWC total score (Table 10).

Table 10. *p*-value results from the paired t-test comparing mean expert opinion scores with actual IWC scores for each subindex and the IWC total score.

Model	Probability
Unweighted	<0.001**
Weighted	0.093

** highly significant difference

Results from the simple linear regression model for the mean expert opinion scores and the weighted and unweighted IWC scores for each wetland showed that the best model fit and least bias was obtained with the weighted IWC data (i.e. the slope was closest to 1 for the weighted IWC data) (Table 11).

Table 11. Simple linear regression model coefficient and R^2 values for the mean expert opinion scores and the weighted and unweighted IWC total scores.

Model	Coefficient	R^2
Unweighted	1.179	0.97
Weighted	1.086	0.957

Results from the Wilcoxon matched pair test showed that the mean expert opinion scores differed significantly from the IWC physical form and hydrology scores and that there was no significant difference between wetland catchment, water properties, soils and biota (Table 12).

Table 12. p-value results from the Wilcoxon matched pair test comparing mean expert opinion scores with actual IWC scores for each subindex.

IWC subindex	Probability
Catchment	0.055
Physical form	<0.001**
Soils	0.131
Hydrology	<0.001**
Biota	0.184
Water properties	0.380

** highly significant difference

The difference observed in hydrology scores between the expert panel and IWC method could be due to two factors. Firstly, the IWC hydrology measure is relatively subjective and its scoring coarse. There are only a few score options possible: 0, 5 and 10, which resulted in many wetlands achieving the same hydrology score. Secondly, the panel were limited to site and air photos to estimate hydrology condition, which is likely to have led to a poor estimate of the condition of hydrology. Similarly the panel were limited to site and air photos to estimate physical form condition, which is likely to have led to a poor estimate of the physical form condition.

5.4 Objective 2: Testing the IWC in different hydrological phases

It was not possible to test this hypothesis because conditions were very dry throughout Victoria over the period of the testing and there was no wet or filling phase.

5.5 Objective 3: Testing the IWC at different wetland types

Hypothesis

The IWC measures condition consistently for wetlands across a number of wetland landscape component types.

Testing approach

The approach to testing this hypothesis consisted of three steps:

1. IWC assessment of 27 wetlands in the Wimmera region of Victoria.
2. Classification of wetlands using types defined by Corrick and Normal (1980) and Corrick (1982) and Department of Sustainability and Environment (2006).
3. Analysis of IWC total scores by wetland type and alignment with the condition gradient.

Results

Three wetland types defined by Department of Sustainability and Environment (2006) had adequate quantitative data for use as test wetlands in the Wimmera region. These were (1) wet flats and gilgai plain, (2) seasonal drainage lines and associated swamps and (3) lakes and swamps. Because the majority of the wetlands (80%) were classified as lakes and swamps, the hypothesis could not be adequately tested using this classification alone. Wetland types defined by Corrick and Norman (1980) and Corrick (1982) were therefore used to classify wetlands for testing purposes (Table 13).

Table 13. Victorian wetland classification (Corrick and Norman 1980, Corrick 1982). Only categories covering naturally occurring wetlands are shown.

Category	Depth (m)
Freshwater meadow These include shallow (up to 0.3 m) and temporary (less than four months duration) surface water, although soils are generally waterlogged throughout winter.	< 0.3
Shallow freshwater marsh Wetlands that are usually dry by mid-summer and fill again with the onset of winter rains. Soils are waterlogged throughout the year and surface water up to 0.5 m deep may be present for as long as eight months.	< 0.5
Deep freshwater marsh Wetlands that generally remain inundated to a depth of 1 – 2 m throughout the year.	< 2
Permanent open freshwater Wetlands that are usually more than 1 m deep. They can be natural or artificial. Wetlands are described to be permanent if they retain water for longer than 12 months, but they can have periods of drying.	<2 >2
Semi-permanent saline These wetlands may be inundated to a depth of 2 m for as long as eight months each year. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	< 2
Permanent saline These wetlands include coastal wetlands and part of intertidal zones. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	< 2 > 2

Approximately 30% per cent of the sites were classified as semi-permanent saline, 22% as permanent open freshwater, 15% as deep freshwater marsh, 15% as permanent saline, 11% as shallow freshwater marsh and 7% as freshwater meadow.

Weighted IWC total scores were plotted against mean expert opinion fuzzy scores and classified according to wetland type (Figure 15). All wetland types contribute to the wetland gradient, indicating that the IWC measured condition consistently across the condition gradient at all wetland types.

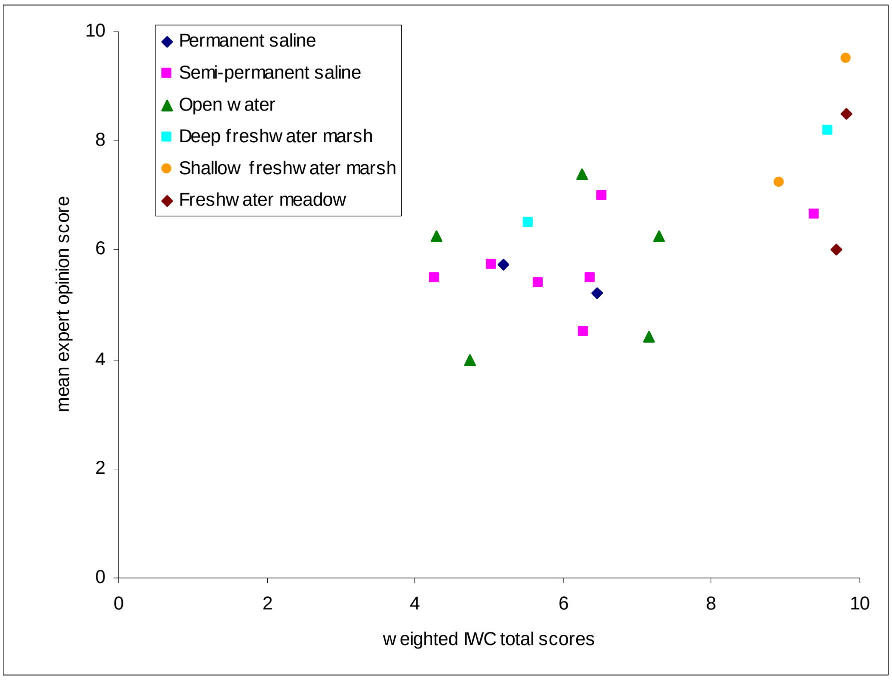

Figure 15. IWC total scores plotted against mean expert opinion scores with wetland types identified (see Table 4).

5.6 Objective 4: Testing IWC results between different users

Hypothesis

The IWC scores measured at a site are not statistically different between different assessors.

Testing approach

The approach to testing this hypothesis consisted of three steps:

1. IWC assessment of 27 wetlands in the Wimmera region of Victoria by two independent groups of assessors.
2. Comparison of IWC scores for each subindex and total IWC scores between the two groups using a non parametric paired test.
3. Comparison of each group with the expert opinion scores to determine which group best matches the expert opinion scores.

Results

Two groups of consultants assessed 27 wetlands (Figure 11 and Table 4) one month apart using the IWC method in the Wimmera region of Victoria. Both groups had the same level of general wetland ecology experience, however only one group had participated in the IWC training.

As the expert opinion and IWC total score data was normally distributed, a paired T-test was applied to test for significant differences between the IWC total scores from the two assessor groups and the mean expert opinion scores at the same wetlands. The IWC subindex scores were however not normally distributed and a paired non-parametric (Wilcoxon matched pair) test was performed on this data.

There were no significant differences in the subindex scores and total scores between the two assessor groups (Table 14). However more subindex scores were significantly different from the mean expert opinion scores in the second (untrained) assessor group, compared to the first (trained) assessor group. The difference between the weighted total score of the second assessor group and the mean expert opinion scores was also significantly different, whereas the difference between the weighted total scores of the first assessor group and the mean expert opinion scores were not (Table 14).

Table 14. *p*-value results from the Wilcoxon matched-pair test (subindices) and paired T-test (IWC total scores) comparing the two assessor groups to the mean expert opinion scores and the two assessor groups to each other.

IWC subindex	Group 1 and Expert opinion	Group 2 and Expert opinion	Group 1 vs Group 2
Wetland catchment	0.055	0.070	0.925
Physical form	<0.001**	<0.001**	0.180
Hydrology	<0.001**	<0.001**	0.317
Water Properties	0.380	0.936	0.705
Soil	0.131	0.02*	0.574
Biota	0.184	0.003**	0.055
IWC total score, unweighted	<0.001**	<0.001**	0.603
IWC total score, weighted	0.093	0.003**	0.102

* significant difference
** highly significant difference

Although the subindex and total weighted and unweighted scores of the two assessor groups were not significantly different, when each group was compared to the expert opinion scores, the untrained group exhibited a larger number of significant differences, including the total score. The training provided to the first assessor group (Section 2) may have resulted in the scores from this group more closely approximating those of the expert panel.

5.7 Testing summary

- The Landscape Disturbance Index (LDI) confirmed that a condition gradient existed across the 27 sites which were selected for the testing program. The LDI was tested against an expert opinion dataset and was found to be relatively robust in determining the condition gradient.
- The modeling, which was based on the expert opinion dataset, produced weights for the IWC subindices. The biota subindex weight was the largest, followed by water properties, hydrology, wetland catchment, soils and physical form component. The IWC calculation was modified according to the new weights.
- There was a significant difference between the mean expert opinion total scores and the unweighted IWC total score but not between the mean expert opinion total scores and the weighted IWC total score. There was a better simple linear regression model fit for weighted IWC scores and mean expert opinion scores than the unweighted IWC scores.
- Mean expert opinion scores differed significantly from the IWC physical form and hydrology scores but not the wetland catchment, water properties, soils and biota. This may be explained by the coarseness of the hydrology data and the lack of suitable hydrology and physical form data provided to the expert panel.

