WETLAND INVENTORY

NORTHERN AGRICULTURAL DISTRICTS OF SOUTH AUSTRALIA

An assessment of selected inland wetlands
of the Northern Agricultural Districts.

Environment Australia
Department of the Environment and Heritage
Department for environment and heritage
National Parks & Wildlife South Australia
Government of South Australia

This report may be cited as:
Seaman, R.L. (2002) *Wetland Inventory of the Northern Agricultural Districts South Australia*. Department for Environment and Heritage, South Australia.

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Geographical Information System Data

Supplied by Geographical Analysis and Research Unit, Planning SA, Department for Transport, Urban Planning and the Arts.

and

The Department for Environment and Heritage, South Australia.

Funding Sources

Environment Australia

Support Organisation

National Parks and Wildlife SA

Acknowledgments

In the preparation of this report the expertise, advice and support of several people is greatly appreciated.

- Rob Walsh
- Roman Urban, DEH.
- Sandy Carruthers, Planning SA.
- Tim Croft, DEH.
- Andrew Graham

Executive Summary

The Wetland Inventory for the Northern Agricultural Districts documents a representative sample of inland wetlands by recording their physical, chemical and biological attributes. Twenty-nine wetlands were surveyed during November 2000; the majority of these wetlands included saline lake systems and brackish water bodies. Nelshaby Reserve (north-east of Port Pirie) is classified as the only freshwater wetland surveyed.

The aquatic invertebrate fauna was notably scarce in many of the wetlands surveyed, and this is attributed to the high conductivity readings in the majority of wetlands. However, nine wetlands displayed good invertebrate trophic levels. The correlation between increasing salinity levels and decreasing biological activity was clear; this decline is of concern for the health of many wetlands.

A number of wetlands surveyed are considered to be nationally important as they meet the ANZECC criteria of being a good example of a wetland type occurring within a biogeographic region in Australia. These wetlands include the saline lake systems within Innes National Park. Three wetlands are recommended for monitoring, these include Gum Flat adjacent to Minlaton, Native Hen Lagoon (south of Yorketown) and Chain of Lakes (Innes National Park).

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SECTION ONE WETLAND INVENTORY

1.0 INTRODUCTION

This Wetland Inventory for the Northern Agricultural Districts (NAD) documents a representative sample of inland wetlands and records their physical, chemical and biological attributes. From this information, aquatic environments that contain high biodiversity are highlighted, and threats are documented. The inventory provides a snap shot of the condition and conservation value of wetlands throughout the Northern Agricultural Districts. Those wetlands that meet one or more of the Australian and New Zealand Environment and Conservation Council (ANZECC) criteria for an important wetland will be nominated for inclusion in the National Directory of Important Wetlands in Australia.

The Wetland Inventory for the Northern Agricultural Districts is an initiative of the Wetland Section-Environment Australia and the South Australian Department for Environment and Heritage.

2.0 REPORT STRUCTURE

This report is divided into three sections, namely the wetland inventory, wetland assessment and wetland monitoring.

Section 1 - Wetland Inventory. Outlines the project aims and inventory methodology.

Section 2 - Wetland Assessment. Provides an analysis of the wetland inventory, which includes the identification of wetland values and threats.

Section 3 – Wetland Monitoring. Discusses frameworks for monitoring, and recommends indicator species for monitoring and specific wetlands to monitor.

3.0 PROJECT SCOPE

The project scope consist of five actions, these are to:

1. To undertake baseline wetland surveys for inland surface waters within the NAD.
2. Identify wetlands of conservation significance, according to agreed ANZECC classification.
3. Provide digital coverage of spatial boundaries of identified wetlands in ARC/INFO compatible format at appropriate scale, in consultation with Planning SA.
4. Produce a report detailing the physical, biological and chemical attributes of wetlands within the NAD.
5. Nominate wetlands of significance for inclusion in the Directory of Important Wetlands in Australia.

4.0 OVERVIEW OF PAST WETLAND INVENTORY STUDIES

The most comprehensive listing of wetlands in South Australia in terms of numbers and coverage is by Lloyd and Balla (1986). This study identified approximately 1500 wetlands and complexes state-wide.

The Lloyd and Balla listing was a desktop study that collated and recorded information within a standard format. This included:

- wetland type
- name
- location
- size
- catchment
- aquatic fauna
- aquatic and fringing vegetation
- wetland condition
- water regime
- landuse
- impacts
- tenure.

The Lloyd and Balla report provides a good starting point in understanding the extent and some attributes of South Australian wetlands. However, the study falls short in providing up to date information on invertebrate composition, water chemistry and basic landform information. Thirty-six wetlands are documented for Yorke Peninsula and thirty-eight wetlands for the mid north/Flinders Ranges regions.

Since Lloyd and Balla's 1986 report, several state-wide studies have mirrored this kind of information collection and presentation, but have generally not collected detailed field baseline wetland information. None-the-less, good information has been generated for certain areas including the Murray River corridor, for example, Thompson's (1986) study documented, mapped and described the River Murray Wetlands and Jensen *et al* (1996) *Wetland Atlas* report of the South Australian Murray Valley Wetlands made inroads into spatially capturing the locations through the use of GIS. The introduction of linking wetlands with GIS enabled the creation of a wetlands GIS database for the Murray Valley Wetlands. In 1997 Carruthers and Hille developed a GIS database for the South East wetlands. This database recorded wetland type, name, complex, watercourses and assigned a condition score and conservation value. The benefits of collecting data and linking it to GIS became evident not only for environmental planning and for information retrieval, but also for reporting to Environment Australia on the extent of wetland resources.

In 1993 the Australian Nature and Conservation Agency published the first edition of '*A Directory of Important Wetlands in Australia'*. A second edition was complied in 1996, which included information on 68 wetlands South Australia. Four coastal wetlands are listed within the NAD (Point Davenport, Wills Creek, Clinton and the Upper Spencer Gulf).

De Jong and Morelli (1996) commented that in compiling the Directory of Important Wetlands it became apparent that several regions within South Australia were lacking baseline wetland information. They suggested that there is a need for systematic inventories, biological surveys and research programs in many areas of the State. Wetland information in regions such as the Great Victoria Desert, Flinders and Olary Ranges, Eyre Peninsula, Yorke Peninsula, Kangaroo Island and Nullarbor are quite inadequate.

The Wetland Inventory for the NAD combines several of these recommendations, including continuing the development of a GIS database and providing baseline information which includes physical, chemical and biological information for wetlands within the NAD.

5.0 WETLAND RISK ASSESSMENT

The wetland risk assessment is a conceptual framework to assist in predicting and assessing change in the ecological character of wetlands. The framework has been adopted by Ramsar (resolution V11.10) and is now promoted as an integral component of the management planning process for wetlands. The relevance of undertaking wetland inventories becomes apparent within this framework. A wetland inventory ultimately collects information for the wetland assessment framework. This information is also critical in order to make recommendations for monitoring.

A central component of the wetland risk assessment is the ability to record the ecological character of a wetland. The Ecological character is the sum of the biological, physical, and chemical components of the wetland ecosystem and their interactions that maintain wetland functions and attributes. Recording changes to the ecological character of a wetland involves the development of a monitoring program, this is further discussed in Section Three – Wetland Monitoring.

6.0 WETLAND INVENTORY METHODOLOGY

A wetland inventory essentially collects information that assists in wetland management. It can provide information for specific assessment and monitoring activities.

6.1 Study area boundaries

The project boundary is based on the NAD Natural Heritage Trust (NHT) boundary, which encompasses all of Yorke Peninsula extending north to Wilmington, east to Clare, with the south-west boundary near Two Wells. Refer to Map 1.

6.2 Site selection

The aim of the wetland selection process was to sample a broad range of inland wetlands across the Northern Agricultural Districts. Factors such as time constraints, accessibility and the project budget were limiting factors in the number of wetlands selected. Wetlands were selected initially by studying the GIS waterbody coverage for the Northern Agricultural Districts. Waterbodies within State government lands, community lands, Council-managed lands, land under management agreements and Heritage Agreements were targeted for further investigation.

A total of 29 wetlands were surveyed within the NAD, the majority of these wetlands are located in the southwest of Yorke Peninsula. Refer to Map 2 for wetland locations.

6.3 GIS Database

This project builds on GIS database initiatives undertaken by Planning SA and the Department for Environment and Heritage. GIS databases have been developed for the Murray River region by Carruthers and Nicolson (1992) and published in the form of an Atlas by Jensen *et al* (1996). A GIS database exists for the South East region of the state and has been published in the form of a technical report by Carruthers and Hille (1997). No other regions in South Australia have a GIS wetland database at present, although databases for the Mount Lofty Ranges, Eyre Peninsula and Kangaroo Island are being developed. One of the project objectives is to provide a digital coverage of spatial boundaries of wetlands surveyed with the NAD.

A State-wide numbering system was developed for identifying wetlands which follows the system established for the Murray River wetlands. The Murray River wetlands have been assigned the numbers S0001 to S0999. The South East region (S1000 to S1999), Eyre Peninsula, (S3000 to S3999), Kangaroo Island numbers S5000 to S5999 and the Mount Lofty Ranges (S2000 to S2999). The Northern Agricultural Districts has been assigned the numbers S4000 to S4999. The software used to produce the wetlands data is the ESRI (Environmental Systems Research Institute) geographic information system (GIS) ARC/INFO. The GIS layer was created initially from the existing land cover layer that contained areas designated as swamps, vegetated swamps, lakes and vegetated lakes. This land cover layer was mapped from 1:40 000 colour aerial photography by the Geographical Analysis and Research Unit, Planning SA, Department for Transport, Urban Planning and the Arts.

7.0 WETLAND INVENTORY SURVEY

In developing the wetland survey, it was critical that information collected could be used for an initial assessment of wetland character. This ultimately involved the collection of physical, biological and chemical parameters. In the development of the survey form, several methodologies were studied and adapted, these include:

- Butcher, R.J. (1999) *Assessing biodiversity in temporary and permanent wetlands. pp* 50-53 in The Other 99%. *The Conservation and Biodiversity of Invertebrates*, ed by Ponder, W. and Lunney, D. (1999). Transactions of the Royal Zoological Society of New South Wales.
- Finlayson, C.M. and Spiers, A.G. (1999). *Techniques for enhanced wetland inventory and monitoring.* Supervising Scientist, Canberra
- Fairweather, P.G. and Napier (1998). *Environmental indicators for national state of the environment reporting - inland waters.* Environment Australia.
- Maher, W. and Liston, P. (1997). *Water quality for maintenance of aquatic ecosystems: Appropriate indicators and analysis. Australia: State of the Environment Technical Paper Series. (Inland waters).* Environment Australia.
- Morelli, J. and de Jong, M. (1996). *A Directory of Important Wetlands in South Australia.* South Australian Department of Environment and Natural Resources, Adelaide.
- Storey, A.W. Lane, J.A.K. and Davies, P.M. (1997). *Monitoring the ecological character of Australia's wetlands of international importance (RAMSAR Convention).* Western Australian Department of Conservation and Land Management and Biodiversity Group of Environment Australia.

7.1 Wetland survey template

For each wetland surveyed the physical, biological and chemical information was collected. A brief outline is given below. The complete wetland survey descriptions are given in Appendix 1.

Physical parameters

- Wetland Reference Number
- Ramsar Site
- Land use
- Land element
- Wetland name
- Description of site
- Tenure
- Geology

Biological parameters

- Vegetation associations
- Biological threats
- Noteworthy flora and fauna
- Aquatic vegetation classes

Chemical parameters

- Dissolved oxygen
- Conductivity
- Turbidity
- pH
- Temperature

SECTION TWO WETLAND ASSESSMENT FOR THE NORTHERN AGRICULTURAL DISTRICTS

8.0 INTRODUCTION

Wetland assessment involves the identification and status of threats to wetlands as a basis for the collection of more specific information through monitoring. In essence, Section Two of this report analyses the survey results by looking at each survey parameter individually. This comprises a background discussion and analysis.

8.1 Wetland overview

The majority of wetlands within the Northern Agricultural District are naturally saline and are varying in environmental condition. The salt lakes located in Innes National Park are in excellent condition and are without doubt the best examples of salt lake systems on Yorke Peninsula. The 'heel' of Yorke Peninsula (near the township of Yorketown) is characterised by over a 100 circular salt lakes. Very little native vegetation in this area remains due to clearance for agriculture. Further north, toward the township of Minlaton, is the last remaining forest of *Eucalyptus camaldulensis* (Red Gum) which is located in a seasonally inundated flat.

Inland wetlands are sparsely distributed over the remainder of the Peninsula, but more saline lake systems are found further north starting at the township of Lochiel. A band of salt lakes located on the Condowie Plains runs parallel to the Hummock and Barunga Ranges. These salt lakes are in agricultural lands that are largely cleared. One of the largest lakes, located near Lochiel (Lake Bumbunga), is a source of gypsum. This band of salt lakes terminates near Crystal Brook in the north.

Several fresh water bodies are located in the Southern Flinders Ranges, with Beetaloo Reservoir contained in Beetaloo Valley being one of the most prominent. No natural wetlands were surveyed in the Southern Flinders Ranges, although it is assumed that there would be freshwater soaks within drainage lines in the Beetaloo Catchment area. Nelshaby Reserve Reservoir near Port Pirie is used as a secondary water supply and contains significant aquatic and terrestrial habitats. This waterbody was the only freshwater wetland surveyed in the region.

Map 2 illustrates the wetland survey locations in the NAD.

9.0 WETLAND LAND USE

9.1 Background

Land use within wetland areas usually dictate the level of protection and the condition of the wetland. Surrounding land uses are a major contributor to the processes that threaten wetlands. Many wetlands within the NAD are under threat from increasing salinity resulting from the clearance of native vegetation.

9.2 Analysis

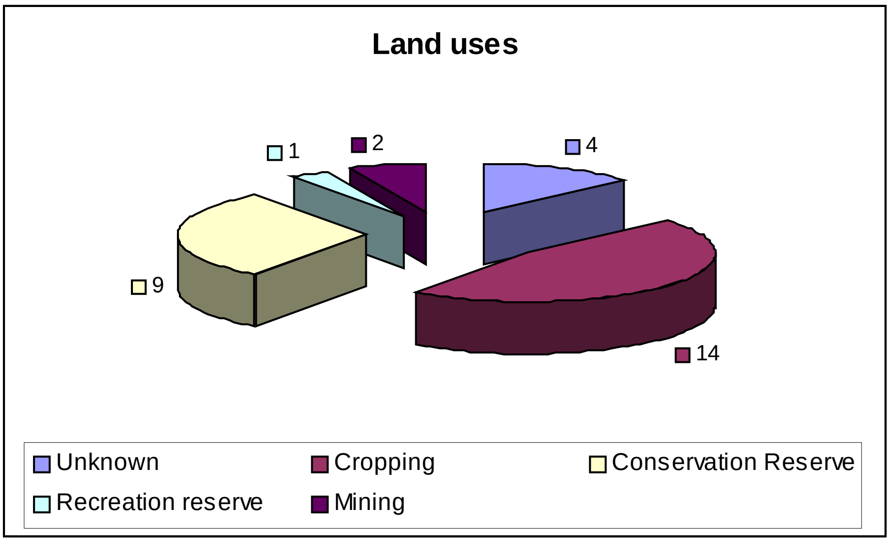

Figure 9-1. On site wetland land uses

The majority of wetlands surveyed have a surrounding land use of grain and legume production (14 sites), and most of these wetlands are in a degraded condition. Nine wetlands have a surrounding land use of conservation management; these include the salt lakes in Innes National Park, one Sanctuary (Tea-tree Swamp) and a council reserve (Gum Flat).

10.0 MANAGEMENT AUTHORITY

10.1 Background

The management authority of a wetland often dictates the type and level of protection and management for the wetland. An understanding of this also allows consideration of different legislation and approaches concerning on-site management and planning for wetland sites.

