MURRAY-DARLING BASIN AUTHORITY

Salinity Targets Review
A process for developing objectives and targets

Report 3 (of 4)
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SUMMARY OF ABBREVIATIONS AND UNITS

Table ES-1 Summary of abbreviations

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BSMS</td>
<td>Basin Salinity Management Strategy</td>
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<tr>
<td>EoVT</td>
<td>end-of-valley target</td>
</tr>
<tr>
<td>IAG</td>
<td>Independent Audit Group</td>
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<tr>
<td>MDB</td>
<td>Murray–Darling Basin</td>
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<td>MDBA</td>
<td>Murray–Darling Basin Authority</td>
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<tr>
<td>NWQMS</td>
<td>National Water Quality Management Strategy</td>
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<tr>
<td>RCI</td>
<td>resource condition indicator</td>
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<td>RCL</td>
<td>resource condition limit</td>
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<tr>
<td>SKM</td>
<td>Sinclair Knight Merz</td>
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<tr>
<td>SMART</td>
<td>specific, measurable, achievable, relevant, time bound</td>
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<td>WQSMP</td>
<td>Water Quality and Salinity Management Plan</td>
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Table ES-2 Units

<table>
<thead>
<tr>
<th>Salinity units</th>
<th>Description</th>
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<tr>
<td>Within this document both electrical conductivity (EC in ( \mu \text{Scm}^{-1} )) and salt concentration (in mg/L) are used to quantify river salinities. The rate of conversion at salinities less than 2,000 EC is assumed to be 1 EC = 0.6 mg/L for the southern Basin, with the Lachlan as the northernmost region. The rate of conversion for the northern Basin is assumed to be 1 EC = 0.67 mg/L. The basis for this conversion factor is discussed within MDBA (2010a). With respect to salinity tolerance for aquatic ecosystems (Appendix A), conversion factor of 0.64 has been used, which is an approximate average of the northern and southern Basin factor.</td>
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1 PURPOSE OF REPORT

In 2009, the Murray–Darling Basin Authority (MDBA) instigated the development of a *Water Quality and Salinity Management Plan* as part of the Basin planning process required under the Australian Government’s *Water Act 2007*. Within this context, SKM was commissioned to carry out a project that would:

1. review the existing end-of-valley targets with the expectation of providing directions on future targets and potential approach for integrating the existing arrangements within the Basin planning process
2. develop a process for setting salinity objectives and targets for inclusion in the MDB *Water Quality and Salinity Management Plan*
3. recommend salinity objectives and targets for inclusion in the *Water Quality and Salinity Management Plan*.

This is the third in a series of four reports that document the outcomes of the project. It provides a process from which to derive water salinity objectives and targets that will be applied to the development of the Basin Plan and to subsequent five yearly reviews of targets.

The process is then applied to establish threshold salinities for environmental values identified in Report 1 (MDBA 2010a) and forms the basis for recommendations on targets to the authority. In considering these recommendations, the authority will need to consider tradeoffs between water quality and quantity outcomes for competing uses. Targets ultimately included in the Basin plan may therefore be decided within a broader framework that considers a range of Basin plan objectives.

The two preceding reports provide key inputs into this report, including the basis for the selection of aquatic ecosystems, raw drinking water and irrigated agriculture as the environmental values upon which to focus salinity objectives and targets (Report 1); the assessment of stream salinity outcomes under historical land and water use across the Basin (Report 1); and the selection of operational monitoring targets as the most appropriate form of target that will satisfy the MDBA criteria for SMART targets (i.e. Targets that are specific, measurable, achievable, relevant and time bound [Report 2]). These companion reports are as follows:

a. Report 1 — *Salinity Targets Review: Environmental values and data analysis* (MDBA 2010a)


This report is followed by a subsequent document


The fourth report provides the final recommendations on salinity targets for consideration by the MDBA in the development of the Basin plan.
2 SCOPE

Under the Water Act 2007 [Cth], the Murray–Darling Basin Authority is charged with developing a Basin plan, which is to include a Water Quality and Salinity Management Plan (WQSMP). The WQSMP must:

a. identify the key causes of water quality degradation in the Murray–Darling Basin
b. include water quality and salinity objectives and targets for the Basin’s water resources.

The Act also requires that the objectives and targets be developed with regard to the National Water Quality Management Strategy (NWQMS).

The scope of this report is limited to issues surrounding objectives and targets (i.e. the second requirement of the WQSMP, as prescribed in the Act). The key causes of water quality degradation are being documented elsewhere by the MDBA.

In keeping with NWQMS, salinity objectives are framed in terms of environmental values or beneficial uses as discussed in Report 1 (MDBA 2010a). Within this report, the term ‘environmental values’ has been adopted, and specifically refers to values associated with aquatic ecosystems, raw drinking supplies and irrigation supplies.

Recreational, industrial and cultural values are also identified as environmental values under the NWQMS; however, the MDBA has advised that:

a. The implications of water salinity changes are considered minimal for recreational and cultural values, with other elements of the Basin plan considering these values
b. Industrial values are best managed through the rigorous application of local planning provisions rather than through Basin-scale planning arrangements.

Management of off-stream values for assets, such as off-stream wetlands, involve other management prerogatives. For example, the Basin plan must promote the conservation of declared Ramsar wetlands and take into account the ecological character descriptions of:

a. all declared Ramsar wetlands within the Murray–Darling Basin
b. all other key environmental sites within the Murray–Darling Basin.

However, the salinity of such sites is a function of the wetting, drying and flushing of wetlands which will vary temporally and spatially for any given wetland and its watering regime. Accordingly, the extent to which salinity objectives and targets are proposed for off-stream environmental values is limited to the salinity of diversions or supplies to off-stream wetlands. In the event that the MDBA decides to include water salinity targets within off-stream wetlands, the targets may need to consider water salinity dynamics that will arise from periodic inundation and the subsequent drying phase.

The impact of groundwater salinity on significant environmental values was also considered to be beyond the scope of this project, as significant changes in groundwater salinities induced by land and water management changes are minimal within planning timeframes. The exception to this is the impact of groundwater extraction, which substantially alters groundwater gradients and fluxes. Basin planning issues associated with achieving groundwater salinity objectives and targets are therefore best considered within other elements of the Basin plan (i.e. the determination of sustainable diversion limits for groundwater).
3 PRINCIPLES

Key principles adopted in the development of the process for the setting of objectives and targets are that:

c. The starting point for setting salinity objectives should be the highest possible qualitative environmental value for aquatic ecosystems, raw drinking water and irrigation supplies. Accordingly, salinity targets that measure progress against objectives should reflect the resource condition limit which is the threshold salinity below which these highest possible environmental values will be achieved (i.e. is the upper limit to acceptable impacts).

d. Salinity related threats vary across different landscapes. The Basin planning process should drive action in those catchments where the most significant risks arise and changed management actions have the highest potential to achieve cost effective improvements in water salinity.

e. The setting of objectives and targets should have regard to existing salinity trends at specific locations. Targets should, wherever possible, reflect no deterioration in existing water salinity.

f. Within the context of risks to agricultural productivity arising from salinities in water supplies, river salinity targets relating to agricultural values should assume irrigator adoption of best management practices.

g. It is recognised that there is tension between setting objectives based upon the highest possible environmental values and the cost effectiveness of actions to prevent or mitigate salinity impacts to deliver these values. The setting of objectives is therefore an iterative process.

h. The determination and review of salinity targets should be conducted with due recognition of the process of continuous improvement. Whilst targets should be based upon the best available science, the Water Act 2007 provides a process that will allow updates over time. Targets recommended through this process should not, therefore, be viewed as necessarily achieving every economic, environmental and social objective.
In-stream salinity has posed a significant threat to water quality within the Murray–Darling Basin for many decades: the first major investigation in 1970 considered ‘conditions under which high salinity levels occur and their frequency, and to recommend action considered desirable to control and mitigate salinity’ (Gutteridge, Haskins and Davey 1970). MDBA (2010b) summarises subsequent key strategy directions and reviews specifically related to issues around water salinity targets that led to the development and endorsement of the Basin Salinity Management Strategy (BSMS) (MDBMC 2001) and Schedule B to the Murray–Darling Basin Agreement (Water Act 2007).

In the development of the Basin plan, the inclusion of salinity management through the Water Quality and Salinity Management Plan is significantly advantaged by this past work, which provides a mature basis upon which to build future initiatives. The mid-term review of the strategy (MDBC 2007) acknowledged that the existing strategy is a robust accountability and reporting framework, and that, with some enhancement, it could address short term peak river salinities and incorporate ecological objectives.

However, areas were also identified for improvement, such as the issue of salt mobilisation from the floodplain. This is a threat that has been aired annually by the IAG-Salinity (MDBMC 2006, MDBA 2009).

Future salinity threats are most likely to be realised during the extremities of the climatic sequence, the extended dry periods when storages levels are low, providing little opportunity for dilution flow, and during wet periods when increased salt is mobilised from tributary valleys, irrigation areas and the Mallee floodplain (Katupitiya and Cuthbert 2008).

The specific recommendations and directions from these policy documents which require consideration to progress the development of a Water Quality and Salinity Management Plan include:

- the need for targets to support real time river operations to offset major risks, such as that posed by post flood salt accessions from the floodplain
- the need for salinity targets below Morgan to address the water quality risk posed to Adelaide’s major water supply off-takes
- the need for the BSMS accountability framework to consider environmental impacts of salinity

These mid-term review directions were considered in the assessment of the strengths and weaknesses of the existing End-of-Valley arrangements within Report 2 (MDBA 2010b). Those identified as pertinent to the setting of objectives and targets included:

- the fact that there is now a comprehensive Basin-wide river salinity monitoring network and system in place to ‘anchor’ any expansion of Basin monitoring; If continued, the monitoring network will provide improved knowledge over time of the major tributary sources of mobilised salt, and hence track future trends in salinity from dryland catchments over wet and dry periods
- the need to refine existing valley arrangements in harmony with the setting of targets under the Water Quality and Salinity Management Plan, which may include:
  - adjustments to the existing Valley arrangements so as to better articulate their role as a broad planning tool, predicting long term tributary and basin scale outcomes of catchment and river management actions
Salinity Targets Review
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- establishing complementary targets within valleys that are aimed more towards valley scale environmental values and comply with MDBA SMART [Specific, Measurable, Achievable, Relevant & Time Bound] directions for targets.

In essence, Report 2 [MDBA 2010b] recommends retention of the framework of the existing end-of-valley arrangements as a planning tool to assess long term average salinity outcomes. It also suggests that the targets under the WQSMP should be considered as operating targets based upon monitoring data, as this approach best satisfies the SMART criteria required by the MDBA.
5 A PROCESS FOR SETTING SALINITY OBJECTIVES AND TARGETS

5.1 Salinity objectives — a matter of scale

The Basin Water Quality and Salinity Management Plan will form part of the overall Basin plan, which must have regard for a range of related national and international initiatives. Based on advice from the MDBA, the anticipated Basin plan objectives for water quality is to:

- protect and enhance water quality to ensure it is sufficient to meet the environmental, social, economic and cultural values of the Basin’s water resources such that water quality is sufficient to meet all uses of the Basin’s water resources.

Lower-level objectives within the Water Quality and Salinity Management Plan must be consistent with this overarching Basin plan objective, and would be expected to be delivered through valley scale water resource plans (WRPs). Together, the objectives within this hierarchy of plans and strategies seek to optimize natural resource outcomes.

The hierarchy for objectives is illustrated in Figure 5.1. In considering the relative roles of the Basin plan and the WRP in influencing water quality for environmental values at a valley scale, it is essential to recognise that relatively high salinities emanate from some landscapes at a local or sub-catchment scale. Local water salinity outcomes (in terms of salt load and a flow regime that provides dilution benefits) are a function of the hydrology and hydrogeology of a particular landscape. The nature of salt storage and mobilisation, along with the role of land use, will in many cases provide a significant barrier to achieving the desired environmental values. The time frame between mitigation activities and any consequential reduction in waterway salinity is one such example.

Given these varying characteristics of landscapes, the setting of objectives and targets within the Basin plan will need to be sufficiently flexible to enable water resource plans to adopt lower environmental values in some valleys. However, the provision of enabling phrases within the plan to provide this flexibility should only allow for a reduced environmental value in certain circumstances. These include situations where the legacy of past land and water management actions and the current or future hydrological/salt mobilisation regime mean that the highest possible environmental values are essentially unachievable over the short to medium, and perhaps even longer, term.

Essentially, this approach recognises local constraints and the needs of local communities, and is consistent with the approach of the NWQMS in considering ‘the ranges of environmental resources, economic opportunities and community preferences associated with their water resources’ [ANZECC & ARMCANZ 1994].

Figure 5.1 — Hierarchy of objectives at different planning scales
5.2 Overview of a process for setting objectives and targets

The proposed approach to setting objectives and targets pursued under this report and the suite of companion reports (MDBA 2010a; 2010b; 2010d) involves the identification and documentation of a series of environmental values based upon advice from the MDBA. These environmental values are documented and mapped in Report 1 (MDBA 2010a), and were identified relatively early during the MDBA Basin planning process. As a consequence, they do not necessarily represent the key environmental values that the MDBA may ultimately decide to address under the Basin plan.

The final decision on key environmental values to be protected by the Basin plan was pending at the time of writing this report. Consequently, the methodology leading to recommendations on objectives and targets requires a transparent process to ensure that its application can be readily applied to other environmental values. Transparency is also desirable so as to enable adjustments or changes to assumptions underpinning recommendations, and will enable statutory reviews of targets to build on the approach taken in the first Water Quality and Salinity Management Plan. It will thus assist in formulating improvements through the application of improved knowledge that can be expected to be gained over the next five years.

The process is broadly described in the following steps, with more detail provided in subsequent sub-sections of this report:

1. determination of preliminary objectives representing the highest possible qualitative environmental value for aquatic ecosystems, raw drinking water and irrigation supplies
2. establishment of a readily available response function describing the relationship between the condition of the environmental value, and the water salinity
3. the determination of water salinity resource condition limits (RCLs) that will ensure that the preliminary objectives are met
4. nomination of a proposed monitoring site for which progress against salinity objectives can be assessed
5. understanding current and future predictions of in-stream salinity relative to RCLs so as to understand threats of exceedance, or whether salinities are so low at a site that the no deterioration principle should apply
6. assessment of risk of RCL exceedance
7. refinement of objectives and targets in light of:
   a. other Basin planning objectives that arise from the sustainable diversion limits and environmental watering planning process
   b. availability of cost effective works or measures to mitigate water salinity outcomes within an acceptable planning timeframe
8. final adoption of the RCL as the target salinity.