- It was not possible to test whether the IWC measured condition consistently between a drying and filling phase as conditions were very dry throughout Victoria over the period of the testing.
- The IWC did not appear to bias condition scores for any particular wetland type.
- The subindex and total weighted and unweighted scores of the two assessor groups were not significantly different to each other, however when the subindex and total scores of each group was compared to the expert opinion scores, the untrained group exhibited a larger number of significant differences.
- The training provided to the first assessor group may have resulted in the scores from this group more closely aligning with those of the expert opinion group.

6 Reporting IWC results

6.1 Calculating the total IWC score and assigning a wetland condition category

The IWC total score is calculated by multiplying each subindex score by its respective final weight (Table 9) and summing the scores. This is represented by the formula:

$$\mathrm{IWC}_{\mathrm{total}} = \sum_{si=1}^{6} (w\ si)$$

Where $\mathrm{IWC}_{\mathrm{total}}$ is the total IWC score, *si* is the subindex score and *w* is the final weight of the corresponding subindex (Table 9).

Each subindex has a maximum score of 20. After the weights are applied, the maximum possible total score is 38.4, which (for ease of reporting), has been scaled to 10 by dividing the total score by 38.4 and multiplying by 10. The score is rounded to the nearest whole number. Five new linguistic (wetland condition) categories have been assigned to the subindex scores (Table 15) and total IWC scores (Table 16) to be consistent with the number of categories used in other condition indices such as the Victorian Index of Stream Condition.

Table 15. Linguistic descriptors assigned to the IWC subindex scores with colour code used for reporting.

Subindex score range	Wetland condition category	Colour code
0–4	Very poor	Red
5–8	Poor	Orange
9–12	Moderate	Purple
13–16	Good	Light blue
16–20	Excellent	Dark blue
N/A	Insufficient data	Light grey

Table 16. Linguistic descriptors assigned to the IWC total scores with colour code used for reporting.

IWC total score range	Wetland condition category	Colour code
0–2	Very poor	Red
3–4	Poor	Orange
5–6	Moderate	Purple
7–8	Good	Light blue
9–10	Excellent	Dark blue
N/A	Insufficient data	Light grey

6.2 Reporting

To maximize the diagnostic capacity of the IWC, the results will be reported at the subindex level and total score. Both the actual score and a colour-coded condition category are presented for each wetland (Tables 15 and 16). For example, for a wetland with the following scores: Wetland catchment = 13, Physical form = 18, Hydrology = 10, Water properties = 5, Soil = 19, Biota = 14, Total score = 6 (using the model and weights outlined in Section 6.1), the scores will be reported as presented in the 'report card' table (Table 17).

Table 17. Example of a wetland condition report card.

Subindex / total	Score	Maximum possible score	Wetland condition category
Wetland catchment	13	20	Good
Physical form	18	20	Excellent
Hydrology	10	20	Moderate
Water properties	5	20	Poor
Soil	19	20	Excellent
Biota	14	20	Good
IWC total score	6	10	Moderate

7 Future development of the IWC

Continued development of the IWC method, information management and training program will ensure that the IWC provides the most practical and scientifically defensible means of assessing wetland condition in Victoria. Further development of some of the IWC measures are required to improve their ability to better discriminate their condition, especially for the water properties and hydrology measures. There is scope to incorporate the LDI, which was used to determine the condition gradient for testing purposes (Section 5), into the wetland catchment subindex as a substitute for the current land use measure. There is also scope to investigate the Catchment Framework Model developed by DSE to improve the catchment subindex.

Proposed enhancements to information management include the upgrade of the data management system to include the generation of detailed reports by project and activation of external user access. There will also be changes to the calculations of the IWC final score based on the outcomes of the testing program (Section 5). The use of electronic data capture for wetland assessments will be investigated.

Wetland vegetation mapping and wetland extent mapping protocols will be further developed and linked to national protocols where applicable. Corrections will be made to existing wetland extent spatial datasets and regional datasets will be collated and made publically available.

Wetland classification frameworks recently developed in other Australian states will be reviewed with the view of adopting similar approaches in Victoria. Such frameworks better depict wetland function. Conceptual models of wetland types will provide a means of developing reference conditions for measures in the water properties and hydrology subindices.

The applicability of the IWC in estuarine and coastal wetlands with a tidal influence will be assessed. This will necessitate the development of additional wetland EVC benchmarks.

A statewide wetland condition assessment program using the IWC has been proposed and is awaiting endorsement.

Appendix 1: Training program feedback form

Training Location (circle one group):

Glenelg-Hopkins/Corangamite/West Gippsland | Mallee/North Central | Goulburn Broken

1. At what level would you say that the information this course provides is pitched?

1	2	3	4	5
Too basic		just right		Too complex

____

____

For the following, please circle your answer from a score of 1 (not at all) to 5 (strong yes)

2. Do you think the PowerPoint presentation added value to the training course?

1	2	3	4	5
No				Yes

____

____

3. Do you think the length of the training was sufficient to cover all aspects of the IWC method adequately?

1	2	3	4	5
No				Yes

____

____

4. As a result of the course information, do you feel you can confidently identify wetland EVCs?

1	2	3	4	5
No				Yes

____

____

5. As a result of the course information, do you feel you can confidently assess the non-vegetation measures for the IWC?

1	2	3	4	5
No				Yes

____

6. **As a result of the course information, do you feel confident in using the IWC method?**

1	**2**	**3**	**4**	**5**
No				**Yes**

7. **Is there other information you would like presenters to get across to participants? please explain**

Thank you for completing this feedback form.
Please hand completed form to Shanaugh McKay at the end of Day 2 or post/fax to Shanaugh at:
Arthur Rylah Institute, PO Box 137, Heidelberg, 3084
Fax:(03)9450 8799

Appendix 2: Feedback from IWC assessors on the IWC method

Subindex or details	Issue	Action
Entire survey	Expertise of assessors and time to do assessments	Provide examples of time taken to do different types of wetlands in manual. The manual already states that assessors need at least Genus level plant identification skills.
Entire survey	Some large wetlands were assessed as separate sites and given separate IWC scores instead of an overall score.	Provide guidance in manual on assessing large wetlands that have separate management that need to be assessed as individual sites (for Biota). Include photos of examples of different management. Provide guidance on how to combine scores together for site. Manual already states that entire area is to be assessed.
Dry conditions	Concerns raised over assessment of sites that have been dry for extended periods of time.	Note added to manual about extreme dry conditions and when not to assess a wetland. A box has been added on the field sheet to record information on number of years a wetland has been dry.
Datum	Inconsistent use of datum.	Datum used is MGA for all site and photo information.
Mapped wetlands	Assessment of non mapped wetlands.	Provide guidance in manual that mapping of wetlands is required before undertaking an IWC assessment. Mapping to be completed by professional following guidelines. Wetland identifiers are to be assigned to the wetlands following DSE naming protocol (under review).
Photos	Photopoints are an optional activity in the IWC protocols. They should be mandatory and more detailed instructions should be given as to the photographic procedure to follow	Photos are compulsory and clear instructions are given in the revised manual and space provided on field sheet for recording three photopoints and extra photos of interest.
General information	Provide space for notes on observations on last page, suggest notes on significant flora and fauna, hydrology etc.	Space provided on the last page to record extra information about the wetland site not captured in the IWC assessment.
Buffer assessment	Add to the buffer definition for clarity.	Add note in manual about interpretation of revegetated areas as buffer if ecologically equivalent to natural buffer.
Land use	More information is required to determine land use in the catchment and the history of land use. Examples of road types for each land use intensity class is needed.	Roads/tracks has been added as examples of land use. Space provided on field sheet to record land use history. The land use theme has been added to the online IWC base map tool and a 250 m buffer boundary layer added.
Land use	Confusion as to the assessment of land use for a wetland when one boundary (or very close to boundary) of a wetland is a river.	Add to definition of assessment area that land use beyond the river/water body should be excluded.
Physical form	More guidance needed on mapping wetland boundary.	Directions to identify the wetland boundary now include suggestion to use air photos to assist in marking the wetland boundary if photos are available.
Hydrology	Hydrology assessment too simplistic.	A matrix table has been added to provide extra information if available on the seasonality, frequency and duration of the water regime and the severity of effect on water supply.
Nutrients	Concerns were raised over assessing the discharge of nutrient-rich water into the wetland when wetlands are dry.	A second step has been added for assessing direct discharge of nutrient-rich water to the wetland to determine if the discharge is occurring at that moment and if the wetland is dry what is the potential risk of it having an impact if the wetland was wet.