10.2 Analysis

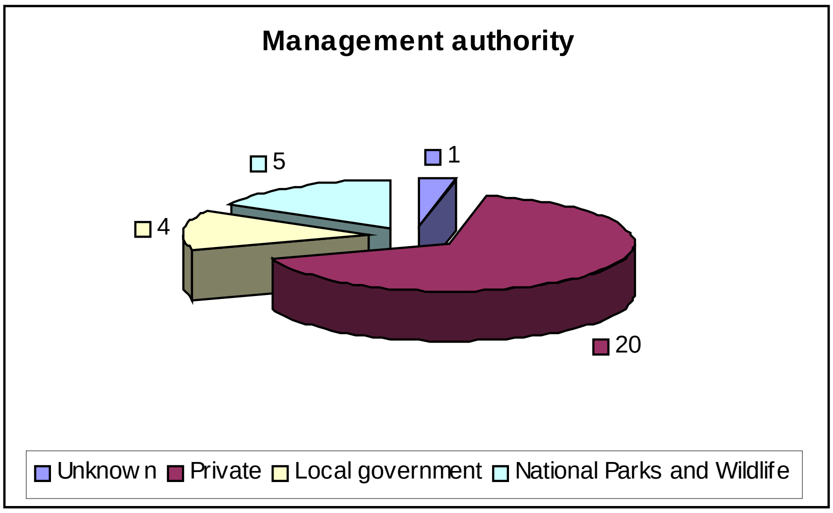

Figure 10-1. Tenure and management

The majority of sites are under private management (20 sites), five sites are managed by National Parks and Wildlife SA which are concentrated in Innes National Park, and the remaining four wetlands are managed by local government. These include Gum Flat and Nelshaby Reserve.

11.0 ENVIRONMENTAL ASSOCIATIONS AND IBRA REGIONS

11.1 Background

The Interim Biogeographic Regionalisation for Australia (IBRA) is a framework for conservation planning and sustainable resource management within a bioregional context. IBRA regions represent a landscape based approach to classifying the land surface from a range of continental data on environmental attributes. In 1999-2000, IBRA version 5 was developed. Eighty-five bioregions have been delineated, each reflecting a unifying set of major environmental influences that shape the occurrence of flora and fauna and their interaction with the physical environment. (See: http://www.ea.gov.au/parks/nrs/ibraimcr/ibra_95/index.html)

Environmental associations are the next level of complexity down from the IBRA regions. These associations were first described and mapped by Laut *et al* (1977).

11.2 Analysis

This Wetland Inventory covers eight environmental associations. Refer to Map 3 for Environmental Associations locations.

Table 11.1 Environmental Associations

Environmental Association	Number of wetlands
Innes	6
Yorketown	16
Urania	2
Bumbunga	2
Hansen	1
Glendella	1
Barung	1
Mallala	1

12.0 WETLAND AREA

12.1 Background

The area of the wetlands was calculated by using ArcView GIS based on waterbody mapping provided by Planning SA.

12.2 Analysis

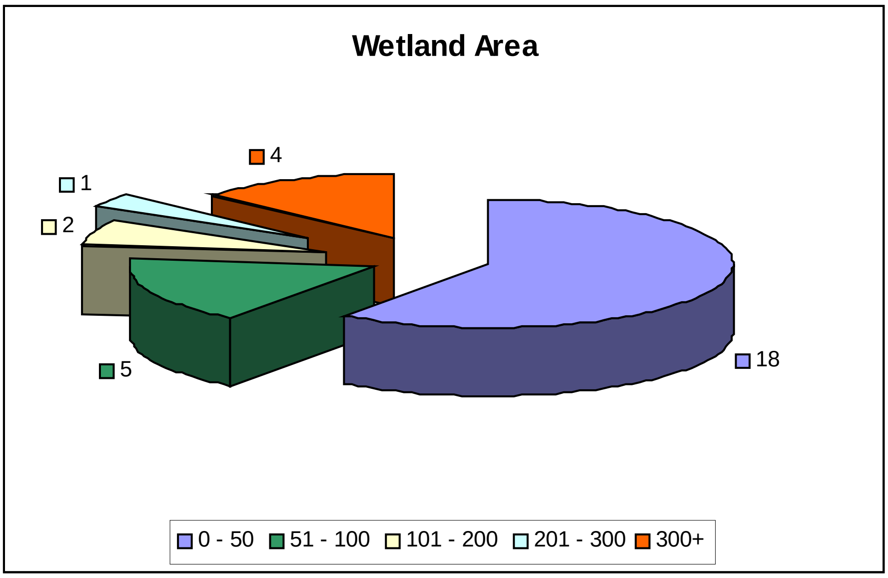

Figure 12-1. Wetland Area in Hectares.

The majority of wetlands have an area between 0 and 50 ha, (18 sites). Five sites recorded areas between 51 and 100 ha and two sites recorded areas between 101 and 200 ha (Warooka dump wetland, Lake Sunday). One site recorded an area between 201 and 300 ha (Old salt works lake) and four sites recorded areas over 300 ha, the largest being Lake Bumbunga at 1,388 ha (pictured below).

Lake Bumbunga, located south of Snowtown, was the largest waterbody (1,388 ha) surveyed within the Northern Agricultural Districts.

Plate 1. Lake Bumbunga.

13.0 LANDFORM ELEMENT

13.1 Background

The landform element definitions used in the wetland inventory has been adapted from *Heard and Channon (1997) Guide to a native vegetation survey using the biological survey of South Australia methodology, Section 3.* Geographic Analysis and Research Unit, Department of Housing and Urban Development. For landform element descriptions, refer to Appendix 1.

13.2 Analysis

Table 13-1. Landform element

Landform element	*Occurrence*
Salt Lake	23
Open depression	1
Closed depression	2
Lagoon	1
Lake	1
Swamp	1
Swale	1

Wetlands are ultimately defined by the surrounding landforms. The majority of wetlands surveyed are defined as salt lakes (a lake which contains a concentration of mineral salts, predominantly sodium chloride in solution, as well as magnesium and calcium sulphate). The majority of the 23 salt lakes are distributed around the south-eastern Yorke Peninsula.

Plate 2. Inneston Lake, a typical salt lake located in Innes National Park.

14.0 GEOLOGY

14.1 Background

Yorke Peninsula forms the southern section of the Northern Agricultural Districts. The Peninsula forms an undulating, elongated landmass of low relief, bounded on both the east and west by shallow gulfs, Gulf St Vincent and Spencers Gulf. During the Teriary Period (64-1.5 million years ago), seas inundated the majority of Yorke Peninsula and the Northern Adelaide plains initiated a sedimentary period. The major rock form during this period was limestone, which can be found across the Peninsula in the form of hardened calcrete sheets and nodules. The next geological change occurred during the Pleistocene Period (1.8 – 10,000 years ago), when the Mount Lofty Ranges were uplifted to their current height and Gulf St Vincent and the Northern Adelaide Plains were covered by rising seas. During this period Yorke Peninsula took its present shape through faulting (Corbett and Scrymgour 1973).

Further inland to the north, the geology of the Northern Agricultural Districts is influenced by the Adelaide Geosyncline, which formed during the upper pre-Cambrian 1,400 million years ago. This formed the southern Flinders Ranges and the smaller ridgelines running north-south (the Hummocks and Tothill Range). Over the next 900 years the valleys between these ridges were filled with sediments.

14.1 Analysis

Table 14-1. Geology underlying surveyed wetlands.

Geological description	Number of wetlands surveyed
Undifferentiated carboniferous permian rocks	11
Alluvial/Fluvial pleistocene sediments	9
Umberatana group/Neoproterozic sturtian glacial sediments	1
Palaeoproterozic orogenic grantoids	3
Bridgewater formation	3
Holocene-lacustrine/playa sediments	3

The undifferentiated carboniferous permian rocks (11 records) and the Holocene-lacustrine/ playa sediments (3 records) are located in south-eastern Yorke Peninsula near the localities of Yorketown and Warooka. This area contains the largest concentration of salt lakes within the Northern Agricultural Districts. The Alluvial/Fluvial pleistocene sediments (9 records) are located between the ridge lines formed by the Adelaide Geosyncline in the northern section of NAD. The one record of Umberatana group containing the Neoproterozic Sturtian glacial sediments is Porter Lagoon, located near the township of Clare. Three records of palaeoproterozic orogenic grantoids were recorded at the south-western part of Yorke Peninsula which includes Innes National Park. The Bridgewater Formation was also recorded for three wetlands in this region.

Of notable interest is the occurrence of stromatolites which are found in Inneston Lake within Innes National Park. This is one of very few examples of living stromatolites and is listed on the National Estate Register as a significant natural site (Graham 2002) The occurrence of this highlights the importance of specialised habitat provided by the saline lagoons in Innes National Park.

15.0 HYDROLOGY

The Wetland Inventory documented the average annual rainfall for wetlands surveyed and made observations on the main sources of water entering the wetlands. The average annual rainfall for the Northern Agricultural Districts is 400 mm a year, with many localities recording lower than this, for example, Wallaroo with 340 mm. Evaporation rates are high and exceed the monthly average rainfall throughout much of the year.

Surface run-off from the surrounding catchments is the main source of water for wetlands within the NAD. Groundwater connections to surface waters were not evident from field observations and little is available from published data. Sibenaler (1976) study of south-western Yorke Peninsula comments that the freshwater basin has been subjected to unsustainable extraction and is now showing signs of saline intrusions.

16.0 FLORA ANALYSIS

A large proportion of wetlands surveyed with the NAD are considered to be saline (>9500 µs or 5225 ppm/mg/L). Aquatic and semi-aquatic flora was noticeably absent in many water bodies, especially in hyper-saline waterbodies. Four wetlands recorded Ruppia (Widgeon Grass); these wetlands are located within the southern tip of Yorke Peninsula (Chain of Lakes and Tea Tree Swamp), and the two other wetlands (Minlaton Salt Lake and un-named wetland) are located near the township of Minlaton.

Soil salinity and length of time of inundation largely determine the vegetation associated with the salt lakes. Many of the salt lakes which have long periods of inundation (such as those found in south-eastern Yorke Peninsula) are devoid of vegetation. Other wetlands where the soil salinity is still high but inundation is less frequent ground cover vegetation such as samphire (*Sarcocornia* spp, *Haloragis* spp and *Arthrocnemum* spp) are usually present. *Melaleuca halmaturorum* often forms the overstorey in these systems with Gahnia spp. occasionally forming tussock bands in open areas between the thickets *of Melaleuca halmaturorum*.

Table 16-1. Vegetation associations at survey sites

Dominant vegetation community adjacent to wetland	Number of wetland sites	Conservation significance
Melaleuca halmaturorum tall shrubland over *Sarcocornia quinqueflora* low open shrubland	9	Tea Tree Swamp (south-west Yorke Peninsula); also contains several species of conservation significance, this includes *Isotoma scapigera* (SA Rare) and *Pleuropappus phyllocalymmeus* (SA Vulnerable).
Sarcocornia quinqueflora low open shrubland over introduced grasses	15	Gum Flat located near Minlaton is included as one of these sites. This wetland contains *Eucalyptus camaldulensis var. camalduensis* which is rated as Vulnerable on Yorke Peninsula.
Eucalyptus porosa over Gahnia lanigera.	1 (un-named wetland)	*Gahnia lanigera* is Identified as a threatened community within the NAD. This species is also not formally conserved.

Dominant vegetation community adjacent to wetland	Number of wetland sites	Conservation significance
Introduced grasses	3	None
Eucalyptus camaldulensis var. camalduensis over Eremophila longifolia, introduced grasses.	1 (Nelshaby Reserve)	Provides excellent habitat for water birds and aquatic flora and fauna.

Plate 3. Tea-Tree Swamp

Plate 4. Gum Flat

Melaleuca halmaturmorum is the dominant vegetation present at many wetlands within the Northern Agricultural Districts, this species forms an effective buffer for water bodies from sediments and nutrients. Greenway (1997) discusses some further direct benefits from *Melaleuca halmaturorum* these include:

Hydrological benefits

- Improved water quality by filtering suspended particles and by removing, recycling, or immobilising contaminants and nutrients, thereby preventing deterioration of downstream aquatic ecosystems (eg Tea Tree Swamp).

- Provide flood mitigation by storing and detaining precipitation and run-off thus reducing flow rates and peak floods.

- Provide groundwater recharge and a water source for people and wildlife.

Ecological benefits

- Melaleuca trees are highly productive at recycling nutrients and function as long-term biomass sinks.

- During major flood events, particulate matter is washed into the rivers and estuaries to provide a food source for heterotrophic mirco-oranisms and detritivores.

- Provide both temporary and permanent habitats for a variety of flora and fauna, including roosting and breeding areas for wildlife. Some Melaleuca swamps support large ibis and egret colonies (eg Native Hen Lagoon).

- Provide vital refuges for wildlife during periods of drought.

- Melaleuca trees flower prolifically and provide a source of nectar for resident and migratory birds, bats, possums, bees and other insects. Their nectar is a particularly valuable food source for migratory honey-eaters and parrots during the autumn/winter months (eg Innes National Park salt lakes).

Threats

There are various key threatening processes which affect the majority of remnant *Melaleuca halmaturorum* woodlands in the NAD. These include increased nutrients moving into the water due to catchment clearance and farming practices. Resulting in dieback and a change in water chemistry which affects aquatic plants and invertebrate composition.

17.0 DEGRADATION AND DISTURBANCE

17.1 Background

Disturbances or threats are defined as any direct or indirect human activities at the site or in the catchment area that may have a detrimental effect on the ecological character of the wetland. The effect may be a low level disturbance (low level grazing) or a major threat such as water diversion schemes.

17.2 Analysis

Table 17-1. Land degradation

Degradation type	Number of Occurrences
Access Tracks	11
Clearance	17
Grazing damage	2
Fence lines	15
Rubbish	8
Altered flows	3

Many wetlands contained disturbances; the two most frequent disturbances recorded were clearance (17 occurrences) and fence lines (15 occurrences). Several sites recorded impacts from domestic livestock grazing of wetland vegetation (two sites). Access tracks dissecting or traversing wetlands were also common (11 sites). A concern with many of these tracks is that they are usually formed from compressed soil and during high rainfall events, sediment often runs into adjacent wetlands. Other disturbances include rubbish dumping (8 sites, eg Munkowurlie Lagoon, Wetland 24 and Diamond Lake). Altered water flows were also recorded. This occurred at three sites, namely Nelshaby Reserve, Lake Sunday and Gum Flat.

Plate 5. Nelshaby Reserve.

Water is being diverted into the lake area in Nelshaby Reserve which has reduced environmental flows for the *Eucalyptus camaldulensis*s populations. This has partly resulted in the death of these trees due to the removal of the hydrological wetting and drying regime.

18.0 AQUATIC VEGETATION CLASSES

18.1 Background

Parameters for seven classes of aquatic vegetation were included in the survey. These records can indicate the types of producers (production of oxygen and plant food) within the wetland system. The diversity of classes recorded may indicate the level of aquatic biodiversity present, the vegetation classes consist of:

Algal and aquatic moss commonly comprise Charophyta (stoneworts) and Chlorophyta (green algae) which forms macroscopic mats either attached to plants or in open water. Algae forms the photosynthetic basis for the open water food sources in many inland waters (Boulton and Brock, 1999).
For images of green algae see: http://www.nmnh.si.edu/botany/projects/algae/Imag-Chl.htm.

Floating vascular/leaved plants have part or all of the leaves at the waters surface. Examples include *Azolla* species floating ferns that host bacteria that fix nitrogen (Romanowski 1998), *Lemna*, *Spirodela* and *Wolffia* (duckweeds) and members of the family *Utricularia* (bladderworts). Members from the family Potamogetonacea (pondweeds) are also common floating plants and can be found in a variety of habitats. All these plants are able to provide habitat for invertebrates, provide shelter for fishes and produce oxygen.

Rooted vascular plants are those rooted in the sediments with either a major proportion of material above water (reeds, rushes and sedges) or totally under water (V*allisneria* spp.). Many of these plants play a key role in nutrient cycling and provide habitat for birds, insects and aquatic invertebrates. Typical genera include *Baumea*, *Bolboschoenus*, *Carex*, *Cyperus*, *Gahnia*, *Schoenus*, *Juncus*, *Triglochin* and *Myriophyllum*. *Myriophyllum* is a distinctive wetland genus that provides food, shelter and spawning or nesting sites for a variety of animals, from invertebrates to fish, frogs and birds (Romanowski 1998).

