Defining reference condition for South Australian streams – Fleurieu Peninsula and Mount Lofty Ranges

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EPA1092/16: This information sheet describes the methods and outcomes of a study to monitor and assess streams of the Fleurieu Peninsula and southern Mount Lofty Ranges that may be in the best ecological condition as reference sites.

Introduction

The Environment Protection Authority (EPA) coordinates a monitoring, evaluation and reporting (MER) program on the aquatic ecosystem condition of South Australian inland waters. This MER program is designed to meet several objectives:

- Provide a statewide monitoring framework for creeks and rivers that revolves through the NRM regions with sufficient frequency to allow for State of the Environment Reporting purposes.
- Describe aquatic ecosystem condition for broad general public understanding.
- Identify the key pressures and management responses to those pressures.
- Provide a useful reporting format that can support environmental decision making within government, community and industry.

The inland MER program aims to assess and rate the ecological condition of creeks and rivers across the state using a six-tiered condition rating system, ranging from ‘Excellent’ to ‘Very poor’[1]. Since the MER program began in 2008, no site has been rated as Excellent. Consequently, a project was conducted by the EPA to determine if an Excellent rated site could be found by specifically targeting stream sites that met certain topographical requirements, which indicated they may be as near to unimpacted by human disturbance as possible. The Adelaide and Mount Lofty Ranges (AMLR) NRM region was chosen as the most suitable study area to focus on due to the high rainfall and high percentage of natural remnant vegetation in the region, particularly in parts of the Fleurieu Peninsula.

An excellent condition site represents one with minimal human disturbance (Figure 1) and can also be considered as being in reference condition. Reference condition can sometimes be defined as sites with a high degree of naturalness, where no or extremely little change in condition has occurred due to human actions or disturbance (eg Johnson *et al* 2013). However, often the degree of human disturbance that has occurred in the landscape, such as land clearance, agriculture and residential development, means the number of sites that can be truly considered to be in such a state are small, if any exist at all. Therefore, reference condition is most often considered to be a ‘least disturbed state’ where

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1 www.epa.sa.gov.au/environmental_info/water_quality/aquatic_ecosystem_monitoring_evaluation_and_reporting

some degree of human disturbance has occurred but has generally caused minimal impact to the aquatic community and water quality (eg Rosenberg *et al* 1999, US EPA 2013).

Reference condition sites are regularly used as a point of comparison for other monitoring sites and to assess the degree of degradation of a site (ie how much it differs from reference condition) due to pollution or some other impacts. Reference-condition approaches to biological assessments have commonly been used in the past to assess the impacts of anthropogenic activity on stream condition (Rosenberg *et al* 1999, US EPA 2013)

The factors used to determine if a site is in reference condition vary from country to country and can, in some cases, be driven by legislative requirements. For example, the European Water Framework Directive requires reference condition sites in the EU Member States to be those that are as near 'natural' as possible with no or very low human pressure (Johnson *et al* 2013). This includes no or very minor alterations in physico-chemical and hydro-morphological elements. In the United States and Canada physical, chemical and biological metrics are all commonly used to determine reference condition, typically based on expert knowledge and opinion (Rosenberg *et al* 1999, US EPA 2013).

This information sheet describes the findings of a project which specifically aimed to select, monitor and assess stream sites that may be in reference (or Excellent) condition in the AMLR NRM region. The focus of this study centred on identifying any streams or reaches in possibly reference condition but had not been sampled or identified through previous work in the region since 1994.

Sites were selected using GIS and expert knowledge of the Mount Lofty Ranges. The condition of streams was assessed through an expert panel deliberation that used a consistent descriptive modelling approach[2]. The panel members comprised an environmental consultant, and two biologists from the EPA. All have at least 15 years experience in monitoring and assessing a range of streams across South Australia.

Site selection

A total of 20 sites were chosen from the AMLR NRM region for monitoring and assessment based on topographical features (Figure 1 and Table 1). To select monitoring sites the region was mapped with GIS layers including towns, EPA licensed activities, sealed roads, dams and native vegetation presented on the map. The number of dams and presence of large dams (>0.05 Ha) within each catchment were identified and counted using GIS techniques. Initially the percentage of native vegetation was calculated for each catchment, based on vegetation present in the whole catchment. After sampling had occurred this calculation was modified to include only the amount of native vegetation upstream of the site. Sites were monitored in spring 2011 and autumn 2012.

[2] www.epa.sa.gov.au/files/477490_info_report_inland.pdf

Figure 1 Map showing sampling sites in the Mount Lofty Ranges and Fleurieu Peninsula

Table 1 Catchment area upstream of each sampling site presented with the percent cover of native vegetation within the catchment