The extent to which these steps can be fully implemented in determining objectives and targets is a function of the current status of knowledge, the available data, and the scale of the analysis. The process is illustrated diagrammatically within Figure 5.2, with those steps not fully implemented in the determination of targets under this project highlighted in grey. Constraints in implementing all of these steps as part of this project are described in Sub-Sections 5.1 to 5.6.
Figure 5.2 — Process for establishing suite of Basin Salinity Objectives and Targets

1. Establish preliminary objectives for Environmental Values (Highest possible Value)
2. Identification of a Response Function
3. Determination of Water Salinity RCL that will ensure objectives are met
4. Best available science
5. Assessment of possible evaluation sites
6. Data analysis:
   - Salt mobilisation and Flow regime (wet & dry scenarios)
   - Current Land & Water Mgt Regime
7. Future scenarios:
   - Salt mobilisation and Flow regime under future climate
   - Future Land & Water Mgt Regime
8. Risk Assessment:
   - Likelihood of target exceedance
   - Consequence of exceedance
   - Options to mitigate risk
9. No deterioration principle
10. Target recommendation on basis of historic salinity
11. Confirm Environmental Value Objective and Targets
12. Target recommended on basis of RCL
13. Benefit warrant investment
14. Assessment of net benefit (TBL outcomes)
15. Benefits don’t warrant investment required
16. Flow regime from preliminary SDLs
17. Preliminary Environmental watering Proposals

Benefits insufficient to warrant such a level of investment
5.2.1 Preliminary objectives

The process commences with the determination of preliminary objectives for the Water Quality and Salinity Management Plan consistent with the ‘Basin plan water quality objectives’ (Section 5.1) and the National Water Quality Management Strategy (NWQMSIG 1998).

First pass objectives are necessarily developed within the spirit of the principle: that objectives should be the highest possible qualitative values (as described in Section 3 of this report) and provide clear and unambiguous purpose and direction to the Water Quality and Salinity Management Plan. Some level of judgement is required as to what is ‘possible’, and the ultimate expression of the objective inevitably requires involvement from a variety of technical specialists and MDBA policy officers familiar with the prevailing expectations of the MDBA.

When applied to the environmental values agreed as being within the scope of this study (i.e. aquatic ecosystems, raw drinking water and irrigated agriculture), the following preliminary objectives were derived:

a. aquatic Ecosystems — water salinity supplied from rivers and streams should be suitable to maintain the ecological character of ecosystem communities

b. raw drinking water — water salinity should be maintained to enable water in the Murray–Darling tributaries to be suitable for domestic use where there are treatment plants and water is extracted for human use

c. irrigated agriculture — water salinity should be maintained at salinity levels below that which will adversely affect the productivity of existing crops under best management practices for irrigation.

With the exception of drinking water, the first pass objectives are established on the premise that river salinity should not compromise the optimum environmental value. As discussed in Section 6.3, this principle has not been applied to drinking water. This is because achieving ‘excellent’ salinity in accordance with the Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) would be outside the realm of practicalities within a developed watershed such as the Murray–Darling Basin.

5.2.2 Development of a response function and a resource condition limit

The means by which progress against objectives is assessed is through monitoring a suitable salinity that provides a metric for assessing in-stream outcomes. The threshold indicator value is the resource condition limit (RCL), which salinity must remain below in order for environmental values to be maintained. The metric used in this report to express salinity is the numerical concentration of total dissolved salts [mg/L]. Total dissolved salts are adopted as the appropriate expression of targets in this and the subsequent report (MDBA 2010d).

Ideally, an RCL will be derived from a response function that, subject to sufficient data, describes a relationship between the environmental values and the causal water salinity. The RCLs may then become the upper value for a target to achieve the related objective. In other words, if the RCL is not exceeded, the values as articulated by the water salinity objective will not be compromised.

A generic response function (commonly termed the ‘bent stick’) is presented in Figure 5.3. It illustrates the threshold salinity and its potential to form the basis for a target tempered by other factors, such as the ‘no deterioration principle’ and subsequent decisions to dampen down objectives on the basis of questionable achievability for the reasons discussed in Section 5.2.6.
In considering this generic response function, it must be recognised that a model describing environmental values at a threshold water salinity, and subsequent decline in response to water quality variations, are invariably simplistic representations based upon a range of assumptions.

Even the concept of a salinity threshold is somewhat simplified, in that salt is a natural part of the Basin landscape. The Basin’s ecology has evolved to have a degree of resilience against saline events. For irrigated agriculture, the impact on productivity of crops, irrigated according to best management practices, is largely determined by the accumulation of salt within the root zone rather than the impact of a sporadic spike in the salinity of the applied irrigation water.

Furthermore, there is significant variability both within and across agricultural and aquatic ecosystem values. For example, the response of irrigated agricultural values to particular water salinity is a function of the range of soil characteristics, crop types and irrigation efficiencies. For ecosystems, the response function is dependent upon which components of the ecosystem are considered of most value (noting that the health of biota are significantly interdependent) and a range of other factors, including exposure time. Variability exists across systems and within sites, and, for ecosystems in particular, the science is not fully understood. Response functions are, therefore, invariably less precise than the generic ideal model (Figure 5.3), and the selection of an RCL is, therefore, not straightforward, requiring rigorous assessment of the data and judgements on assumptions and limitations.

For raw drinking water, the RCL is more straightforward, as there are nationally published and accepted salinity values, i.e. the *Australian Drinking Water Guidelines* (NHMRC and NRMMC 2004). It is therefore a relatively simple process to select the numerical value associated with the judgement on the highest possible value.
In acknowledging that current understandings and data sets are imperfect, it should be recognised that the legislation underpinning the Basin plan (the Water Act 2007) provides for a five yearly review of targets. It thus implicitly recognises that progress towards optimum outcomes will be achieved through a process of continuous improvement. This is the basis for the principle of continuous improvement articulated in Section 3.

5.2.3 Nomination of a proposed monitoring site

The setting of targets requires a monitoring and evaluation system designed to enable reporting on progress in achieving objectives. The process for setting targets therefore requires a complementary monitoring network.

A significant achievement of the existing salinity management framework is the Basin water quality network. In selecting appropriate monitoring sites for evaluation against targets, these networks [specifically the BSMS end-of-valley assessment sites] are considered as the starting point for evaluation of the appropriateness of an operational monitoring network.

A key approach in reviewing the suitability of end-of-valley target sites as operational sites, as well as any additional proposed sites, is the need for sites to satisfy measurability and relevance criteria — attributes of the SMART criteria (an acronym for Specific, Measurable, Achievable, Relevant and Time bound) requested by the MDBA office. Report 2 [chapter 6] explores this criteria in the context of operational and simulated targets, concluding that, for local scale environmental values, an operational form of target best fits the SMART criteria.

‘Relevance’ is addressed in the process by pursuing sites in a river reach that will monitor water supply to clusters of environmental values. Accordingly, mapping of locations is a key part of the process, as described within Report 1 [MDBA 2010a]. Making a site relevant to as many environmental values as possible improves the efficiency of the monitoring and evaluation program.

Measurability criteria relates more to the hydrological characteristics of a site. The five ‘measurable’ criteria largely analogous with the attributes against which end-of-valley target sites were assessed in Report 2 [MDBA 2010b] are as follows:

- Totality of flow: stations should be capable of measuring the total flow at the site or, with appropriate modelling, be able to account for total flow at the site if there are overland flows, anabranches or effluent streams.
- Interference: stations should be located well downstream of the ‘mixing zone’ of any tributaries and sites where stratification is possible. Stations should also be located well upstream of any possible backwater effects.
- Minimum Monitoring: at a minimum, sites should capture flow and salinity (e.g. water elevation is not sufficient).
- Frequency: stations should have a frequency of reading that is commensurate with the river characteristics and the importance of the site, and be capable of providing this without excessive data infilling.
- Historical: stations preferably should have 15 years of reliable flow and salinity records up to 2009.
The generalised process for selection of monitoring sites associated with specific environmental values is as follows:

a. At least one designated monitoring site is warranted within any river valley that harbours a defined environmental value.

b. A preferred site for monitoring under (a) is the existing BSMS end-of-valley target, which builds synergies and efficiencies in the monitoring regime between the BSMS valley arrangements and the Water Quality and Salinity Management Plan monitoring initiatives.

c. If the site identified under (b) is in the general vicinity of environmental values and complies with the measurability criteria above, then it should be adopted. If not, then an assessment of alternative existing monitoring sites within the valley should be pursued.

d. Selection of complementary upstream target sites should be pursued if there are deemed to be environmental values within the valley that would not be adequately assessed by the site adopted under (c).

This process is illustrated within Figure 5.4, with its application in recommending sites discussed in Section 7, Appendix D and Report 4 (MDBA 2010d).

In applying this process, it may be prudent to recognise that where the risk of not meeting a non-site specific RCL (such as in-stream aquatic ecosystems) is low, the costs associated with monitoring, reporting and auditing may well exceed the benefits, and hence may not justify an operational monitoring site.
Figure 5.4 — Process for selection of monitoring sites (within a valley)

1. Identification of Valley containing Environmental Values (Irrigation & Aquatic Ecosystems)
2. Assess existing end-of-valley target monitoring site as an operational target site (Relevance)
3. Mapping of Environmental Values
4. Confirm target site (subject to assessment against measurability criteria)
5. Other Environmental Values not monitored by selected site?
   - Yes: Assess alternative sites in the vicinity of Environmental Values (Relevance)
   - No: Suite of recommended target sites for Valley finalised

- Suitable
- Unsuitable
5.2.4 Understanding in-stream salinity — current levels and future predictions

An understanding of future salinities near environmental values is a necessary part of the process for setting objectives and targets, as it enables comparison with the most salt sensitive environmental value associated with the site. This comparison is a necessary input to the risk assessment (Section 5.2.5), for if risks are high, it will be necessary to contemplate options and investment necessary to mitigate risk.

If risks are low, it may be necessary to adopt existing salinity peaks as the basis for a target rather than the RCL, in accordance with the ‘no deterioration’ principle (Section 3).

As in the past, future salinities within valleys and the lower reaches of the arterial Murray–Darling system will be temporally variable depending upon the degree of salt load accessions and the river flow regime. The presentation of statistics should, therefore, be based upon a timeframe that adequately represents the cumulative impacts of prevailing wet and dry conditions over a period of time. As described in Report 1 [MDBA 2010a], a salinity range based upon a five year rolling daily average was considered a reasonable methodology for representing upper and lower bounds for salinity that would be likely to emerge as a consequence of extended wet or dry sequences.

5.2.5 Assessing the salinity risk posed to environmental values

As articulated within the MDBC Risk Assessment Guidelines for 2008 [SKM & CSIRO 2008], a risk assessment indicates the magnitude and likelihood of impacts and determines whether corrective actions [treatments] are justified.

Within the context of setting objectives and targets, the risk assessment is useful as a means of informing the MDBA as to whether setting the salinity target equivalent to an RCL is achievable. It therefore identifies whether such a target would satisfy the full suite of SMART attributes considered desirable by the MDBA and discussed in Report 2 (MDBA 2010b).

In conducting a full risk assessment, it is necessary to have knowledge on both the consequence and likelihood (at an environmental value scale) of RCL exceedance.

Consequence analysis

The consequence associated with the RCL exceedance should relate directly to the preliminary objectives, which are documented in Section 5.2.1 as:

a. Raw drinking water — water salinity should be maintained to enable water in the Murray–Darling tributaries to be suitable for domestic use where there are treatment plants and water is extracted for human use.

b. Aquatic ecosystems — water salinity supplied from rivers and streams should be suitable to maintain the ecological character of ecosystem communities.

c. Irrigated agriculture — water salinity should be maintained at salinity levels below that which will adversely affect the productivity of existing crops under best management practices for irrigation.

In the event that a detailed response function was available for each ‘environmental value’ across the full suite of locations identified in Report 1 [MDBA 2010a], a qualitative determination of the impact upon the environmental values could be deduced. However, for some environmental values (particularly aquatic ecosystems), there is much additional knowledge required in order for the development of such models to progress, particularly if they are to be tailored for specific values (e.g. the ecological character of a particular Ramsar or Living Murray site).
Whilst the response function secured for drinking water from the *Australian Drinking Water Guidelines* (NHMRC and NRMMC 2004) is relatively straightforward, the consequences of RCL exceedance for the myriad of urban supplies scattered across the Basin are highly varied. This is because diversion from a particular stream source is not the only source of supply for many towns. Some have access to groundwater supplies or combine sources from different catchments, and so have some capability to dilute high salinity with fresher supplies from another source.

Given that the implications of an increase in salinity relate largely to taste (NHMRC and NRMMC 2004), consequences are also political rather than health related. Hence consequence rating in terms of ‘suitability’, as it pertains to the above objective, is relatively subjective.

For irrigated agriculture, difficulties in quantifying consequences arise from:

- impacts on productivity being largely an outcome of long term average salinity rather than incidents of peak daily salinity
- changes in crop types and varieties to those with higher salinity tolerances
- limitations on the adequacy of data underpinning the RCLs as described in Section 6.

Hence, within the scope of this project, the scale of the study, and the readily available data for valley scale environmental values, a full consequence analysis could not be achieved. This is considered best conducted at the valley scale, possibly as part of the development of water resource plans.

**Likelihood analysis**

Salinity dynamics and mobilisation processes are intrinsically driven by the location of salt within the landscape, local salt mobilisation processes and in-stream salt transport mechanisms. Understanding the statistical likelihood involves a detailed appreciation of the Basin’s groundwater and surface water hydrology, past and future land and water management actions, and the likelihood associated with alternative future climatic regimes. These will all directly influence biophysical processes, as well as leading to feedback impacts in terms of management responses to diversion limits and river operations.

Some constraints in conducting a likelihood analysis include:

- The statistics generated must reflect a prevailing land and water management regime and an anticipated climatic scenario. In Report 1 (MDBA 2010a), the analysis reflects the current land and water management regime, and therefore the statistics are not necessarily indicative of the impacts of a future land or water management regime or of the hydraulic or salt mobilisation response that may arise from climate change.
- The outputs from an analysis are dependent upon the methodology. For example, a 12 monthly rolling average daily salinity would generate different 95 percentile upper and lower bounds than would the five year rolling average adopted in this project (MDBA 2010a).

Improvements in data sets may be forthcoming in a future review of targets, with the MDBA having recently initiated a project investigating the risk of climate change impacts on salinity dynamics and mobilisation.
Risk Ranking

As documented in SKM & CSIRO (2008), risk ranking (or risk rating) is the process of combining the conclusions related to consequence level and likelihood into an overall score. The work by SKM & CSIRO (2008) may form a suitable basis for future risk assessments, but was not pursued in this first assessment of objectives and targets due to constraints on understanding consequence and likelihood, as indicated above. If risk ranking were to be pursued within the current data constraints, it would be more appropriately conducted once the impacts of sustainable diversion limits and environmental watering plan proposals were put forward so as to get a better understanding of likely future water management regimes.

The statistical analysis provided by Report 1 (MDBA 2010a) does not provide for a changed climate in the future, but it does provide a basis for comparison of salinity trends with RCLs over 35 years. It is therefore deemed to be an adequate substitute for a formal risk assessment, and is utilised for this purpose as a likelihood analysis within Report 4 (MDBA 2010d).

5.2.6 Refinement of objectives and targets

One of the principles underpinning this report is that the starting point for the setting of salinity objectives should be the highest possible qualitative environmental value (Section 3). However, the setting of an appropriate value is ultimately the prerogative of governments, who invariably take into account the views and expectations of communities. Community input into decision making is essentially the reason for the statutory requirement for a formal consultation process as part of Basin planning.

Tradeoffs between the principle of the ‘highest possible qualitative environmental value’ and other Basin plan objectives include decisions around the optimum use of flows. This is because flow regime is a key determinant (along with salt accessions) of water quality outcomes due to its impact in diluting and flushing salts.

Accordingly, the sharing of water and the timing of deliveries will play a critical role in whether targets will be achieved. It is therefore imperative that the implications of the Basin sustainable diversion limit (SDL) determinations and the environmental watering plan on water salinity outcomes (each of which are complementary elements to the Basin plan) are clearly understood. From a purely water quality-based perspective, the flow regime under these two instruments would be optimized so as to maximize water quality outcomes. However, the process also needs to recognize the SDL and environmental flow objectives which will, at times, have competing requirements for particular flow regimes.