18.2 Analysis

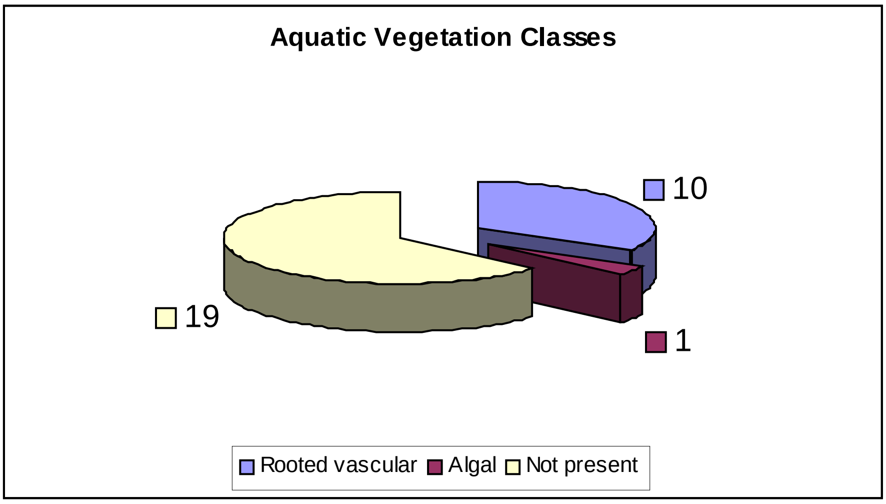

Figure 18-1. Aquatic vegetation types recorded

The majority of wetlands surveyed recorded no aquatic vegetation classes (19 sites). Rooted vascular plants are the most common form of vegetation class within the surveyed wetlands. Commonly recorded flora species included *Ruppia* and *Myriophllum*.

19.0 AQUATIC FAUNA ANALYSIS

19.1 Invertebrates

Macro and micro invertebrates are an essential component of the wetland food web. They are responsible for a significant proportion of the secondary production occurring in wetlands, and form two interconnected wetland food chains, a grazing food chain and a detrital food chain. Invertebrates comprise much of the diet of waterfowl populations the diversity and abundance of waterfowl can be a direct consequence of the invertebrate food supply.

19.1.1 Ecological benefits

Yen and Butcher (1997) provide some examples of direct ecological benefits that invertebrates contribute.

Tangible direct benefits:

1. Plant pollination
2. Effects on soil: soil formation and fertility.
3. Decomposition: fragmentation and recycling of dead plant and animal material.
4. Position in the food web: invertebrates are the principle food for many vertebrates.
5. Preditation and parasitism. Invertebrates are involved in the natural regulation of populations of other species through predation and parasitism, and thus form the basis of biological control.

Indirect ecological benefits:

1. Ecosystem stability: the loss of species from highly interrelated systems is likely to cause a cascade of further losses.

2. Evolutionary time: the diversity within ecosystems over time maintains diversity.

19.1.2 Trophic dynamics

Standing water communities are dynamic systems which reflect change in many variables. The trophic state of a wetland depends on nutrient inputs from the catchment and within the wetland (Boulton and Brock 1999). Invertebrates were collected during the Wetland Inventory and classified according to trophic levels. If samples from all trophic groups are collected, this could suggest that the aquatic ecosystem is in a reasonable state of equilibrium. The top of the food chain is occupied by vertebrate predators, including fish, water rats and water birds. These terrestrial predators can be considered to be on the top of the aquatic food chain, and provide a pathway for the export of nutrients and other material from the wetland ecosystem (Boulton and Brock 1999). These trophic levels are described below.

Primary producers

Primary producers form two groups, those that are suspended or floating and those attached to substrate or other plants. Attached macrophytes includes fringing reeds and submerged plants and periphyton (the biota attached to submerged surfaces). Suspended or floating forms generally consist of the phytoplankton and algae groups. Phytoplankton form the basic photosynthetic basis for the open water food web in most standing waters.

Consumers

There are two main types of consumers based on diet: grazers that consume plants and predators that consume other animals.

Grazers

Grazers consist of aquatic snails (Gastropoda) and some mayfly nymphs (Ephemeroptera), caddisfly larvae (Trichoptera) and beetles (Coleoptera). These groups are usually found near the edges of the water body.
Within the open water, some of the important grazers are zooplankton, including water fleas (Cladocera) and copepods (Calanoida and Cyclopoida).

Vertebrate Grazers

Vertebrate grazers generally consist of groups such as tadpoles, fish and waterbirds. Vertebrate grazers can influence the food web considerably when attracted to water bodies in times of flood or in types of drought.

Predators

Predators include dragonfly larvae (Odonata) which tend to ambush prey and invertebrates that hunt in open water, such as diving beetles (Dytiscidae, Coleoptera) (Boulton and Brock 1999). Areas such as the littoral zone tend to have high biodiversity of grazers which in turn attracts many invertebrate predators.

19.2 Saline Systems

The majority of wetlands within the Northern Agricultural Districts contain saline wetlands. The invertebrate composition changes with different salinities and the vegetation structure also influences invertebrate composition and abundance. Freshwater organisms in Australia generally tolerate salinities up to about 300 Ms/m (3000 EC), beyond this there is a change in community composition, with decreased richness and increased abundance (Williams, 1998; Skinner *et al,* 2001).

A high diversity of invertebrates can occur within salt lakes, examples include rotifers, anostracan, cladocerans, calanoid copepods and ostracods. Fishes are usually absent from saline lake systems and the top consumers are mostly water birds. In general, invertebrate species richness in salt lakes declines with increasing salinity, but at intermediate salinities where many species tolerances are broad, other factors such as biological interactions and pH will affect community composition (Skinner *et al* 2001; Williams, 2000). Studies by Skinner *et al* (2001) indicates that salinization shifts invertebrate community structure and algae tends to also become dominant at the higher salinity levels. This could lead to insufficient food for animals higher in the trophic level, including fish and waterfowl.

19.3 Analysis

Analysis of invertebrates is discussed in four areas.

1. frequency of invertebrate occurrence
2. trophic levels
3. number of invertebrate records for each surveyed wetland
4. invertebrate lists for each wetland tabled in Appendix 2.

19.3.1 Frequency of invertebrate occurrence

Table 19-1 lists the invertebrate species identified from collections made during the Wetland Inventory in December 2000, with the frequency of occurrence given against each identified invertebrate. A total of 35 species were recorded, with 18 species recorded once and 17 species recorded more than once. Of these 79 species, two species recorded six or more occurrences (*Diacypris sp.* seven occurrences, *Mytilocypris cf. Ambiguosa six* occurrences and *Mytilocypris cf. tasmanica chapmani, six* occurrences). Ten sites recorded no species.

Table 19-1. Frequency of invertebrate species occurrence

Identified invertebrates		**Frequency of occurrence**
Cypricercus	*sp.*	3
Mytilocypris	*cf. Ambiguosa*	6
Mytilocypris	*cf. tasmanica chapmani*	6
Boeckella	*triarticulata*	2
Metacyclops	*mortoni*	2
Daphnia	*carinata*	1
Lynceus	*sp.*	2
Agraptocorixa	*sp*	3
Diaprapacorus	*sp*	1
Austrolestes	*annulosus*	1
Anisops	*sp*	3
Diacypris	*cf spinosa.*	2
Calomoecia	*salina*	5
Diacypris	*sp.*	7
Daphniopsis	*pusilla*	4
Parartemia	*cf zietziana*	5
Coxiella	*sp.*	1
Diacypris	*cf paracompacta*	4
Apacocyclops	*dengizicus*	1
Mesochra	*baylyi*	2
Austrochiltonia	*australis*	2
Alona	*sp.*	1
Macrothrix	*spp*	3
Austrolestes	*analis*	1
Daphniopsis	*australis*	1
Odontomyia	*larvae*	1
Austrolestes	*sp*	1
Mortoni		1
Berosus	*sp*	1
Tanytarsini	*sp*	1
Australocyclops	*australis*	1
Austrolestes	*sp*	1
Hesperocordula	*sp*	1
Procladius	*sp*	1
Chironomus	*sp*	1

Invertebrate identification by Robert Walsh, 2000.

19.3.2 Trophic levels

Invertebrate composition analysis is affected by the study of trophic levels present in each wetland. Conclusions made about the ecosystem health of a wetland based on the invertebrates could not be made due to the limited sample size, and can only provide an indication at the time of the sampling.

Invertebrate scoring method

Invertebrate scores were assigned for each wetland, each sample was identified to family level and the trophic level of each family recorded. From the samples identified the diversity and abundance was recorded and the following scoring system was developed.

Score 1 = (Low) sampled one family from one trophic level, usually from a lower level trophic level, (eg detritivores and herbivores).

Score 3 = (Moderate) sampled more than one family with representatives from one or more trophic levels, (eg herbivores and carnivores).

Score 5 = (High) sampled more than two families with representatives from three or more trophic levels, (eg detritivores, herbivores, omnivores and carnivores).

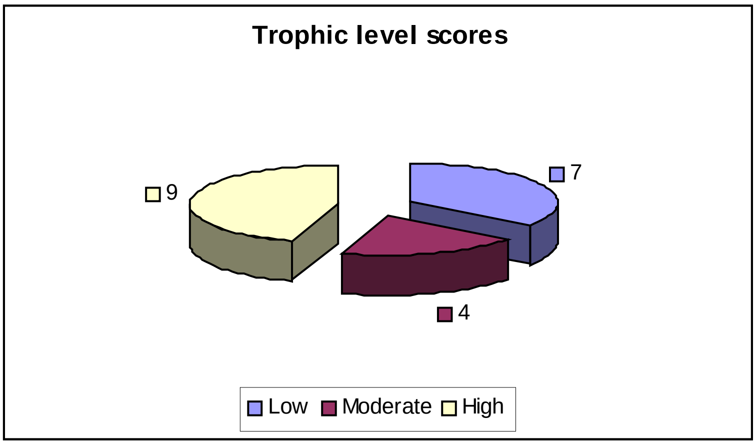

Figure 19-1. Invertebrate scores.

Nine sites recorded high trophic levels included the freshwater wetland of Nelshaby Reserve, Gum Flat and Inneston Lake within Innes National Park. Wetland sites that received a moderate score are characteristically well vegetated and are protected under formal conservation. Three sites are within Innes National Park, namely Deep Lake, Brown Lake and Chain of Lakes. At fourth site (Tea Tree Swamp) has sanctuary status. Seven sites received a low score, the majority of these sites are located on private lands and have been degraded through land clearance.

Table 19-2. Trophic scores

Wetland number	Wetland name	Trophic score
S4002	Chain of Lakes	3
S4003	Brown Lake	3
S4004	Deep Lake	3
S4005	Inneston Lake	1
S4006	Inneston Lake 2	5
S4018	Diamond Lake	1
S4010	Old Salt Works Lake	1
S4014	Lake Sunday	1
S4016	Yorketown Center Lake	1
S4017	Pink Lake	1
S4020	Minlaton Salt Lake	5
S4019	Gum Flat	5
S4021	Un-named Wetland	5
S4025	Un-named Wetland 3	5
S4026	Native Hen Lagoon	5
S4027	Bookamurray Lagoon	5
S4028	Nelshaby Reserve	5
S4029	Porter Lagoon	1
S4007	Tea Tree Swamp	3

19.3.3 Invertebrate records for each surveyed site

Table 19-3 lists the number of invertebrate records identified at each wetland site surveyed. Bookamurray Lagoon and Gum Flat both returned high abundance levels.

Table 19-3. Number of invertebrate records for wetlands

Wetland number	Wetland name	Number of records
S4002	Chain of lakes	2
S4003	Brown Lake	3
S4004	Deep Lake	2
S4005	Inneston Lake	1
S4006	Inneston Lake 2	5
S4018	Diamond Lake	1
S4010	Old Salt Works Lake	1
S4014	Lake Sunday	1
S4016	Yorketown Center Lake	1
S4017	Pink Lake	1
S4020	Minlaton Salt Lake	5
S4019	Gum Flat	11
S4021	Un-named Wetland	6
S4025	Un-named Wetland 3	4
S4026	Native Hen Lagoon	7
S4027	Bookamurray Lagoon	12
S4028	Nelshaby Reserve	7
S4029	Porter Lagoon	1
S4007	Tea Tree Swamp	3

20.0 AVI-FAUNA

The inventory did not record bird activity within the surveyed wetlands, however on five wetlands various species were recorded, these are listed below.

Table 20-1. Avi-fauna

Wetland	Scientific name	Common name
Gum Flat	*Egretta novaehollandiae*	White Faced Heron
	Vanellus miles	Masked Lapwing
	Himantopus himantopus	Black Winged Stilt
	Anus superciliosa	Pacific Black Duck
Minlaton Salt Lake	*Himantopus himantopus*	Black Winged Stilt
	Vanellus miles	Masked Lapwing
	Anus gracilis	Grey Teal
	Aythya australis	White Eyed duck
Unnamed Wetland	*Himantopus himantopus*	Black Winged Stilt
	Vanellus miles	Masked Lapwing
Native Hen Lagoon	*Anus gracilis*	Grey Teal
	Himantopus himantopus	Black Winged Stilt
	Gallinula mortierii	Black-tailed Native Hen
Nelshaby Reserve	*Cygnus atratus*	Black Swan
	Ardea pacifica	White Faced Heron
	Tachybaptus novaehollandiae	Australasian Grebe
	Fulica atra	Eurasian Coot
	Gallinula ventralis	Black-tailed Native-Hen
	Anus gracilis	Grey Teal

21.0 WATER CHEMISTRY

Chemical processes in permanent and temporary waters are extremely complex. The chemistry of the water directly influences the biological process (such as photosynthesis). The physical features of the wetland also has a strong influence on both the chemical and biological processes. These three factors (chemical, physical and biological) are constantly in a state of flux and change. Changes in these parameters are most pronounced in temporary wetlands where a wetting and drying cycle occurs. The majority of wetlands within The Northern Agricultural Districts have seasonal water regimes, filling during winter and remaining dry throughout summer.

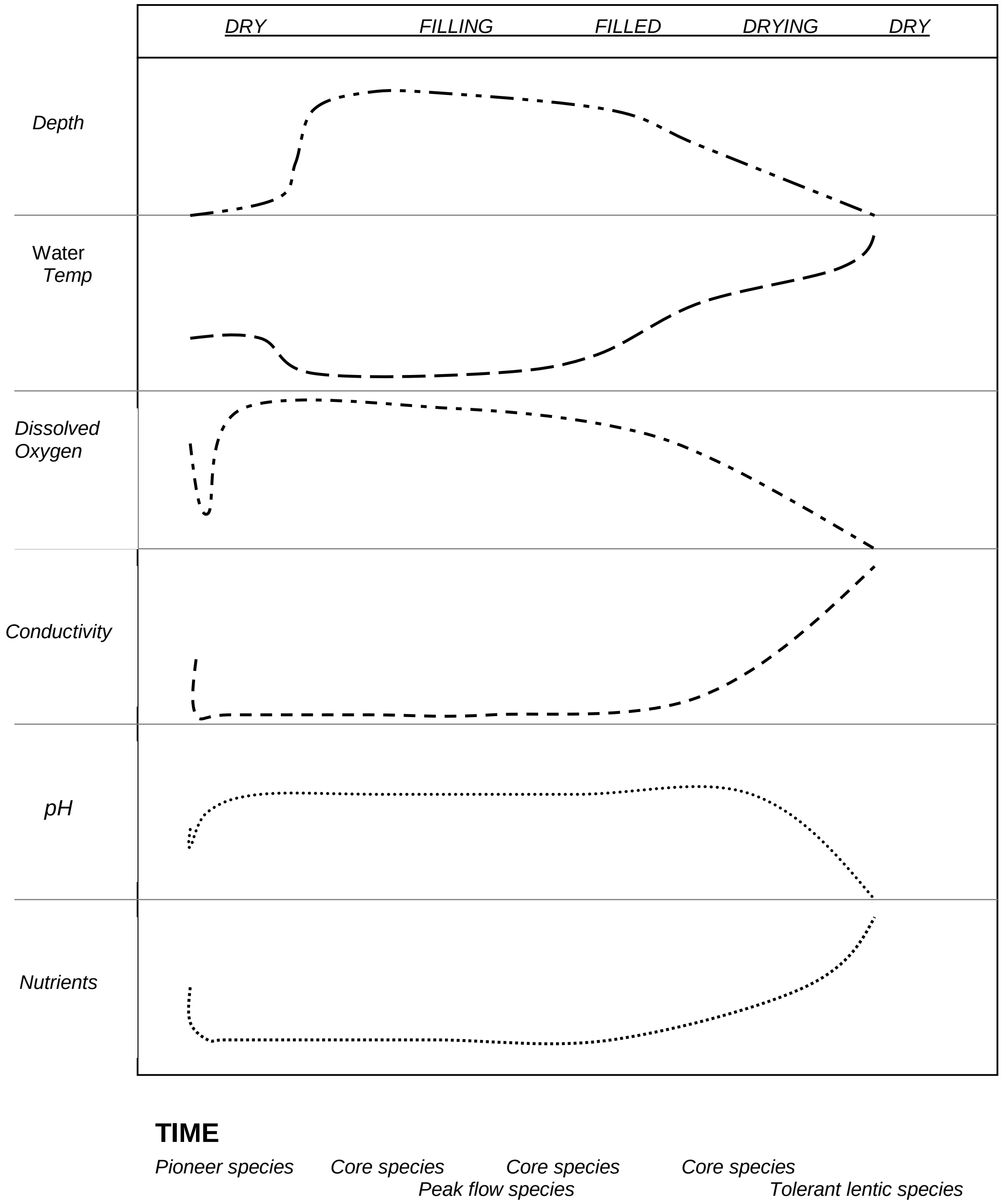

Figure 21-1. Temporary wetland cycles

Brock and Boulton (1999) state that changes in water quality during drying and filling depend on factors including:

1. sediment properties (composition, nutrients and organic content)
2. type of drawdown (gravity or evaporative)
3. severity of drying (rate of drying, temperature, weathering)
4. conditions of refilling (origin of water, degree of sediment disruption).