Site name	Catchment area (ha)	% cover of native vegetation
Tributary of Sixth Creek, near Montacute Conservation Park	713	55
Fifth Creek, near Black Hill	950	75
First Creek, near Cleland Conservation Park	310	86
First Creek, near Fourth Falls	164	94
Brownhill Creek, Brownhill Creek Recreation Park	537	59
Minno Creek, near Long Gully	387	56
MacKereth Creek, near Scott Bottom	349	86
Tributary of Peters Creek, near Kangarilla Hill	972	12
Tributary of Hindmarsh River, near Hindmarsh Tiers	510	36
Wild Dog Creek, near Myponga Conservation Park	837	31
Boundy River, near Mount Alma	1,835	35
Waterfall Creek, near the waterfall	1,042	15
Dog Trap Creek, near Deep Creek Conservation Park	2,196	25
Tunkalilla Creek, near Eric Bonython Conservation Park	1,616	12
Callawonga Creek, downstream of Gold Diggings Swamp	1,264	23
Unnamed Creek, Deep Creek Conservation Park	228	100
The Wither Swamp, near Deep Creek Conservation Park	289	40
Boat Harbor Creek, at the mouth	1,989	45
The Deep Creek, at the waterfall	1,360	66
Aaron Creek, near Cobbler Hill	247	97

Sites were initially sampled in spring to eliminate those sites that were dry and would have no biological (macro-invertebrate) data for assessment. Many streams in South Australia are dry during the warmer months but have water during the winter and spring months. An assumption was made that if sites were dry in spring they would likely be dry in autumn as well. As it was important to know the macro-invertebrate assemblage that could exist at a site determined to be in Excellent condition, the dry sites were not included as part of this study.

Of the 20 sites which had water in spring 2011, three (Minno Creek, Fifth Creek and MacKereth Creek) were dry in autumn 2012. Sites were assessed using the same methodology used to assess other creek and river sites monitored through the South Australian EPA monitoring, evaluation and reporting program[3].

[3] www.epa.sa.gov.au/files/477490_info_report_inland.pdf

Sampling method

Macro-invertebrate samples were collected from each site according to the Australian River Assessment System (AUSRIVAS) sampling protocol for South Australia. This involved sampling a 10-m section of edge or riffle habitat using a triangular dipnet with 30-cm sides and a 250-µm mesh (Aurivas 1997). Edge and riffle habitats were sampled separately but all available micro-habitats (eg sandy bank, rocky section, reed beds) were sampled. Each sample was placed in a plastic screw-topped jar and preserved with methylated spirits in the field.

Macro-invertebrate samples were processed using the AUSRIVAS processing method for South Australia. This involved a subsampling technique where 10% of the sample was processed. If less than 200 individuals were counted in the first 10%, more of the sample was processed until 200 individuals had been enumerated and identified and the percentage of the sample processed was recorded. Specimens were identified by microscopy to the lowest taxonomic level possible using a collection of published and unpublished taxonomic guides.

At each site oxidised nitrogen, total Kjeldahl nitrogen, total nitrogen, total phosphorus, and chlorophyll *a* and *b* were analysed. Water samples were collected in plastic PET bottles and transported to a NATA accredited laboratory on ice for analysis. Samples collected for oxidised nitrogen analysis were first filtered in the field through a Sartorius filter (45 µm). Chlorophyll analysis was conducted by filtering 200 mL of water through a Whatman glass microfibre filter paper. The filter paper was then wrapped in alfoil and kept on ice during transportation to the laboratory for analysis. Field water quality parameters were also recorded at each site using a calibrated YSI multimeter and included pH, dissolved oxygen, conductivity and water temperature.

Other observations were also recorded in field including substrate type, presence and types of aquatic plants, coverage of aquatic plants and algae, and assessments on the degree and type of terrestrial vegetation, riparian vegetation, and sediment quality (ie colour, odour and presence of sulfidic sediment). The land use surrounding the site was also recorded.

The assessment

Members of the expert panel individually rated each site using a descriptive model for interpreting change in aquatic ecosystems in relation to increasing levels of disturbance (Davies and Jackson 2006). The assumption in this assessment is that biological (ecological) condition deteriorates as the degree of human disturbance in the catchment increases, and conversely, the best condition (or reference condition) occurs where there is little to no human disturbance of the environment (Figure 2).

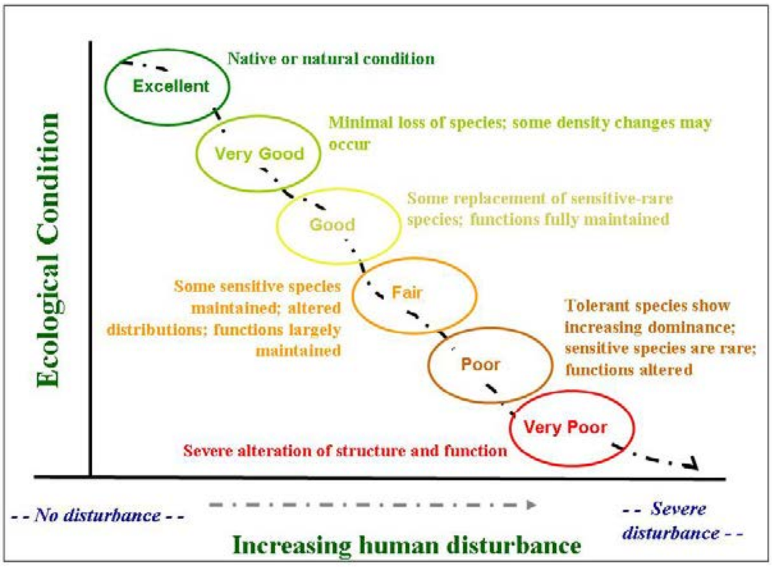

Figure 2 **Human disturbance gradient showing the six different ecological condition grades or ratings ranging from excellent to very poor with a brief definition of each condition**

The process used to grade or rate sites involved the following steps:

1 A conceptual model describing the ecological responses to a general disturbance gradient in the AMLR NRM region was developed, reviewed and updated by the panel (Appendix 1).