Conducting the associated modelling and testing various salinity implications of future water management regimes is beyond the scope of this project. However, it will ultimately be necessary to ensure that the various elements of the Basin plan are coordinated and work together to optimize overall objectives. This integration of the various elements of the Basin plan has the potential to lead to a requirement for refinement of salinity objectives. The iterative nature of this process is illustrated in Figure 5.5.

Other works and measures that may be available to satisfy the achievability component of the required SMART criteria for targets must be cost effective and deliver in-stream outcomes within a defined time frame.

Detailed investigations into the range of options available to achieve proposed targets, including their benefits and limitations, is beyond the scope of this study; however, an overview of the types of options available is provided in Report 4 (MDBA 2010d). If cost effective options are not available, this is also likely to require the refinement of targets as illustrated within Figure 5.2.
Where the risks of not meeting a target are medium to high, it is envisaged that the authority would evaluate the options to mitigate the risk and increase the associated net benefits to social, economic and ecological outcomes. Such an evaluation may indicate that achieving targets would be impractical given other NRM priorities and the level of investment required.

Given the scale of the Basin plan, it may be more appropriate to provide for this iteration at the valley scale through the water resource planning process. Enabling this to occur will require flexibility in the application of the Basin targets as articulated within Section 5.1.

Figure 5.5  Process for managing synergies and tradeoffs in deciding upon salinity objectives and targets as part of the wider NRM objectives of the Basin plan
6 RESPONSE FUNCTIONS AND RESOURCE CONDITION LIMITS FOR ENVIRONMENTAL VALUES

6.1 Context

Within the previous section, the overall process for the development of salinity objectives and targets is broadly described, with some reference to the work conducted in recommending objectives and targets provided within Report 4 (MDBA 2010d).

A critical step within this process is the determination of resource condition limits for the selected environmental values, which are to be the subject of the objectives and targets. The following sections describe the process leading to the selection of these RCLs, which must be viewed within the context of the best available science in a Basin scale assessment of valley values.

6.2 Aquatic ecosystems

6.2.1 Introduction

Determining salinity trigger levels for managing aquatic ecosystems is a complex (and not yet resolved) science; however, sufficient data exists upon which to draw broad scale conclusions between salt concentrations and biotic response. In simple terms, biota have individual preferences for salinity levels, and this varies between biotic groups (Appendix A). Generally, as salinity increases there will be little or no effect until a threshold is reached, above which longer term exposure will result in species disappearance and/or mortality (Watson et al 2008). However, sub-lethal effects can occur below this threshold and impact on earlier developmental stages (Figure 6.1) (Nielsen et al 2003).

Salinity tolerance data is typically described as the highest value that a species (or 50% of a population) will survive, but not the point at which damage to a population begins to occur. However, the approach presented in the generic response function (presented in Figure 5.3) is to propose a resource condition limit ‘beyond which there will be a decline in the environmental value’ of the aquatic ecosystem. This approach is consistent with the principle of setting salinity objectives that achieve the highest possible environmental value, and it necessitates that the value be less than the reported tolerance values for biota. Arriving at an appropriate resource condition limit will involve:

1. a knowledge of biotic salinity tolerances
2. a determination of the salinity regimes that support biota across the aquatic ecosystem environmental values identified in Report 1 [MDBA 2010a].

The current salinity level of the water supply to environmental values provides a starting point from which to assess an appropriate and locally relevant resource condition limit.
Figure 6.1 Changes in life history traits as a consequence of modifying the delivery of salt. A: Natural delivery. B: Increased delivery. Solid line indicates increasing salinity over time. Dotted lines indicate tolerance levels for each life history phase. The time available for completion of each stage is decreased as the rate of delivery of salt is increased (Nielsen et al 2003).
Complexities and considerations for biota

Ascribing salinity tolerances for biota has been made difficult by several factors, which include:

a. Different approaches making comparisons between and within biotic groups complicated:
   i. Cause and effect data — experimental approaches lack complex ecological interactions but give direct cause and effect relationships between a prescribed salinity level and a species response function. A standard approach determines the concentration that will result in mortality to 50% of a population over a short period such as 72 hours (72-hr LC\textsubscript{50}). The usefulness of such data is limited to the time frame used, and it represents a concentration at which populations are already heavily impacted.
   
   ii. Correlative data — observational data is often used to correlate the presence or absence of biota from field studies to a salinity concentration. The absence of a species from observations is often attributed to the salinity concentration observed but due to the complexity of natural systems causality can only be implied.

b. Differences in salinity tolerance between life stages: it is becoming increasing apparent that early life stages of many biota are more salt sensitive than adult stages. Mature native fish, for example, have a high tolerance to elevated salt concentrations, but where studies have been undertaken on immature stages (egg/larvae), results have indicated significantly lower salinity thresholds. Furthermore, macroinvertebrate data indicates that the lethal sensitivity of young life-stages is greater than the sub-lethal sensitivity of their dominant life-stages [Kefford et al 2006]. Therefore establishing resource condition limits based on mature life stage thresholds will overestimate the viability of aquatic communities already under stress through exposure to elevated salinity.

c. There is evidence of distinct differences among individual species between regions within the Murray–Darling Basin, and generalised species tolerance may not adequately capture the prevailing tolerance variation [Dunlop et al 2008].

d. Sub-lethal, indirect and interaction effects are 'real world’ dynamics which increase the complexity of interactions between salt concentrations and biotic responses. Sub-lethal effects can reduce the fitness of a population, while indirect effects describe responses such as predator-prey interactions. For example, the loss of a salt sensitive species may indirectly impact on salt tolerant species, either by the loss of a food resource or a reduction in competition for a resource.

e. Salt composition — differing chemical forms of salt can measure with the same EC or TDS value but have very different impacts on biota. For example, salts dominated by sodium and chloride are more toxic than those dominated by magnesium, calcium and carbonates. Therefore a species of known salinity tolerance may not perform as expected on the basis of TDS in a system where the composition of salt differs from that which underpinned the experimental results.

f. Biota response is determined not just by salinity concentration, but also by the period of time to high salinity concentrations (i.e. salinity exposure). This is important when considering the effects of exposure due to a salinity pulse rather than ongoing high salinities.

Despite these complexities, generalised salinity tolerance ranges can be established for the various biotic groups and a generalised performance of biota inferred against their tolerance range (Appendix A). Setting a conservative value for the resource condition limit protects the majority of biota assuming 'no effect’ until that limit is exceeded.
6.2.2 Complexities and considerations for valley scale aquatic ecosystem values

Salinity levels in aquatic ecosystems naturally vary over time and space, generally in response to changes in volumes of water. These differences in salinity and hydrological regimes promote and maintain biodiversity within the landscape. Consequently, salinity resource condition limits need to take into account the natural salinity regime for each location, as well as predicted future trends for both wet and dry periods, and they need to reflect the maintenance of an aquatic ecosystem’s ‘natural’ salinity regime. There will be justification for higher trigger values where environmental values have a history of naturally higher salinity. However, it needs to be determined whether prevailing salinities are ‘natural’ or due to human developments (with the latter requiring a more conservative approach).

In keeping with the concept of pragmatic and practical triggers to achieve WQSM objectives, preservation of the ecological character of aquatic ecosystems ideally requires that salinity be maintained at or below the target value for 100% of the time. However, in considering the implications of exceedance, the broader hydrology [both historic and current] needs to be taken into account. For example, prior to river regulation salt concentrations within pools in the River Murray may have exceeded 10,000 mg/L (Williams 1999), and in the Darling River there are inflows of saline water caused by the natural ground water head during low flow periods (Oliver et al 1999). Critical to the survival of ecosystems during these high salinity periods is the timing of high salinities relative to recruitment. Given such incidences will occur on occasions and invariably lead to exceedance of the recommended RCL for aquatic ecosystems, management of low flow-high salinity outcomes should strive to avoid such events coinciding with recruitment times due to the sensitivities of early life stage biota. In general, water quality should replicate as much as possible the historic past, with low salinities predominating in the River Murray and southern tributaries during winter/spring and in the more northern parts of the basin (the Darling River and the upper tributaries) during the summer–autumn when rainfall is dominant.

It is also worth noting that there are aquatic ecosystems within the MDB that are naturally saline and support saline adapted biota. These need to be preserved within the landscape as they contribute to the diversity of aquatic ecosystems and the biotic diversity within the Murray–Darling Basin. However, maintenance of these high salinity environments is not covered within the scope of this project, which is focused towards aquatic ecosystems directly connected to the rivers as articulated in Report 1 (MDBA 2010a).

6.2.3 Historical understandings of resource condition limits

Historically, a salinity of 1000 mg/L has been seen as defining a threshold above which ‘direct adverse biological effects are likely to occur’ (Hart et al. 1991); this threshold was largely based on mature stage life forms. More recent research has indicated that effects are occurring at much lower salinities. For example, salt concentration above ~600 mg/L is known to increase the prevalence of abnormalities in some tadpole species, while some frogs produce decreasing sized eggs in response to even lower concentrations (50–400 mg/L) (Francis 2003). There are also indications that salinities below 1000 mg/L may impact on the survival of native fish eggs (Chotipuntu 2003).

6.2.4 An aquatic ecosystem resource condition limit for the WQSM

The NWQMS (ANZECC and ARMCANZ 2000) provide guidelines on defining low risk trigger values for aquatic ecosystems (Table 6.1). Whilst these are analogous with an RCL, they are not intended to be used as ‘magic numbers’; rather, they are to be ‘used in conjunction with professional judgement to provide an initial assessment of the state of a water body’. 
Table 6.1  Ranges of default trigger values for conductivity (EC, salinity) indicative of slightly disturbed ecosystems in south-east Australia

<table>
<thead>
<tr>
<th>Ecosystem Type</th>
<th>Salinity (μS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland Rivers</td>
<td>30–350</td>
</tr>
<tr>
<td>Lowland Rivers</td>
<td>125–2200</td>
</tr>
</tbody>
</table>

(source: ANZECC and ARMCANZ 2000)

Given salinity variability within natural systems, a resource condition limit for aquatic ecosystems would ideally be designed for specific biota within key reaches of the Basin’s rivers. However, system complexities and a paucity of data mean that the current state of knowledge is insufficient to generate relationships that describe ecological character at a given water salinity, particularly at a Basin scale; in addition, the framework provided by the NWQMS for determining low risk triggers is largely tailored for much smaller scale ecosystems. In light of this, it is necessary for the initial determination of aquatic ecosystem RCL to rely upon professional judgement. Given the Basin scale approach of this project, an RCL of 500 mg/L is proposed, but with the following caveats around this judgement:

- A Basin scale RCL of 500 mg/L should be recognised as a ‘first step’ with potential for future improvements as the knowledge base expands. Improved knowledge is required and is likely to lead to adjustments in future reviews of targets, which are required every five years.
- Valley or sub-catchment scale RCLs are advisable as an input into the development of future targets, along with linked research priorities in the development of water resource plans. Such local scale RCLs should be tailored for local ecosystem types within particular river reaches.

As an indicator of salinity variability across the basin, five year rolling average salinity exceedance assessments within Report 1 (MDBA 2010a) provide some guidance. The report includes upper bound analysis of 53 sites and lower bound analysis of 45 sites. This data indicated five sites exceeding 800 EC at the 95 percentile in the lower bound, while 18 sites exceeded 800 EC at the 95 percentile in the upper bound. A value of 800 EC is analogous with 500 mg/L, with some variation depending upon the prevailing chemistry of the total dissolved salts.

A 500mg/L RCL is therefore at the higher end of the current salinity variability in many tributaries. For catchments that do not routinely generate variability around 500 mg/L or higher, the process provided for the setting of targets (Figure 5-2) provides for a target based upon the no deterioration principle. Hence, within these catchments, the target will reflect this lower variability and lower peaks rather than the 500mg/L as determined by the RCL. Furthermore, the naturally lower salinities within most upland tributaries means that targets derived from tributaries with the lower value of (i) the RCL and (ii) the existing salinity trends are highly likely to be within the guideline range provided for within Table 6.1.

In the pursuit of research priorities, a Basin scale equivalent of the probable risk assessment tool available for use in Queensland catchments should be considered. This tool assists in determining hypothetical salinity values to protect 80%, 95% or 99% of species. With additional work, this tool may become valuable to inform future reviews of the targets by providing guidance for protection of percentile ranges above the ‘no effect trigger’ value (Hart et al 2003, Dunlop et al 2008). Revisions of the NWQMS are likely to take this approach and provide a research basis for its use beyond Queensland.
6.2.5 Summary

System resilience is a concept that is difficult to measure, so exceedance of a resource condition limit does not necessarily imply a permanent decline in the ecological character, as presented in the generic response function (Figure 5.3). Similarly, salinity levels below the resource condition Limit do not necessarily guarantee complete protection. Aquatic ecosystems have evolved to cope with wet and dry periods and corresponding alternating salinity levels. The outcome of exposure beyond the resource condition limit will depend on a number of inter-relating components mentioned above, but the complexity of assessing risks increases with rising salinity.

In light of the above, salinity water quality targets based upon a maximum of 500 mg/L will provide a pragmatic approach for the protection of biota, given current knowledge and in light of the application of the "no deterioration" principle in the final recommendation on targets (MDBA 2010d).

Within water resource plans and future reviews of Basin scale targets, the next generation of RCL[s] should be refined so as to reflect the needs and character of biotic communities. In other words, these improvements should aim to provide greater relevance to the valley scale or river reach environmental values.

6.2.6 Future research

To support future reviews of targets and the development of valley scale WRPs, continued research effort is required, particularly within the areas of:

a. gathering of early life stage and sub-lethal tolerance data which exists only for a minority of taxa, in which further research will be important to better estimate recruitment performance and salt impacts to aquatic communities
b. the effects of wetlands acting as salt accumulating sinks in the landscape, in terms of impacts on aquatic ecosystems
c. knowledge on the effects of salinity pulses, including their concentration, duration and number of cycles above biotic threshold levels
d. review, and possibly development of, the Queensland probabilistic risk assessment tool for application across the Basin, so as to determine hypothetical salinity values that will protect a percentage of aquatic ecosystem species.

6.3 Raw drinking water

6.3.1 Introduction

Many towns and cities, both within and outside the Basin, rely on its waters for consumptive purposes.

As documented in Section 5.2.1, the preliminary objective for raw drinking water for inclusion in the Water Quality and Salinity Management Plan is that salinity should be maintained in the Murray–Darling tributaries so that water is suitable for domestic use where there are treatment plants and it is extracted for human use.

The Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) have been developed through the National Water Quality Management Strategy for chemical (e.g. salinity, nutrients), physical
[e.g. temperature, suspended solids], and biological indicators [e.g. macroinvertebrate counts]. The guidelines express requirements for contaminants that relate to health risks [e.g. algal toxins] and for those that affect the aesthetic values of water [colour, taste, odour etc]. At salinity levels generally experienced in Basin rivers, salinity predominately affects the aesthetic values, rather than health impacts, as palatability concerns arise well before health issues.

6.3.2 Location of environmental values

Offtakes for raw drinking water are diffusely located across the Murray-Darling system and its tributaries, with variable densities supplying significant cities and small rural communities. Significant populations outside the Basin are also supplied, including in Adelaide, Melbourne and Ballarat. Urban centres are shown in Figure 7.3 of Section 7.