Subindex or details	Issue	Action
Salinity	Concerns were raised about the accuracy of the current method of assessing salinity risk.	The soil salinity layer has been added to the IWC base map tool for improved accuracy in matching secondary salinity risk areas with individual wetlands.
Soils	Further definition on soil pugging is needed and the soil disturbance measure is too simplistic for sites experiencing a range of severities in soil disturbance across the wetland.	The definition of pugging now includes pugging caused by feral animals. Photographic examples are provided in the manual. The process of determining the soil disturbance score for a wetland now includes an estimate of percentage of wetland soils affected by disturbance activities within each of the three soil disturbance severity classes. This replaces the collective score that was used previously.
Biota – landscape diagrams	The landscape diagrams are a bit simplistic.	Consultant is looking into the possibility of developing an EVC key similar to the Victorian Vegetation key developed for CMA use.
Biota	Confusion of lifeform grouping definition.	Highlight in manual that the lifeform grouping definition is different to the Habitat Hectares method and that lifeforms are assessed for size at maturity.
Biota	There is a large element of subjectivity in the allocation of individual EVCs.	Highlight importance (during training) of going through the method of selecting an EVC with the manual – add note to field sheet. Similar EVCs will give similar EVC scores.
EVC selection	Method for assessing EVCs on heavily cleared/grazed land need to be clarified.	EVC 999 (indeterminate) has been added to the benchmarks and manual with directions on when to use this EVC and to still assess using the same process.
EVC selection	There is some degree of uncertainty with EVC selection due to the widespread invasion of terrestrial plants and displacement of wetland species due to prolonged drought conditions.	The manual highlights when biota should not be assessed and that all other measures for the remaining 5 sub-indices should be recorded.
EVC selection	Clarification needed on the use of EVC aggregates.	Add note to use aggregate if unable to identify a component.
Biota	There is no analysis of faunal or habitat indicators in the IWC.	Reasons for not including these are given in the manual. The addition of the flora and fauna layer to the DSE base map tool and space to record observations will provide this extra information.
Biota	When entering the IWC assessments onto the IWC database there is some confusion when scores have not been circled on the field sheet as there are cases where scores appear twice in the weeds and vegetation structure/health matrix or multiple EVC assessments are entered on the one sheet.	A note has been added to the field sheet that the score needs to be circled. The IWC manual already states that each EVC assessment should be entered on a separate vegetation assessment sheet.
EVC	Confusion as to assessment/scoring of EVC 990 (Unvegetated).	Clarify in manual and training that EVC 990 – Unvegetated defaults to full score.
EVC	Confusion over inclusion of additional 'high threat' weeds in assessment of percentage cover.	Include in definition of high threat weeds – the ability to displace native vegetation. Highlight that high threat weeds added by assessor are included in % cover assessment.
Field sheet curation	Some field sheets received were photocopies and difficult to read.	Inform consultants that original hardcopies are required.
Scoring & weightings	Concerns over the equal weightings of the sub-indices and the scoring bands for the Hydrology and Water Properties subindex. The scoring system seems to rank wetlands in better condition than would appear to be the case from field inspections and prior experience with wetlands across the State.	Testing of the IWC has helped inform subindex weightings. Further R & D is needed to help inform the Hydrology and Water Properties subindex measures and scoring. Changes have been made to the linguistic categories and scoring bands for the subindex and overall wetland scores to align with the Index of Stream Condition (ISC).

Appendix 3: Example of a completed scoring sheet used to independently determine wetland condition using expert interpretation of comprehensive datasets

Overall Score / Subindex	Score [1-10, 10 is best condition]	Scoring rationale and weighting [including assumptions]	Confidence [1-5: 5 is most confident]	Confidence rationale	Tools / Datasets used [mark cell with an 'x']	
Overall score	4	Poor catchment except for that in immediate area which doesn't look that good. Apparent water quality problems	3	Lack expertise in water quality data. Don't know reference for this.	Wetland table	x
					Landuse map	x
					Base map	x
					Air photo	x
					Site photo(s)	x
					Geomorphology/soils	
					Electrical conductivity	x
					pH	x
					Nutrients	x
					Turbidity	x
					Cations	
					Wetland plants	x
					Birds	
					Frogs	
					Diatoms	
					Macroinvertebrates	
					Zooplankton	
					Rotifers	
Wetland catchment [condition of surface water catchment]	4	Assume primarily ground water fed wetland. Immediate surface water catchment in conservation reserve but buffer doesn't look continuous and is very narrow in places. Wider surface water catchment cropped/grazed and cleared. Turbidity high – indicates possible inflow of sediments from surface water catchment.	4	No incoming streams evident. Consistent evidence from ground photos, air photo, base map, land use map. But don't know about groundwater water source		
					Landuse map	x
					Base map	x
					Air photo	x
					Site photo(s)	
					Geomorphology/soils	
					Electrical conductivity	
					pH	
					Nutrients	
					Turbidity	x
					Cations	
					Wetland plants	
					Birds	
					Frogs	
					Diatoms	
					Macroinvertebrates	
					Zooplankton	
					Rotifers	

<table>
<tr><th>Overall Score / Subindex</th><th>Score [1-10, 10 is best condition]</th><th>Scoring rationale and weighting [including assumptions]</th><th>Confidence [1-5: 5 is most confident]</th><th>Confidence rationale</th><th colspan="2">Tools / Datasets used [mark cell with an 'x']</th></tr>
<tr><td rowspan="18">Physical form [physical modification to wetland]</td><td rowspan="18">9</td><td rowspan="18">Original area intact. Only modification to form is presence of a couple of fencelines that go in a short way.</td><td rowspan="18">4</td><td rowspan="18"></td><td>Wetland table</td><td>x</td></tr>
<tr><td>Landuse map</td><td></td></tr>
<tr><td>Base map</td><td>x</td></tr>
<tr><td>Air photo</td><td>x</td></tr>
<tr><td>Site photo(s)</td><td>x</td></tr>
<tr><td>Geomorphology/soils</td><td></td></tr>
<tr><td>Electrical conductivity</td><td></td></tr>
<tr><td>pH</td><td></td></tr>
<tr><td>Nutrients</td><td></td></tr>
<tr><td>Turbidity</td><td></td></tr>
<tr><td>Cations</td><td></td></tr>
<tr><td>Wetland plants</td><td></td></tr>
<tr><td>Birds</td><td></td></tr>
<tr><td>Frogs</td><td></td></tr>
<tr><td>Diatoms</td><td></td></tr>
<tr><td>Macroinvertebrates</td><td></td></tr>
<tr><td>Zooplankton</td><td></td></tr>
<tr><td>Rotifers</td><td></td></tr>
<tr><td rowspan="18">Soil [soil disturbance, soil condition]</td><td rowspan="18">9</td><td rowspan="18">Ground photos show no evidence of stock access or other soil disturbance except maybe a bit around fencelines in wetland. Wetland seems to be fenced. Hypersaline wetland – no reason for stock to enter.</td><td rowspan="18">4</td><td rowspan="18">Ground photos show no soil disturbance.</td><td>Wetland table</td><td>x</td></tr>
<tr><td>Landuse map</td><td></td></tr>
<tr><td>Base map</td><td></td></tr>
<tr><td>Air photo</td><td>x</td></tr>
<tr><td>Site photo(s)</td><td>x</td></tr>
<tr><td>Geomorphology/soils</td><td></td></tr>
<tr><td>Electrical conductivity</td><td></td></tr>
<tr><td>pH</td><td></td></tr>
<tr><td>Nutrients</td><td></td></tr>
<tr><td>Turbidity</td><td></td></tr>
<tr><td>Cations</td><td></td></tr>
<tr><td>Wetland plants</td><td></td></tr>
<tr><td>Birds</td><td></td></tr>
<tr><td>Frogs</td><td></td></tr>
<tr><td>Diatoms</td><td></td></tr>
<tr><td>Macroinvertebrates</td><td></td></tr>
<tr><td>Zooplankton</td><td></td></tr>
<tr><td>Rotifers</td><td></td></tr>
</table>

Overall Score / Subindex	**Score [1-10, 10 is best condition]**	**Scoring rationale and weighting [including assumptions]**	**Confidence [1-5: 5 is most confident]**	**Confidence rationale**	**Tools / Datasets used [mark cell with an 'x']**	
Hydrology [modification to natural hydrology]	6	State of surface water catchment indicates disturbance to surface water flows and possible changes to groundwater table	2	Hard to be certain about hydrological changes – making assumptions		
					Landuse map	x
					Base map	x
					Air photo	x
					Site photo(s)	x
					Geomorphology/soils	
					Electrical conductivity	
					pH	
					Nutrients	
					Turbidity	
					Cations	
					Wetland plants	
					Birds	
					Frogs	
					Diatoms	
					Macroinvertebrates	
					Zooplankton	
					Rotifers	
Biota [all biota]	5	Wouldn't expect much diversity in hypersaline wetland	1	Very little data to go on. No reference data. Lack of expertise	Wetland table	x
					Landuse map	
					Base map	
					Air photo	
					Site photo(s)	
					Geomorphology/soils	
					Electrical conductivity	
					pH	
					Nutrients	
					Turbidity	
					Cations	
					Wetland plants	x
					Birds	
					Frogs	
					Diatoms	
					Macroinvertebrates	x
					Zooplankton	
					Rotifers	

<table>
<tr><th>Overall Score / Subindex</th><th>Score [1-10, 10 is best condition]</th><th>Scoring rationale and weighting [including assumptions]</th><th>Confidence [1-5: 5 is most confident]</th><th>Confidence rationale</th><th colspan="2">Tools / Datasets used [mark cell with an ‘x’]</th></tr>
<tr><td rowspan="17">Water properties [water quality]</td><td rowspan="17">2</td><td rowspan="17">High turbidity, High N and P. Salinity high but expect that in hypersaline wetland. Would expect hypersaline wetland to be clear.</td><td rowspan="17">2</td><td rowspan="17">No reference data. Lack of expertise</td><td>Wetland table</td><td>x</td></tr>
<tr><td>Landuse map</td><td></td></tr>
<tr><td>Base map</td><td></td></tr>
<tr><td>Air photo</td><td></td></tr>
<tr><td>Site photo(s)</td><td></td></tr>
<tr><td>Hydrogeomorhology</td><td></td></tr>
<tr><td>Electrical conductivity</td><td></td></tr>
<tr><td>pH</td><td>x</td></tr>
<tr><td>Nutrients</td><td>x</td></tr>
<tr><td>Turbidity</td><td>x</td></tr>
<tr><td>Cations</td><td></td></tr>
<tr><td>Wetland plants</td><td></td></tr>
<tr><td>Frogs</td><td></td></tr>
<tr><td>Diatoms</td><td></td></tr>
<tr><td>Macroinvertebrates</td><td></td></tr>
<tr><td>Zooplankton</td><td></td></tr>
<tr><td>Rotifers</td><td></td></tr>
</table>

Appendix 4: Literature review – testing rapid assessment methods

1 Introduction

Various rapid assessment methods have been developed for assessing the condition of wetlands and other natural assets. Some of these methods are reviewed in Department of Sustainability and Environment (2007).