2 A species list was compiled for the region based on data collected in this study, describing the expected biotic assemblage for each of six possible ratings (Appendix 2).

3 Each site was given a rating based on the macro-invertebrate assemblages, vegetation assemblages and extent, water chemistry, and sediment condition recorded during autumn and spring sampling periods. Note that for sites that were dry, only the vegetation data, sediment and habitat features were used to provide a rating.

4 The individual ratings derived by the panel members were averaged to produce an overall, or final, rating for each site (Appendix 3).

Results

The panel members assigned the same rating to only one site but the results for the remaining 19 sites only differed from each other by one rating class. All sites were rated Very Good, Good or Fair (Table 2). No site was rated as being in Excellent condition.

The sites that rated Very Good included the Tributary of Sixth Creek near Montacute Conservation Park, Boat Harbour Creek at the mouth, The Deep Creek at the waterfall, Aaron Creek near Cobbler Hill, First Creek in the Cleland Conservation Park and First Creek near Fourth Falls. All of these sites had at least part of their catchment within a conservation park. While these sites provided habitat for a variety of sensitive and rare species of macroinvertebrates, and their catchments are covered by a large percentage (>45%) of native vegetation, there were still signs of human disturbance and impacts to the ecosystem due to elevated concentrations of some nutrients, excessive cover of aquatic plants or the presence of filamentous algae.

Table 2 Overall rating for sites monitored in the AMLR NRM region

Condition rating	Number of sites
Excellent	0
Very Good	6
Good	9
Fair	5
Poor	0
Very Poor	0

Nine sites were rated as Good: Fifth Creek near Black Hill, Brownhill Creek at Brownhill Creek Recreation Park, MacKereth Creek near Scott Bottom, Tributary of Peters Creek near Kangarilla Hill, Wild Dog Creek near Myponga Conservation Park, Waterfall Creek near the waterfall, Dog Trap Creek near Deep Creek Conservation Park, Callawonga Creek downstream of Gold Diggings Swamp and The Wither Swamp near Deep Creek Conservation Park. These sites provided habitat for some rare and sensitive species of macroinvertebrates but there was also emerging signs of nutrient enrichment and often weedy riparian zones.

Five sites were rated only Fair including Minno Creek near Long Gully, Tunkalilla Creek near Eric Bonython Conservation Park, Boundy River near Mount Alma, Tributary of Hindmarsh River near Hindmarsh Tiers, and Unnamed Creek in Deep Creek Conservation Park. While these sites did provide habitat for a few rare and sensitive species of macroinvertebrates, they were mostly dominated by generalist and opportunistic taxa. Most of these sites showed obvious signs of nutrient enrichment, evidenced through either elevated concentrations of nutrients or excessive growth of aquatic plants. Considerable fine sediment deposition was also noticed at all of these sites and some of the sites showed obvious signs of stock access, either through the presence of faeces within the channel or evidence of stock trampling the banks.

The influence of certain water chemistry (eg nutrients, oxygen levels, conductivity) and habitat attributes (eg maximum flow and shade) on the biota at the sampled sites was assessed using principal coordinates analysis (Figure 3). There was clear overlap between the three condition ratings (Very Good, Good and Fair) but some patterns were apparent. High maximum flows and higher dissolved oxygen were associated with those sites considered to be in Very Good condition and higher amounts of shade were associated with those sites considered to be in either Very Good or Good condition. Lower concentrations of nutrients occurred at the very good sites. Some basic statistics of water quality parameters for sites in each of the Very Good, Good and Fair categories has been presented in Appendix 4.