6.3.3 Assumptions

A key assumption for determining an RCL for raw drinking water is that the palatability of water is affected by salt long before it poses a threat to human health. This effectively means that managing salinity for drinking water is driven by social and political priorities, with health concerns a secondary consideration. The Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) do not specify a guideline value for health needs; rather, they identify a threshold based on palatability.

It is also assumed that the RCL for raw drinking water should be consistent for all urban supplies, as a ‘suitable’ drinking water supply is a reasonable expectation for all communities, regardless of population size or location.

6.3.4 Response function

The Bruvold and Daniels (1990) tabulation (Table 6.2) provides a qualitative description of water quality and its associated salt concentration, and so provides a reasonable basis for a response function. It has been adopted in the Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) and provides judgements about the palatability of drinking water in terms of total dissolved salt concentrations.

Table 6.2 — Resource condition limits developed for raw drinking water

<table>
<thead>
<tr>
<th>Concentration (mg/L)</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;80</td>
<td>Excellent</td>
</tr>
<tr>
<td>80–500</td>
<td>Good</td>
</tr>
<tr>
<td>500–800</td>
<td>Fair</td>
</tr>
<tr>
<td>800–1000</td>
<td>Poor</td>
</tr>
<tr>
<td>→1000</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

[source: NHMRC and NRMMC 2004]

6.3.5 Resource condition limit for raw drinking water

The RCL proposed for all raw drinking water supplies across the Basin has been selected in accordance with the Australian Drinking Water Guidelines definition of ‘good’ water quality. Currently, ‘good’ is defined as up to 500 mg/L (Table 6.2). An RCL could be set at higher salinities without affecting human
health; however, the palatability of higher salinity water is not considered to be ‘satisfactory’ and hence would not fully protect the environmental value.

An RCL set at below 500 mg/L is not considered to be a feasible within the principle of the ‘highest possible qualitative value’, as articulated within Section 3. Furthermore, as the palatability of drinking water is not significantly compromised at 500mg/L, pursuit of a lower salinity threshold is unlikely to significantly add to the environmental value.

6.3.6 Summary

The salinity levels of raw drinking water in the Murray–Darling Basin are determined by palatability considerations and naturally-occurring spikes in river salinity. Palatability of drinking water becomes an issue well before water salinity poses a threat to human health, meaning that health issues are assumed to be avoided if the taste of water is acceptable. An RCL for raw drinking water across the Basin of 500 mg/L thus addresses these issues while being considered generally achievable within the natural environment of the Basin.

6.4 Irrigated agriculture

6.4.1 Introduction

The salinity of applied irrigation water needs to be carefully managed in areas where the quality of the water supply approaches thresholds that have the potential to have detrimental impacts upon crop productivity. High salinity of irrigation water can affect crops through damage to foliage or through toxicity or osmotic effects arising from the accumulation of salts within the root zone.

As documented in Section 5.2.1, the preliminary objective for inclusion of irrigated agriculture in the Water Quality and Salinity Management Plan is that water salinity should be maintained at levels below that which will adversely affect the productivity of existing crops under best management practices for irrigation.

There are a range of attributes of the agricultural landscape that determine the influence that salt has upon plant growth and productivity. These include crop sensitivity to salt, method of irrigation, soil type and the leaching fraction. The leaching fraction is the amount of water applied through irrigation or received through rainfall that is in excess of plant requirements and direct evaporation, and hence available to leach salts from the plant root zone. Accordingly, the effects of salinity are site specific, and salinity targets for irrigation cannot be generalised for different locations across the Basin [NWQMSIG 1998].

Irrigation occurs within almost every major tributary within the Basin, as identified in Report 1 [MDBA 2010a]. As it is not pragmatic to consider the development of targets for every reach of river for which water is diverted for irrigation, the focus for the development of recommended targets that consider irrigation impacts is largely constrained to shared water delivery systems (i.e. areas normally described as ‘irrigation areas’). Also included were several river reaches containing private diversions where the data analysis in Report 1 (MDBA 2010a) indicates 95 percentile salinities in excess of 1000 EC, namely for the lower Darling, downstream of Menindee Lakes, and the Namoi in the vicinity of Narrabri.

The location of the irrigation areas provided for under valley scale shared infrastructure is mapped in Figure 7.4 of Section 7, with significant areas in all Basin states.
Assuming no limitations on data availability, the approach for developing RCLs for these shared irrigation schemes would be a variation on the method presented in the *National Water Quality Management Strategy* (NWQMSIG 1998) for evaluating salinity and sodicity impacts of irrigation water. Elements of this assessment process are diagrammatically presented in Figure 6.4.

**Figure 6.2** Knowledge requirements in the determination of salinity RCLs for irrigation supplies

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### 6.4.2 Complexities and considerations for irrigated agriculture

The impacts of salinity upon irrigated agriculture vary significantly between locations. The establishment of a resource condition limit (RCL), as generically presented in Figure 5.3 of this report, must therefore be applied across individual irrigation regions, with the elements of knowledge illustrated in Figure 6-2 being required for each region. These knowledge requirements are discussed, in turn, below.

Water quality (salinity and sodicity)

Salts within water comprise a range of ions that affect plant growth in a number of different ways. The *NWQMS* (NWQMSIG 1998) pays significant attention to irrigation toxicity and the soil structural implications arising from sodicity. However, the scope of this project is limited to addressing total dissolved salts (TDS), with other water quality issues considered elsewhere by the Murray–Darling Basin Authority (MDBA). In considering TDS, it is assumed that high levels of TDS reflect a proportionately high level of dissolved sodium chloride.
Soil properties

Soil properties are an important consideration in the application of irrigation water, as more permeable soils provide increased drainage and therefore greater leaching opportunities. Conversely, slower draining soils (e.g. clays) are more likely to experience a build up of salts in the root zone. Soil types, however, are highly variable at a district, farm and even paddock scale. Given the regional scale of the proposed setting of RCLs, the broad issues of variability in soil types have been incorporated into the leaching fraction discussion below.

Rainfall

Within the Mallee region of SA, Victoria and NSW, the relatively arid climate means that leaching due to rainfall is largely insignificant. Leaching requirements are, therefore, almost fully dependent upon surplus irrigation. However, for the less arid areas of the Basin, rainfall provides an additional opportunity for leaching. In these areas, determination of leaching requirements from irrigation would need to consider the benefits derived from annual average rainfall.

Irrigation practices

Prior to the extended drought in the southern Basin over the last decade, relatively high water allocations provided irrigators with some flexibility in managing salt accumulation by applying higher volumes of irrigation water. Reduced water allocations in recent years have limited the opportunity of farmers to use this practice.

In years of high allocation, RCLs could therefore theoretically be set higher, providing irrigators were able to regularly apply surplus water to aid leaching. However, permitting relatively high river salinities under the WQSMP and offsetting these impacts on productivity by encouraging high leaching fractions is not in the long term interests of water resources, particularly within the Mallee zone where the greatest water quality problems arise. Within this region, root zone drainage is known to displace saline regional groundwater to the river and further increase river salinity [Salient Solutions 2008]. Given the emphasis of the Basin Salinity Management Strategy [MDBC 2001] in combating the impacts of irrigation root zone drainage on river salinity, salinity thresholds for irrigation water must be based upon minimal leaching fractions to avoid compromising other downstream salinity objectives or the need for further expenditure on salt mitigation works.

Management practices

Management practices relate to the method of applying water, rather than the volume of water, which is deemed to be covered by the above irrigation practices discussion.

Historically, management of irrigation included a broad range of irrigation methods, including overhead sprays. In recent years there has been a move away from spray irrigation in horticultural areas in recognition of its poor efficiency. Within the lower Murray region, this trend has also been a consequence of the occasional [and in some cases prolonged] exposure to relatively high river salinities whereby over canopy irrigation risks foliar damage.

This on-going threat, and the publicity around long term public and private investment in salinity management, means that there is sufficient justification to argue that irrigators should generally have adopted best management practices, including moving away from poor irrigation application methods and adopted crop plantings [cultures, varieties and rootstocks] that are relatively resistant to elevated
soils salinities [RMCG 2009]. In other words, RCLs developed for irrigation should not be aimed towards salinity thresholds that reflect poor management practices.

Leaching fractions

A number of the elements described above and contained within Figure 6-2, namely soil properties, expected rainfall, irrigation volumes, and irrigation management, affect the leaching outcome that determines soil salinity and agronomic impacts of applied water salinity. Subject to adequate knowledge for these factors, the required leaching fraction can be calculated so as to achieve an acceptable average root zone salinity [discussed below].

As each element within the leaching fraction calculation varies substantially across the Basin [and, in some cases, even within a defined region], a range of assumptions and generalisation are normally required in this calculation.

Plant response

In light of the expectation of best management practices included in on-farm irrigation systems, an understanding of the plant response in determining the RCL relates to its response to soil salinity rather than sensitivity of foliage to canopy spray.

The plant response to soil salinity varies according to culture and cultivar. The internationally recognised Maas and Hoffman [1977] response function, which applies the generic model presented in Figure 5-3 tailored for specific crops, is considered appropriate for this purpose.

This Maas and Hoffman [1977] response function has general acceptance within the Murray–Darling Basin, as it underpins the Basin Salinity Management Strategy registers [MDBC 2001], which provide the platform for managing the agricultural economic impacts of salinity along the Murray River.

Average root zone salinity

Subject to the availability of published soil salinity thresholds for a given crop, the salinity of applied irrigation water and the leaching fraction can be utilised to determine the threshold water salinity.

The application of the FAO Water Quality for Agriculture formula [Ayers & Westcot 1985] outlined below is considered to be the most appropriate means of determining the threshold salinity for the Mallee Region. RMCG (2009) recommend this method for the Mallee region, rather than the modified Rhoades equation proposed in the NWQMS [NWQMSIG 1998].

\[
EC_w = \frac{\text{Leaching Fraction} \times 5EC_e}{\text{Leaching Fraction} + 1}
\]

Where:
EC_w = salinity of irrigation water
EC_e = crop soil salinity tolerance
LF - assumed leaching fraction [expressed as a fraction]

(Ayers & Westcot 1985)
Critical to the application of this equation is the assumption that irrigation water is the sole provider of leaching water. While this is reasonable for the relatively arid regions of the Basin, this equation will give an underestimate of the threshold water salinity for regions of the Basin with higher rainfall.

6.4.3 Identification of most sensitive crop

Diversity of land use within the landscape requires the development of RCLs that reflect an understanding of both sensitive crops and the economic value they represent to a region.

Cropping regimes are not consistent over time, with the spatial extent of annual crops typically varying significantly from year to year due to water availability, commodity prices and the impact of entitlement trade away from some regions. The footprint of perennial horticulture crops is also subject to change, particularly over the recent decade, with reduced annual irrigations leading to retirement of horticulture in some areas.

This spatial and temporal variability in cropping regimes creates additional challenges in determining a RCL that adequately accounts for the value and use of irrigation water. Guided by the MDBA, it was deemed that:

- RCLs for irrigated agriculture should be based upon existing/recent crop types, and not attempt to predict future crop types and distributions (which will be affected by market prices, climate and water availability). The prescribed 5 year review of targets required under the Act provides the mechanism for future refinement of targets to better suit future cropping regimes.

- RCLs are not intended to protect the establishment of highly salt sensitive crops where the salinity of water supply significantly exceeds the RCL. Rather, RCLs should aim to protect the most salt sensitive established crop that makes a set economic contribution within a region.

- In accordance with Best Management Practices, it can be assumed that growers establish the most salt resistant varieties available where irrigation water is subject to salinity spikes.

Given diversity of crops within every area, a pragmatic approach, adopted with guidance from the MDBC office, was to determine the most salt sensitive crop currently contributing 10% of the gross value of irrigated agricultural production for each region and to base a regional RCL upon that crop.

The gross value of irrigated crops was sought for the areas that most closely aligned with the areas identified as irrigated in the companion report (MDBA 2010a). However, an alignment of gross value for individual irrigated crops was not available for each of these identified areas. Hence, the methodology adopted had two phases. The initial phase involved determining the value of agricultural production of each crop within the Basin’s natural resource management (NRM) regions. NRM regions were chosen as they were considered to provide the best available detail. This information was provided by the ABS (2009) report *Value of Agricultural Commodities Produced, Australia, 2007-08*, with the second phase involving liaison with agency or team personnel with local experience within that region.

During the first pass assessment, data accessed from the ABS (2009) provided gross value and local value information for crops, livestock and livestock products by NRM region in the Murray–Darling Basin. In each region, crops were assumed to be either wholly irrigated or not irrigated, an assumption that was checked during the second phase. The publication *Water and the Murray–Darling Basin — A Statistical Profile, 2000–01 to 2005-06* (ABS 2008) was used to provide guidance on whether or not crops should be considered as irrigated.
6.4.4 Methodology for determining RCLs

Subject to adequate knowledge about each of the above elements, the preferred approach to establishing an RCL for each irrigation area was to utilise the soil salinity thresholds from the Maas & Hoffman (1977) response function for the most sensitive crop and then apply a suitable leaching model to establish the water salinity that would lead to a decline in crop productivity.

Notwithstanding some gaps in knowledge, there is considered to be sufficient data for the Mallee region to develop generic RCLs for irrigation supplies in this area. In other parts of the Basin, however, rainfall plays an important role in determining acceptable leaching, and there has been less work conducted on leaching requirements across different soil types. An alternative approach was therefore required to determine RCLs for irrigation areas outside the Mallee. Given the paucity of data, it was deemed appropriate to pursue the available regional or state departmental literature, which in some areas involves best management practice recommendations for the applied water salinities to crops within that area.

Within the Riverine Plains of northern Victoria and southern NSW, the focus of salinity management has been towards providing drainage to enable leaching to take place during the winter/spring period. Recommended salinity thresholds have been established as part of the focus of encouraging the re-use of moderately saline subsurface drainage water under regional catchment strategies.

Within the northern Basin, water salinity issues have generally been less significant. Broad indications of acceptable salinities for the generalised crops are available [DPI 2006; DERM 2009]; however, these recommendations have not been specifically tailored for local soils.

Given the above, a geographical approach has been adopted to identify RCLs for irrigated agriculture. This approach is summarised below, with detail on the application and limitations on RCL determinations captured in Appendix C.

Lower Murray and Mallee

As the Mallee region is arid, and significant region-specific work has been conducted on leaching and root zone drainage due to the risks of groundwater displacement to the Murray River, it is considered appropriate to apply the Ayers & Westcot (1985) formula discussed in Section 6.4.2.

In applying this equation to the specified crops identified for each region, threshold ECe values were sourced from Ayers & Westcot (1985) for each crop. For some crops, the ECe threshold was not provided within Ayers & Westcot (1985) and values were therefore sourced from local publications. One example of where a wider search of the literature was warranted related to apples, where Ayers & Westcot (1985) indicates that it is a sensitive crop with an indicative ECe range of between 0 and 1000 EC. Various state guidelines were consulted to establish specific RCLs applicable to each state.

The values chosen were those at which there would be no reduction in yield potential, in line with the agricultural environmental value objective documented in Section 5.2.1.