Figure 21-1 shows the changes in chemical variables over time during the phases of filling and drying in temporary wetlands. Seasonal changes in invertebrate composition is also noted.

21.1 pH

21.1.1 Background

The pH value of water indicates how acidic or alkaline it is on a scale 1-14. Acids have a low pH of about 2 for a strong acid like sulphuric acid and about 4 for a weak one like lactic acid. Alkalis have a high pH of about 12 for sodium hydroxide. Pure distilled water has a pH of 7 which is neutral. From pH 7 to 0, a liquid becomes increasing acidic and from pH 7 to 14, a liquid becomes increasingly alkaline.

Generally in South Australia, the pH of natural water ranges between 6.0 and 8.5 with most water bodies in the range of 7.0-8.0. The higher pH of natural water bodies is caused by high bicarbonate levels in the water and can raise the pH during the day and lower pH at night. Chemicals entering the water can also affect the pH.

PH is an important environmental indicator. At extremely high or low pH values, the water becomes unsuitable for most organisms.

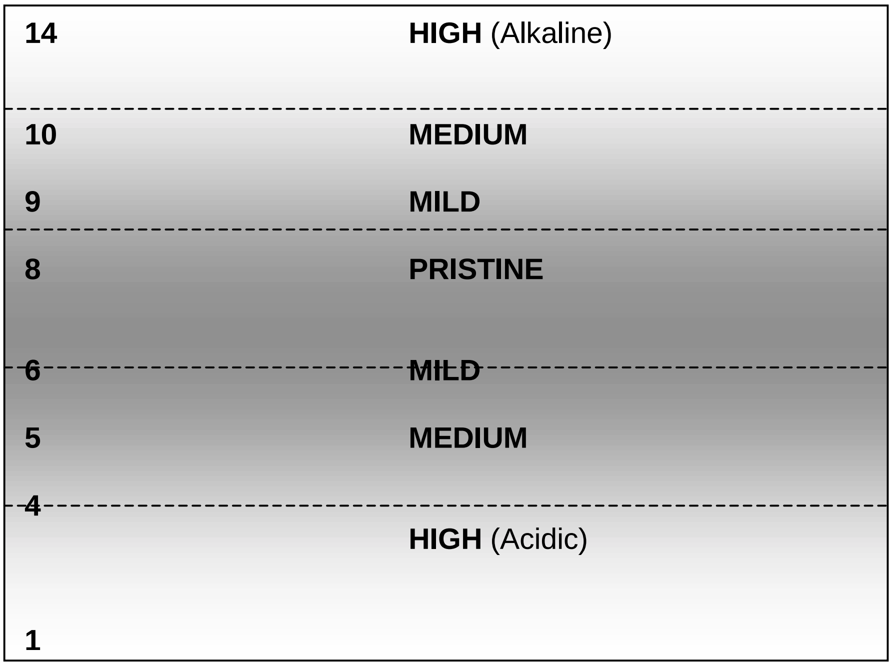

Figure 21-2. pH values

21.1.2 Analysis

The average pH of wetlands surveyed ranged between pH 6 and 8 (22 sites), which falls into a neutral pH value. Five sites recorded a pH reading of alkaline (pH between 9-14) Un-named Wetland 3 and Gum Flat recorded the highest pH readings of 9.57 and the lowest recorded pH value was 7.45 at Lake Bumbunga.

21.2 Conductivity

21.2.1 Background

Salinity is a serous threat to aquatic ecosystems throughout Australia. The National Land and Water Resources Audit 2001 estimates that up to 41,300 Kilometres of streams could be salt affected by 2050 and that 24 of 79 river basins studies exceeded recommended salinity parameters.

Salinisation causes serious biological effects including;

- changes to the natural character of water-bodies
- loss of biodiversity
- less salt-tolerant species are replaced by more tolerant species.

These effects can cause permanent degradation and ecosystem collapse (Williams 2001). The loss of biodiversity is probably greater than generally realised since very little research has occurred in this area. Salinisation also leads to significant decreases in water quality for irrigation and water supply (leading to high economic costs); the loss of amenity and aesthetic values is also of concern.

Limited data are available for assessing the risk of adverse effects from salinity in different ecosystem types, particularly wetlands. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2001) tables wetlands in South Australia with ‘no data’ related for assessing adverse effects of salinity. Guidelines developed for Western Australia state that lakes, reservoirs and wetlands should have a salinity range between 300-1500µs. Values at the lower end of the range are during rainfall events, those at the higher range are found in salt lakes and marshes.

Figure 21-1 is based on the salt measurement conversions guide from the Land Management Society Inc. This guide indicates salinity levels and tolerance levels for different parameters. These guidelines form the basis of analysis for the Wetland Inventory.

21.1.2 Analysis

Table 21-1 outlines the salinity recordings for 26 wetlands. Nelshaby Reserve recorded the lowest reading of 566 µs, which is regarded as freshwater. One wetland (Gum Flat) recorded brackish readings and a total of 22 wetlands recorded high to extreme salinity levels.

Table 21-1. Salinity guidelines.

Salinity in micro-siemens per cm µs/cm	Water definition	Guides	Surveyed Wetlands
0 - 900	Fresh	Fresh	Nelshaby Reserve (566 µs)
900 - 2700	Marginal	Maximum for hot water systems, dam water starts to go clear, maximum for people.	No records
3000 - 9100	Brackish	Maximum for milking cows and poultry, crop losses start.	Gum Flat
9500 +	Salt	9500 = Yabbie growth starts to slow, maximum for horses. 14500 = Yabbie growth ceases 64.0 Ms/cm = Sea Water 100.0 Ms/cm = Limit for salt bush	A total of 23 wetlands fall into this category with the highest reading occurring at Lake Bumbunga (185.0 Ms/cm)

Nelshaby Reserve near Port Pirie recorded the lowest conductivity reading of 566 µs

Plate 6. Nelshaby Reserve.

21.3 Turbidity

Turbidity is a measure of water clarity and can be affected by the amount of suspended particles of clay, silt, plankton, industrial wastes and sewage in water. Turbidity is caused by small particles suspended in water which are too small to settle out, but big enough to scatter light. At higher levels of turbidity, water loses its ability to support a diversity of aquatic organisms, and water becomes warmer as suspended particles absorb heat from the sun. Turbidity leads to less light penetrating the water, thereby decreasing photosynthesis, which in turn reduces dissolved oxygen concentrations. Suspended particles may also clog aquatic invertebrate appendages and fish gills, reduce growth rates, and prevent egg and larval development. The plant community structure and biomass in an ecosystem is determined by the light regime, in conjunction with nutrients and temperature. Changes in water clarity may produce changes in the dominant phytoplankton groups. A common result from increased clarity tends to reduce the primary productivity of systems. Changes to the primary producers will also effect the other trophic components of the ecosystem (Liston and Maher 1997).

Turbidity can have a significant effect on the microbiological quality of drinking-water, and its presence can interfere with the detection of bacteria in drinking-water. Turbid water has been shown to stimulate bacterial growth since nutrients are adsorbed on to particulate surfaces, thereby enabling the attached bacteria to grow more rapidly than those in free suspension. The major problem associated with turbidity is its effect on disinfection. High levels have been shown to protect microorganisms from the action of disinfectants and to increase the chlorine and oxygen demand.
(http://www.who.int/water_sanitation_health/GDWQ/Chemicals/turbidity.htm).

Turbidity in water is measured in units called Nephelometric Turbidity Units (NTU's,). It is calculated by measuring the dispersion of a light beam passed through a sample of water. Fine particles, silt, and suspended matter will cause a light beam passing through the water to be scattered. It has been found that the amount of scattering is proportionate to the amount of turbidity present. Therefore, this process gives a good indication of the relative turbidity of a water sample.

The measurement of NTU does not give the sizes of the particles, nor does it indicate the amount of particles present. It is a qualitative, rather than quantitative way of measuring turbidity.

21.3.1 Background

To understand the results fully, information about the natural levels of turbidity within all the survey wetlands at various times of the year is really required. This is important because normal levels of turbidity can vary greatly in wetlands from clear flowing zones to murky areas. Natural variations are also related to flow events such as floods, winter rains, road run-off which can increase levels dramatically.

The *Australian Water Quality Guidelines for Fresh and Marine* Waters do not set a turbididty guideline for the protection of aquatic ecosystems, but recommend that increases in suspended solids should be less than 10% of the seasonal mean NTU. This reinforces the need to ascertain the natural turbidity levels within waterbodies in the Northern Agricultural Districts.
Bek and Robinson (1991) also suggest that turbidity below 50 NTU is suitable for protecting aquatic animals and plants. The 2000 update of *Australian Guidelines for Water Quality Monitoring* does provide some turbidity ranges for South-Central Australia. These ranges however are so broad they could not be used as a measure against the Wetland Inventory turbidity results for the Northern Agricultural Districts.

The New South Wales Environmental Protection Agency, (EPA) has developed the following general guidelines for turbidity. These guidelines provide a useful method for comparing the turbidity values collected during the Wetland Inventory.

- good (< 5 NTU)
- fair (5-50 NTU)
- poor (> 50 NTU)

Refer to: http://www.epa.nsw.gov.au/soe/97/ch3/11.htm for more information.

The National Advisory Committee to Water on the Web has developed regional trends of fresh water fish activity against turbidity values and time, (figure 21-5).
(See: http://wow.nrri.umn.edu/wow/under/parameters/turbidity.html for more information)
These trends correspond well to those guidelines developed by the NSW EPA, mentioned above.

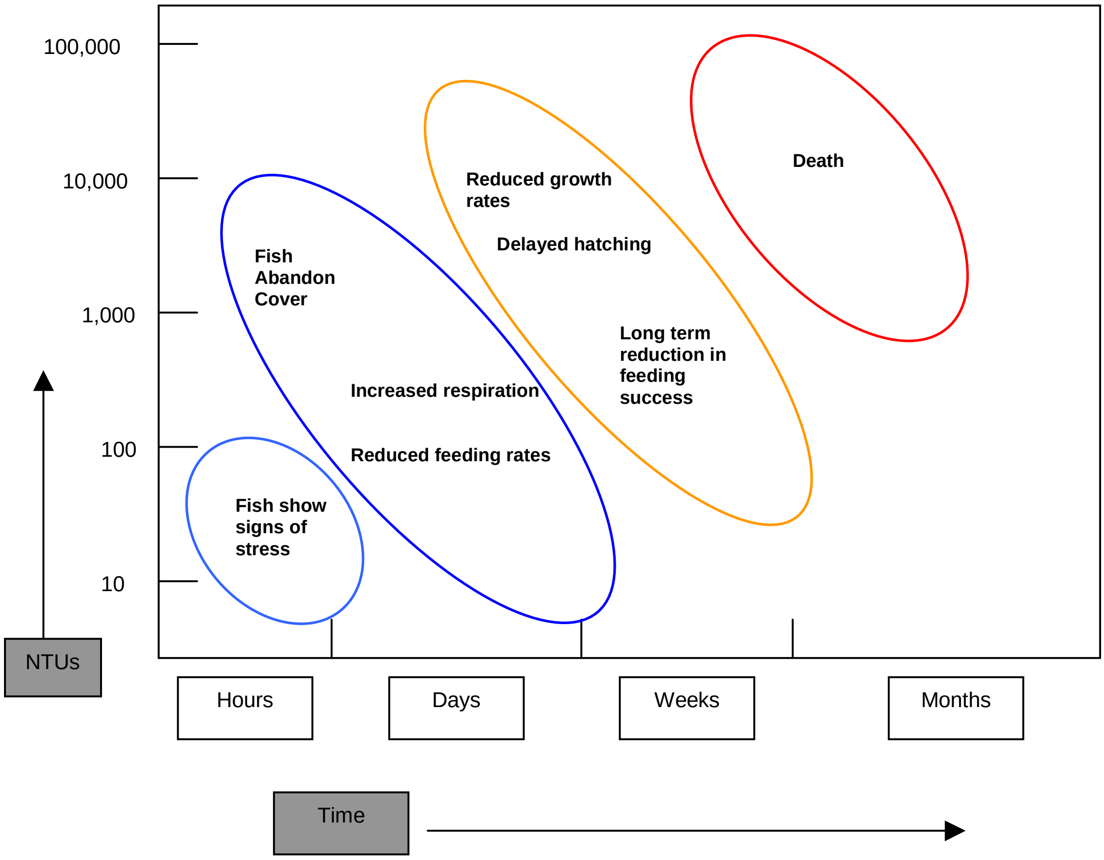

Figure 21-3. Fish activity against turbidity values and time

21.3.2 Analysis

Table 21-2 illustrates the number of surveyed wetlands against the turbidity guidelines developed by the NSW EPA. The majority of wetlands recorded a NTU value less than 5 (15 sites). Ten sites recorded NTU readings between 5-50, and two sites (Lake Sunday and Snowtown Golf Lake) recorded the highest reading of 80 and 81 NTU's.

Table 21-2. Turbidity guidelines.

Guideline	NTUs	Number of Wetlands
Good	**<5**	**15**
Fair	**5-50**	**10**
Poor	**>50**	**2**

Plate 7. Snowtown golf lake.

Snowtown Golf Lake is a highly turbid waterbody. , The direct cause is unknown, but sediment from catchment run-off is likely.

21.4 Water Temperature

21.4.1 Background

Many of the physical, biological and chemical characteristics of a wetland are directly affected by temperature. Temperature affects the solubility of oxygen in water with warmer water holding less oxygen than cooler water. These factors affect the rate of photosynthesis by algae and larger water plants, with warm water being susceptible to eutrophication and therefore algal blooms. The sensitivity of organisms to toxic waste, parasites and diseases is also related to water temperature. Organisms can become stressed as temperatures rise and become less resilient to other stresses. This results in most aquatic organisms having a narrow temperature range in which they can function effectively.

Most aquatic organisms are cold-blooded which means they are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms. To a point, the higher the water temperature, the greater the biological activity. Fish, insects, zooplankton and other aquatic species all have preferred temperature ranges. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are few, or none.

The most obvious reason for temperature change in lakes is the change in seasonal air temperature and water levels. Daily variation also may occur, especially in the surface layers, which are warm during the day and cool at night. In deeper lakes (typically greater than 5m for small lakes and 10m for larger ones) during summer, the water separates into layers of distinctly different density caused by differences in temperature, this process is called thermal stratification.