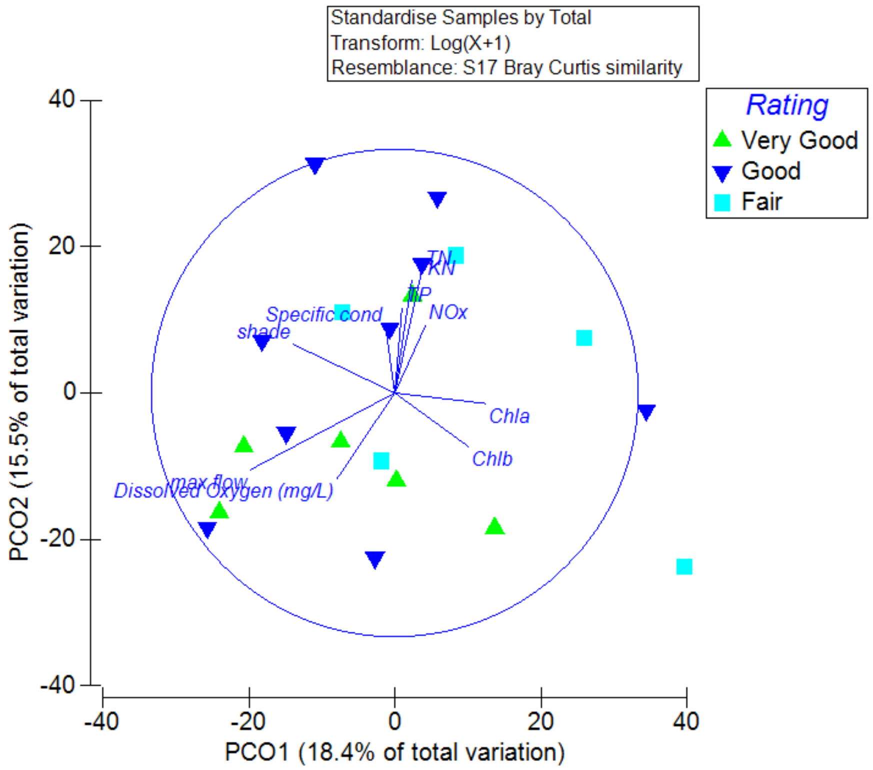

Figure 3 **PCO of macro-invertebrate data showing major relationships between variables and site classifications. (TN = total nitrogen, TKN = total Kjeldahl nitrogen, TP = total phosphorus, NOx = oxidised nitrogen, Chla = chlorophyll *a*, Chlb = chlorophyll *b*)**

What might an excellent site look like?

A site in Excellent condition in the southern Mount Lofty Ranges and Fleurieu Peninsula region would be in near natural condition with no unnatural pressures or stressors. No human induced contaminants would be present, such as hormones or pesticides and nutrient levels would be low (ie TN <0.5 mg/L, TP <0.01 mg/L). The creek would have natural habitat present with no introduced species and flow patterns would also be natural with no influence from farm dams or other impoundments. A range of sediment types would probably be present but sediments may occasionally be anaerobic. There would be no obvious human disturbances although some roads may be present. Very sparse rural housing could also be present in the catchment but no point sources of pollution input to the creek would occur, and diffuse pollution would not be detectable due to the buffering extent of vegetation surrounding the creek. This description of near ‘naturalness’ aligns with the definition of reference condition used in many monitoring programs around the world.

The AMLR NRM region and possibly the Flinders Ranges and Far North are likely to be the only regions in South Australia where reference sites may be located. However, previous monitoring in these regions has shown that introduced flora and fauna, widespread cattle and sheep grazing, and cropping land uses are impacting on stream condition in these regions. In the AMLR NRM region, an area with high rainfall and high naturalness, the criteria for an excellent condition site were still not met. There needs to be some thought given to what reference condition current monitoring sites in South Australia should be compared against. If Excellent sites do not exist any longer, what should be the benchmark against which monitored sites are measured?

How do we define reference condition?

Finding sites with a high degree of naturalness, to act as reference sites, is problematic for other regions of Australia and overseas, not just South Australia. As such, there has often been some confusion about the term reference condition with sites designated as reference sites often just representing 'the best of what's left' (Stoddard *et al* 2006, US EPA 2013) rather than a state of no or minimal human disturbance.

The use of the term reference condition can also have different meanings for different people and for different studies (Stoddard *et al* 2006). For example, occasionally reference condition can be used to indicate a state prior to a discharge of wastewater into a stream, or upstream of the discharge point. In other words, pre-disturbed from the discharge, rather than pre-disturbed from any human pressure.

To overcome the confusion as to what defines a reference site Stoddard *et al* (2006) suggested using different terms in place of reference condition, to clearly explain the expected condition to which current conditions are to be compared. For example, 'minimally disturbed condition', 'historical condition', 'least disturbed condition' and 'best attainable condition' (Figure 4).

The definitions from Stoddard *et al* (2006) on the condition of a stream are as follows:

- 'minimally disturbed condition' – absence of significant human disturbance
- 'historical condition' – either pre-intensive agriculture or pre-European settlement
- 'least disturbed condition' – best available physical, chemical and biological condition given the current landscape
- 'best attainable condition' – expected ecological condition of least-disturbed sites if best management practices were implemented

'Best attainable condition' sites should be no better than 'minimally disturbed condition' but no worse than 'least disturbed condition' (Figure 4).