An acceptable average rootzone salinity was calculated using a median leaching value of 10% [Salient Solutions 2008], recognising that a theoretical leaching fraction is not fully effective at removing salts from the root zone. RMCG (2009) considered leaching efficiencies to be in the order of 70–80%, such that to achieve an actual leaching fraction of 10%, irrigators may apply somewhere between 12.5% and 14.3% of irrigation water above plant water requirements.
Due to the variability of each of the various elements contributing to salt accumulation within an irrigated area, there are clearly limitations in establishing a generalised leaching fraction. For example, it is recognised that some irrigators with highly efficient micro-irrigation systems use just 5% of applied water for leaching (RMCG 2009). Productivity under highly efficient irrigation management systems may therefore be compromised by a salinity target based upon a theoretical leaching fraction of 10%. These threats to highly efficient irrigators are offset by the fact that it is proposed that the target be operational (i.e. real time). A proposed daily operational target based upon a RCL more aligned with long term average salinity of applied water will therefore normally be conservative. This is because the average salinity over the irrigation season is ultimately the determining factor for leaching requirements, rather than the daily peak upon which the target is based.

**Riverine Plains**

Within the less arid Riverine Plains, where there is less data on generalised required leaching fractions, an appropriate EC$_w$ was investigated for the predominant sensitive crop, with local work having taken into account the additional leaching effects of annual rainfall. Local publications were sought to inform the development of RCLs for this region. Pertinent outcomes of this literature search included:

- Boland et al (2001) recommend, ‘as a general rule’, that the irrigation water for stone and pome fruit be no more than 1.0 dS/m.
- The Victorian Department of Primary Industries (2006) recommends that, for the Shepparton Irrigation Region (SIR), irrigation water for apples not exceed 500 EC (300 mg/L). This is close to the value calculated using the FAO formula and a soil salinity of 1.0 dS/m, and hence was the RCL adopted for this region.

**Northern Basin**

As in the Riverine Plains, the FAO equation is considered inappropriate in this part of the Basin because it does not account for the leaching effects of annual rainfall. Furthermore, there is a significant lack of data on water management and soils at a regional scale. State publications have thus been sought for the development of RCLs for the northern Basin.

The New South Wales and Queensland governments both publish salinity limits that depend upon the soil type where various crops are grown. It should be noted that both the NSW and Queensland recommendations draw upon the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). These guidelines use a different formula for relating leaching fraction, soil salinity and irrigation water salinity and significantly higher leaching fractions. They also provide irrigation salinity thresholds that factor in soil type, giving a higher threshold for faster draining soils. For example, the recommended limit of 700 EC for pasture in NSW assumes that soils are at least ‘slow draining’, meaning that pasture or crops grown on ‘very slow draining soils’ may suffer some yield loss. In determining RCLs, soils have assumed to be slow draining (or equivalent) where crop salinity thresholds are provided by soil type.

### 6.4.5 Recommended resource condition limits

A summary of recommended RCLs for irrigated agriculture for the WQSMP is contained in Table 6.3. A full description of the basis for RCLs (including source reference material) can be found in Appendix C.
### Table 6.3 Resource condition limits developed for each irrigated area

<table>
<thead>
<tr>
<th>Irrigated area</th>
<th>Target sites</th>
<th>Most sensitive crop</th>
<th>Salinity threshold (EC&lt;sub&gt;c&lt;/sub&gt;, mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverland Irrigation</td>
<td>426522 River Murray at Murray Bridge</td>
<td>Grapes</td>
<td>680 410</td>
</tr>
<tr>
<td></td>
<td>426544 River Murray at Morgan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>426514/4260663 River Murray at Berri</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverland Irrigation</td>
<td>A4261001 River Murray at border [i.e. flow to South Australia]</td>
<td>Grapes</td>
<td>680 410</td>
</tr>
<tr>
<td>Sunraysia Irrigation</td>
<td>414204 Murray River at Red Cliffs</td>
<td>Grapes</td>
<td>680 410</td>
</tr>
<tr>
<td>Boort Irrigation</td>
<td>407229 Loddon River at Serpentine</td>
<td>Grapes</td>
<td>680 410</td>
</tr>
<tr>
<td>Campaspe Irrigation District</td>
<td>406218 Campaspe River at Campaspe Weir</td>
<td>Pasture, cereals and other crops cut</td>
<td>800 480</td>
</tr>
<tr>
<td>Shepparton Irrigation, Central Goulburn Irrigation, Rochester</td>
<td>405259 Goulburn River at Goulburn Weir</td>
<td>Apples</td>
<td>500 300</td>
</tr>
<tr>
<td>Torrumbarry Irrigation, Murray Irrigation, Murray Valley Irrigation</td>
<td>409204 Murray River at Swan Hill</td>
<td>Pasture, cereals and other crops cut</td>
<td>700 420</td>
</tr>
<tr>
<td></td>
<td>409207 Murray River at Torrumbarry 409216 Murray River at Yarrawonga Weir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Darling diversers</td>
<td>425007 Darling River at Burtundy</td>
<td>Grapes</td>
<td>680 410</td>
</tr>
<tr>
<td>Colleambally Irrigation, Murrumbidgee Irrigation</td>
<td>410023 Murrumbidgee River at Berembed</td>
<td>Grapes</td>
<td>1000 600</td>
</tr>
<tr>
<td>Jemalong Irrigation</td>
<td>412004 Lachlan River at Forbes</td>
<td>Grapes</td>
<td>1000 600</td>
</tr>
<tr>
<td>Narromine, Trangie–Nevertire, Tenandra, Buddah Lake, Mathaguy, Nevertire, Greenhide</td>
<td>421001 Macquarie River at Dubbo</td>
<td>Cotton</td>
<td>1000 670</td>
</tr>
<tr>
<td>Namoi private diversions</td>
<td>419002 Namoi River at Narrabri</td>
<td>Cotton</td>
<td>1000 670</td>
</tr>
<tr>
<td>St George Irrigation</td>
<td>422207A Ballandool River at Hebel-Bollon Road</td>
<td>Sorghum</td>
<td>3100 2080</td>
</tr>
<tr>
<td></td>
<td>402012 Narran River at New Angelool</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.4.6 Additional comments

The approach used in this assessment is considered to be broadly adequate at the Basin scale. It provides a balance between the application of a first principles approach to the lower Murray, where the risks of water salinity impacts on agriculture are highest, and the adoption of recommendations from local literature elsewhere in the Basin. Where local data on soils and irrigation is poor, the salinity risks of applied water is, with some exceptions, less significant, as significant work has already been conducted by local agencies.

Specific limitations that should be recognised in the proposed RCLs listed in Table 6-1 include:

- Livestock and livestock products are, in some cases, ultimately generated from irrigated produce grown on farms, such as pasture or other cereals. Such irrigated produce is not captured in the ABS data.
- There were a number of crops which are known to be irrigated within parts of the Basin that were not identified in the statistics for 2007-08. These included maize in the northern Basin and tobacco in north eastern Victoria.
- Broad acre crops interpreted as being irrigated were limited to rice, cotton and, for some NRM regions, pasture and cereals for hay.
- Gross values, rather than local values, are used for each crop, as these represent the total value of each crop (gross value is the sum of the local value and associated marketing costs).
- In order to account for regional differences, published crop salinity thresholds have been sought from state agencies and departments. However, these thresholds are likely to be different between states. For example, NSW DPI (2006) recommends a threshold of 1000 EC for cotton seedlings, and a general threshold of 1700 EC. The lowest threshold for cotton published by DERM (2009), however, is 4000 EC. Despite these differences, this report has adopted the relevant state guideline salinities, as these are considered to best account for regional differences such as soil properties and rainfall.
- The classification of wheat as non-irrigated will be erroneous in some areas of the northern Basin. In recent years, some cotton farmers in the Queensland regions have reportedly used their reduced water allocations to grow irrigated wheat when there was inadequate water for cotton (Phil Cole, pers. comm. 2009). The paucity of data prevents a determination as to whether irrigated wheat is in excess of 10% of the irrigation production of any region. However, this is considered immaterial in the context of this study, as wheat is less salt sensitive than the crops ultimately selected for these Queensland regions.
- The glossary for the ABS (2009) data notes the following: ‘Gross and local value of agricultural commodities produced involve some duplication as they include certain agricultural commodities which are consumed as raw materials to produce other agricultural commodities [e.g. hay consumed by livestock]’. For example, the value of hay may be underestimated due to on-farm consumption.
- The ABS (2009) data set used for this study was sourced from a single year (2007-08) when areas sown to rice and cotton were very low due to low water availability. In years where these crops are more widely planted, they will make a larger contribution to the irrigated agricultural production, meaning that the relative contribution of other crops may decrease. As a consequence, an RCL set in such years would be much higher due to the relative salt tolerance of cotton and rice.
Gross value statistics for nurseries, cut flowers and cultivated turf enterprises reflect the business value rather than a crop type, as species and varieties will vary significantly within the category. Lack of data on what cultures are underpinned by this category and their individual gross value means that they have not been considered within the analysis.

Future analysis will benefit from more rigorous data sets, with a report on Experimental Estimates of the Gross Value of Irrigated Agricultural Production (GVIAP) (ABS in press) for 2007-2008 expected to be available in the near future. Availability of this data will eliminate the error of assuming that an entire crop is irrigated or not, as it uses survey data to determine the quantities of irrigation water used and the crops it was applied to. This data will also provide longer term values of gross agricultural production, as it is to be based upon data for the period 2000-01 to 2007-08. It therefore eliminates some of the vagaries of crop prices or annual allocations that impact upon production in any one year (May 2009).

Complying with state guidelines may in some cases compromise the preliminary objectives of maintaining salinity levels below that which will adversely affect existing crop productivity, as local recommendations may not have been based upon no salinity-induced yield declines. For example, the Victorian Department of Primary Industries recommend a limit of 800 EC for water applied to pastures (Batey 2008), whereas applying an 800 EC irrigation water for pasture on Goulburn Clay Loam could be expected to lead to a 24% decline in white clover production (Batey 2008). However, this specific example has no implications for the setting of targets for the Shepparton Irrigation Region, as recommendations on an irrigation related RCL is based upon apples rather than pasture (Table 6.3).

### 6.4.7 Summary

RCLs have been developed for each irrigation area, but there are some significant limitations in the data underpinning some areas. Limitations in data availability include the distribution of irrigated crops and soils across the Basin.

As a consequence of data constraints, future application of the process in determining irrigation should pursue improvements in the available knowledge. The release of Experimental Estimates of the Gross Value of Irrigated Agricultural Production (GVIAP) by the ABS will provide some improvements, as it will provide detailed data on the value of irrigated agricultural production by NRM region. This, however, still does not circumvent the problem of matching NRM-level information with specific irrigation areas or the lack of regional specific recommendations on salinity thresholds that will lead to no adverse impact on crop productivity within regional irrigation areas.

These limitations in the determination of RCLs for irrigated agriculture are considered to be only a significant issue within the lower Murray and several of the more saline tributaries identified in MDBA (2010a). More broadly across the basin, the likelihood of salinities exceeding the RCL for most crops across these regions is low, and hence irrigation based targets are, outside the Mallee, generally likely to be based upon the no deterioration principle rather than on the salt sensitivity of the particular crops.
7 SELECTION OF MONITORING SITES TO ASSESS PROGRESS AGAINST TARGETS

7.1 Introduction

Application of the site selection process documented in Section 5.2.3 can broadly be summarised as follows:

a. Monitoring sites and irrigation and ecological values were mapped across the Basin.

b. At least one designated monitoring site was warranted within any river valley that harboured a defined irrigation or ecological environmental value identified within Report 1 [MDBA 2010a]. It was not deemed necessary to explicitly identify monitoring sites in order to evaluate outcomes against targets based upon drinking water RCLs, as urban treatment plants are required to undertake rigorous monitoring of water diversions. There is potential for arrangements to be developed to access this data rather than instigating a parallel monitoring program.

c. The preferred site for any valley warranting monitoring under (a) would be the existing BSMS end-of-valley target site in order to build synergies and efficiencies in the monitoring regime.

d. If the site identified under (c) was in the general vicinity of most ecological and agricultural environmental values mapped in Report 1 [MDBA 2010a], and complied with the measurability criteria [Section 5.2.3], then it was adopted. If not, an assessment of alternative existing monitoring sites was then undertaken.

7.2 Evaluation of the end-of-valley target sites

In accordance with the process contained within Section 5.2.3, BSMS end-of-valley sites were assessed to establish their potential role as operational sites. A summary of this evaluation is contained within Appendix D.

For those end-of-valley sites deemed to be suitable from a location perspective [Appendix D], i.e. relevant in terms of SMART targets, they were scored against the ‘measurable’ criterion identified in Section 5.2.3. The basis for scoring was similar to that utilised in the assessment of sites against end-of-valley target site attributes, [MDBA 2010b] as follows:

- for sites that satisfy the ‘measurable’ criterion to a ‘low’ degree, a score of 5 is given
- for sites that satisfy the ‘measurable’ criterion to a ‘medium’ degree, a score of 10 is given
- for sites that satisfy the ‘measurable’ criterion to a ‘high’ degree, a score of 15 is given.

Table 7-1 summarises this ‘measurability’ assessment.
Salinity Targets Review
A process for developing objectives and targets

Table 7-1  Assessment of 12 end-of-valley monitoring evaluation sites against the SMART ‘measurable’ criterion to assess their potential role as operational assessment sites

<table>
<thead>
<tr>
<th>Number</th>
<th>River</th>
<th>Site</th>
<th>Totality</th>
<th>Interference</th>
<th>Minimum Monitoring</th>
<th>Frequency</th>
<th>Historical</th>
</tr>
</thead>
<tbody>
<tr>
<td>426544</td>
<td>Murray</td>
<td>Morgan</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>44261001</td>
<td>Murray</td>
<td>Border</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>426514/4260663</td>
<td>Murray</td>
<td>Berri</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>426522</td>
<td>Murray</td>
<td>Murray Bridge</td>
<td>5</td>
<td>15</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>412004</td>
<td>Lachlan</td>
<td>Forbes</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>425008</td>
<td>Darling</td>
<td>Wilcannia</td>
<td>12.5</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>415200</td>
<td>Wimmera</td>
<td>Horsham</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>408203</td>
<td>Avoca</td>
<td>Quambatook</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>406218</td>
<td>Campaspe</td>
<td>Camp. Weir</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>405259</td>
<td>Goulburn</td>
<td>Goulb. Weir</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>422207A</td>
<td>Ballandool</td>
<td>Hebel-B Rd.</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>422012</td>
<td>Narran</td>
<td>N.Angeldool</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>AVERAGE</td>
<td></td>
<td></td>
<td>13.1</td>
<td>15</td>
<td>14.2</td>
<td>14.2</td>
<td>11.7</td>
</tr>
</tbody>
</table>

These existing sites were therefore deemed to be suitable as operational targets and have been included as recommended target sites in Report 4 (MDBA 2010d). However, as identified in Appendix D, the Murray at Murray Bridge will need flow measurement arrangements to be put into place in order to fully satisfy measurability criteria.
7.3 Evaluation of the ‘measurability’ of sites

In assessing the end-of-valley target sites and the location of assets, the need for additional monitoring sites was identified. Sites identified during this process (Appendix D) are listed in Table 7.2.