Little effort has been devoted to evaluating rapid assessment methods (Spencer et al. 1998). The spatial variability in wetland ecosystems, the paucity of information on the natural temporal variance for wetland components and the scarcity of unimpacted reference sites all contribute to concerns about whether rapid assessment methods can provide scientifically valid measures of wetland condition (Spencer et al. 1998). In order for rapid assessment methods to be adopted by management agencies and community groups, consistency in application, interpretation, and repeatability needs to be demonstrated (Healey unpublished).

The review aimed to highlight ways of testing and calibrating methods that may be useful for testing and validating the IWC. Some of the wetland assessment methods discussed in this review are explained in more detail in Department of Sustainability and Environment (2007).

2 Testing approaches of rapid assessment methods for aquatic ecosystems

This review incorporates information on a number of different approaches to testing wetland, riverine and terrestrial based assessment methods. These assessment methods are predominantly from North America as the majority of literature was from this region with some information on methods used in Australia (Table A1).

A number of natural resource assessment methods discuss in a general sense the need to test the method, however, there is limited agreement as to what constitutes a suitable testing approach or set of methods. A number of Australian methods have not undergone testing, including Habitat Hectares (Parkes et al. 2003) and the Wetland Care Australia Wetland Assessment Technique (Cassie Burns, WetlandCare Australia, pers. comm.).

The Index of Stream Condition underwent a pilot study trial to refine the measurement procedures and ensure the results were 'reasonable' or more closely satisfied the objectives of the project team (Ladson et al. 1999). An additional pilot study of the ISC will soon be undertaken to relate field measurements to lidar imagery. A sentinel site program with approximately 140 sites across Victoria will investigate the consistency in measurements taken to test for inter-operator variability. This program will run for a total of five years. As all ISC field data is collected in autumn, there is no need to assess consistency of the method between seasons. (P. Wilson, Department of Sustainability and Environment, pers. comm.).

We have reviewed ten Australian and North American natural resource assessment methods (Table A1) in more detail and examined their testing design and methodological features for similarities/consistencies, differences, successes and failures. The review is structured around the following themes:

- validation using existing data;
- establishing an *a priori* condition gradient using direct measures of wetland components;
- establishing an *a priori* condition gradient using remote-sensed data and human disturbance measures;
- determining relationships between the rapid assessment method and direct measures of wetland components;
- determining relationships between two different wetland condition assessment methods;
- accounting for seasonal and inter-annual variability;

- ensuring the method is applied consistently by different assessors and that assessors have different skill bases;
- analysing data; and
- calibrating: refining index scoring and weighting.

Table A1. Summary of some selected natural resource assessment techniques that have undergone testing in Australia and the United States of America.

Key agency/key researcher	Project	Method of testing	Comments
Australia Spencer et al. (1998)	Rapid appraisal wetland condition index for the Murray-Darling Basin	Tested against independent monitoring data collected over 18 months for 30 wetlands in the Ovens and Murray River floodplains.	- ten of the 30 wetlands were ranked from best to worst condition based on independent water quality, vegetation and zooplankton data - tested for the influence of the season on index values - tested for the influence of wetland assessor on index values - the rapid index scores were positively correlated with rankings of condition based on independent monitoring data
Australia Healey (unpublished)	Testing Spencer et al. (1988) method on coastal floodplain wetlands of Northern NSW	Tested for inter-observer and inter-seasonal differences in index scores	- 12 wetlands sampled in each of three locations in Northern NSW by pairs of wetland assessors and independently to assess inter-observer differences - wetland assessors asked to score the same wetlands in summer and winter to examine inter-seasonal differences in wetland condition - t-tests performed on data and mean subindex scores plotted for summer and winter - median subindex scores and total index scores obtained during initial training were plotted and showed no variability between training participants and trainer
Australia Australian Water Resources (unpublished)	National Framework for the Assessment of River and Wetland Health (FARWH)	Tested the Index of Stream Condition (ISC) and the Conservation of Freshwater Ecosystem Values (CFEV) program against another set of indices with similar components	- three catchments in Victoria and Tasmania tested - subindex scores compared as well as overall index score - strong relationship for overall index score (FARWH Vs ISC) (increased due to use of same or similar data for biota and hydrology)
Australia Jansen et al. (2005)	Rapid Appraisal of Riparian Condition (RARC)	RARC index scores tested against more detailed measures for riparian zones	- RARC index tested in Murrumbidgee and Gippsland regions - positive correlation between litter decomposition rates in the soil and the COVER subindex in Summer and Autumn - highly significant relationship between bird communities and all sub-indices and the total RARC score - recent extension to riparian zone sin semi-arid regions of South Australia
United States Sutula et al. (2006)	CRAM (California Rapid Assessment Method).	Tested against existing data	- proposed to test CRAM against three independent data sets (i.e. bird and macroinvertebrate diversity, landscape indices) to test for signal:noise ratio issues, range of results, responsiveness, and redundancy of measures. No results as yet. - a Landscape Development Intensity Index is under development to measure overall wetland condition to compare against the CRAM scores

Table A1. (continued)

Key agency / key researcher	Project	Method of testing	Comments
United States Brooks et al. (2005)	A stream-wetland-riparian (SWR) Index for assessing condition of aquatic ecosystems in small watersheds along the Atlantic slope of the Eastern U.S.	Used existing biological, physical and water chemistry data sources to test correlations	- the datasets differed in their criteria for site selection (random vs. targeted), sampling season, sample methods. Sample processing and data analysis (i.e. the types of measures and multi-measure indices computed) - made series of comparisons using non-parametric correlation analysis - the SWR index and associated Landscape Indices were shown to correlate highly with biological indicators of stream condition
United States Mack (2000)	Ohio Rapid Assessment Method (ORAM) for wetlands	The ORAM index was tested against the Vegetation Indices of Biotic Integrity (VIBIs)	- ORAM tested against VIBI, developed for emergent, forested, and scrub-shrub wetland vegetation classes in the USA - VIBI scores were compared to ORAM scores showing a strong linear trend
United States Miller et al. (2006)	A plant-based index of biological integrity (IBI) for headwater wetlands in central Pennsylvania	Tested method against existing data	- data from 47 sites collected for a wetland monitoring project were used to test for correlations with the index - sites were divided into three disturbance categories (high, moderate, and low) based on existing data on ecological condition associated with forest cover. - the measures and IBI scores for both data sets were significantly correlated with disturbance
United States Reiss (2006)	Florida Wetland Condition Index (FWCI) for depressional forested wetlands	Tested correlations between an independent index and existing data	- an independent measure of the human disturbance gradient, the Landscape Development Intensity (LDI) index was initially developed for selection of measures for inclusion into the FWCI based on strength of correlation with LDI - significant correlations were found among the FWCI, the six measures, and LDI with measured chemical and physical water and soil variables - tested correlations between the state wide and regional scoring approaches
United States Lopez and Fennessy (2002)	Testing the floristic quality assessment index as an indicator of wetland condition. (FQAI)	Method tested for correlation with plant biomass production and water/soil chemistry	- tested the effectiveness of the plant community-based tool at 20 wetlands - prior to calculating the floristic index each site was assigned a disturbance rank using a three-tiered ranking system - the disturbance rank was plotted against the floristic value (FQAI value). Data points show that the index and the disturbance rank are negatively correlated

3 Validation using existing data

Existing data plays a significant role in the testing of rapid assessment methods and data can be used to:

- develop an independently assessed and empirical (as opposed to mere expert judgment) condition gradient, so that sites can be selected across the gradient for testing (e.g., Ogden unpublished, Spencer et al. 1998),
- develop a surrogate index, such as a landscape disturbance index, to establish an inferred condition gradient or to compare against the method (e.g., Mack 2000, Reiss 2006); and
- to establish relationships between the rapid method and the existing data (e.g., Jansen and Healey 2003, Lopez and Fennessy 2002).

There are some complicating issues when using existing datasets. There may be a temporal difference between when data were collected and when the index was calibrated and difficulty locating datasets collected using standardised methods at sites representing the disturbance gradient (Sutula et al. 2006). The temporal effect might be a simple issue of the existing data having been collected years before and conditions having since changed, or the existing data having been collected at a different season or when the wetland was in a different hydrological state. Recently collected data for use in testing is most desirable but may be too expensive to obtain (Sutula et al. 2006). Existing data are often used to establish a condition gradient against which the index can be tested and to determine relationships between the index and the more detailed data.