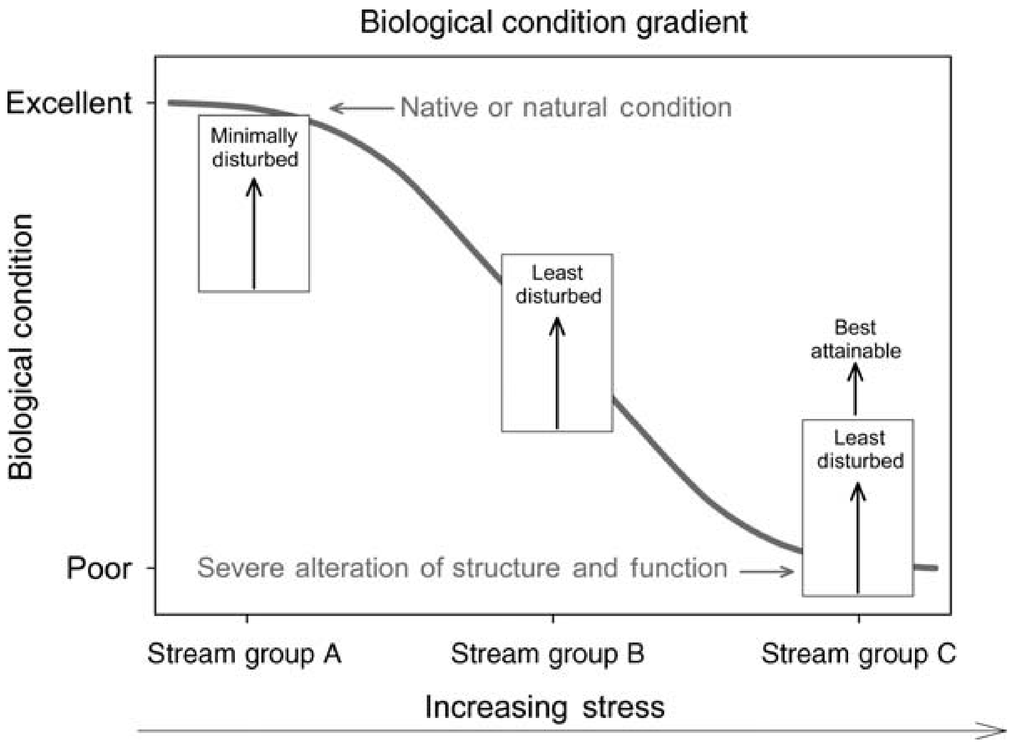

Figure 4 The different levels of human disturbance overlaid with the more realistic ideas of what reference condition may look like at different points along the disturbance gradient. Diagram taken from Stoddard *et al* (2006)

It is important to recognise that human uses have caused a certain level of disturbance in the landscape. For example, it is unrealistic to expect a 'pristine' or 'minimally disturbed' condition to exist in urbanised areas. The 'best attainable condition' may be only Good on the human disturbance gradient (Figure 2), and it would be unrealistic to compare urban sites with a reference (eg Excellent) condition site, as this would suggest that an Excellent condition state could be attainable in an urban setting.

In South Australia where land clearance, agricultural land uses and urbanisation has changed much of the landscape, the use of the concept 'best attainable condition' may be more appropriate than reference condition for many reasons. In other words, it is acceptable to not find, or even at the outset of a monitoring program, not expect to find sites in reference or Excellent condition in a region known to be moderately or heavily disturbed by human activity. Establishing a 'best attainable condition' for our more developed regions of the state, will provide a more suitable and realistic benchmark for stream rehabilitation and water quality improvement programs. Similarly, for parts of the Flinders Range and Far North where stock grazing and feral animals are the major disturbances present, 'least disturbed condition' appears the logical benchmark.

References

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Further information

Legislation

Online legislation is freely available. Copies of legislation are available for purchase from:

Service SA Government Legislation Outlet
Adelaide Service SA Centre
108 North Terrace
Adelaide SA 5000

Telephone:	13 23 24
Facsimile:	(08) 8204 1909
Website:	<shop.service.sa.gov.au>
Email:	<ServiceSAcustomerservice@sa.gov.au>

General information

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Appendix 1

Table A.1 Conceptual model of ecological responses to a disturbance gradient in the Adelaide and Mount Lofty Ranges NRM region

Response category	Rating					
	Excellent	**Very good**	**Good**	**Fair**	**Poor**	**Very poor**
Stressor description	As naturally occurs; probably no longer present in the western Mount Lofty Ranges due to the level of vegetation clearance and landscape modification. Streams with natural vegetation communities, such as First and Sixth creeks and low-order streams in the upper South Para River in the Mount Lofty Ranges, and coastal creeks on the southern Fleurieu Peninsula (eg Aaron Creek, lower Deep Creek) may represent this state on occasions but generally the presence of introduced species and nutrient enrichment precludes rating sites in the region as Excellent.	Least impacted streams with largely natural vegetation communities, such as First and Sixth creeks and low-order streams in the upper South Para River in the Mount Lofty Ranges, and coastal creeks on the southern Fleurieu Peninsula (eg Aaron Creek, lower Deep Creek). Very few introduced species and little sign of nutrient enrichment.	Showing initial signs of enrichment; likely to occur in streams with large areas of natural vegetation remaining in their catchments and generally characterised by permanent/near permanent, flowing, freshwater habitats but may also include more ephemeral habitats. Numerous streams in the watersheds of all the water reservoirs in the region would be expected to represent this condition in most years.	Moderate nutrient enrichment: likely to commonly occur in the region due to the extent of vegetation clearance and associated agricultural development.	Gross nutrient enrichment or degradation: likely to commonly occur in the region due to the extent of vegetation clearance and associated agricultural development and urbanisation. Ephemeral and saline streams in the region are likely to show extensive enrichment effects due to the lack of substantial dilution flows in most years.	Severely altered: may occur in the region in urban stream reaches, downstream from wastewater discharges and highly degraded ephemeral and more permanent streams in extensively cleared agricultural settings. Sites assigned to this rating will be affected by a toxicant or other disturbance that significantly limits the diversity and abundance of aquatic life present in a stream.