<table>
<thead>
<tr>
<th>Number</th>
<th>River</th>
<th>Site</th>
<th>Totality</th>
<th>Interference</th>
<th>Minimum Monitoring</th>
<th>Frequency</th>
<th>Historical</th>
</tr>
</thead>
<tbody>
<tr>
<td>410023</td>
<td>M'tidgee</td>
<td>Berembed</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>421001</td>
<td>Macquarie</td>
<td>Dubbo</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>419002</td>
<td>Namoi</td>
<td>Narrabri</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>418001</td>
<td>Gwydir</td>
<td>Pailamallawa</td>
<td></td>
<td></td>
<td>7.5(4)</td>
<td>7.5(4)</td>
<td>7.5(4)</td>
</tr>
<tr>
<td>425007</td>
<td>Darling</td>
<td>Burtundy</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>407229</td>
<td>Loddon</td>
<td>Serpentine</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A hydrographic site inspection will be necessary to establish these attributes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>409216</td>
<td>Murray</td>
<td>Yarrawonga W</td>
<td>n/a</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>409207</td>
<td>Murray</td>
<td>Torrumbarry</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>409204*</td>
<td>Murray</td>
<td>Swan Hill</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>414204*</td>
<td>Murray</td>
<td>Red Cliffs</td>
<td></td>
<td></td>
<td>5(6)</td>
<td>5(6)</td>
<td>0(6)</td>
</tr>
</tbody>
</table>

# These sites were previously interpretation sites.
(1) Good data only post-2000.
(3) Site became non-active in 1995. 419039 at Mollee, 12 km downstream, could be used. Salinity not measured.
(4) Good flow records back to 1972. Salinity not measured.
(5) Salinity now continuous. How far back in time this goes is uncertain.
(6) Flow not measured. Salinity site was non-representative and daily only until pontoon with continuous EC installed circa 2005

This preliminary assessment also deems these sites suitable as operational sites, although it will be necessary for a qualified hydrographer to conduct an inspection prior to a final decision to adopt these as monitoring sites under the WQSM.

Figure 7.1 on the following page shows the location of the operational monitoring sites. Figures 7.2–7.4 show the locations of sites for aquatic ecosystems, raw drinking water and irrigated agriculture respectively.
Figure 7.1  Operational monitoring sites
Figure 7.2  Aquatic ecosystem sites
Figure 7.3  Urban centres and operational sites
Figure 7.4  Irrigation areas and irrigated agriculture monitoring sites
8 CONCLUSION

This report provides a broad process for the development of salinity objectives and targets for defined valley scale environmental values for inclusion within the Water Quality and Salinity Management Plan. The process has then been applied to the necessary extent to develop RCLs for aquatic ecosystems, raw drinking water and irrigated agriculture. These RCLs are subject to a range of limitations documented within the report, and would be expected to be improved under future five yearly reviews of targets under the Act subject to investment in knowledge during the intervening years. Given the Basin scale of the study, it is anticipated that a more detailed determination of RCLs would be warranted during the water resource planning process to better articulate the RCLs within valley scale data sets.

Application of the RCLs to the process to derive recommendations on salinity objectives and targets is contained within a companion report (MDBA 2010d).
LIMITATIONS

The sole purpose of this report and the associated services performed by Sinclair Knight Merz ('SKM') is to develop a process for developing salinity objectives and targets in the Murray–Darling Basin in accordance with the scope of services set out in the contract between SKM and the Murray–Darling Basin Authority ('MDBA'). That scope of services, as described in this report, was developed with the MDBA.

In preparing this report, SKM has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the MDBA and/or from other sources. Except as otherwise stated in the report, SKM has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

SKM derived the data in this report from information sourced from the MDBA (if available) and/or obtainable in the public domain at the time or times outlined in this report. The passage of time and the manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, including re-evaluation of the data, findings, observations and conclusions expressed in this report. SKM has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by SKM for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, the MDBA, and is subject to, and issued in accordance with, the provisions of the agreement between SKM and its MDBA. SKM accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.
10 REFERENCES


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Boland A, Corrie J, Bewsell, D and Jerie, P 2001, Best Management Practice and Benchmarking for Irrigation, Salinity and Nutrients of Stone and Pome Fruit. Institute of Sustainable Irrigated Agriculture, Tatura..


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Water Act 2007 (Cth)

Salinity Targets Review
A process for developing objectives and targets


**APPENDIX A**

**SYNTHESIS OF SELECTED SALINITY TOLERANCE FOR AQUATIC ECOSYSTEM**

**Table 1**

This table represents a synthesis of selected salinity tolerances. No attempt has been made to reconcile differences between conflicting reports for the same species; instead, the lower value has been chosen to provide greater protection to that species, thus ‘upper limit’ implies the lower upper limit reported. The present approach also uses approximate roundings since all units have been converted to mg/L using a conversion factor of 0.64 as used in the recent aquatic systems salinity review by Watson et al (2008). Juvenile life form tolerances are reported where indicated.

<table>
<thead>
<tr>
<th>Biotic Grouping</th>
<th>Threshold mg/L NaCl (all figures approximate roundings)</th>
<th>Effect</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>mostly unknown</td>
<td>Very high salinities may restructure microbial communities and modify nutrient release</td>
<td>Hart et al (1991)</td>
</tr>
<tr>
<td>Blue–green algae</td>
<td>⇐6000</td>
<td>Freshwater forms will persist. Salt tolerant forms will persist up to 23,000 mg/L</td>
<td>Hart et al (1991)</td>
</tr>
<tr>
<td>Conclusion</td>
<td>5000 mg/L can cause shifts in specialist microbial processes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macro algae</td>
<td>1000–3000</td>
<td>Disappeared from wetlands</td>
<td>Garcia (1999)</td>
</tr>
<tr>
<td></td>
<td>1000–5000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td>3000–5000 mg/L: important upper threshold but mortality as early as 1000 mg/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microinvertebrates</td>
<td>Knowledge of Australian taxa poor</td>
<td>Overseas studies suggest substantial reductions in diversity when salinity is →2000 mg/L</td>
<td>Green &amp; Mengestou (1991)</td>
</tr>
<tr>
<td></td>
<td>⇐1000</td>
<td>largely restricted to waters ⇐1000 mg/L salinity with significant reductions above 1000 mg/L</td>
<td>Nielsen et al (2003)</td>
</tr>
<tr>
<td>Conclusion</td>
<td>6000 mg/L: an important upper threshold but affects apparent ⇐1000 mg/L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Macroinvertebrates

<table>
<thead>
<tr>
<th>Salinity (mg/L)</th>
<th>Effect Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;550</td>
<td>Changes to community structure</td>
<td>Dunlop (2005)</td>
</tr>
<tr>
<td>1000</td>
<td>Reductions in the abundance of many animals within this group</td>
<td>Hart et al (1991)</td>
</tr>
<tr>
<td>2000</td>
<td>Adverse to most groups</td>
<td>James et al (2003)</td>
</tr>
<tr>
<td>5000</td>
<td>Significant reduction in populations</td>
<td>Cameron (1991)</td>
</tr>
<tr>
<td>9000</td>
<td>Uppermost salinity for most</td>
<td>Hart et al (1991)</td>
</tr>
</tbody>
</table>

Using 72-h LC₅₀ to determine acute tolerance scores

<table>
<thead>
<tr>
<th>Salinity (mg/L)</th>
<th>Tolerance Score</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000–10,000</td>
<td>Reported as “Sensitive” species</td>
<td>Horigan et al (2007)</td>
</tr>
<tr>
<td>13,500–15,000</td>
<td>Reported as “Tolerant” species</td>
<td></td>
</tr>
<tr>
<td>18,500–27,000</td>
<td>Reported as “Very tolerant” species</td>
<td></td>
</tr>
</tbody>
</table>

Selected non-arthropod and insect and mite

<table>
<thead>
<tr>
<th>Salinity (mg/L)</th>
<th>Effect Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000–7000</td>
<td>Proportionately half of these taxa disappear between 5000–7000 mg/L</td>
<td>Kefford et al (2007)</td>
</tr>
</tbody>
</table>

Conclusion

- **5000 mg/L:** an important upper threshold but affects apparent < 1000 mg/L
- Several families capable of saline concentrations well above previously reported figures.

**Frogs (tadpoles)**

<table>
<thead>
<tr>
<th>Salinity (mg/L)</th>
<th>Effect Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>50–400</td>
<td>Sublethal effects to egg development</td>
<td>Francis (2003)</td>
</tr>
<tr>
<td>1300</td>
<td>Prolonged exposure adverse to larvae of L. tasmaniensis.</td>
<td>Quincey (1991)</td>
</tr>
<tr>
<td>4000</td>
<td>Development delayed at ~1900 mg/L.</td>
<td>Flowers (2004)</td>
</tr>
<tr>
<td>← 2100</td>
<td>No effect to gradual exposure L. tasmaniensis</td>
<td>Smith et al (2007)</td>
</tr>
<tr>
<td>1800–5600</td>
<td>Several species with no predicted effect</td>
<td>Quincey (1991); Christy and Dickson (2002); Chinathamby et al (2006)</td>
</tr>
<tr>
<td>→ 4200</td>
<td>General tadpole mortality across several key species. L. ewingii not effected until → 4200 mg/L</td>
<td>Quincey (1991); Smith et al (2007)</td>
</tr>
<tr>
<td>3500–5000</td>
<td>Disappearance of some key species</td>
<td>Christy and Dickson (2002)</td>
</tr>
<tr>
<td>8000</td>
<td>Mortality time dependent for L. aurea but no effect at 1400mg/L.</td>
<td>Baumgarten (1991)</td>
</tr>
</tbody>
</table>

Conclusion

- **5000 mg/L:** an upper threshold for frog mortality but affects apparent < 1000 mg/L
- Three species reported as surviving

**Macrophytes**

<table>
<thead>
<tr>
<th>Salinity (mg/L)</th>
<th>Effect Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lethal effects for some submerged species</td>
<td>Bailey and James (2000)</td>
</tr>
<tr>
<td>1000</td>
<td>Onset of sub-lethal effects</td>
<td>Hart et al (1991)</td>
</tr>
</tbody>
</table>
### Salinity Targets Review

A process for developing objectives and targets

<table>
<thead>
<tr>
<th>Conclusion</th>
<th>4000 mg/L: an important upper threshold but community and sub-lethal affects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian vegetation</td>
<td>( \rightarrow 1000 ) Reduction in germination and resultant community diversity and abundance</td>
</tr>
<tr>
<td></td>
<td>( \rightarrow 2000 ) Adverse impacts to many species</td>
</tr>
<tr>
<td></td>
<td>( \rightarrow 3000 ) Reduced germination for some sensitive taxa</td>
</tr>
<tr>
<td></td>
<td>( \rightarrow 7000-9000 ) Stimulation of growth in seedlings</td>
</tr>
<tr>
<td></td>
<td>( \rightarrow 19,000 ) mg/L Soil salinity threshold for E. calmaldulensis (Red Gum)</td>
</tr>
<tr>
<td></td>
<td>( \rightarrow -35,000 ) mg/L Soil salinity for E. largiflorens (Black Box)</td>
</tr>
</tbody>
</table>

### Conclusion

- **1000 mg/L**: Effects on germination and resultant community diversity and abundance
- **300–1000 mg/L**: Reduced germination for some sensitive taxa
- **4000 mg/L**: Few freshwater macrophytes persist, but most disappear from wetlands

### Conclusion

- **20,000–35,000 mg/L**: Stimulation of growth in seedlings
- **3000 mg/L**: Seed germination decreases
- **7000–9000 mg/L**: Stimulation of growth in seedlings
- **19,000 mg/L**: Soil salinity threshold for E. calmaldulensis (Red Gum)
- **−35,000 mg/L**: Soil salinity for E. largiflorens (Black Box)

### Conclusion

- **2000–2300 mg/L**: 1-day LC\(_{50}\) for Murray and Trout Cod
- **280 mg/L**: Upper tolerance limit for larvae
- **2000 mg/L**: Eggs vulnerable
- **2000–4500 mg/L**: Adverse effects
- **3000–5000 mg/L**: Optimal range
- **8000 mg/L**: Upper limit
- **13,700 mg/L**: LC\(_{50}\) for fingerlings
- **8800 mg/L**: Upper limit
- **11,700 mg/L**: Upper limit
- **48,000 mg/L**: Upper limit

### Conclusion

- **10,000–40,000 mg/L (and greater)**: Upper limit for adults but early life stage mortality possible
## Waterbirds


## Conclusion

### large gaps in knowledge but will invariably involve indirect effect dynamics

## Other

### Freshwater tortoises possessing functional salt glands

| Freshwater tortoises possessing functional salt glands | 5000 | Indirect evidence suggests they may be able to cope up to this level | Hart et al., 1991 |

#### Nutrients


## Conclusion

### Nutrient release can be affected ← 1000 mg/L

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APPENDIX B

SETTING A SALINITY TARGET FOR IRRIGATION WATER

By Phil Cole, Murray–Darling Basin Authority

1. Salinity is the presence of soluble salts in waters or in soils. High salinity levels will result in reduced plant productivity. Sodicity is a related process that can result in soil structural deterioration due to the presence of a high proportion of sodium (Na+) ions relative to calcium (Ca2+) and magnesium (Mg2+) ions in soil or water. The impact of salinity on crops is due to:
   a. osmotic pressure of the water in the rootzone limiting water uptake
   b. ion toxicity from a build up of some ions [e.g. chloride, sodium] in the soil
   c. foliar ‘burning’ caused by overhead irrigation with saline water
   d. change of soil structure and permeability as a result of the effect of sodium on clay particles (sodicity).

2. In irrigated enterprises rainfall, applied water, crop water demand, leaching, and evaporation are in constant flux in the soil. The relationship between the salinity of irrigation water and the impact on crop growth and yield is thus complex and dependent on a number of factors, some of which may be influenced by the water manager and some by the water user.