When the surface water cools again to approximately the same temperature as the lower water, the stratification is lost and the wind can turbulently mix the two water masses together because their densities are so similar. A similar process also may occur during the spring as colder surface waters warm to the temperature of bottom waters and the lake mixes. The lake mixing associated with a turnover often corresponds with changes in many other chemical parameters and this can affect biological communities (The National Advisory Committee to Water on the Web 2001).

For aquatic systems the maximum recommended increase in the natural temperature range of any inland or marine water is 2^0C (Waterwatch Manual 1994). Because the Wetland Inventory has recorded the first readings for many wetlands, this natural temperature range is largely unknown. As a general guide, temperatures between zero and 20 degrees are acceptable limits for Mediterranean climates, while temperatures over 20 degrees can start impacting on aquatic fauna and fauna.

21.4.1 Analysis

The lowest water temperature recorded was 17 degrees Centigrade (Tea Tree Swamp) and the highest was 28 degrees, (Pineville Wetland). The most frequently recorded temperature was 21 degrees (6 sites). Generally there was an even spread of temperatures across all the wetland surveyed. Temperature readings are required over several time periods and during different seasons to attain a true indication of temperature regimes for wetlands.

22.0 RAPID ASSESSMENT

The rapid assessment component of the survey provides a quick snap shot of the condition within different riparian habitats. This score is a subjective one given by the observer, it is an estimate of the percentage of intact native vegetation and the diversity and abundance of aquatic flora and fauna.

22.1 Aquatic Fauna

This is a subjective score according to the abundance and diversity of invertebrates, fish and birds located within the waterbody.

- Low (1) refers to no fish or birds with little or no invertebrate presence
- Moderate (3) refers to some bird presence and good vertebrate abundance, fish usually are not present
- High (5) indicates good bird and invertebrate diversity and abundance with or without the presence of fish.

Nineteen sites recorded a low score and ten sites recorded a moderate score.

22.2 Aquatic flora

The rapid assessment for aquatic flora records the abundance and diversity of aquatic vegetation. The following scoring method has been developed:

- Low (1) indicates no or very little aquatic vegetation
- Moderate (3) indicates some aquatic vegetation cover either in the form of floating or rooted vegetation
- High (5) indicates good diversity of aquatic vegetation with a range of rooted vegetation such as reeds and rushes and floating vegetation such as water ribbons.

Twenty-one sites recorded a low score and eight sites recorded a moderate score.

22.3 Riparian Vegetation Rapid Assessment

Riparian native vegetation is assessed in three zones. These are the toe of bank (low water to high water), bank (high water mark to buffer) and buffer (top of the bank to the buffer which can extend between 10 metres and 100 metres). The vegetation association for each zone consists of the dominant or co-dominant overstorey species and understorey species. The vegetation association for each zone is scored on the basis of the level of disturbance and vegetation cover within each zone.

The vegetation association scoring system consists of:

- Degraded or no vegetation (1) with less than 30% vegetation cover, and a high level of disturbance
- Natural (3) between 30 – 75% vegetation cover, with little disturbance
- Intact (5) over 75% vegetation cover with little or no disturbance.

22.3.1 Analysis

Table 22-1. Rapid Assessment scores

	Low	Moderate	High
Toe of bank	10	18	2
Bank	14	12	4
Buffer	24	4	2

Riparian vegetation was generally in either a degraded or a natural state. Very few wetlands recorded riparian vegetation as intact. Those wetlands located within the National Parks and Wildlife reserve system scored high rapid riparian vegetation assessment scores. The buffer score is of interest because it illustrates that much of the vegetation buffering surveyed wetlands is in a degraded state (24 sites).

Plate 8. Chain of Lakes.

Chain of Lakes is a good example of a wetland with an intact bank and buffer.

Plate 9. Diamond Lake.

Diamond Lake scored very poorly in the rapid assessment scores. The bank and buffer have been extensively cleared.

23.0 WETLAND CONDITION SCORE

The wetland score reflects the previous rapid assessment scores for aquatic fauna, aquatic vegetation and riparian vegetation values. The combination of these values and the interpretation of other parameters recorded during the survey (such as land degradation and water chemistry) form the basis of the wetland condition score.

The wetland score consists of:

- Degraded (1) those sites that have a high level of disturbance and received low rapid assessment scores.
- Natural (3) those sites that have little disturbance, received moderate to high rapid assessment scores and that are sites usually located within National Parks and Wildlife reserves or managed on private lands for conservation purposes.
- Intact (5) those sites with no obvious sign of disturbance, scored very highly in the rapid assessment and are formally conserved within National Parks and Wildlife reserves.

No sites recorded an intact score, seven sites recorded a natural score and 22 sites recorded a degraded score. The seven natural sites are within National Parks and Wildlife reserves or are private or local government reserves.

24.0 RAPID ASSESSMENT TOTAL SCORE

The total score provides an indication of the environmental attributes of wetlands surveyed. These values are an interpretation of the biological, chemical and physical parameters. This score consist of a tally of all the rapid assessment scores, including the wetland condition scores. The findings for the NAD were:

- 0 – 6 low wetland values = 8 wetlands
- 7 – 18 moderate wetland values = 19 wetlands
- 19 – 30 high wetland values = 2 wetlands.

These scores provided a quick means of assessing the environmental attributes of wetlands based on survey parameters. Those wetlands scoring high wetland scores should be more closely examined in terms of land ownership, placement within the landscape and the likely success of monitoring and protective measures.

Table 24-1. Wetlands with high rapid assessment scores.

Wetland name	Management Authority
Chain of Lakes	National Parks and Wildlife
Inneston Lake 2	National Parks and Wildlife

25.0 ANZECC WETLAND CRITERIA

These criteria are used for determining nationally important wetlands in Australia, and forms the basis for the inclusion in the Directory for Important Wetlands. These criteria were agreed to by the ANZECC Wetlands Network in 1994.

A wetland may be considered nationally important if it meets at least one of the following criteria:

1. *It is a good example of a wetland type occurring within a biogeographic region in Australia.*

2. *It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.*

3. *It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.*

4. *The wetland supports 1% or more of the national populations of any native plant or animal taxa.*

5. *The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.*

6. *The wetland is of outstanding historical or cultural significance.*

Application of the criteria to individual wetland sites involves a degree of subjectivity. Aspects of a site's significance can be interpreted differently by different surveyors, and information gaps often exist which make it difficult to judge whether or not a site meets a particular criterion.

The Interim Biogeographic Regionalisation for Australia (IBRA) is used as the framework for applying Criterion 1, which identifies wetlands that are unique or representative within a biogeographic region in Australia.

25.1 Analysis

Eight sites recorded Criterion 1 (*good example of a wetland type occurring within a biogeographic region in Australia)*. These are listed below.

• Gum Flat	DC Minlaton
• Native Hen Lagoon	Private ownership
• Chain of Lakes	NPWSA
• Brown Lake	NPWSA
• Deep Lake	NPWSA
• Inneston Lake	NPWSA
• Inneston Lake 2	NPWSA
• Tea Tree Swamp	Private sanctuary

26.0 WETLAND TYPES

The definition of a wetland used in the survey is one adopted by the Ramsar Convention under Article 1.1.

"Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent of temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

Within this definition, the wetland classification system used in the Directory of Important Wetlands identifies 40 different wetland types in three categories: A-Marine and Coastal Zone wetlands, B-Inland wetlands, and C-Human-made wetlands. This wetland survey does not include Category A – Marine and Coastal Zone wetlands .
The system is based on that used by the Ramsar Convention in describing Wetlands of International Importance, but was modified slightly to suit the Australian situation.

For the purposes of this wetland inventory a category has been included which documents artificial wetlands that have conservation values. This is classified as C10.

A – Marine and Coastal Zone wetlands

1. Marine waters - permanent shallow waters less than six metres deep at low tide, includes sea bays straits
2. Subtidal aquatic beds, includes kelp beds, sea-grasses, tropical marine meadows
3. Coral reefs
4. Rocky marine shores, includes rocky offshore islands, sea cliffs
5. Sand, shingle or pebble beaches, includes sand bars, spits, sandy islets
6. Estuarine waters, permanent waters of estuaries and estuarine systems of deltas
7. Intertidal mud, sand or salt flats
8. Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
9. Intertidal forested wetlands, includes mangrove swamps, nipa swamps, tidal freshwater swamps forests
10. Brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea
11. Freshwater lagoons and marshes in the coastal zone
12. Non-tidal freshwater forested wetlands

B – Inland wetlands

1. Permanent rivers and streams includes waterfalls
2. Seasonal and irregular rivers and streams
3. Inland deltas(permanent)
4. Riverine floodplains, includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
5. Permanent freshwater lakes (8 ha) includes large oxbow lakes
6. Seasonal/intermittent freshwater lakes (>8 ha) floodplain lakes
7. Permanent saline /brackish lakes
8. Seasonal/intermittent saline lakes
9. Permanent freshwater ponds (<8 ha) marshes and swamps on inorganic sols, with emergent vegetation waterlogged for at least most of the growing season
10. Seasonal/intermittent freshwater ponds and marshes on inorganic soils includes sloughs, potholes, seasonally flooded meadows, sedge marshes
11. Permanent saline/brackish marshes
12. Seasonal saline marshes
13. Shrub swamps, shrub dominated freshwater marsh, shrub carr, alder thicket on inorganic soil
14. Freshwater swamp forest, seasonally flooded forest, wooded swamps, on inorganic soils
15. Peat lands, forest, shrubs or open bogs
16. Alpine and tundra wetlands: includes alpine meadows, tundra pools, temporary waters from snow melt
17. Freshwater springs, oasis and rock pools
18. Geothermal wetlands
19. Inland, subterranean karst wetlands

C- Human-made wetlands

1. Water storage areas; reservoirs, barrages, hydro-electric dams, impoundment's (generally over 8 ha).
2. Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3. Aquaculture ponds; fish ponds shrimp ponds
4. Salt exploitation, salt pans, salines
5. Excavations; gravel pits; borrow pits, mining pools.
6. Wastewater treatment areas; sewage farms, settling ponds, oxidation basins.
7. Irrigated land; includes irrigation channels and rice fields, canals, ditches
8. Seasonally flooded arable land, farm land
9. Canals
10. Artificial wetlands with conservation values, Includes constructed wetlands and dams

26.1 Analysis

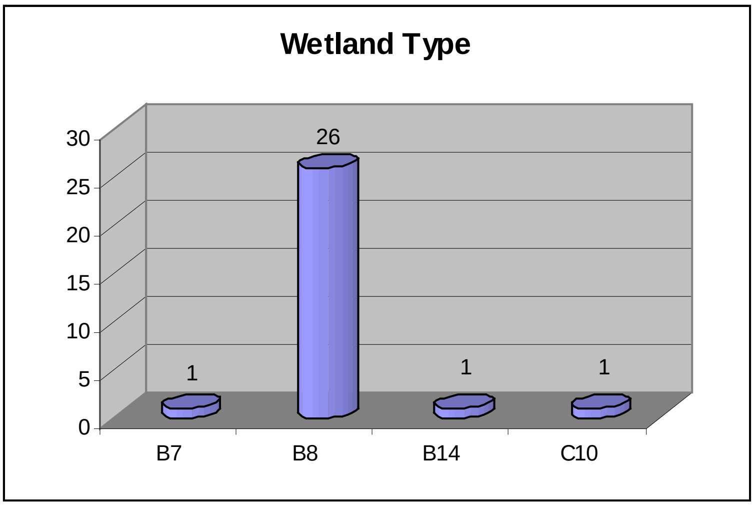

Figure 26-1. Wetland types of surveyed wetlands within the NAD.

The majority of the wetlands surveyed are classified as seasonal/intermittent saline lakes (B8). The other classifications that occurred include, Gum Flat (B14), Nelshaby Reserve (C10) and Tea Tree Swamp (B7).

Plate 10. Tea Tree Swamp.

Tea Tree Swamp is an excellent example of B7 - Permanent saline /brackish lake.

SECTION THREE WETLAND MONITORING

27.0 INTRODUCTION

There are three important steps in developing monitoring protocols that can be applied effectively within the South Australian wetland management context.

These consist of:

1. Identification of wetland values (collating and collecting existing information and undertaking baseline surveys)
2. Identification of wetland threats (from the analysis of wetland values)
3. Development of monitoring indicators that highlight early changes in ecological Character.

> *"Monitoring essentially means the keeping of a continual record of certain parameters, advising whether they are being maintained within prescribed limits and warning if undesirable changes occur" (Hart 1980).*

Finlayson and Eliot (2001) expand on this definition by emphasising that the information derived from monitoring provides a platform on which management actions are both based and judged.

Finlayson and Mitchell (1999) identified the following five major reasons for monitoring wetlands:

- To characterise variations in responses of wetlands to natural variability in the environment;
- To collect baseline data on wetlands as part of inventory processes;
- To record ecological changes that may be occurring as a result of specific natural or anthropogenic events;
- To measure progress toward set objectives of a management program; and
- To audit the performance of management agencies and land users.

27.1 Ecological change

The Ramsar Convention for Internationally Important Wetlands states that in order to record ecological change, the ecological character needs to be defined. Once defined it is possible to monitor for changes in ecological character.

Ecological character is 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. The process of completing a wetland inventory assists in establishing the ecological character for wetlands surveyed.

The 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 (www.ramsar.org/key_guide-list-e.html).

The Ramsar Convention provides detailed guidelines for monitoring the ecological character of wetlands. These include guidelines for initiating and conducting a risk assessment framework. The Ramsar risk assessment framework consists of six steps, these are:

Step 1 - Identification of the problem. This is the process of identifying the nature of the problem and developing a plan for the remainder of the risk assessment based on this information. It defines the objectives and scope of, and provides the foundation for, the risk assessment. In the case of a chemical impact, it would include obtaining and integrating information on the characteristics (for example, properties, known toxicity) and source of the chemical, what is likely to be affected, and how is it likely to be affected, and importantly, what is to be protected.

Step 2 - Identification of the adverse effects. This step evaluates the likely extent of adverse change or impact on the wetland. Such data should preferably be derived from field studies, as field data are more appropriate for assessments of multiple impacts, such as occur on many wetlands. Depending on the extent of adverse change and available resources, such studies can range from quantitative field experiments to qualitative observational studies. For chemical impacts, on-site ecotoxicological bioassays constitute appropriate approaches, whereas for changes caused by weeds or feral animals, on-site observation and mapping may be all that is required.

Step 3 - Identification of the extent of the problem. This step estimates the likely extent of the problem on the wetland of concern by using information gathered about its behaviour and extent of occurrence elsewhere. In the case of a chemical impact, this includes information on processes such as transport, dilution, partitioning, persistence, degradation, and transformation, in addition to general chemical properties and data on rates of chemical input into the environment. In the case of an invasive weed, it might include detailed information on its entry into an ecosystem, rate of spread and habitat preferences. While field surveys most likely represent the ideal approach, use of historical records, simulation modeling, and field and/or laboratory experimental studies all represent alternative or complementary methods of characterising the extent of the problem.

Step 4 - Identification of the risk. This involves integration of the results from the assessment of the likely effects with those from the assessment of the likely extent of the problem, in order to estimate the likely level of adverse ecological change on the wetland. A range of techniques exist for estimating risks, often depending on the type and quality of the likely effects and their extent. A potentially useful technique for characterising risks in wetlands is via a GIS-based framework, whereby the results of the various assessments are overlaid onto a map of the region of interest in order to link effects to impact. In addition to estimating risks, such an approach would also serve to focus future assessments and/or monitoring on identified problem areas.

Step 5 - Risk management and reduction**.** This is the final decision-making process and uses the information obtained from the assessment processes described above, and it attempts to minimize the risks without compromising other societal, community or environmental values. In the context of the Ramsar Convention, risk management must also consider the concept of *wise use* and the potential effects of management decisions on this. The result of the risk assessment is not the only factor that risk management considers; it also takes into account political, social, economic, and engineering/ technical factors, and the respective benefits and limitations of each risk-reducing action. It is a multidisciplinary task requiring communication between site managers and experts in relevant disciplines.