Response category	Rating					
	Excellent	Very good	Good	Fair	Poor	Very poor
Water chemistry conditions	As naturally occurs; no human contaminants present and pest species not impacting on water quality (eg nutrients, hormones).	Least disturbed with high proportion of natural features means well oxygenated water and low nutrients and turbidity; may be highly coloured due to tannins from native vegetation.	Largely unremarkable water quality but with at least some nutrients present at higher than expected concentrations, coupled with at least one plant indicator showing emerging signs of enrichment effects (eg either chlorophyll *a* >10 ug/L, macrophyte cover >10% cover and/or filamentous algae >35% cover) but site not overwhelmed.	Fair water quality with generally saturated dissolved oxygen (when sampled during the day), at least one nutrient present at high concentrations and high algal and higher plant growths (eg either chlorophyll *a* >10 ug/L, macrophyte cover >10% cover and/or filamentous algae >35% cover) evident on occasions.	Poor water quality with generally saturated dissolved oxygen (when sampled during the day), nutrients present at high concentrations and high plant productivity evident at the site (eg usually chlorophyll *a* >10 ug/L, macrophyte cover >10% cover and filamentous algae >35% cover most of the time).	Very poor water quality with at least one parameter at a toxicant concentration that limits aquatic diversity; often very low dissolved oxygen and may be saline and enriched in nutrients but algal and plant growth limited.
Physical habitat and flow patterns	Natural habitat and flow patterns; no farm dams present; range of sediment types present and not always anaerobic.	Near natural habitat and flow regimes; mostly well vegetated catchments with few dams present; range of sediment types present and not always anaerobic.	Good habitat structure and flow patterns; extent of dam development has not caused an obvious loss of riffle habitats; range of sediment types present and not always anaerobic.	Fair habitat structure and flow patterns; many dams may be present in the catchment; anaerobic fine sediments usually present, except for coarse sandy sediments or when large algal growths oxygenate the sediments.	Poor habitat structure and flow patterns; may have many dams present in the catchment; anaerobic fine sediments usually present except when large algal growths are present and aerate the sediments.	Severe modifications to physical habitat and flow patterns; little to no remnant native vegetation remaining; cleared agricultural or urban sites; anaerobic fine sediments often dominate.

Response category	**Rating**					
	Excellent	**Very good**	**Good**	**Fair**	**Poor**	**Very poor**
Human activities and sources in the catchment	No obvious human disturbances but may include roads and sparse rural housing; no point sources, and diffuse pollution not detectable due to the extent of vegetation surrounding each stream.	No significant human disturbances but may include some rural housing and roads; no point source discharges and diffuse pollution not obviously affecting the aquatic ecosystem due to the extent of native vegetation surrounding each stream.	Effects of human disturbance becoming obvious; point sources may be present but do not dominate flows; good buffer zones and/or riparian vegetation present that help to mitigate diffuse pollution effects from surrounding land uses.	Point and diffuse source enrichment effects evident; riparian zone not effective at mitigating nutrients and fine sediment typically enters these waterways.	Obvious point and diffuse source enrichment effects present; unbuffered channel with ineffective or no riparian vegetation remaining other than introduced grasses; major changes to catchment landuse with little remnant vegetation remaining and agriculture and/or urban uses dominate.	Severe point and/or diffuse source effects that may include toxicant responses; effects dominate water quality and biological response with little signs of the original waterway evident; unbuffered channel that has undergone extreme modifications in an agricultural or urban setting.

Appendix 2

Table A.2 List of biota expected to occur for each rating in the Adelaide and Mount Lofty Ranges NRM region

Attribute	Excellent	Very Good	Good	Fair	Poor	Very Poor
Attribute 1 **Rare and/or regionally endemic**	**Trichoptera** *Ulmerochorema; Tasimia Atriplectides, Maydenoptila, Orthotrichia, Notalina fulva;* **Odonata** *Synthemis;* **Diptera** *Parochlus, Aphroteniella;* **Pisces** *Galaxias brevipinnis*	**Trichoptera** *Atriplectides*, *Ulmerochorema, Notalina fulva;* **Odonata** *Synthemis;* **Diptera** *Austrothaumalea*; **Pisces** *Galaxias brevipinnis*	**Trichoptera** *Ulmerochorema, Notalina fulva;* **Diptera** *Austrothaumalea;* **Pisces** *Galaxias brevipinnis*	None present	None present	None present
Attribute 2 **Sensitive, rare or vulnerable specialist taxa with narrow environmental requirements**	**Ephemeroptera** *Offadens*, *Nousia fuscula;* **Plecoptera** *Illiesoperla, Riekoperla; Newmanoperla;* **Trichoptera** *Orphninotrichia, Leptorussa, Oxyethira;* **Odonata** *Austrogomphus;* **Coleoptera** *Simsonia;* **Diptera** *Paracnephia*, good diversity of non-biting midges (more than 15 genera); **Mites** Good diversity of mite families (more than 5 taxa)	**Ephemeroptera** *Offadens*, *Nousia fuscula;* **Plecoptera** *Illiesoperla, Riekoperla*; *Newmanoperla;* **Trichoptera** *Lingora, Triplectides similis, Taschorema, Apsilochorema, Oxyethira columba, Orphninotrichia, Leptorussa;* **Odonata** *Austrogomphus;* **Diptera** *Paracnephia; Simulium melatum*, good diversity of non-biting midges (10 to 15 genera); **Coleoptera** *Simsonia;*	**Ephemeroptera** *Offadens;* **Plecoptera** *Illiesoperla, Riekoperla, Newmanoperla;* **Trichoptera** *Lingora, Triplectides similis, Taschorema, Hydroptila calcara, Apsilochorema;* **Odonata** *Austrogomphus;* **Diptera** *Paracnephia;* **Coleoptera** *Simsonia;* **Mites** Average diversity of mite families (2 or 3 taxa)	**Ephemeroptera** *Offadens*; **Plecoptera** *Illiesoperla;* **Trichoptera** *Lingora, Triplectides similis, Taschorema* **Mites** Low diversity of mite families (less than 2 taxa)	None present	None present