The rationale for testing any wetland condition method is to determine whether the measures, subindex and overall index scores are good predictors of wetland condition, as measured against the results of more intensive (e.g. quantitative) and independent measures of wetland condition (Sutula et al. 2006). In using more intensive datasets questions are raised as to how to interpret the data and how intensive the data are.

3.1 Establishing a condition gradient with comprehensive data

The purpose of a condition gradient is to ensure that the assessment method is tested on natural assets (e.g. streams and wetlands) with a known range of condition. Such gradients can be developed using comprehensive biological, physical or chemical datasets as used by Spencer et al. (1998) and Sutula et al. (2006).

Spencer et al. (1988) developed and tested a rapid appraisal wetland condition index in the Murray-Darling Basin. They stated that the major issue with rapid-appraisal indices based on indicators is how well the method reflected differences relative to 'natural' habitats and conclusions based on long-term, highly structured monitoring data. Spencer et al. (1998) tested the agreement of their index with independent monitoring data collected over an 18 month study of the effects of farming and river regulation on the ecology of over 30 wetlands in the Ovens and Murray River floodplains (Ogden unpublished). Ten of the 30 wetlands studied were ranked by Ogden from best to worst condition based on water quality (total phosphorus, total nitrogen and turbidity), vegetation and zooplankton data. These sites were revisited once over a three-day period and assessed using the wetland condition index and compared to Ogden ranking. There was a relatively strong positive relationship between the overall index score and the Ogden rank. Each subindex was also compared to the overall score, with soils and fringing vegetation sub-indices showing relatively strong correlations with the Ogden rank.

Sutula et al. (2006) developed a wetland rapid assessment method called the California Rapid Assessment Method (CRAM). To verify CRAM, 118 wetlands representing high quality and low quality conditions for each of the wetland classes (wetland types used in California) were selected. The *a priori* classification of condition for the wetlands was based on consensus of expert opinion after reviewing available data and field visits. Assessment at these 118 wetlands provided preliminary assurances that the draft measures were able to distinguish between wetlands of different) condition (Sutula et al. 2006).

The CRAM was calibrated using existing data that were considered to represent a disturbance gradient. Data were collected within one to three years of calibrating the CRAM. Conceptual models developed during the early stages of CRAM development were used to identify the kinds of data that would be most appropriate for calibration purposes (Sutula et al. 2006). Because of the temporal offset, a decision was made to eliminate from the calibration dataset those sites which had undergone a substantial natural disturbance or recovery from stressors (e.g. flood, fire, or land use change), since the intensive data would likely no longer reflect current site conditions (Sutula et al. 2006). CRAM was tested against three independent data sets to test for signal to noise ratio issues, range of results, responsiveness, and redundancy of measures (E. Stein, Southern California Coastal Water Research Project, pers. Comm..). The three measures used were: riparian, bird and macroinvertebrate diversity and abundance; an associated index of biotic integrity; and indices of landscape context including the Landscape Development Intensity Index developed for California. The calibration process explored correlations between the calibration data and overall CRAM scores, components and measures (Sutula et al. 2006).

3.2 Establishing a condition gradient using remote-sensed data and human disturbance measures

It has been suggested that landscape condition or ecosystem health is strongly related to the surrounding intensity of human activity, and that ecological communities are affected by the direct, secondary, and cumulative impacts of activities in the surrounding landscape (Brown and Ulgiati 2005). Numerous methods of quantifying a human disturbance gradient have been used in parallel with biotic indices as corroborative confirmation of measured biological integrity or to test the precision (consistency and bias) of the assessment method (Mack et al. 2000, Reiss 2006, Mack 2007). There are limitations with using one indirect assessment procedure (i.e. a landscape disturbance index) to validate a rapid in-situ assessment method as a lot of assumptions are made as to the likely impact and mechanisms by which wetlands are affected by processes occurring in their surrounding catchment. The use of remote sensed data to infer wetland condition is a non empirical approach which identifies threatening factors and the likely wetland condition from exposure of the wetland to these threats.

Reiss (2006) used an independent human disturbance gradient, the Landscape Development Intensity Index (LDII) developed by Brown and Vivas (2005). The LDII is based on the amount of non-renewable energy used within a 100 m buffer around a wetland. The LDII was initially used to determine measures for inclusion into the Florida Wetland Condition Index (FWCI) based on the strength of correlation of the measures with the LDII. The strong correlation between the landscape scale human disturbance gradient (LDII) and the local wetland scale index of biological integrity (FWCI) demonstrated the potential value of using the LDII as an initial indication of biological integrity (Reiss 2006).

Lane and Brown (2007) also used the LDII for development of an Index of Biological Integrity (IBI) for diatoms through correlation of the metrics against the human disturbance gradient. The LDII was also used for selecting sites across a gradient of human disturbance.

The Australian National Framework for the Assessment of River and Wetland Health (FARWH) index (National Water Commission 2007) uses a Catchment Disturbance Index (CDI) to provide a measure of human-induced changes to river and wetland systems. The data has been sourced from a national dataset on land use change and also remote-sensed spatial data. The CDI is one component of the assessment and uses three sub-indices that characterise changes in land use including: infrastructure, land use and land cover change. The CDI classifies land use and then applies a weighting depending on the known impact of a particular land use on water quality run-off to rivers and wetlands (Australian Water Resources unpublished). Care should be taken when selecting the index categories to avoid issues of autocorrelation caused by the position of sites in the catchment (R. Norris, University of Canberra pers. comm.).

The United States Environmental Protection Agency (USEPA) Index of Biotic Integrity (IBI) evaluates wetland condition in response to human disturbance (United States Environmental Protection Agency 2002a). They have tested IBIs on multiple human disturbance gradients.

Miller et al. (2006) assessed the ability of the plant based IBI to distinguish between categories of condition that could be used in a regulatory framework. Sites were divided into three disturbance categories (high, moderate, and low) based on information on surrounding land use, buffer characteristics, and an assessment of potential site stressors. The IBI clearly distinguished three categories of condition that corresponded with the disturbance categories (Miller et al. 2006).

In order to test a plant community based wetland assessment tool (floristic index) on 20 depressional wetlands in Ohio, Unites States of America (Lopez and Fennessy 2002), a disturbance rank was applied to the test wetlands using a three-tiered ranking system. The 20 wetlands were classified by type and ranked to form a disturbance gradient based on surrounding land cover characteristics, vegetated buffer characteristics, and the extent of human-induced hydrologic alteration (Lopez and Fennessy 2002). The disturbance rank was plotted against the floristic value (FQAI value) and shown to be strongly negatively correlated (Lopez and Fennessy 2002). The strong relationship between the index and disturbance rank was found, which suggested the index was responsive to a combination of disturbance factors including dominant adjacent land cover, vegetation buffer characteristics, and hydrologic alterations (Lopez and Fennessy 2002).

The Gippsland Lakes Index of Wetland Condition project employed a process to select sites for assessing condition across a disturbance gradient (relatively undisturbed to severely damaged) (Department of Sustainability and Environment unpublished b). The initial sites were selected with the use of a Landscape Subindex (LSI). The LSI was developed with the collation of historical information from baseline survey data and reports, to personal communications. The LSI scores allowed the initial selection of monitoring sites across a condition gradient (Department of Sustainability and Environment unpublished b).

A feature of many human disturbance ranking systems or indices is that they rely heavily on remote-sensed and/or spatial data. Such measures include: percentage of catchment in different land use categories (Reiss 2006, Sutula et al. 2006, Lopez and Fennessy 2002, Department of Sustainability and Environment unpublished b), land cover characteristics (Lopez and Fennessy 2002), percent of a watershed that is logged, percent of watershed with impervious surfaces and distance of wetlands to nearest road or farm (United States Environmental Protection Agency 2002b).

A rapid method for broad-scale mapping and prioritising palustrine and estuarine wetlands for conservation in New Zealand has been developed with the use of landscape indicators for pressure measures on New Zealand wetlands (Ausseil et al. 2007). A range of GIS indicators are used to account for anthropogenic pressure on wetlands which will be used to rank wetlands into priority order (A-G. Ausseil, Landcare Research, New Zealand, pers comm.). The rapid methodology means that consistent wetland rankings can be produced efficiently without having to wait until the collection of detailed biologic information and conservation resources are better targeted (Ausseil et al. 2007).

Brazner et al. (2007) used a Human Disturbance Index (HDI) for the evaluation of human influences on wetland indicators for the Great Lakes, USA. Sites were selected across a human disturbance gradient based on an integrated measure of anthropogenic stress to characterise human disturbance. A total of 149 disturbance related variables (i.e. agriculture, atmospheric deposition, land cover, human population and point source pollution) were quantified with ArcGIS and ArcView software and analysed in a principal components analysis to quantify the generalised human disturbance index (HDI).

The indirect method of establishing a condition gradient using human disturbance measures is a threat-based approach that does not seek to identify wetland condition empirically but is a standard desktop method of categorising wetland sites into condition classes. The human disturbance measures and various indices described (e.g. catchment disturbance index) have various applications in the development and validation of rapid assessment methods, such as: to determine metrics for inclusion into the method; to distinguish condition and then select sites across a condition gradient and to validate the rapid method. It is important to emphasise that many assumptions are made as to the relationship of wetland condition and the 'health' of the surrounding catchment, most of which are probably untested in the Australian environment.

3.3 Determining relationships between the rapid assessment method and existing intensive data

Fennessy et al. (2004) acknowledge the importance of establishing the relationship between the rapid assessment method and comprehensive data. Once the relationship is established, the rapid assessment method can then be used to extrapolate the more detailed ecological results. Confidence limits on the rapid assessment method can then be determined, therefore increasing the reliability and defensibility of the method.