Step 6 - Monitoring**.** Monitoring is the last step in the risk assessment process and should be undertaken to verify the effectiveness of the risk management decisions. It should incorporate components that function as a reliable early warning system, detecting the failure or poor performance of risk management decisions prior to serious environmental harm occurring. The risk assessment will be of little value if effective monitoring is not undertaken.

The choice of endpoints to measure in the monitoring process is critical. Further, a GIS-based approach will most likely be a useful technique for wetland risk assessment, as it incorporates a spatial dimension that is useful for monitoring adverse impacts on wetlands.

28.0 MONITORING PROTOCOLS AND INDICATORS

The underlying concept of indicators is that effects can be detected before actual environmental impacts occur. While such a 'early warning' may not necessarily provide firm evidence of larger scale environmental degradation, it provides an opportunity to determine whether intervention or further investigation is warranted.

Early warning indicators can be defined as:

> *"The measurable biological, physical or chemical responses to a particular stress, preceding the occurrence of potentially significant adverse effects on the system of interest".*
> (http://ramsar.org/key_guide_risk_e.htm)

Typically, indicators are ecological communities or assemblages of organisms, habitat or keystone-species. Indicators are usually closely linked to ecosystem-level effects. In selecting an indicator it is important that the ecological character of a wetland which includes the biological, chemical and physical components of the ecosystem. Therefore, it may be useful to select early warning indicators according to which of the above three components are considered more susceptible to change within the wetland (Finlayson and Spiers, 1999).

The concepts of early warning and ecological relevance can conflict. As an example, biomarker responses can offer exceptional early warning of potential adverse effects. However, there exists very little evidence that observed responses result, or culminate in adverse effects at an individual level, let alone the population, community or ecosystem level (Finlayson and Spiers 1999). If the primary assessment objective is that of early detection, then it is likely that it will be at the expense of ecological relevance (Finlayson and Spiers, 1999).

van Dam *et al* (*in press*) in Finlayson and Spiers (1999), suggests early warning indicators should be:

1. **anticipatory**: it should occur at levels of organisation, either biological or physical, that provide an indication of degradation, or some form of adverse effect, before serious environmental harm has occurred;

2. **sensitive**: in detecting potential significant impacts prior to them occurring, an early warning indicator should be sensitive to low levels, or early stages of the problem;

3. **diagnostic**: it should be sufficiently specific to a problem to increase confidence in identifying the cause of an effect;

4. **broadly applicable**: it should predict potential impacts from a broad range of problems;

5. **correlated to actual environmental effects/ecological relevance**: an understanding that continued exposure to the problem, and hence continued manifestation of the response, would usually or often lead to significant environmental (ecosystem-level) adverse effects;

6. **timely and cost-effective**: it should provide information quickly enough to initiate effective management action prior to significant environmental impacts occurring, and

be inexpensive to measure while providing the maximum amount of information per unit effort;

7. **regionally or nationally relevan**t: it should be relevant to the ecosystem being assessed;

8. **socially relevant**: it should be of obvious value to, and observable by stakeholders, or predictive of a measure that is socially relevant;

9. **easy to measure**: it should be able to be measured using a standard procedure with known reliability and low measurement error;

10. **constant in space and time**: it should be capable of detecting small change and of clearly distinguishing that a response is caused by some anthropogenic source, not by natural factors as part of the natural background (that is, high signal to noise ratio);

11. **nondestructive**: measurement of the indicator should be nondestructive to the ecosystem being assessed.

Finlayson and Spiers (1999) discuss that the importance of the above attributes cannot be over-emphasized, since any assessment of actual or potential change in ecological character will only be as effective as the indicators chosen to assess it. However, an early warning indicator possessing all the ideal attributes cannot exist, as in many cases some of them will conflict, or will simply not be achievable.

28.1 Early warning indicators

Finlayson and Spiers (1999) outline a number of early warning indicators, these are placed into three broad categories:

1. rapid response toxicity tests;
2. field early warning tests; and
3. rapid assessments.

Each of the techniques may meet different objectives in water quality assessment programs. Although the majority of early warning indicators are of a biological nature, physico-chemical indicators do exist and often form the initial phase of assessing water quality (Finlayson and Spiers, 1999).

28.2 Toxicity tests

These represent rapid and sensitive responses to one or more chemicals. They provide an indication that there may be a risk of adverse effects occurring at higher levels of biological organization (for example, communities and ecosystems). Laboratory toxicity tests are of particular use for a chemical or chemicals yet to be released into the aquatic environment (for example, a new pesticide or a pre-release waste water). They provide a basis upon which to make decisions about safe concentrations or dilution/release rates, thereby eliminating, or at least minimizing, adverse impacts on the aquatic environment. However, there are major differences in the ecological relevance of responses that can be measured (Finlayson and Spiers, 1999).

28.3 Field early warning indicators

These comprise of a range of techniques that are grouped together because they are used to measure responses or patterns in the field and thus provide a more realistic indication of effects in the environment. In contrast to rapid response toxicity tests, early warning field tests predict and/or assess the effects of existing chemicals. Some of the techniques can also be applied to biological and physical problems (Finlayson and Spiers, 1999).

28.4 Rapid Assessments

Rapid assessment is essentially the method used for this wetland inventory, and has the appeal of enabling ecologically-relevant information to be gathered over wide geographical areas in a standardised fashion and at relatively low costs. The trade-off is that rapid assessment methods are usually relatively ‘coarse’ and hence are not designed to detect subtle impacts.

Finlayson and Spiers (1999) point out that the attributes of rapid assessment include:

1. measured response is widely regarded as adequately reflecting the ecological condition or integrity of a site, catchment or region (that is, ecosystem surrogate);
2. approaches to sampling and data analysis are highly standardised;
3. response is measured rapidly, cheaply and with rapid turnaround of results;
4. results are readily understood by non-specialists; and
5. response has some diagnostic value.

The most powerful impact assessment programs will generally be those that include two types of indicator, namely those associated with early warning of change and those closely associated with ecosystem-level effects. The ecosystem-level indicator might include ecologically important populations (keystone species). With both types of indicators used in a monitoring program, information provided by ecosystem-level indicators may then be used to assess the ecological importance of any change observed in an early detection indicator.

29.0 RECOMMENDED INDICATORS FOR MONITORING SURVEYED WETLANDS

Monitoring **water chemistry** is recommended as an **early warning indicator** and monitoring **invertebrate composition** as an **ecosystem level indicator**.

Before these indicators can be used effectively in a monitoring program, more research and surveys are required. The wetland surveys undertaken within the NAD recorded information rapidly at one location and at one time of the year. An understanding of the natural levels of water chemistry and invertebrate composition for selected wetlands is needed before effective monitoring can occur.

29.1 Early warning indicators – Water chemistry

The collection of water chemistry parameters is suggested as the means for monitoring for early change in wetlands. Parameters essential to collect include conductivity, dissolved oxygen, temperature, turbidity and pH. Conductivity will probably play an important indicator providing the first early warning change within wetlands.

29.2 Ecosystem based indicator

Invertebrates are recommended as indicators for ecosystem monitoring. Yen and Butcher (1997) outline the important features of invertebrates which make them useful as indicators. These include;

1. Invertebrates are ecologically and functionally important.
2. Invertebrates are diverse, providing a good range from which to choose suitable taxa.
3. Many species are habitat specific.
4. Many species are abundant and are relatively simple to collect.

Indicator taxa should be selected on a regional basis and that are sensitive to environmental change. Indicator species should also be selected that have been identified as keystone species, these species play critical ecological roles, and their loss may result (directly or indirectly) in the disappearance of several other species (Soule and Kohm, 1989; Lawton, 1991 in Yen and Butcher, 1997).

Research is required towards developing these indicators. Yen and Butcher (1997) suggest research in the following areas:

- The link between invertebrate biodiversity and ecosystem functioning.
- The value of using guilds or functional groups to monitor ecosystem processes.
- Identifying keystone taxa.
- The existence of redundant species.

The interaction between invertebrate composition and water chemistry also requires more research. Without an understanding of the dynamics between these two parameters, interpretation of ecological change will be hindered.

An example of how the invertebrate monitoring program can be applied to detect change in ecological character is to study the trophic dynamics or functional groups. The presence of both invertebrate grazers and predators indicates functional invertebrate dynamics. The loss of either group quickly indicates change in the ecological character of the wetland.

The development of keystone indicator species requires further research, However, as a starting point there are several families that can be used in starting to develop these indicators. Representative grazers and predators are important to include as indicators due to their importance in the trophic chain.

Keystone species to monitor include:

Grazers: zooplankton, including Cladocera, Copepods, Calanoida and Cyclopoida.

Predators: dragonfly larvae (Odonata) and the families Dytiscidae and Coleoptera.

29.3 Other considerations

Monitoring is also required for many other parameters. Programs need to include whole of catchment parameters that cause change in the ecological character of wetlands. Monitoring of threats to wetlands such as land clearance and management, drainage, land ownership changes and land use changes all need to be documented and included in the monitoring program. Ideally an action plan to alleviate and manage threats should be developed for nominated wetlands in conjunction with a monitoring program.

30.0 RECOMMENDED WETLANDS TO MONITOR

Those wetlands that received a high wetland score and fulfilled the ANZECC criteria for an important wetland are priority wetlands to monitor. The second criteria used to identify priority wetlands is the management authority. Those wetlands that are under public ownership are targeted as preferential sites to monitor, unless significant wetland values are identified on private lands. The reasoning behind this is that wetlands within the community land classification or under State government ownership may be easier to access and manage a monitoring program. At this early stage of developing a monitoring program the nominated sites will assist in refining techniques and develop monitoring protocols.

Once monitoring techniques have been developed and tested, the opportunity to expand monitoring to other wetlands with high conservation value on private property is feasible. Other protection measures can be developed for wetlands on private property before monitoring occurs. Actions such as buffering wetlands with revegetation, fencing, removing rubbish and the development of wise use of wetland programs for landowners are currently required to manage wetland threats. The following wetlands that are recommended for monitoring cover a broad range of wetland types, display different water regimes, vegetation structure and geographical locations.

30.1 Recommended priority wetlands to monitor

Table 30-1. Recommended wetlands to monitor

Wetland site number	Wetland name	Wetland features	Management Authority
S4019	Gum Flat	Gum Flat, located near Minlaton contains *Eucalyptus camaldulensis var. camalduensis* which is rated as Vulnerable on Yorke Peninsula. This wetland also displayed good invertebrate trophic levels. A report by Moore and Ciganovic (1999) provides several different management strategies for this area and if implemented, monitoring should also occur to evaluate success.	District Council of Yorke Peninsula
S4026	Native Hen Lagoon	Interesting seasonal waterbody with an abundance of invertebrate species present. Groups of Stilts and Native hens were observed and 300 Grey teals were counted. Good remnants of *Melaleuca halmaturorum tall shrubland* over *Gahnia lanigera* open sedgeland is present, (*Gahnia lanigera* is not formally conserved in South Australia).	Private. Although under private ownership, this wetland is one of the last remaining (if not the last) in the Yorketown saline lake district with reasonable biodiversity values.
S4002	Chain of Lakes	Good example of a intact saline lake	National Parks and Wildlife

Plate 11. Gum Flat

Plate 12. Native Hen Lagoon.

Plate 13. Chain of Lakes.

31.0 RECORDING MONITORING PARAMETERS

The wetland inventory template (refer to Section One and Appendix 1) should be used for the collection of baseline data. Once collected, analysis of the results is required to determine the values of the wetland, threats and possible key indicator groups. Routine collection of information is required in order to establish which monitoring indicators to use (early warning and ecosystem indicators). After a given time period, (to be determined for each site) comparison of the data is required to identify if any ecological change has occurred. Defining acceptable limits of ecological change will be difficult and may take some time until the wetland processes are understood. The suggested wetlands to monitor will be of value in developing reference sites for other wetlands in the region. The three wetlands suggested to monitor represent different wetland types, within different landforms and under a range of management regimes.

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http://www.who.int/water_sanitation_health/GDWQ/Chemicals/turbidity.htm

http://www.epa.nsw.gov.au/soe/97/ch3/11.htm

http://wow.nrri.umn.edu/wow/under/parameters/turbidity.html

www.ramsar.org/key_guide-list-e.html

http://ramsar.org/key_guide_risk_e.htm

Other useful web sites

Water Watch
http://www.sa.waterwatch.org.au/

Environment Australia
http://www.ea.gov.au/water/wetlands/

Wetland Care Australia
http://www.wetlandcare.com.au/

Environmental Protection Agency
http://www.environment.sa.gov.au

AusRivas
http://ausrivas.canberra.edu.au/

Catchment Water Management Boards
http://www.catchments.net/

Invertebrates
http://www.umesci.maine.edu/ams/inverts.htm

Appendix 1 Wetland Inventory descriptions

Wetland Reference Number*:* The wetland reference number is critical for clearly defining wetland locations within regions of the State. The wetland reference number acts as the primary key for records for each wetland, this enables data transfer between databases and GIS tables.

Wetland Name*:* The name of the site.

Ramsar Site**:** If the wetland is listed as a Ramsar site.

Description of Site*:* A general description of the location features, closest roads or landmarks.

Current Land use

> ***On site****:* Current human use of the designated wetland area.
>
> ***Surrounding area****:* Human use on land adjacent to the wetlands, and more broadly in the surrounding catchment.

Tenure/ownership

> ***On site****:* Details of land ownership of the wetland site if possible.
>
> ***Surrounding****:* Details of the tenure type that is dominant in the surrounding areas if possible.

Jurisdiction and management authority*:* The name of the body or bodies responsible for management of the wetland.

Complied by: Name of person undertaking data collection.

Organisation: Organisation that is managing the data collection

Date/time*:* Date and time of data collection.

Region: Geographical region (eg Eyre Peninsula, Yorke Peninsula and Kangaroo Island)

Environmental Regions: This refers to broad environmental regions within South Australia as described by Laut P (1977), or regions described within the Regional Biodiversity Plans developed by the Department for Environment and Heritage (2000 – 2001).

Key Bio diversity Areas*:* The Department for Environment and Heritage has developed key biodiversity areas within the Regional Biodiversity Plans for South Australia. The key biodiversity areas have been developed by analysis of biological assets of the area and information from community groups. There are six key biodiversity areas identified within the three wetland study regions; these are: coastal wetland habitat areas, fragmented habitat areas, grassland habitat, large remnant area, ridgeline systems, threatened habitat area.

GPS reading*:* Taken in Latitude and Longitude or easting and northing.

Map Sheet and Reference*:* Record of map sheet name and number with grid reference if required.

***Approximate Area**:* usually recorded after of before survey by GIS query.

Elevation: in meters above sea level. Preferably recorded from GPS and compared with map sheet elevation values.

***Landform Element**:* Landform element definitions have been adapted from Heard and Channon (1997) Guide to a native vegetation survey using the biological survey of South Australia methodology, Section 3. Geographic Analysis and Research Unit, Department of Housing and Urban Development.

Sandy Plain: Large, very gently inclined or level element composed of fine grains of weathered rocks of quartz.

Limestone plain: Large, very gently inclined or level element of hard almost horizontally bedded limestone, which contains at least 80% of the carbonates of calcium or magnesium.

Rock outcrop: Any exposed area of rock that is inferred to be continuous with underlying bedrock on a large, very gently inclined or level element.

Drainage depression: Level to gently inclined, long, narrow, shallow open depression with smoothly concave cross-section, rising to moderately inclined side slopes, eroded or aggraded by sheet wash.

Open depression: Landform element that extends at the same elevation, or lower, beyond the locality where it is observed.

Closed depression: Landform element that stands below all points in the adjacent terrain.

Flat: Planar landform element that is neither a crest nor a depression and is level or very gently inclined (<3% slope).

Swale: Linear, level-floored open or closed depression excavated by wind, or left relict between ridges built up by wind or waves, or built up to a lesser height than them. Or long, curved open or closed depression left relict between scrolls built up by channelled stream flow.

Lagoon: Closed depression filled with water that is typically salt or brackish, bounded at least in part by forms aggraded or built up by waves or reef building organisms.