Attribute	Excellent	Very Good	Good	Fair	Poor	Very Poor
		Mites Good diversity of mite families (4 or 5 taxa)				
Attribute 3 **Sensitive, ubiquitous taxa**	**Ephemeroptera** *Thraulophlebia, Atalophlebia*; **Plecoptera** *Dinotoperla, Austrocerca;* **Diptera** *Austrosimulium*	**Ephemeroptera** *Thraulophlebia, Atalophlebia*; **Plecoptera** *Dinotoperla, Austrocerca;* **Diptera** *Austrosimulium*	**Ephemeroptera** *Thraulophlebia, Atalophlebia*; **Plecoptera** *Dinotoperla, Austrocerca;* **Diptera** *Austrosimulium*	**Ephemeroptera** *Thraulophlebia, Atalophlebia;* **Plecoptera** *Dinotoperla, Austrocerca;* **Diptera** *Austrosimulium*	**Ephemeroptera** *Atalophlebia*	None present
Attribute 4 **Opportunistic or generalist taxa**	**Mollusca** *Angrobia, Glyptophysa;* **Ephemeroptera** *Tasmanocoenis*; **Trichoptera** *Notalina*, *Oecetis, Triplectides, Hellyethira, Ecnomus, Lectrides;* **Odonata**, *Hemicordulia,* Aeschnidae, Telephlebiidae; **Diptera** Dixidae, Chironomidae *(Eukiefferiella, Thienemaniella, Botryocladius, Bryophaenocladius, Stictocladius, Stempellina, Riethia)*	**Mollusca** *Angrobia, Glyptophysa;* **Ephemeroptera** *Cloeon*, *Tasmanocoenis*; **Trichoptera** *Notalina*, *Oecetis, Triplectides, Hellyethira, Ecnomus, Lectrides;* **Odonata**, *Hemicordulia,* Aeschnidae, Telephlebiidae*;* **Diptera** Dixidae, Chironomidae *(Eukiefferiella, Thienemaniella, Rheotanytarsus, Bryophaenocladius, Stempellina, Riethia)*	**Mollusca** *Angrobia, Glyptophysa;* **Ephemeroptera** *Cloeon*, *Tasmanocoenis*; **Trichoptera** *Notalina*, *Oecetis, Triplectides, Hellyethira, Ecnomus, Lectrides;* **Odonata** *Hemicordulia,* Aeschnidae, Telephlebiidae*;* **Diptera** Dixidae, Chironomidae *(Eukiefferiella, Thienemaniella, Cladotanytarsus, Rheotanytarsus);* **Coleoptera** *Sternopriscus, Platynectes*	**Mollusca** *Angrobia, Glyptophysa;* **Ephemeroptera** *Cloeon*, *Tasmanocoenis*; **Trichoptera** *Notalina*, *Oecetis, Triplectides, Hellyethira, Ecnomus, Lectrides;* **Odonata** *Austrolestes*, *Hemicordulia;* **Diptera** Dixidae, Chironomidae *(Eukiefferiella, Thienemaniella, Cladotanytarsus, Rheotanytarsus);* **Coleoptera** *Sternopriscus, Platynectes*	**Mollusca** *Angrobia, Glyptophysa;* **Ephemeroptera** (in low numbers) *Cloeon*, *Tasmanocoenis*; **Trichoptera** *Triplectides, Hellyethira;* **Odonata** *Austrolestes*, *Hemicordulia;* **Diptera** Chironomidae *(Tanytarsus);* **Coleoptera** *Sternopriscus, Necterosoma, Platynectes*	**Coleoptera** *Necterosoma*

Attribute	Excellent	Very Good	Good	Fair	Poor	Very Poor
Attribute 5 **Tolerant taxa**	**Oligochaeta, Amphipoda** *Austrochiltonia*; **Diptera** *Simulium*; **Odonata** *Ischnura*	**Oligochaeta, Amphipoda** *Austrochiltonia*; **Diptera** *Simulium;* **Odonata** *Ischnura*	**Oligochaeta, Amphipoda** *Austrochiltonia*; **Decapoda** *Paratya, Cherax;* **Diptera** *Simulium,* Culicidae, Stratiomyidae, Ceratopogonidae, *Cricotopus;* **Hemiptera** *Micronecta;* **Odonata** *Ischnura*	**Turbellaria, Oligochaeta, Mollusca** Hydrobiidae*;* **Amphipoda** *Austrochiltonia*; **Decapoda** *Paratya, Cherax*; **Collembola, Diptera** *Simulium*, Culicidae, *Cricotopus,* Stratiomyidae*;* **Hemiptera** *Micronecta, Sigara, Agraptocorixa, Anisops, Enithares;* **Odonata** *Ischnura*	**Turbellaria, Oligochaeta, Mollusca** Hydrobiids; **Amphipoda** *Austrochiltonia*; **Decapoda** *Paratya, Cherax*; **Collembola, Diptera** *Simulium,* Culicidae, Ceratopogonidae, *Cricotopus*, Stratiomyidae; **Hemiptera** *Micronecta, Sigara, Agraptocorixa, Anisops, Enithares;* **Odonata** *Ischnura*	**Oligochaeta** (often in large numbers); **Amphipoda** *Austrochiltonia*; **Collembola**, **Diptera** *Procladius*, *Chironomus* (often in large numbers), Culicidae, Ceratopogonidae, Stratiomyidae; **Hemiptera** *Micronecta, Anisops*
Attribute 6 **Non-endemic or introduced taxa**	None	**Mollusca** *Physa, Potamopyrgus* in low numbers; **Decapoda** *Cherax tenuimanus*	**Mollusca** *Physa, Potamopyrgus* in low numbers; **Decapoda** *Cherax tenuimanus*	**Mollusca** *Physa, Potamopyrgus;* **Fish** *Gambusia*	**Mollusca** *Physa, Potamopyrgus;* **Fish** *Gambusia*	**Mollusca** *Physa;* **Fish** *Gambusia* (rarely due to poor water quality)