Miller et al. (2006) tested a plant-based Index of Biological Integrity (IBI) against data collected as part of a wetland monitoring project in the USA and found the measures and IBI scores for both data sets were significantly correlated, and all *r* values were significant.

Jansen and Healey (2003) tested the agreement of detailed frog survey data against wetland condition assessed using the index developed by Spencer et al. (1998). Most individual taxa showed significant relationships with one or more components of wetland condition.

Lopez and Fennessy (2002) tested the ability of the Floristic Quality Assessment Index (FQAI) developed in the USA to characterise wetland site disturbance and isolation, focusing on plant biomass production, water chemistry, and soil chemistry. There was no correlation between the index and differences in wetland surface water chemistry. The index was positively correlated with soil organic carbon, phosphorus and calcium.

Sutula et al. (2006) discuss calibration of their method that will compare existing data to overall CRAM scores, sub-indices and measures. Intensive measures of bird and benthic macroinvertebrate community composition, considered robust indices of community structure and high order functioning of the ecosystem, will be used to evaluate CRAM performance at the attribute (subindex) level. It is important to consider the assessment endpoint, level of confidence in the quality of the intensive datasets, and factors such as temporal offsets between the datasets when choosing existing data to make comparisons (Sutula et al. 2006).

4 Relationships between two different field based rapid assessment methods

Miller et al. (2006) compared their plant-based Index of Biological Integrity (IBI) to other IBIs utilising other taxa (i.e. amphibians and macroinvertebrates) with correlating types of measures (i.e. species richness, composition, tolerance and habitat measures). They found that the use of other indices provided a more comprehensive site assessment but also served as an additional validation of the plant based IBI.

The Ohio Rapid Assessment Method (ORAM) for wetlands developed by Mack (2000) was tested against the Vegetation Indices of Biotic Integrity (VIBIs), developed for emergent, forested, and scrub-shrub wetland vegetation classes in the USA. The VIBI scores were compared to ORAM scores showing a strong linear trend.

The National Framework for the Assessment of River and Wetland Health (FARWH) index has undergone testing in Victoria and Tasmania (National Water Commission 2007). The Index of Stream Condition (ISC) and the Conservation of Freshwater Ecosystem Values (CFEV) were compared against the FARWH index. Sub-indices that had similar measures at a similar spatial scale were compared to the aquatic biota, fringing vegetation, physical form, hydrology and water quality subindices for the ISC and FARWH. There was high agreement for the aquatic biota indices due to the use of the same measures. The relationship between the remote-sensed data with the ISC measured data for fringing vegetation was fairly strong. The relationship of the two physical form indices was shown to be poor and indicated that different things are being assessed by the two methods. The same data are used for the hydrology index and therefore the relationship is very strong although strongly skewed (National Water Commission 2007).

The overall ISC and FARWH index were strongly correlated, which was helped by the use of the same or similar data for the biota and hydrology subindices (Australian Water Resources unpublished). The decision to test the total index score or the subindex score will depend on the comparability and reliability of other condition indices, sub-indices and data. The precision of the rapid assessment method can be tested by comparing its outputs with those from another like rapid assessment method (Sutula et al. 2006).

It is important to note that the value of comparing the method to an untested rapid assessment method is questionable.

5 Accounting for seasonal and inter-annual variability

Temporal variation in the hydrological cycle is characteristic of all wetlands. The Victorian Index of Wetland Condition (IWC) was designed to assess wetlands at any time of the year and should therefore be tested for consistency between seasons/hydrological phases. Four wetland phases have been recognised in the IWC assessment: filling, full, drying and dry. It is recognised that all four wetland phases should be included in testing purposes but may not be possible within the scope of testing during periods of extended drought.

Lopez and Fennessy (2002) assessed seasonal variability of the Floristic Quality Assessment Index (FQAI) in 20 depressional wetlands in central Ohio, USA. They sampled three vegetation types (emergent, scrub-shrub, and forested wetlands) during summer and autumn at nine sites and also year to year for six of these sites (1996 and 1997). Eleven additional sites were sampled for vegetation in 1996 and 1997 (Lopez and Fennessy 2002). A potential disadvantage of using plant based indices to assess the effects of landscape stressors is that they may be so temporally variable as to be unreliable, from year to year or from season to season (Lopez and Fennessy 2002). The index values were reported for summer and the combined summer-autumn values. The total number of plant species recorded at each site increased in autumn compared to summer but the summer-only and the combined summer-autumn index values were strongly positively correlated. Although index values increased by a mean value of three points, between the two seasons there was little change in the relative ranking of the sites (Lopez and Fennessy 2002).

Spencer et al. (1998) tested their rapid appraisal wetland condition index for 10 wetlands on the floodplain of the Kiewa Valley (North East Victoria) in autumn and winter. There was little agreement between scores for the aquatic vegetation subindex and water quality subindex scores obtained from wetlands in the two seasons. Local rainfall and winter flood increased water levels in the wetlands, removing floating vegetation resulting in lower scores for vegetation cover. The water quality subindex scores all fell within a very narrow range and were mostly high but no correlation between season was evident. The fringing vegetation subindex, soil subindex and total index scores were very similar between seasons (Spencer et al. 1998). This method however, overestimated the condition of wetlands used for permanent water storage and underestimated the condition of ephemeral wetlands when they were dry.

Healey (unpublished) tested the method developed by Spencer et al. (1998) (for permanent floodplain wetlands) on similar coastal floodplain wetlands in northern New South Wales. Scores from assessments in summer and winter were compared to examine if the index revealed inter-seasonal differences in wetland condition. There were minor differences in subindex scores between seasons at some locations (Healey unpublished). Jansen et al. (2005) tested the Rapid Appraisal of Riparian Condition (RARC) index against more detailed measures of the biodiversity and functioning of riparian zones in the Murrumbidgee and Gippsland regions. Positive correlations were found between litter decomposition rates in the soil and the COVER subindex in both summer and autumn.

6 Testing the consistent application of the method by different assessors

To ensure that the IWC measures condition consistently, it is critical that there is minimal variation in the results between different assessors. During the testing process of CRAM, Sutula et al. (2006) found areas where the assessment method required refinement because of inconsistencies among wetland assessors. Some measures did not perform as well as required because the narrative statements were unclear to some wetland assessors, producing too much variability in their interpretation (Sutula et al. 2006). CRAM has undergone preliminary tests of user consistency to see if different teams were able to independently produce the same results for a given site (E. Stein, Southern California Coastal Water Research Project, pers. Comm..).

Spencer et al. (1998) examined the effect of different wetland assessors using their method. To do this a set of 11 wetlands on the Murrumbidgee River near Wagga Wagga, NSW were surveyed by two independent groups (three weeks apart) without knowledge of the ranking obtained by each other. The two independent teams that tested the index on 11 floodplain wetlands produced consistent scores. Healey (unpublished) examined the robustness of the index developed by Spencer et al. (1998) when used by different investigators at northern New South Wales coastal floodplain wetlands, as a measure of consistency in application. Healey (unpublished) found that the rapid assessment index appears relative robust when used by different investigators.

The subjective nature of the categories used in many indexes allow for inconsistencies to arise between wetland assessors. A theory known as 'fuzzy set theory' is a procedure that accounts for uncertainty in data obtained where numerous categories exist (Regan and Colyvan 2000; Akcakaya et al. 2000).

7 Refining index scoring and weighting

The concept of calibration is to determine whether the index scores are good predictors of wetland condition, as measured against the results of more intensive data collected for a range of wetland across a condition gradient (Sutula et al. 2006).

Calibration of the scoring ranges used in the Ohio Rapid Assessment Method (ORAM) for wetlands were made using actual measures of wetland biology and function. The scoring ranges were calibrated based on biological data collected from one region of Ohio. Therefore caution should be applied when using this calibration method on wetlands located within other regions with different vegetation types and landscape settings (Mack 2000). Based on results of testing the ORAM the scoring breakpoints for the index were revised and the scoring ranges adjusted for forested and scrub-shrub wetland vegetation communities (Mack 2000).

In a review of the vegetation assessment method Habitat Hectares, McCarthy et al. (2004) recommended a thorough assessment of the scores allocated to the different habitat components, through validation, to ensure that they encapsulate the intended logic of the authors.

Earlier versions of the Ohio Rapid Assessment Method (ORAM) for wetlands (Mack 2000) had a number of shortcomings including: the failure to expressly address the hydrology of a wetland and human alterations to the wetland; a clear preference for wetlands located near streams and discrimination against groundwater or surface-run off fed wetlands; and the failure to include an express evaluation of the importance or quality of vegetation communities for a wetland, or whether the species present were invasive weeds and/or disturbance-tolerant native plants. These problems led to the over scoring of low quality, highly disturbed wetlands that happened to have multiple vegetation classes and/or proximity to surface waters, as well as underscoring of high quality, undisturbed wetlands with a single vegetation class. It may be possible to shift category boundaries, but this would need to be done on an empirical and independent basis if the condition classes are not be totally arbitrary.

8 Data analysis methods

A number of data analysis methods are appropriate for testing a rapid assessment method. Methods will vary according to the objectives of the testing program. Some common approaches are explained below.