3. The factors that influence the salinity impact of water used for irrigated agriculture include:
   a. crop yield response
      i. Crops and species, and annual, perennial and woody crops differ in their response to salinity. There is published yield-salinity data available for field, vegetable and fruit crops for osmotic and toxic ion effects [see Ayers and Westcot 1985, which includes quoted reference material of Glenn Hoffman and Gene Maas, US Department of Agriculture Agricultural Research Service, United States Salinity Laboratory, Riverside, California].
      ii. The effect of increased osmotic pressure of the water in the soil [more specifically, in the rootzone] as soil salinity increases is to decrease the ability of the crop to extract water from the soil, which in turn can stress the crop and reduce the growth and yield. The osmotic pressure is determined by the concentration of salt in the soil (measured as electrical conductivity units of a saturated soil water extract, ECe).
      iii. The response, however, may also vary with the different growth stages of a crop [germination, vegetative growth, maturation etc] as crop sensitivity to soil salinity continually changes during the growing season; most plants become increasingly tolerant as they grow older. Some vegetable crops are sensitive to salinity during emergence and early seedling stages, requiring adoption of specific management practices. Reliable data on these aspects is limited.
      iv. Extensive studies have been undertaken to determine the relative yield responses of many crop species. The salinity yield response internationally adopted and based on the best scientific information is one developed by the United States Salinity Laboratory, by Maas and Hoffman (1977). This model describes the relationship between the salinity of water in the soil (in the crop rootzone, measured as ECe) and relative yield as a ‘bent stick’. The relationship indicates a threshold [crop specific] soil salinity, with no yield loss at soil salinity levels up to this value. Above the threshold, as soil salinity increases, yields are assumed to decline at different, given rates for different crops. Some research suggests an alternative yield response curve which more accurately describes the crop response to root zone salinity as sigmoidal. The ‘bent stick’ represents an approximation of the sigmoidal relationship.
v. The threshold point and the decline above the threshold differs between crops and even, within crop types, between varieties and rootstocks. Crop selection and breeding can increase crop tolerance to salinity.

b. crop water requirement and water use
   i. The volume of water required to meet crop water requirements is determined by crop type and the prevailing climatic conditions.
   ii. Failure to fully meet crop water requirements may also lead to higher soil solution salt concentrations.

c. leaching fractions and leaching efficiency
   i. The removal of salts from soils through the processes of leaching and drainage is necessary to prevent accumulation of salt in the rootzone. Sound irrigation management will aim to keep the soil salinity below the threshold levels for the particular crop, as described above. A number of factors determine soil salinity, including the salinity of the applied water (ECw), the leaching fraction (the proportion of the applied irrigation water that drains from the soil), and the leaching efficiency (the effectiveness of the leaching fraction in removing salt from the soil). Soil type can influence both the leaching fraction and leaching efficiency — the potential to leach salt from heavier (greater clay content) soil is less than for sandy soil.
   ii. A study of root zone drainage for the MDBA identified that root zone drainage rates for irrigated crops in the Mallee zone were highly variable within a range of 5% to 25% of the applied irrigation plus rainfall.
   iii. The leaching efficiency relates to the water and salt transport process in the soil. The process of preferential flow means that water does not move through all the soil pores equally, and as a result some salt will not be leached. A lower leaching efficiency alternatively implies that a greater leaching fraction is required to prevent salt accumulation in the soil.
   iv. Recent monitoring in the Riverland has demonstrated that growers practising highly water efficient irrigation applications are experiencing a gradual accumulation of salts in the root zone. For a pressurised drip irrigated vineyard, the leaching efficiency was found to be 70%, whereas previous studies implicitly assumed 100% leaching efficiency. By implication, there is a risk of salt accumulation in the rootzone if efficient irrigation is practiced.
   v. When the irrigation method, the soil type and the leaching efficiency are combined, an effective leaching fraction can be determined.
   vi. A number of alternative formulae for calculating soil salinity (ECe) from ECw of applied irrigation water and the leaching fraction/leaching efficiency have been explored. These are:
      1. Hoffman GJ and van Genuchten MT (1983). This equation is currently favoured by SARDI researchers in South Australia.
      2. The formula quoted in the National Water Quality Management Strategy as proposed by Department of Natural Resources in Queensland [National Water Quality Management Strategy, 2000] — noting that this formula was developed in locations with summer rainfall.
vii. Recent advice to the MDBA [RMCG 2009] recommends that the FAO formula be adopted as a better reflection of field tested conditions.

viii. Higher leaching fractions can have unintended environmental impacts. A higher leaching fraction implies larger drainage volumes, which in poor drainage locations will lead to saturated subsoils, watertable development, potentially capillary rise of salts to the surface and local salinisation. Large drainage volumes may not be disposed readily and may require drainage infrastructure and imply greater volumes of water required for irrigation.

ix. Modern sustainable irrigation practice promotes the minimisation of drainage (and leaching). In irrigated areas of the MDB mallee zone, drainage (and leaching) volumes may be regulated to not exceed 15% of the irrigation application [eg Water Allocation Plan for the River Murray Prescribed Watercourse, SAMDBNRM Board 2004]; salinity accountability [groundwater] modelling used by the MDBA has adopted drainage volumes of 10% of the irrigation application. With microirrigation systems, the volume may be even less [RMCG 2009 suggest 3.5% for microirrigation].

d. Sodicity is the presence of a high proportion of sodium (Na+) ions relative to calcium (Ca2+) and magnesium (Mg2+) ions in soil or water. Sodicity degrades soil structure by breaking down clay aggregates, which makes the soil more erodible and less permeable to water and reduces plant growth.

e. irrigation methods

i. Irrigation methods that result in non-uniform water application will result in salt accumulation at locations with lower water application and less leaching.

ii. Leaching efficiency may vary between irrigation methods, as noted above — there is lower leaching efficiency with microirrigation techniques.

f. Irrigation methods that result in foliar wetting and foliar salt application can lead to salt uptake with potential toxicity impacts from sodium and chloride. In extreme situations, water application at times of high evaporative demand [hot, windy days] can result in rapid leaf burn, defoliation and even crop death. Where salinity risks are significant, under-canopy irrigation or drip should be adopted. When overhead irrigation must be used, the recommended practice would be to irrigate at night [cooler and calmer weather conditions] to reduce canopy evaporation and minimise salinity effects on crop health.

g. Irrigation headworks that can supply water to the field at a flow and frequency for scientifically based irrigation scheduling [the right amount of water applied at the right time] allows the irrigator to adopt efficient irrigation practice and to manage in such a way as to minimise salinity risks.

h. Frequency of irrigation: ‘real time’ soil salinity [the concentration of salt in the soil solution] will be lowest immediately after irrigation and will gradually increase as the crop extracts water, but not salt, through evapotranspiration, until the concentration reaches a maximum immediately before the next irrigation. An irrigation schedule that refills the soil more frequently will result in a lower expression of soil salinity to the crop than one that refills the soil infrequently. In other words, crops will experience lower stress under a frequent irrigation schedule, as might be applied by daily drip irrigation, than a less frequent irrigation schedule as might be applied by sprinkler or surface irrigation.

i. long-term salinity impacts on crops
i. The toxic effects of Na and Cl are particularly deleterious on woody perennials. Woody fruit and nut crops can over time accumulate Na and Cl to toxic levels causing leaf burn, necrosis and defoliation. Irrigated woody crops may demonstrate minimal signs of salinity stress for a number of years, with the predominant effect being osmotic, and it may not be for 5-10 years after irrigation with saline water that the symptoms of toxicity will occur, with major impacts on orchard production.

ii. The woody tissue may provide a sink for the storage of Na and Cl ions, and when this storage capacity is exceeded the ions flood into other parts of the plant. It is difficult to predict when this storage capacity may be reached and if a subsequent lowering of salinity levels will provide a period of recovery for the plant. Salt tolerant rootstocks may reduce the uptake of toxic ions.

j. Short periods of elevated salinity

i. The existing yield–salinity relationships are based more on average rather than peak salinity levels. For irrigated crops, the impact of salinity peaks is also related to the:
   1. duration of peak salinity
   2. maximum peak salinity
   3. state of crop development/physiological stage
   4. mitigation strategies available to reduce the potential on-farm impacts.

v. Assessing the risk posed by short periods of high salinity water would include assessment of:
   1. the duration of a high salinity event likely to cause a salinity impact on growth
   2. any crops that may be more susceptible to salinity at different physiological stages
   3. opportunities and practicalities of farmers increasing leaching or other irrigation management actions to minimise the salinity impact.

4. Salinity targets may allow for periods of higher salinity at less critical times in growth cycles, or at cooler times of the year when water demand is lower.

5. An important goal is to maintain the productivity of irrigated agricultural land and associated water resources, in accordance with the principles of ecologically sustainable development and integrated catchment management. This should be a key consideration in any irrigation strategy, alongside maximum yield and economic viability, and requires, amongst other things, drainage minimisation and safe management of saline drainage waters.

6. The effects of salinity in irrigation waters are very situation-specific, requiring the setting of water quality target values at the local/regional level. The key steps to determining the suitability of irrigation water with respect to salinity are:
   a. Step 1, estimate the effective leaching fraction under the proposed irrigation regime
   b. Step 2, select the threshold soil salinity for the specific crop, from published data, above which salinity related yield decline occurs: average root zone salinity is considered the key limitation to plant growth in response to salinity levels in irrigation water (although note that the impact of salinity can be modified by management practices)
   c. Step 3, estimate the corresponding irrigation water salinity for the given leaching fraction, crop type and acceptable yield decline, using an appropriate leaching formula.

These three steps have been followed to construct the following table:
### Suitability of irrigation water for various crops

<table>
<thead>
<tr>
<th>Crop type</th>
<th>examples ranked in sensitivity to salinity</th>
<th>Leaching fraction (expressed as the fraction of the volume of the applied irrigation water applied to maintain soil salinity at the threshold value) (note that a leaching fraction above 0.15 does not meet sustainability criteria)</th>
<th>Soil salinity threshold value ECe [the maximum soil salinity above which yield decline due to osmotic effects occurs, from FAO]</th>
<th>Irrigation water calculated threshold ECw [based on the FAO equation; the salinity of applied irrigation water, above which yield reduction occurs, given the leaching fraction and the threshold ECe]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry</td>
<td></td>
<td>0.1</td>
<td>0.7</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>0.7</td>
<td>460</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>0.7</td>
<td>1100</td>
</tr>
<tr>
<td>Almond</td>
<td></td>
<td>0.1</td>
<td>1.5</td>
<td>680</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>1.5</td>
<td>970</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>1.5</td>
<td>2350</td>
</tr>
<tr>
<td>Clover</td>
<td></td>
<td>0.1</td>
<td>1.5</td>
<td>680</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>1.5</td>
<td>970</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>1.5</td>
<td>2350</td>
</tr>
<tr>
<td>Potato</td>
<td></td>
<td>0.1</td>
<td>1.7</td>
<td>770</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>1.7</td>
<td>1100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>1.7</td>
<td>2650</td>
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<tr>
<td>Tomato</td>
<td></td>
<td>0.1</td>
<td>2.5</td>
<td>1150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>2.5</td>
<td>1650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>2.5</td>
<td>3900</td>
</tr>
<tr>
<td>Rice</td>
<td></td>
<td>0.1</td>
<td>3.0</td>
<td>1350</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>3.0</td>
<td>1950</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>3.0</td>
<td>4650</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td></td>
<td>0.1</td>
<td>5.6</td>
<td>2550</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>5.6</td>
<td>3650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>5.6</td>
<td>8750</td>
</tr>
<tr>
<td>Cotton</td>
<td></td>
<td>0.1</td>
<td>7.7</td>
<td>3500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>7.7</td>
<td>5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>7.7</td>
<td>12000</td>
</tr>
</tbody>
</table>
d. Step 4, determine the risk of sodicity, caused by irrigation water quality, on soil structure. Poor soil structure can reduce plant yields by limiting aeration, water infiltration and root growth:

i. Calculate the sodium adsorption ratio (SAR) and, through comparison with published tables, predict soil structure stability. The SAR value measures the relative concentration of sodium (Na+) to calcium (Ca2+) and magnesium (Mg2+); higher SAR values will increase the risk of soil structure breakdown.

e. Step 5, consider toxicity issues, particularly those due to chloride, sodium and boron: using chloride as the example, FAO 29 suggests that, for woody horticultural crops, the chloride concentration in the soil solution should not exceed the range 10–20 MEQ/l, which corresponds to a ECw of 800–1600 EC using the FAO leaching equation. The ANZEC guidelines suggest horticultural crops are very sensitive to both chloride and sodium, with safe ranges below a corresponding 800 Ecw..

f. Step 6, consider other salinity management issues including seasonal variability in salinity of water, salinity peaks, extent and duration of periods of higher salinity, especially with a focus on achieving salt load targets while not compromising concentration targets

g. Step 7, consider salinity problems within the framework of broader catchment issues such as regional watertables, groundwater and surface water quality: watertable salinity develops in response to excess water and salts accumulating in sensitive parts of the landscape. Excess water can percolate to groundwaters as a result of drainage from irrigated soils.

7. Clearly there is no unique solution for setting water quality and salinity targets for irrigated crops. The more salt sensitive horticultural crops that are important in regional economies require water quality of 700–1000 EC if yield loss of less than 10% and leaching fractions of 10–15% are adopted. Field crops may be managed with up to 5000 EC, although at higher salinities sodicity risks increase.

8. The above steps are outlined in the following table. Using almonds as a case study, with microirrigation, 10% effective leaching fraction, sandy soils, high standard of irrigation management, sustainable practices and no yield loss as the inputs, then the target salinity would be 680 ECw. Short term impacts also need consideration (step 6).
9. Crop spatial distribution might influence salinity target consideration if cropping patterns followed underlying salinity trends in irrigation supply waters. Rivers in the Murray–Darling Basin tend to have lower salinities upstream. However, the distribution of crops is dependent on climate, soils, markets, processing infrastructure, and water availability, and there is little reason to anticipate any wide adjustment from the current spatial patterns with salt sensitive horticultural crops generally downstream (Riverland/Sunraysia) and salt tolerant pasture, cotton and rice upstream. Within a broad generalisation, the downstream locations have soils and climate suitable for horticultural crops while upstream are more suited to field crops. It is unlikely that cropping patterns will change to any extent in the short to medium term.
### APPENDIX C  SUMMARY OF RCL DETERMINATIONS FOR EACH IRRIGATED AREA