Hill crest: Very gently inclined to steep crest, smoothly convex, eroded mainly by creep and sheet wash. A typical element of mountains, hills, low hills and rises.

Hill slope: Gently inclined to precipitous slope, commonly simple and maximal, eroded by sheet wash, creep, or water-aided mass movement.

Gully: Open depression with short, precipitous walls and moderately inclined to very gently inclined floor or small stream channel, eroded by channelled stream flow and consequent collapse and water-aided mass movement.

Stream channel: Linear, generally sinuous open depression, in parts eroded, excavated, built up and aggraded by channelled stream flow. This element comprises stream bed and banks.

Flood out: Flat inclined radially away from a point on the margin or at the end of a stream channel, aggraded by over bank stream flow, or by channelled stream flow associated with channels developed within the over-bank flow part of a covered plain landform pattern.

Fan-alluvial: Large gently inclined to level element with radial slope lines inclined away from a point, resulting from aggradation, or occasionally from erosion, by channelled, often braided, stream flow, or possibly by sheet flow.

Estuary: Stream channel close to its junction with a sea or lake, where the action of channelled stream flow is modified by tide and waves. The width typically increases downstream.

Lake: Large water-filled closed depression.

Salt lake: Lake, which contains a concentration of mineral salts, (predominantly sodium chloride in solution as well as magnesium and calcium sulphate).
Swamp: Almost level closed, or almost closed depression with a seasonal or permanent water table at or above the surface, commonly aggraded by over-bank stream flow and sometimes biological (peat) accumulation.

Perched swamp: A tract of land that is permanently saturated with moisture and is positioned on an elevated landform.

Playa/pan: Large, shallow, level-floored closed depression, intermittently water-filled, but mainly dry due to evaporation, bounded as a rule by flats aggraded by sheet flow and channelled stream flow.

Geological formation name*:* Name of geological formation defined from the physical geography data sets available from http://www.atlas.sa.gov.au/

*Soil types****:*** Soil type definitions have been adapted from Heard and Channon (1997) Guide to a native vegetation survey using the biological survey of South Australia methodology, Section 3. Geographic Analysis and Research Unit, Department of Housing and Urban Development.
To determine soil texture take a small handful of soil below the crust and add water working the soil into a an elongated ball (bolus) until it just fails to stick to the fingers. The behaviour of the bolus and of the ribbon produced by shearing (pressing out) between the thumb and forefinger characterise the texture. The behaviour and feel, smoothness or graininess, during bolus formation are also indicative of its texture.

Sand: Coherence nil to very slight, cannot be moulded. Sand grains of medium size, single sand grains adhere to fingers. Commonly less than 5% clay content.

Loam: Bolus coherent and rather spongy, smooth feel when manipulated but with no obvious sandiness. May be somewhat greasy to the touch if organic matter in present. Will form a ribbon of about 25mm.

Clay Loam, Sandy: Coherent plastic bolus with medium size sand grains visible within a finer matrix, forms a ribbon between 40-50mm. Clay contents between 30% – 35%.

Medium clay: Smooth plastic bolus, can be moulded into rods without fracture. Will form a ribbon of 75 mm or more. Clay contents between 45% - 55%.
Medium heavy clay: Same properties as medium clay but with a higher clay content of 50% or more.

Loamy sand: Slight coherence, sand grains of medium size, can be sheared between thumb and forefinger to give minimal ribbon of about 5 mm. Approximate clay content of about 5%.

Silty loam: Coherent bolus, smooth, often silky when manipulated, will form a ribbon of about 25mm. Clay content between 25% with 25% or more of silt.
Silty clay loam: Coherent smooth bolus, plastic and often silky to the touch, will form a ribbon of 40-50mm. Clay contents between 30%-35% and with silt 25% or more.

Clayey sand: Slight coherence, sand grains of medium size, sticky when wet, many sand grains stick to fingers. Will form a minimal ribbon of 5-15 mm, discolours fingers with clay stain. Clay contents between 5%-10%.
Sandy clay loam: Strongly coherent bolus, sandy to touch, medium size grains visible in finer matrix, will form ribbon of 25 – 40mm. Clay contents between 20% - 30%.
Light clay: Plastic bolus, smooth to touch, slight resistance to shearing between thumb and fore finger, will form ribbon of 50 – 75 mm. Clay content between 35% - 40%.

Heavy Clay: Smooth plastic bolus, handles like stiff plasticine, can be moulded into rods without fracture, has firm resistance to ribboning shear. Will form a ribbon of 75 mm or more. Clay contents of 50% or more.

Sandy loam: Bolus coherent but very sandy to touch, will form a ribbon of 15-25 mm, dominant sand grains are of medium size and are readily visible. Clay contents between 10% - 20%.

Clay loam: Coherent plastic bolus, smooth to manipulate and will form a ribbon of 40 – 50 mm. Clay contents between 30% and 35%.

Light medium clay: Plastic bolus, smooth to touch, slight to moderate resistance to ribboning shear, will form a ribbon of about 75 mm.

Peat: Brownish or blackish fibrous substance produced by anaerobic decay of vegetation and found in boggy areas.

Comments: Any comments regarding soil structure, surface materials, rock contents or other soil attributes.

***Source of water supply**:* The main sources of water that enter the water body, most commonly a combination of catchment run-off, ground-water and rainfall.

***Rainfall estimate**:* Isohyet information gained from the Bureau of Meteorology for annual average rainfall. Also easily accessed by overlaying GIS isohyet information on the wetlands.

***Dominant riparian vegetation association**:* Describes the dominant or co-dominant over storey species and understorey species.

***Significance – why the wetland is important**:* Details any significance of the wetland within its regional setting or ecological function.

***Noteworthy flora**:* Threatened species: threatened flora at national or State level that occur on the site (includes any threatened species identifies under national or State legislation, ANZECC lists or action plans). Composition information on the composition of any plant species or communities for which the wetland is particularly important.

***Noteworthy fauna**:* Threatened species: list of threatened fauna at national or State level that are present at the site. (includes any threatened species identifies under national or State legislation, ANZECC lists or action plans). Composition: information regarding composition of important fauna that may inhabit the wetland permanently or seasonally including migratory species. An indication of population sizes, breeding colonies, migration stopovers is also given where available.

***Land Degradation**:* disturbances or threats are defined as any direct or indirect human activities at the site or in the site or in the catchment area that may have a detrimental effect on the ecological character of the wetland. The effect may be a low level disturbance (eg low level grazing) or a major threat (eg water diversion schemes). Examples include disturbance by stock, water extraction, river regulation, siltation, salinity, urban development, drainage, pollution, excessive human activity, and impact of invasive species. There are several typical types of land degradation that may affect wetlands; these are listed as a standard template within the survey.

- Access tracks
- Cleared land
- Fire breaks
- Off-Road vehicles
- Rubbish dumping
- Pollution
- Pest vertebrate presence
- Altered water flows
- Borrow pits/Quarry
- Drains
- Fence lines
- Power lines
- Slashing/clearance
- Watering points
- Grazing damage
- Wetland drainage

***Comments**:* Clarification of the severity of the threats and other comments.

***Potential disturbances**:* Any threats that could impact on the wetland in the future, for example, a planned change in adjoining land use.

***Conservation measures taken and measures proposed**:* Details of conservation measures being undertaken at the site (for example, fencing or revegetation) and the names of any protected areas established at or around the wetland. Details of management plans for the site and status of the site in terms of National Estate, Ramsar or World Heritage listing can also be included.

***Current scientific research**:* Outline any research activities by scientific bodies such as CSIRO or universities or other recognised research organisations.

***Current conservation education**:* Documents the existence of interpretive facilities, use of the area by school groups or other organisations.

***Recreation and tourism**:* Records recreation facilities present on the site and if there are tourism uses or values with the site.

***Social and Cultural Values**:* Documents pre-European and European historical and social values of the site.

***References**:* Lists relevant references associated with the site.

Aquatic Vegetative Classes

This parameter provides a snap shot of aquatic vegetation structure, vegetation classes recorded include:

- Algal
- Aquatic moss
- Rooted vascular
- Floating leaved
- Floating vascular
- Unknown submergent
- Unknown surface

Aquatic Flora Sample

Records any aquatic vegetation sample collected with the wetland number, wetland name, GPS location, and habitat location. Samples should be placed into a snap lock plastic bag with water and labels placed inside and outside the bag. If field trips are longer than for one day, samples should be dried and pressed that day. Pressed samples will need the paper changed every other day to avoid the specimen rotting. The Plant Biodiversity Centre can assist with plant identification and a good reference books for aquatic plant identification include *Waterplants in Australia* by G.R. Sainty (1994) and *Aquatic and wetland plants* by Nick Romanowski (1998).

Aquatic Fauna Sample

Collecting Sample Material: This is achieved by two methods.

1. **Plankton Net**. This is a small round net of approx. 200-250um pore size. Attached to the net is a length of string. One end of the string is tied to the plankton net. The other should be tied to the user of the net. The net is thrown into the water and is pulled through the water, towards the user. This procedure is done several times until sufficient sample material is collected.

If the water is too shallow then the net may be used by holding the metal rim and scooped through the water until sufficient sample material is collected in the plastic vial at the end of the net.

The sample material is then transferred from the sample vial to another vial, and 40% formalin is added to the sample to make up a mixture of approx.10% Formalin and 90% sample fluid.

2. **Hand Net**. The use of the hand net is a simple method. This is used in weedy habitats or shallow areas where the plankton net may become stuck or lost on objects. The net is used to prod at the base of vegetation and is run closely to the bottom of shallow water bodies. This is done over approx. 10-20 metres distance to obtain a representative sample from the water body.

The material in the net then is transferred to one or two sample vials.

Washing the Nets: This is done between sampling of each site in an attempt to clean the net of invertebrates to stop cross “contamination” of samples between sites. Cleaning of the net between sites is achieved by simply washing the net in the water of the site, without the sample vial attached. Ideally this should be done before and after a sample is taken.

Labelling Sample Vials: This is extremely important and should be done in a legible manner. The label should clearly and legibly be written upon and information recorded should be clearly stated.

Information recorded includes:

- Wetland number
- Name of wetland
- Date of Sample
- Grid Reference of site
- Method of collection (hand net or plankton net).

Material preservation of sample: material collected should be preserved with approximately 10% formalin as soon as possible after the sample is collected. This stops decomposition of the sample and also many of the invertebrates from eating each other. Formalin is used as many of the microinvertebrates become soft and mushy, denaturing in the 70% alcohol solution, used to preserve macroinvertebrates and vertebrates.

The formalin supplied is 40% by volume. This should be added to the sample material to make up approximately 10% formalin and 90% sample material. This is only a guide and should be used by the sampler with a degree of care.

Formalin is a dangerous chemical and is a fixative. Do not inhale it and wash your hands after use thoroughly. Read instructions on the label before use.

Water phys-chemistry

Five standard water chemistry parameters are collected; these are described below.

PH : is recorded using a Hanna HI 9025 pH meter. The meter is placed into the water body (ensuring that the probes do not touch the substrate). The reading is then given on the display. Calibration and maintenance of the pH unit is often needed, these procedures are outlined in the pH manual supplied with the unit.

Conductivity: is recorded using a Hanna HI 9635 meter. This meter can measure in the 0 to 199 µS/cm range. It can be used to measure any sample from deionised water to highly saline water. The meter is placed in the water body ensuring that the probe does not touch the substrate and the reading is given on the display when stable. Calibration and maintenance procedures required are outlined in the manual.

Turbidity: is recorded using a Hanna HI 93703 portable microprocessor turbidity meter. The unit is designed to perform measurements according to the ISO 7027 International Standard. The instrument functions by passing a beam of light through a vial containing the sample being measured. A sensor, positioned at 90º with respect to the direction of light, detects the amount of light scattered by the undissolved particles present in the sample. These readings are given in NTU units. The manual accompanying the unit outlines measurement, calibration and maintenance procedures.

Dissolved O^2: is recorded using a Hanna HI 9142 dissolved oxygen meter. Dissolved oxygen is indicated in tenths of parts per million (ppm=mg/l). The dissolved oxygen probe has a membrane covering the polarographic sensors and a built in thermistor for temperature measurements and compensation. The thin permeable membrane isolates the sensor elements from the testing solution, but allows oxygen to enter. When a voltage is applied across the sensor, oxygen that has passed through the membrane reacts causing current to flow, allowing the determination of oxygen content.

Water Temperature: Water temperature is read from the pH or Dissolved Oxygen meter.

Rapid assessment (conservation values)

The rapid assessment component of the survey provides a quick snap shot of the vegetation associations and condition within different riparian habitats. Other parameters such as aquatic fauna and wetland condition is also recorded.

Aquatic Fauna*:* is a subjective score according to the abundance and diversity of invertebrates, fish and birds located within or on the water body.

- Low (1) refers to no fish or birds with little or no invertebrate presence.
- Moderate (3) refers to some bird presence and good vertebrate abundance, fish usually are not present.
- High (5) indicates good bird and invertebrate diversity and abundance with the presence of fish.

Aquatic Vegetation*:* records the abundance and diversity of aquatic vegetation.

- Low (1) indicates no or very little aquatic vegetation.
- Moderate (3) indicates some aquatic vegetation cover either in the form of floating or rooted vegetation.
- High (5) indicates good diversity of aquatic vegetation with a range of rooted vegetation such as reeds and rushes and floating vegetation such as water ribbons.

Riparian Vegetation

Riparian vegetation is assessed at three zones, these are the
- toe of bank (Low water – High water),
- bank (high water mark – buffer) and
- buffer (top of the bank to the buffer which can extend between 10 meters and 100 meters).

The vegetation association for each zone consists of the dominant or co-dominant over storey species and understorey species. The vegetation association for each zone is scored considering the level of disturbance and vegetation cover within each zone.

The vegetation association scoring system consists of:
- Degraded or no vegetation (1) with less than 30% vegetation cover, with high level of disturbance.
- Natural (3) between 30 – 75% vegetation cover, with little disturbance.
- Intact (5) over 75% vegetation cover with little or no disturbance.

Wetland Condition

The wetland score should reflect the previous rapid assessment scores for aquatic fauna, aquatic vegetation and riparian vegetation values. The combination of these values and the interpretation of others parameters recorded during the survey (such as land degradation and water chemistry) form the basis of the wetland condition score.

The wetland score consists of:
- Degraded (1) those sites that have a high level of disturbance and received low rapid assessment scores.
- Natural (3) those sites that have little disturbance, received moderate to high rapid assessment scores and that are sites usually protected within the reserve system or by private conservation.
- Pristine (5) those sites with no obvious sign of disturbance, scored very highly in the rapid assessment and are formally conserved within the reserve system.

Photographic records

Photographic records for this survey have been recorded by digital camera in JPEG and BITMAP format. The following records should be kept when using a digital camera. It is recommended that a Laptop computer be taken on surveys for ease of cataloguing photographs.

All pictures need the following information recorded:

- Picture number and wetland number
- Direction and features if relevant
- Photographer name and date.

ANZECC wetland criteria

This criteria is used for determining nationally important wetlands in Australia, and form the bases for the inclusion in the Directory. These criteria are those agreed to by the ANZECC Wetlands Network in 1994.

A wetland may be considered nationally important if it meets at least one of the following criteria:

- It is a good example of a wetland type occurring within a biogeographic region in Australia.

- It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.

- It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.

- The wetland supports 1% or more of the national populations of any native plant or animal taxa.

- The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.

- The wetland is of outstanding historical or cultural significance.

Many of the sites in the Directory meet more than one of the criteria. Application of the criteria to individual wetland sites involves a degree of subjectivity. Not only may certain aspects of a site's significance be interpreted differently by different investigators, but information gaps often exist which make it difficult to judge whether or not a site meets a particular criterion.
The Interim Biogeographic Regionalisation for Australia (IBRA) is used as the framework for

applying Criterion 1, which identifies wetlands that are unique or representative within a biogeographic region in Australia.

<u>*Wetland type*</u>

The definition of a wetland used in the survey is one adopted by the Ramsar convention under Article 1.1.

"Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent of temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

Within this definition, the wetland classification system used in the Directory of Important Wetlands identifies 40 different wetland types in three categories: A-Marine and Coastal Zone wetlands, B-Inland wetlands, and C-Human-made wetlands. This wetland survey does not include Category A – Marine and Coastal Zone wetlands .