A common method of analysing the relationship of wetland assessment method scores to other data is simply by plotting a linear regression graph and reporting the regression equation R^2 value, slope, intercept, and correlation coefficient. Spencer et al. (1998) represented the relationship of the scores as a linear regression graph and found that their rapid index results compared very favorably with the rankings based on the long term (18 month) monitoring data. The relationship between condition subindex scores for wetlands as well as total index scores are compared between autumn and winter and also between the two wetland assessor groups. Healey (unpublished) performed *t*-tests on the data collected from wetland assessors and plotted the mean subindex scores for summer and winter. The median subindex scores and total index scores obtained during the initial training were also plotted to assess consistency of wetland scores between wetland assessors and the trainer.

Jansen et al. (2005) tested the Rapid Appraisal of Riparian Condition (RARC) index against more detailed measures of biodiversity and functioning of the riparian zones. Jansen and Robertson (2001) classified sites into three groups based on the grazing regime (i.e. light, irregular and standard). Bird surveys (abundance and diversity) and a number of location and habitat measures were recorded at each site. Multivariate analysis was performed using the PRIMER software package (Carr 1996) and bird communities recorded at each site were grouped according to grazing regime (Jansen and Robertson 2001). There were highly significant relationships between the riparian condition index scores (RARC) and bird communities (Jansen and Robertson 2001). The relationship between grazing, riparian condition and bird communities is represented clearly in a non-metric multi dimensional scaling plot. It is clear that there was a strong trend of changing bird communities as condition scores (RARC score) varied (Thompson et al. 2003).

As previously discussed, fuzzy classification can be applied to data to account for uncertainty. The approach can be used where categorical data exists, such as in the IWC. The method will be utilized where appropriate in the IWC. Fuzzy classification is a method that could be applied when using comprehensive wetland datasets and applying expert opinion to produce wetland condition ratings. In the case where consensus about the best estimate of wetland condition is not possible, it may be necessary to pool different estimates from different experts or from several assessment methods and express the result as an interval which is represented as a fuzzy number (Akcakaya et al. 2000).

Fuzzy classification is useful for applications where values or scores are combined to form one score such as with the IWC. In simple terms it is similar to applying a confidence interval to the score obtained. The process of applying fuzzy classification to a set of indices is discussed in Icaga (2007) and describes the application of fuzzy rules to several measured variables which results in an index value from the summed values. This may have value when refining the IWC scoring and weighting system and accounting for uncertainty and inconsistencies that arise between wetland assessors using the IWC.

Glossary

Artificial neural network (ANN): a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase.

Bayesian network (or a belief network): probabilistic graphical model that represents a set of variables and their probabilistic independencies. For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases.

Calibration: process of adjusting IWC measures, sub-indices and overall scores to better fit correlations with more intensive/quantitative data across a known condition gradient (Mack 2000, Sutula et al. 2006).

Ecological character: The sum of the biological, physical, and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions, and attributes. Change in ecological character is 'the impairment or imbalance in any biological, physical or chemical components of the wetland ecosystem, or in their interactions, which maintain the wetland and its products, functions and attributes.' (Ramsar Convention 1999).

Ecological Vegetation Class (EVC): The concept of an EVC was introduced in the Old Growth Study of East Gippsland (Woodgate et al. 1994). EVCs are a type of native vegetation classification described through a combination of floristics, life forms and ecological characteristics, and through an inferred fidelity to particular environmental attributes. Each EVC includes a collection of floristic communities that occur across a biogeographic range, and although differing in species, have similar habitat and ecological processes operating.

Ecosystem services: The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (Millennium Ecosystem Assessment (2003).

Fuzzy cognitive maps (FCM): graphical models related to Bayesian networks (BN) and artificial neural network (ANN) models. *See Bayesian networks* and *artificial neural network*.

Index: An index can be defined as a number derived from a formula, used to characterise a set of data or a number that represents the change in value or other measurable quantity in comparison with a reference number for a previous period of time.

Index of Wetland Condition (IWC): a rapid method for determining wetland condition in Victoria. The IWC is a hierarchical index with six sub-indices based on the characteristics that define wetlands: wetland catchment, physical form, hydrology, soils, water properties and biota (Department of Sustainability and Environment 2005).

Indicator: An expression of the environment that estimates the condition of ecological resources, magnitude of stress, exposure of a biological component to stress, or the amount of change in a condition (Breckenridge et al. 1995).

Landscape Disturbance Index (LDI): an index developed to select wetlands across the spectrum of condition for testing the IWC. The index measures disturbance caused by human activities in the area surrounding the wetland based on the assumption that there is a relationship between such disturbance and wetland condition.

Lidar: Light detection and ranging. Lidar is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. Like the similar radar technology, which uses radio waves, which is light that is not in the visible spectrum, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal (Wikipedia 2009).

Monitoring: Collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management. (Note that the collection of time-series information that is not hypothesis-driven from wetland assessment should be termed surveillance rather than monitoring, as outlined in Resolution VI.1 of the Ramsar Convention (2002b).

Measure: same as *Indicator* and *Variable*.

Natural: The term 'natural' in the IWC refers to a state unmodified by human activities associated with European settlement in Victoria.

Parameter: a statistical term to describe a distribution (e.g., mean, standard deviation). Not the same as *Variable* or *Indicator*.

Phase: See Wetland Phase.

Products: Generated by wetlands include: wildlife resources; fisheries; forest resources; forage resources; agricultural resources; and water supply. These products are generated by the interactions between the biological, chemical and physical components of a wetland (Ramsar Convention 1999).

Rapid assessment: For the scope of the IWC, rapid assessment implies an assessment of wetland condition can be undertaken at a wetland in less than three hours.

Score: A numerical value assigned to the measure that is based on its departure from reference or another benchmark. The measure scores are used to determine an overall score that reflects the condition of the asset. In the IWC the reference is the condition of the wetland at the time of European settlement.

Threats: Activities that lead to impacts on wetlands.

Values: See Ecosystem services.

Validation: testing the hypotheses outlined in Section 6 of this document. Validation is used interchangeably with calibration and verification by different authors. Sutula et al. (2006) refer to validation as the process of ensuring that the calibration holds for wetlands outside of the reference range and that validation is a long term, ongoing process that results in a more robust method over time. The National Water Commission (2007) approach uses validation as a way of checking that the measure actually assesses the environmental/ecological feature it is intended to measure.

Variable: Same as Indicator and Measure.

Verification: Sutula et al. (2006) use verification as a means of determining if the draft attributes and measures selected in the method development phase are comprehensive and appropriate; sensitive to a gradient in conditions; able to separate between wetlands at different ends of the reference network; and able to foster repeatable results among different practitioners.

Wetland: For the scope of the CDI, wetlands are naturally occurring, waterbodies with static water and without a marine hydrological influence.

Wetland assessment: The identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Ramsar Convention 2002a).

Wetland components: Specific measurable elements or features of a wetland. For example, soil biota, soil physical properties, soil chemical properties and water chemical properties.

Wetland condition: The state of the 'biological, physical, and chemical components of the wetland ecosystem and their interactions'. Synonymous with the Ramsar definition of ecological character (Ramsar Convention 1999). The reference state is the condition of the wetland at the time of European settlement.

Wetland phase: The hydrologic state of the wetland with respect to flooding. Wetland phases include 'full', 'filling', 'drying', 'dry'.

References

Akcakaya, H.R., Ferson, S., Burgman, M.A., Keith, D.A., Mace, G.M. and Todd, C.R. (2000) Making consistent IUCN classifications under uncertainty, *Conservation Biology* **14**: 1001–13

Alluvium (unpublished) Spatial database users' guide for dryland area wetlands program. Unpublished report (2008) to the North Central Catchment Management Authority, Huntly

Ausseil, A-G.E., Dymond, J.R. and Shepherd, J.D. (2007) Rapid mapping and prioritisation of wetland sites in the Manawatu–Wanganui region of New Zealand, *Environmental Management* **39**: 316–325

Australian Water Resources (unpublished) River and wetland health: A framework for comparable assessment of the ecological condition of Australian rivers and wetlands (Draft). Australian Water Resources, Canberra

Batzer, D.P. and Sharitz, R.R. (eds) (2006) Ecology of Freshwater and Estuarine Wetlands, University of California Press, Berkeley

Boulton, A.J. and Brock, M.A. (1999) Australian Freshwater Ecology Processes and Management. Gleneagles Publishing, Glen Osmond, SA

Brazner, J.C., Danz, N.P., Niemi, G.J., Regal, R.R., Trebitz, A.S., Howe, R.W., Hanowski, J.M., Johnson, L.B., Ciborowski, J.J.H., Johnston, C.A., Reavie, E.D., Brady, V.J and Sgro, G.V. (2007) Evaluation of geographic, geomorphic and human influences on Great Lakes wetland indicators: A multi-assemblage approach, *Ecological Indicators* **7(3)**: 610–35

Breckenridge, R.P., Kepner, W.G., and Mouat, D.A. (1995) A process for selecting indicators for monitoring conditions of rangeland heath, *Environmental Monitoring and Assessment* **36:** 4560

Brooks, R.P., Easterling-McKenney, M., Brinson, M., Rheinhardt, R., Havens, K., O'Brien, D.O., Bishop, J., Rubbo, J., Armstrong, B. and Hite, J. (2005) A Stream-Wetland-Riparian (SWR) Index for assessing condition of aquatic ecosystems in small watersheds along the Atlantic slope of the Eastern U.S, Atlantic Slope Consortium

Brown, M.T. and Ulgiati,S. (2005) Emergy, transformity, and ecosystem health. In: *Handbook of ecological indicators for assessment of ecosystem health* (eds S. E. Jorgensen, R. Costanza and F. Xu) pp. 333-52. CRC Press, Boca Raton, Florida, USA