<table>
<thead>
<tr>
<th>Irrigated area</th>
<th>NRM region for data source</th>
<th>Target sites</th>
<th>Major irrigated crops</th>
<th>Most sensitive crop</th>
<th>Major crops assumed to be not irrigated</th>
<th>Salinity RCL</th>
<th>Literature</th>
<th>Basis for RCL estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverland Irrigation</td>
<td>SA MDB</td>
<td>426522 River Murray at Murray Bridge</td>
<td>Grapes</td>
<td>Grapes</td>
<td>Wheat</td>
<td>680</td>
<td>410</td>
<td>Ayers &amp; Westcot (1985)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>426544 River Murray at Morgan</td>
<td>Potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rhoades equation and EC&lt;sub&gt;e&lt;/sub&gt; for grapes of 1.5 ds/m from Ayers &amp; Westcot (1985). Leaching fraction assumed to be 10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>426514/4260663 River Murray at Berri</td>
<td>Almonds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rhoades equation and EC&lt;sub&gt;e&lt;/sub&gt; for grapes of 1.5 ds/m from Ayers &amp; Westcot (1985). Leaching fraction assumed to be 10%</td>
</tr>
<tr>
<td>Riverland Irrigation</td>
<td>Mallee</td>
<td>AA261001 River Murray at Border (i.e. flow to SA)</td>
<td>Grapes</td>
<td>Grapes</td>
<td>Wheat Barley</td>
<td>680</td>
<td>410</td>
<td>Ayers &amp; Westcot (1985)</td>
</tr>
<tr>
<td>Sunraysia Irrigation</td>
<td>Mallee</td>
<td>414204 Murray River at Red Cliffs</td>
<td>Grapes</td>
<td></td>
<td></td>
<td>680</td>
<td>410</td>
<td>Rhoades equation and EC&lt;sub&gt;e&lt;/sub&gt; for grapes of 1.5 ds/m from Ayers &amp; Westcot (1985). Leaching fraction assumed to be 10%</td>
</tr>
<tr>
<td>Boort Irrigation</td>
<td>North Central</td>
<td>407229 Loddon River at Serpentine</td>
<td>Grapes</td>
<td></td>
<td>Wheat Barley</td>
<td>680</td>
<td>410</td>
<td>Ayers &amp; Westcot (1985)</td>
</tr>
<tr>
<td>Campaspe Irrigation District</td>
<td>North Central</td>
<td>406218 Campaspe River at Campaspe Weir</td>
<td>Pasture, cereals and other crops cut for hay</td>
<td>Grapes</td>
<td>Wheat Barley</td>
<td>800</td>
<td>480</td>
<td>Batey 2008 (DPI, Vic)</td>
</tr>
<tr>
<td>Shepparton Irrigation, Central Goulburn Irrigation, Rochester</td>
<td>Goulburn-Broken</td>
<td>405259 Goulburn River at Goulburn Weir</td>
<td>Nurseries, cut flowers and cultivated turf Pasture, cereals and other crops cut for hay Apples / pomefruit</td>
<td>Apples</td>
<td>-</td>
<td>500</td>
<td>300</td>
<td>DPI &amp; DSE (Vic) 2006 Boland et al. 2001 RCL for irrigation water applied to apples taken from Victorian DPI guidelines for the SIR</td>
</tr>
<tr>
<td>Torrumbarry Irrigation, Murray Irrigation, Murray Valley Irrigation</td>
<td>Murray</td>
<td>409204 Murray River at Swan Hill</td>
<td>Pasture, cereals and other crops cut for hay</td>
<td>Tomatoes</td>
<td>Wheat Barley</td>
<td>700</td>
<td>420</td>
<td>DPI (NSW) 2006 RCL taken from NSW DPI guidelines. Note that NSW DPI gives a lower recommended salinity threshold for common pastures than Vic DPI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>409207 Murray River at Torrumbarry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>409216 Murray River at Yarrawonga Weir</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oranges</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rhoades equation and EC&lt;sub&gt;e&lt;/sub&gt; for grapes of 1.5 ds/m from Ayers &amp; Westcot (1985). Leaching fraction assumed to be 10%</td>
</tr>
<tr>
<td>Irrigated area</td>
<td>NRM region for data source</td>
<td>Target sites</td>
<td>Major irrigated crops</td>
<td>Most sensitive crop</td>
<td>Major crops assumed to be not irrigated</td>
<td>Salinity RCL EC&lt;sub&gt;W&lt;/sub&gt;</td>
<td>Salinity RCL mg/L</td>
<td>Literature</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------</td>
<td>---------------------</td>
<td>-----------------------------------------</td>
<td>-----------------------------</td>
<td>---------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Colleambally Irrigation, Murrumbidgee Irrigation</td>
<td>Murrumbidgee</td>
<td>410023 Murrumbidgee River at Berembed</td>
<td>Grapes Oranges Pasture, cereals and other crops cut for hay</td>
<td>Grapes</td>
<td>Wheat</td>
<td>1000</td>
<td>600</td>
<td>DPI (NSW) 2006</td>
</tr>
<tr>
<td>Jemalong Irrigation</td>
<td>Lachlan</td>
<td>412004 Lachlan River at Forbes</td>
<td>Grapes Potatoes Melons</td>
<td>Grapes</td>
<td>Pasture, cereals and other crops cut for hay Wheat Barley</td>
<td>1000</td>
<td>600</td>
<td>DPI (NSW) 2006</td>
</tr>
<tr>
<td>Narromine, Trangie–Nevertire, Tenandra, Buddah Lake, Mathaguy, Nevertire, Greenhide</td>
<td>Central West</td>
<td>421001 Macquarie River at Dubbo</td>
<td>Cotton</td>
<td>Cotton</td>
<td>Wheat Pasture, cereals and other crops cut for hay Barley Oats Canola</td>
<td>1000</td>
<td>670</td>
<td>DPI (NSW) 2006</td>
</tr>
<tr>
<td>Private Diversions</td>
<td>Namoi</td>
<td>419002 Namoi River at Narrabri</td>
<td>Cotton</td>
<td>Cotton</td>
<td>Sorghum Wheat Barley Pasture, cereals and other crops cut for hay</td>
<td>1000</td>
<td>670</td>
<td>DPI (NSW) 2006</td>
</tr>
<tr>
<td>St George Irrigation</td>
<td>Condamine, Maranoa–Balonne &amp; Border Rivers</td>
<td>422207A Ballandool River at Hebel-Bollon Road 402012 Narran River at New Angeldool</td>
<td>Cotton Sorghum</td>
<td>Sorghum</td>
<td>Wheat Pasture, cereals and other crops cut for hay</td>
<td>3100</td>
<td>2080</td>
<td>DERM (Qld) 2009</td>
</tr>
</tbody>
</table>
APPENDIX D  APPRAISAL OF MONITORING SITES

The following provides an overview of the assessment of end-of-valley targets sites in terms of their role as SMART target sites for operational monitoring and evaluation of progress against targets. The ‘measurability’ aspects under SMART are documented in Section 7. Additional monitoring sites were looked at to ensure coverage of environmental values.

### Site Attributes

<table>
<thead>
<tr>
<th>Site</th>
<th>Operational Site?</th>
<th>Reasons for Inclusion/Exclusion from Operational Sites</th>
<th>Site Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>42654 River Murray at Morgan</td>
<td>Y</td>
<td>Whilst Schedule B explicitly includes this site as basis for assessing progress against the simulated basin target i.e. &lt;800EC for at least 95% of the time during the Benchmark Period, it is also widely seen by the broader community as a de facto operational site with the MDBA reporting on performance against this quantum over the June to July period of each year, in their annual report. As it has a long history of monitoring and public reporting on real time outcomes, is downstream of all Joint Interception Works, and storages, it would be readily accepted as a lends itself to operational intervention.</td>
<td>High ratings for totality, interference, minimum monitoring, frequency and historical categories</td>
</tr>
<tr>
<td>A4261001 River Murray at Border</td>
<td>Y</td>
<td>This is at the beginning of major SA irrigation development. In addition it is the vicinity of the Chowilla Ramsar site and Lindsay-Wallpolla. The setting of this target needs to be a joint exercise involving the MDBA and the jurisdictions.</td>
<td>High ratings for totality, interference, minimum monitoring, frequency and historical categories</td>
</tr>
<tr>
<td>426514/4260663 River Murray at Berri</td>
<td>Y</td>
<td>The Berri site is well placed as an operational site in the proximity of major irrigation development.</td>
<td>High ratings for totality, interference, minimum monitoring, frequency and historical categories</td>
</tr>
<tr>
<td>426522 River Murray at Murray Bridge</td>
<td>Y</td>
<td>Three reasons for adopting this as a site to have an operational target are it is just upstream of the Alexandrina/Albert/Coorong Ramsar site, it is in proximity to an irrigated horticulture offtake which has had an expensive pipeline installed, and it is effectively the end of the whole system and reflects the sum total of all management undertaken upstream. However, it currently lacks flow monitoring and this needs to be implemented.</td>
<td>Low ratings for totality, minimum monitoring, frequency and historical categories; high rating for interference</td>
</tr>
<tr>
<td>412004 Lachlan River at Forbes</td>
<td>Y</td>
<td>Not in proximity to main ecological assets, but close to irrigation. Therefore warranted as an operational site.</td>
<td>High ratings for totality, interference, minimum monitoring and frequency categories; medium rating for historical</td>
</tr>
<tr>
<td>425008 Darling River at Wilcannia</td>
<td>Y</td>
<td>Being just upstream of the Menindee Lakes Storages, which have the potential to influence salinity of supply for irrigation and ecological assets, and therefore this is appropriate as an operational site.</td>
<td>High ratings for interference, minimum monitoring, frequency and historical categories; medium-high rating for historical</td>
</tr>
<tr>
<td>415200 Wimmera at Horsham</td>
<td>Y</td>
<td>Appropriate as an operational site because of the Lake Albacutya Ramsar site downstream.</td>
<td>High ratings for totality, interference, minimum monitoring, frequency and historical categories</td>
</tr>
<tr>
<td>408203 Avoca River at Quambatook</td>
<td>Y</td>
<td>The Ramsar-listed Avoca Marshes a short distance downstream qualify this site as an operational site.</td>
<td>High ratings for totality, interference, minimum monitoring, frequency and historical categories</td>
</tr>
<tr>
<td>406218 Campaspe River at Campaspe Weir</td>
<td>Y</td>
<td>This is a key operational site because supply to the Campaspe Irrigation District is via the Campaspe Weir Pool.</td>
<td>High ratings for totality, interference, minimum monitoring, frequency and historical categories</td>
</tr>
<tr>
<td>405259 Goulburn River at Goulburn Weir</td>
<td>Y</td>
<td>This Weir is the offtake point for all of that part of the Goulburn Murray Irrigation District supplied with Goulburn water.</td>
<td>High ratings for totality, interference, minimum monitoring and frequency categories; medium rating for historical</td>
</tr>
<tr>
<td>422207A Ballandool River at Hebel-Bollon Road</td>
<td>Y</td>
<td>This is nominated as an operational site because of its proximity to irrigation.</td>
<td>High ratings for interference, minimum monitoring and frequency categories; medium rating for totality and low rating for historical</td>
</tr>
<tr>
<td>40212 Narran River at New Angeldool</td>
<td>Y</td>
<td>This is nominated as an operational site because of its proximity to irrigation.</td>
<td>High ratings for interference, minimum monitoring and frequency categories; medium rating for totality and low rating for historical</td>
</tr>
<tr>
<td>410023 Murrumbidgee River at Berembed</td>
<td>Y</td>
<td>Salinities at the End-of-valley target site [410130: Murrumbidgee River at d/s Balranald Weir] did not exceed the nominal threshold. Salinity hotspots known to exist in the upper catchment, e.g. Jugiong Creek (one small urban centre u/s) and Muttama Creek (one medium urban centre u/s). 410023 selected as indicative of the salinities of the supplied water to Coleambally and Murrumbidgee irrigation areas.</td>
<td>High ratings for minimum monitoring and frequency, and a medium rating for historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
</tbody>
</table>
## Salinity Targets Review

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<table>
<thead>
<tr>
<th>Reference</th>
<th>Location</th>
<th>Y/N</th>
<th>Note</th>
<th>Selection Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>410130</td>
<td>Murrumbidgee River d/s Balranald Weir</td>
<td>N</td>
<td>See above</td>
<td>High ratings for totality, interference, minimum monitoring and frequency categories; medium rating for historical.</td>
</tr>
<tr>
<td>421001</td>
<td>Macquarie River at Dubbo</td>
<td>Y</td>
<td>Upstream of irrigation development and the Macquarie Marshes</td>
<td>High ratings for minimum monitoring and frequency, and a medium rating for historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>419002</td>
<td>Namoi River at Narrabri (will need to use 419003: Narrabri Creek)</td>
<td>Y</td>
<td>Upstream of irrigated agriculture</td>
<td>419002 became non-active some decades ago when works diverted Namoi River &lt; 30,000 ML/d into Narrabri Creek. Propose to use 419003: Narrabri Creek.</td>
</tr>
<tr>
<td>418001</td>
<td>Gwydir River at Pallamallawa</td>
<td>Y</td>
<td>Located upstream of Gwydir Wetlands and irrigation area. Downstream of high salinity reaches within the Gwydir</td>
<td>Low-medium ratings for minimum monitoring, frequency and historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>425007</td>
<td>Darling River at Burtundy</td>
<td>Y</td>
<td>Salinities at the End-of-valley target site [425008: Darling River @ Wilcannia Main Channel] exceeded the threshold amount. 425007 selected as indicative of Murray River water quality supplied to SA irrigated Riverland, and aquatic ecosystems.</td>
<td>High ratings for minimum monitoring, frequency and historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>407229</td>
<td>Loddon River at Serpentine</td>
<td>Y</td>
<td>Indicative of incoming supply quality to irrigation areas and the Kerang Lakes Ramsar Wetlands. Salinities at the End-of-valley target site [407203: Loddon R @ Laanecoorie] exceeded the nominal threshold.</td>
<td>High ratings for minimum monitoring, frequency and historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>409216</td>
<td>Murray River at Yarrawonga Weir</td>
<td>Y</td>
<td>Selected to monitor water quality of irrigations supply to the Murray Valley Irrigation Area (Vic) and the Murray Irrigation region (NSW).</td>
<td>High ratings for minimum monitoring and frequency, and a medium rating for historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>409207</td>
<td>Murray River at Torrumbarry</td>
<td>Y</td>
<td>Selected to monitor water quality of irrigation supply to the Torrumbarry Irrigation Area. Note that the modelled data used for this site is the modelled data at 409219.</td>
<td>High ratings for minimum monitoring, frequency and historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>409204</td>
<td>Murray River at Swan Hill</td>
<td>Y</td>
<td>Supply to irrigation in the Swan Hill region.</td>
<td>High ratings for minimum monitoring, frequency and historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>414204</td>
<td>Murray River at Red Cliffs</td>
<td>Y</td>
<td>Supply to irrigation in Sunraysia region.</td>
<td>Low rating for minimum monitoring and frequency, no rating for historical. A site inspection will be required to determine the degree of totality and interference.</td>
</tr>
<tr>
<td>416001</td>
<td>Macintyre River at Mungindi</td>
<td>N</td>
<td>No defined irrigation area and no Basin scale ecological aquatic ecosystem identified by MDBA.</td>
<td>Totality of flow, historical salinity and flow. High rating for interference.</td>
</tr>
<tr>
<td>421023</td>
<td>Bogan River at Gongolgon</td>
<td>N</td>
<td>Neither irrigation nor wetlands downstream. No connection with Macquarie Marshes.</td>
<td>High ratings for interference, minimum monitoring, frequency and historical categories; low rating for totality.</td>
</tr>
<tr>
<td>421012</td>
<td>Macquarie River at Carinda [Bells Bridge]</td>
<td>N</td>
<td>Downstream of Macquarie Marshes.</td>
<td>High ratings for minimum monitoring, frequency and historical categories; medium rating for interference and low rating for totality.</td>
</tr>
<tr>
<td>420020</td>
<td>Castlereagh River at Gungalman Bridge</td>
<td>N</td>
<td>No identified irrigation or ecological assets</td>
<td>High ratings for interference, minimum monitoring and frequency categories; medium rating for totality and low for historical.</td>
</tr>
<tr>
<td>419026</td>
<td>Namoi River at Goanga</td>
<td>N</td>
<td>No Basin scale defined aquatic ecosystem environmental values. Too far downstream to adequately assess salinity risk to diversions on the Namoi.</td>
<td>High ratings for interference, minimum monitoring and frequency categories; medium rating for totality and historical.</td>
</tr>
<tr>
<td>418058</td>
<td>Mehi River at Bronte</td>
<td>N</td>
<td>No defined irrigation area and no Basin scale ecological aquatic ecosystem identified by MDBA</td>
<td>High ratings for interference, minimum monitoring and frequency categories; medium rating for totality and historical.</td>
</tr>
</tbody>
</table>
### Salinity Targets Review

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<table>
<thead>
<tr>
<th>Reference</th>
<th>Location</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>407203</td>
<td>Loddon River at Laanecoorie</td>
<td>N</td>
</tr>
<tr>
<td>404217</td>
<td>Broken Creek at Casey’s Weir</td>
<td>N</td>
</tr>
<tr>
<td>403241</td>
<td>Ovens River at Peechelba-East</td>
<td>N</td>
</tr>
<tr>
<td>402205</td>
<td>Kiewa River at Bandiana</td>
<td>N</td>
</tr>
<tr>
<td>17204A</td>
<td>Moonie River at Fenton</td>
<td>N</td>
</tr>
<tr>
<td>422209A</td>
<td>Bohkara River at Hebel</td>
<td>N</td>
</tr>
<tr>
<td>422211A</td>
<td>Braire Creek at Wooler billa-Hebel Rd</td>
<td>N</td>
</tr>
<tr>
<td>422015</td>
<td>Culgoa River at Brenda</td>
<td>N</td>
</tr>
<tr>
<td>424201A</td>
<td>Paroo River at Caiwarro</td>
<td>N</td>
</tr>
<tr>
<td>423004</td>
<td>Warrego River at Barri ngun No.2</td>
<td>N</td>
</tr>
<tr>
<td>423005</td>
<td>Cuttaburra Creek at Turra</td>
<td>N</td>
</tr>
</tbody>
</table>

**High ratings for totality, interference, minimum monitoring, frequency and historical categories; medium rating for interference.**