The system is based on that used by the Ramsar Convention in describing Wetlands of International Importance, but was modified slightly to suit the Australian situation.

A – Marine and Coastal Zone wetlands

- Marine waters - permanent shallow waters less than six metres deep at low tide, includes sea bays straits
- Subtidal aquatic beds, includes kelp beds, sea-grasses, tropical marine meadows
- Coral reefs
- Rocky marine shores, includes rocky offshore islands, sea cliffs
- Sand, shingle or pebble beaches, includes sand bars, spits, sandy islets
- Estuarine waters, permanent waters of estuaries and estuarine systems of deltas
- Intertidal mud, sand or salt flats
- Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
- Intertidal forested wetlands, includes mangrove swamps, nipa swamps, tidal freshwater swamps forests
- Brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea
- Freshwater lagoons and marshes in the coastal zone
- Non tidal freshwater forested wetlands

B – Inland wetlands

- Permanent rivers and streams includes waterfalls
- Seasonal and irregular rivers and streams
- Inland deltas(permanent)
- Riverine floodplains, includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
- Permanent freshwater lakes (8 ha) includes large oxbow lakes
- Seasonal/intermittent freshwater lakes (>8 ha) floodplain lakes
- Permanent saline /brackish lakes
- Seasonal/intermittent saline lakes
- Permanent freshwater ponds (<8 ha) marshes and swamps on inorganic sols, with emergent vegetation waterlogged for at least most of the growing season
- Seasonal/intermittent freshwater ponds and marshes on inorganic soils includes sloughs, potholes, seasonally flooded meadows, sedge marshes
- Permanent saline/brackish marshes

- Seasonal saline marshes
- Shrub swamps, shrub dominated freshwater marsh, shrub carr, alder thicket on inorganic soil
- Freshwater swamp forest, seasonally flooded forest, wooded swamps, on inorganic soils
- Pearlands, forest, shrubs or open bogs
- Alpine and tundra wetlands: includes alpine meadows, tundra pools, temporary waters from snow melt
- Freshwater springs, oasis and rock pools
- Geothermal wetlands
- Inland, subterranean karst wetlands

C- Human-made wetlands

- Water storage areas; reservoirs, barrages, hydro-electric dams, impoundment's (generally over 8 ha).
- Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
- Aquaculture ponds; fish ponds shrimp ponds
- Salt exploitation, salt pans, salines
- Excavations; gravel pits; borrow pits, mining pools.
- Wastewater treatment areas; sewage farms, settling ponds, oxidation basins.
- Irrigated land; includes irrigation channels and rice fields, canals, ditches
- Seasonally flooded arable land, farm land
- Canals

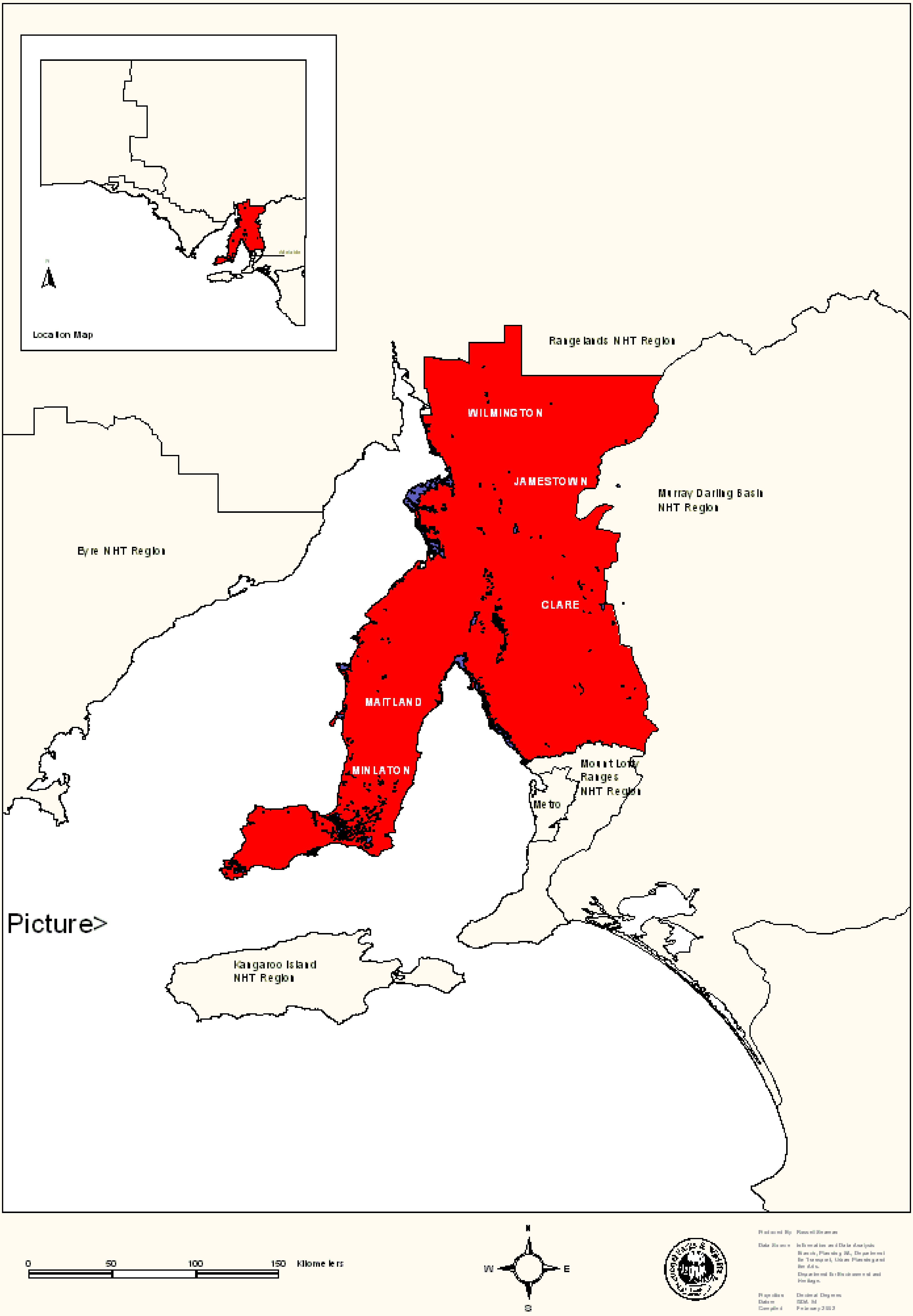
Appendix 2 Invertebrate records for surveyed wetlands

Wetland reference number	Family	Genus	Species
4001 – Thompsons Creek Wetland	Cyprididae	*Cypricercus*	*sp.*
	Cyprididae	*Mytilocypris*	*cf. Ambiguosa*
	Cyprididae	*Mytilocypris*	*cf. tasmanica chapmani*
	Centropagidae:	*Boeckella*	*triarticulata*
		Metacyclops	*mortoni*
	Daphniidae	*Daphnia*	*carinata*
		Lynceus	*sp.*
	Corixidae	*Agraptocorixa*	*sp*
	Corixidae	*Diaprapacorus*	*sp*
	Lestidae	*Austrolestes*	*annulosus*
	Notonectidae	*Anisops*	*sp*
S4002 – Chain of Lakes	Cyprididae	*Diacypris*	*cf spinosa.*
	Centropagidae	*Calomoecia*	*salina*
S4003 – Brown Lake	Cyprididae	*Diacypris*	*sp.*
	Centropagidae	*Calomoecia*	*salina*
	Daphniidae	*Daphniopsis*	*pusilla*
S4004 – Deep Lake	Cyprididae	*Diacypris*	*cf spinosa.*
		Parartemia	*cf zietziana*
S4005 – Inneston Lake		*Parartemia*	*cf zietziana*
S4006 – Inneston Lake 2	Cyprididae	*Diacypris*	*sp.*
	Cyprididae	*Mytilocypris*	*cf. ambiguosa*
	Centropagidae	*Calomoecia*	*salina*
		Parartemia	*cf zietziana*
	Hydrobiidae	*Coxiella*	*sp.*
S4018 – Diamond Lake		*Parartemia*	*cf zietziana*
S4010 – Old Salt Works Lake	Cyprididae	*Diacypris*	*sp.*
S4014 – Lake Sunday	Cyprididae	*Diacypris*	*sp.*
S4016 – Yorketown Center Lake	Cyprididae	*Diacypris*	*cf paracompacta*
S4017 – Pink Lake	Cyprididae	*Cypricercus*	*sp.*
S4020 – Minlaton Salt Lake	Cyprididae	*Diacypris*	*sp.*
	Cyprididae	*Mytilocypris*	*cf. tasmanica chapmani*
		Apacocyclops	*dengizicus*
		Mesochra	*baylyi*
	Ceiniidae	*Austrochiltonia*	*australis*

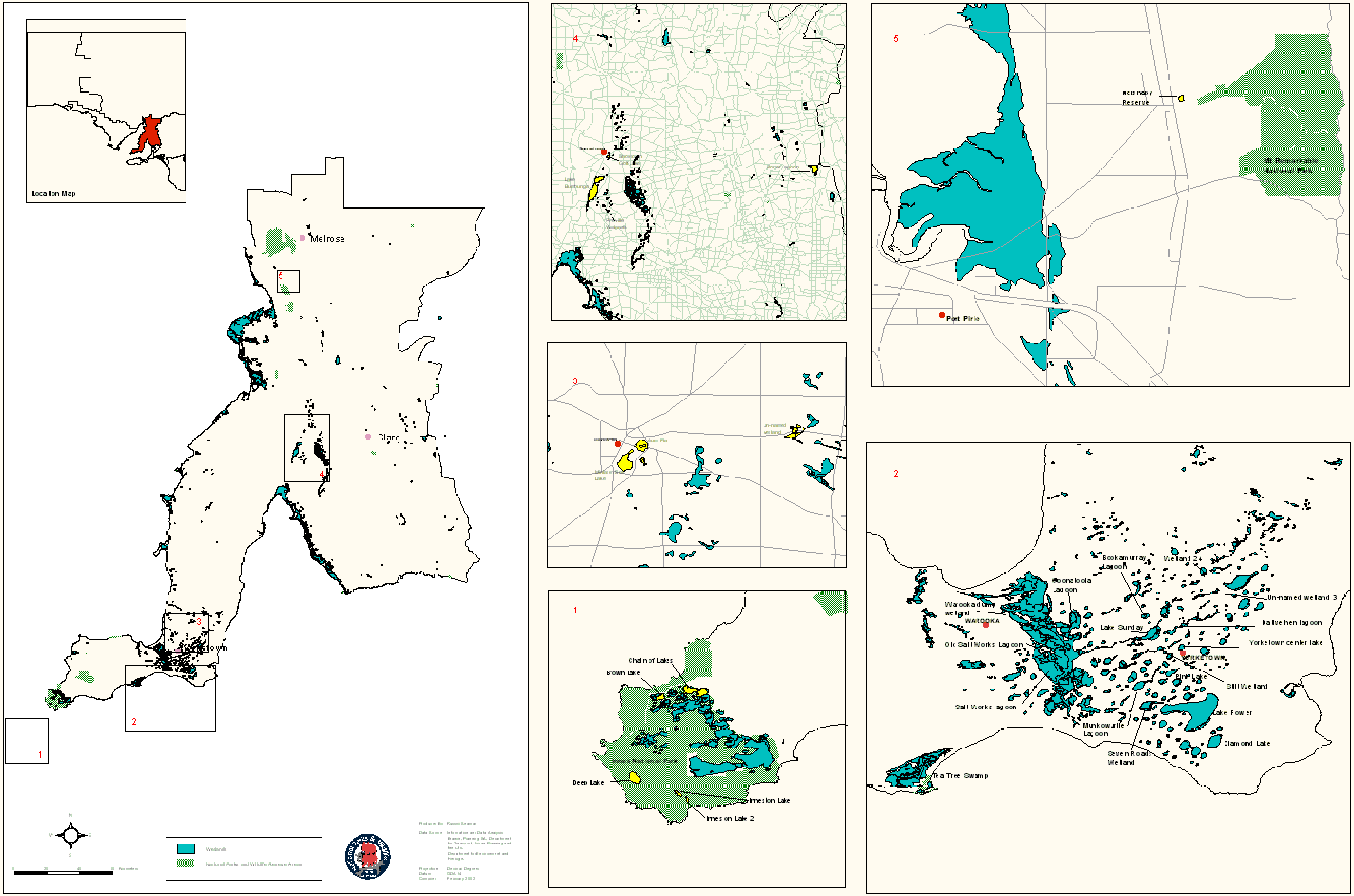
Wetland reference number	**Family**	**Genus**	**Species**
S4019 – Gum Flat	Cyprididae	*Diacypris*	*cf spinosa.*
	Cyprididae	*Mytilocypris*	*cf. Ambiguosa*
	Cyprididae	*Mytilocypris*	*cf. tasmanica chapmani*
	Centropagidae	*Boeckella*	*triarticulata*
		Metacyclops	*mortoni*
	Chydoridae	*Alona*	*sp.*
	Macrothricidae	*Macrothrix*	*spp*
		Lynceus	*sp.*
	Corixidae	*Agraptocorixa*	*sp*
	Lestidae	*Austrolestes*	*analis*
	Notonectidae	*Anisops*	*sp*
S4021 – Un-named Wetland	Cyprididae	*Diacypris*	*cf paracompacta*
	Cyprididae	*Mytilocypris*	*cf. tasmanica chapmani*
	Centropagidae	*Calomoecia*	*salina*
		Metacyclops	*mortoni*
		Mesochra	*baylyi*
	Daphniidae	*Daphniopsis*	*australis*
S4025 – Unnamed Wetland 3	Cyprididae	*Cypricercus*	*sp.*
	Cyprididae	*Mytilocypris*	*cf. ambiguosa*
	Daphniidae	*Daphniopsis*	*pusilla*
	Stratiomyidae	*Odontomyia*	*Larvae*
S4026 – Native Hen Lagoon	Cyprididae	*Diacypris*	*cf paracompacta*
	Cyprididae	*Mytilocypris*	*cf. ambiguosa*
	Cyprididae	*Mytilocypris*	*cf. tasmanica chapmani*
	Centropagidae	*Boeckella*	*triarticulata*
	Daphniidae	*Daphniopsis*	*pusilla*
	Macrothricidae:	*Macrothrix*	*spp*
	Lestidae	*Austrolestes*	*sp*
S4027 – Bookamurray Lagoon	Cyprididae	*Diacypris*	*sp.*
	Cyprididae	*Mytilocypris*	*cf. ambiguosa*
	Cyprididae	*Mytilocypris*	*cf. tasmanica chapmani*
	Metacyclops	*mortoni*	
	Daphniidae	*Daphniopsis*	*pusilla*
	Macrothricidae	*Macrothrix*	*spp*
		Lynceus	*sp.*
	Ceiniidae	*Austrochiltonia*	*australis*
	Lestidae	*Austrolestes*	*annulosus*
	Notonectidae	*Anisops*	*sp*
	Hydorphillidae	*Berosus*	*sp*
	Chironomidae	*Tanytarsini*	*sp*
S4028 – Nelshaby Reserve		*Australocyclops*	*australis*
	Corixidae	*Agraptocorixa*	*sp*
	Lestidae	*Austrolestes*	*sp*
	Notonectidae	*Anisops*	*sp*
	Oxygastridae	*Hesperocordula*	*sp*
	Chironomidae	*Procladius*	*sp*
	Chironomidae	*Chironomus*	*sp*

Wetland reference number	**Family**	**Genus**	**Species**
S4029 – Porter Lagoon		*Parartemia*	*cf zietziana*
S4007 – Tea Tree Swamp	Cyprididae	*Diacypris*	*sp.*
	Cyprididae	*Diacypris*	*cf paracompacta*
	Centropagidae	*Calomoecia*	*salina*

Map 1. Northern Agricultural Districts Natural Heritage Trust boundary



Map 2. Wetland survey locations within the Northern Agricultural Districts



Map 3. Environmental Associations containing surveyed wetlands