Appendix 3

Table A.3 Condition ratings given by each panel member and final overall rating for each of the 20 sites monitored in the Adelaide and Mount Lofty Ranges NRM region during 2011–12

Notes

Habitat information shows if the site was dry, edge (E), and edge and riffle (ER) aquatic habitats sampled

Spring 2011 and autumn 2012 periods separated by comma; so E, ER means edge present in spring and both edge and riffle present in autumn.

Refer to WaterConnect[4] for the site map coordinates and the site based aquatic ecosystem condition reports.

Site name	Habitats	Excellent	Very Good	Good	Fair	Poor	Very Poor	Final rating
Tributary of the Sixth Creek, near Montacute Conservation Parkt	ER, E		2	1				**Very Good**
Fifth Creek, near Black Hill	ER, dry			2	1			**Good**
Minno Creek, near Long Gully	E, dry				3			**Fair**
Brownhill Creek, Brownhill Creek Recreation Park	ER, ER		1	2				**Good**
Mackereth Creek, near Scott Bottom	E, dry		1	2				**Good**
Dog Trap Creek, near Deep Creek Conservation Park	E, E			2	1			**Good**
Tunkalilla Creek, near Eric Bonython Conservation Park	E, ER			1	2			**Fair**
Callawonga Creek, downstream of Gold Diggings Swamp	E, E		1	2				**Good**
Wild Dog Creek, near Myponga Conservation Park	ER, E			2	1			**Good**
Tributary of Peter Creek, near Kangarilla	ER, ER		1	2				**Good**
Boundy River, near Mount Alma	ER, ER			1	2			**Fair**
Waterfall Creek, near Ingalla Falls	ER, ER		1	2				**Good**
Tributary of Hindmarsh River, near Hindmarsh Tiers	E, ER			1	2			**Fair**
Unnamed Creek, Deep Creek Conservation Park	E, E			1	2			**Fair**

4 https://www.waterconnect.sa.gov.au/Systems/EPAWQ/SitePages/Map.aspx

Site name	Habitats	Excellent	Very Good	Good	Fair	Poor	Very Poor	Final rating
The Wither Swamp, near Deep Creek Conservation Park	E, E		1	2				**Good**
Boat Harbor Creek, at the mouth	ER, E		2	1				**Very Good**
The Deep Creek, at the waterfall	ER, ER	1	2					**Very Good**
Aaron Creek, near Cobbler Hill	E, E		2	1				**Very Good**
First Creek, Cleland Conservation Park	ER, ER	1	2					**Very Good**
First Creek, near Fourth Falls	E, E		2	1				**Very Good**

Appendix 4

Table A.4 Basic statistical calculations of water quality parameters measured for Very Good, Good and Fair rated sites

Condition rating		Chlorophyll *a* (µg/L)	Chlorophyll *b* (µg/L)	NOx (mg/L)	TN (mg/L)	TP (mg/L)	TKN (mg/L)	Water Temp (°C)	Conductivity (µS/cm)	Specific conductivity (µS/cm)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH
Very Good	Maximum	11	2.68	0.392	1.14	0.062	1.13	18.8	2,662	3,413	11.01	100.9	8.14
	Minimum	0.24	0.26	0.006	0.14	0.006	0.13	7.5	188.1	249	2.62	26	6.67
	Median	0.695	0.6	0.0135	0.53	0.027	0.475	13.315	561	663.5	8.52	83.5	7.36
Good	Maximum	9.45	0.69	0.171	2.19	0.313	2.13	18.19	2210	2,701	10.99	99	8.35
	Minimum	0.55	0.15	0.005	0.21	0.009	0.2	8.2	338	416	6.9	63.8	6.56
	Median	2.23	0.28	0.051	0.805	0.035	0.715	13.25	618.5	814.5	9.08	88	7.425
Fair	Maximum	11.8	0.72	1.16	1.95	0.117	1.14	19.32	854	958	10.8	91.9	7.72
	Minimum	0.44	0.18	0.008	0.39	0.021	0.38	8.3	231	274	4.08	44.9	7.1
	Median	2.55	0.24	0.273	0.79	0.037	0.61	12.3	616	812	8.32	81.4	7.44