Brown, M.T and Vivas, M.B. (2005) A landscape development intensity index, *Environmental Monitoring and Assessment*, **101**: 289–309

Butcher, R. (unpublished) Wimmera Wetland Assessment Project –Technical Report, Report to the Wimmera Catchment Management Authority. May 2005

Carr, M.R. (1996) PRIMER (Plymouth Routines in Multivariate Ecological Research). Plymouth Marine Laboratory, Plymouth, UK

Corrick, A.H. and Norman, F.I. (1980) Wetlands of Victoria I. Wetlands and waterbirds of the Snowy River and Gippsland Lakes catchment, *Proceedings of the Royal Society of Victoria*. **91**: 1–15

Corrick, A.H. (1981) Wetlands of Victoria II. Wetlands and waterbirds of South Gippsland. *Proceedings of the Royal Society of Victoria* **92**: 187–200

Corrick, A.H. (1982) Wetlands of Victoria III. Wetlands and waterbirds between Port Phillip Bay and Mount Emu Creek, *Proceedings of the Royal Society of Victoria*. **94(2)**: 69–87

Department of Sustainability and Environment (2005) The Index of Wetland Condition: Conceptual framework and selection of measures. Department of Sustainability and Environment, Melbourne

Department of Sustainability and Environment (2006) The Index of Wetland Condition: Assessment of wetland vegetation, update. Department of Sustainability and Environment, Melbourne

Department of Sustainability and Environment (2007) The Index of Wetland Condition: Review of wetland assessment methods. Department of Sustainability and Environment, Melbourne

Department of Sustainability and Environment (unpublished a) The Index of Wetland Condition: Methods manual. Department of Sustainability and Environment, Melbourne

Department of Sustainability and Environment (unpublished b) Gippsland Lakes - Index of Wetland Condition. Department of Sustainability and Environment, Bairnsdale

Department of Sustainability and Environment (2009) Land use spatial data.

Ecology Australia (unpublished a) Priority action plan for lower Broken River wetlands: public document. Unpublished report (2006) for the Goulburn Broken Catchment Management Authority. Ecology Australia, Fairfield

Ecology Australia (unpublished b) Wetland implementation plan - peatland and spring-soak wetlands - stage 1 Unpublished report (2007) for the Goulburn Broken Catchment Management Authority. Ecology Australia, Fairfield

Ecosystem Management Australia (unpublished b) Comparison between 1788, 1994 and new wetland layers. Unpublished report (2006) to the West Gippsland Catchment Management Authority. Ecosystem Management Australia, Bairnsdale

Fennessy, M.S., Jacobs, A.D. and Kentula, M.E. (2004) Review of rapid methods for assessing wetland condition. EPA/620/R-04/009. Washington D.C., U.S. Environmental Protection Agency

Healey, M. (unpublished) Testing of a rapid assessment condition index on permanent coastal floodplain wetlands - DRAFT. NSW Department of Land and Water Conservation, Parramatta

Icaga, Y. (2007) Fuzzy evaluation of water quality classification, *Ecological Indicators* **7**:710–718

Jansen, A. and Robertson, A.I. (2001) Relationships between livestock management and the ecological condition of riparian habitats along an Australian floodplain river, *Journal of Applied Ecology* **38**:63–75

Jansen, A, Robertson, A., Thompson, L. and Wilson, A. (2005) River and riparian land management, technical guideline No. 4 A. Rapid Appraisal of Riparian Condition - Version Two. Land and Water Australia

Jansen, A. and Healey, M. (2003) Frog communities and wetland condition: relationships with grazing by domestic livestock along an Australian floodplain river, *Biological Conservation* **109**:207–19

Ladson, A.R., White, L.J., Doolan, J.A., Finlayson, B.L., Hart, B.T., Lake, P.S. and Tilleard, J.W. (1999) Development and testing of an index of stream condition for waterway management in Australia. *Freshwater Biology* **41**:453–68

Lane, C.R. and Brown, M.T. (2007) Diatoms as indicators of isolated herbaceous wetland condition in Florida, USA, *Ecological Indicators* **7(3):**521–540

Lopez, R.D. and Fennessy, M.S. (2002) Testing the floristic quality assessment index as an indicator of wetland condition, *Ecological Applications* **12**:487–97

Mack, J.J. (2000) ORAM v.5.0 Quantitative score calibration. Environmental Protection Agency, USA - Division of Surface Water, Columbus, Ohio

Mack, J.J. (2007) Developing a wetland IBI with state wide application after multiple testing iterations, *Ecological Indicators* **7:** 864–881

McCarthy, M.A., Parris, K.M., van der Ree, R., McDonnell, M.J., Burgman, M.A., Williams, N.S.G., McLean, N., Harper, M.J., Meyer, R., Hahs, A. and Coates, T. (2004) The habitat hectares approach to vegetation assessment: An evaluation and suggestions for improvement, *Ecological Management and Restoration* **5**:24–7

Miller, S.J., Wardrop, D.H., Mahaney, W.M. and Brooks, R.P. (2006) A plant-based index of biological integrity (IBI) for headwater wetlands in central Pennsylvania, *Ecological Indicators* **6**:290–312

Millennium Ecosystem Assessment (2003) *Ecosystems and Human Well-Being. A Framework for Assessment*, Island Press, viewed 21 January 2009, (www.millenniumassessment.org/en/Framework.aspx)

National Water Commission (2007) Australian Water Resources 2005 Assessment of River and Wetland Health: A Framework for Comparative Assessment of the Ecological Condition of Australian Rivers and Wetlands. National Water Commission. Canberra. Viewed 17 June 2008, (www.water.gov.au/publications/index.aspx?Menu=Level1_9)

Norman, F.I. and Corrick, A.H. (1988) Wetlands in Victoria: A Brief Review. *In*. The Conservation of Australian Wetlands. McComb, A.J. and Lake, P.S. (eds.) Surrey Beatty and Sons Pty. Ltd. Chipping North, NSW. Pp 17–34

Ogden, R. (unpublished) The effects of farming and river regulation on billabongs of the eastern Murray River and Lower Ovens River. Australian National University (1996)

Parkes, D., Newell, G. and Cheal, D. (2003) Assessing the quality of native vegetation: The 'habitat hectares' approach', *Ecological Management and Restoration* **4**:s29–s38

Ramsar Convention (1999) Resolution VII.10. Wetland Risk Assessment Framework, Ramsar Convention on Wetlands, viewed 23 June 2008, (www.ramsar.org/key_guide_risk_e.htm)

Ramsar Convention (2002a) *The Ramsar Strategic Plan 2003-2008*, Ramsar Convention on Wetlands, viewed 23 June 2008, (www.ramsar.org/key_strat_plan_2003_e.htm)

Ramsar Convention (2002b) *Resolution VIII.6. A Ramsar Framework for Wetland Inventory*, Ramsar Convention on Wetlands, viewed 23 June 2008, (www.ramsar.org/res/key_res_viii_06_e.htm)

Regan, H.M. and Colyvan, M. (2000) Fuzzy sets and threatened species classification, *Conservation Biology* **14**:1197–9

Reiss, K.C. (2006) Florida Wetland Condition Index for depressional forested wetlands, *Ecological Indicators* **6**:337–52

Sinclair Knight Mertz (unpublished a) Wetland extent and drainage line mapping project. Unpublished report (2006) for the Wimmera Catchment Management Authority. Sinclair Knight Mertz, Armidale

Sinclair Knight Mertz (unpublished b) Mallee CMA wetlands management GIS user manual. Unpublished report (2006) for the Mallee Catchment Management Authority. Sinclair Knight Mertz, Armidale

Smith, M.J., Cant, B., Ough, K, Scroggie, M.P., Kohout, M., Jin, C., and Turnbull, D. (2008) Wetlands, biodiversity, and salt. The impacts of secondary salinity on victoria's non-riverine wetland ecosystems: Revised summary. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria

Spencer, C., Robertson, A.I. and Curtis, A. (1998) Development and testing of a rapid appraisal wetland condition index in south-eastern Australia, *Journal of Environmental Management* **54**:143–59

Sutula, M.A., Stein, E.D., Collins, J.N., Fetscher, A.E. and Clark, R. (2006) A practical guide for the development of a wetland assessment method: the California experience, *Journal of the American Water Resources Association* **42**:157–75

Thompson, L., Robertson, A., Jansen, A. and Davies, P. (2003) Identifying best management practices for riparian habitats in Gippsland dairy regions: Riparian condition and relationships with farm management. Charles Sturt University, Wagga Wagga, NSW

United States Environmental Protection Agency (2002a) Methods for Evaluating Wetland Condition: Introduction to Wetland Biological Assessment. Office of Water, US Environmental Protection Agency, Washington, DC. EPA-822-R-02-014

Unites States Environmental Protection Agency (2002b) Methods for Evaluating Wetland Condition: Land-Use Characterization for Nutrient and Sediment Risk Assessment, Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-025

Wikipedia (2009) *LIDAR* . Viewed 18 June 2009, (en.wikipedia.org/wiki/LIDAR)

Woodgate, P.W., Peel, W.D., Ritman, K.T., Coram, J.E., Brady, A., Rule, A.J. and Banks, J.C.G. (1994) *A study of the old growth forests of East Gippsland*, Department of Conservation and Natural Resources, Victoria

Zimmermann, H. J. (1996) Fuzzy set theory – and its applications. 3rd edition. Kluwer, Dordrecht, The Netherlands

ISBN 978-1-74242-326-5 (print)
ISBN 978-1-74242-327-2 (online)