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General review of salinity management in the Murray–Darling Basin

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General review of salinity management in the MDB

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Cover image: Photo taken from Poltalloch overlooking low water levels in Lake Alexandrina (photo by Rob Kingham, 2008).

Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray–Darling Basin Authority acknowledges and pays respect to the Traditional Owners, and their Nations, of the Murray–Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. The MDBA understands the need for recognition of Traditional Owner knowledge and cultural values in natural resource management associated with the Basin.

The approach of Traditional Owners to caring for the natural landscape, including water, can be expressed in the words of Darren Perry (Chair of the Murray Lower Darling Rivers Indigenous Nations) —

> *‘the environment that Aboriginal people know as Country has not been allowed to have a voice in contemporary Australia. Aboriginal First Nations have been listening to Country for many thousands of years and can speak for Country so that others can know what Country needs. Through the Murray Lower Darling Rivers Indigenous Nations and the Northern Basin Aboriginal Nations the voice of Country can be heard by all’.*

This report may contain photographs or quotes by Aboriginal people who have passed away. The use of terms ‘Aboriginal’ and ‘Indigenous’ reflects usage in different communities within the Murray–Darling Basin.

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Foreword

It has been my pleasure to chair the steering committee of the General Review of Salinity Management and to work with all of the review contributors to set a basis for an updated strategy for collaborative management and governance of salinity in the shared water resources of the Basin. The challenge has been to logically assemble and clearly express what is known from several decades of collective salinity management effort. Thanks to the quality of review contributions, I believe that this challenge has been met.

Members of the steering committee and their support staff have committed much time and energy over a seven month period. They have participated in meetings, workshops, and teleconferences and have responded to numerous requests for input. The committee advised on the review scope and direction, and provided inputs on policy and technical matters. Committee members shared a diversity of perspectives and experiences, robustly debated issues and constructively commented on iterations of the review reports.

The review was driven by a dedicated MDBA project team supported by independent technical experts. This review was supported by modelling work which was subject to an independent peer review. Inputs were made by subject matter experts including MDBA staff experienced in modelling, salt interception and river management; an independent peer reviewer; specialist staff in other government agencies and members of the Independent Audit Group for Salinity.

The initial key findings of this review were presented to the Basin Officials Committee and Ministerial Council meetings, where agreement was reached for the development of an updated cost-effective salinity management program, Basin Salinity Management 2030 (BSM2030) and review of Schedule B of the Murray–Darling Basin Agreement.

I am confident that the outputs meet the requirements of a General Review of Salinity Management activities in the Basin. This report provides a contemporary understanding of the salinity risk to the shared water resources of the Basin, assessment of future salinity risk and uncertainty, and assessment of feasible and cost-effective salinity management options, taking into account changes arising from water recovery and use under the Basin Plan, and future land and water management activities.

Further work is recommended by June 2015 to progress the findings of the review. This includes further investigation of adaptive salt interception scheme operations, and the concurrent development of the proposed strategy BSM2030 and the review of Schedule B of the Murray–Darling Basin Agreement via a coordinated and iterative approach. The review along with the further work provides a technically robust foundation to support development of an updated and necessary salinity management strategy for the next 15 years.

Denis Flett

Denis Flett
Independent Chair

Executive summary

Salinity in the Basin has long been identified as a significant issue affecting all jurisdictions, with the aggregate impact most apparent as higher river salinities within the mid and lower reaches of the River Murray. Jurisdictions have recognised a shared responsibility in responding to this threat through a partnership response with joint and state investment reflected in the Salinity and Drainage Strategy 1988–2000 and Basin Salinity Management Strategy 2001–2015. The benefit of a collaborative inter-jurisdictional approach has seen collective actions reducing salinity impacts as demonstrated by achievement of the Basin Salinity Target (modelled salinity assessed as being less than 800 EC 95% of the time) at Morgan, South Australia, since 2010. Through cooperative management and governance, major salinity-related consequences have been avoided, providing substantial social and economic benefits to the Basin's communities while protecting environmental assets and values.

With the implementation of the Basin Plan, which complements the previous salinity strategies outlined above, and the fact that the Basin Salinity Management Strategy (BSMS) is reaching the end of its 15 year term, the Basin Officials Committee (meeting 22 of 8 August 2013) requested a review of joint salinity management activities. Key drivers for this review include the emerging and expected significant changes in Basin salinity risks arising from water recovery and use under the Basin Plan, and future land and water management activities.

This General Review of Salinity Management was conducted in line with a Terms of Reference (Appendix 1) and guided by a jurisdictional steering committee with an Independent Chair.

In addressing the key questions outlined in the Terms of Reference, the approach undertaken for the review was to:

- establish a contemporary understanding of the salinity risk to the shared water resources of the Murray–Darling Basin within the context of the flow regimes provided under the Murray–Darling Basin Agreement. A landscape context is used to characterise salinity contributions in terms of the sources of salt and the role of the flow regime in contributing to salinity outcomes. Current risks are described in terms of the intrinsic threats, development contributions to these threats, the trends in salt loads emanating from those sources, the controls in place to manage these threats, and the residual risk
- assess the future salinity risk within the context of a changed flow regime anticipated from implementing the Basin Plan, and the potential for changes in salt loads to the river arising from changed land and water management practices, and projected increases in salt loads arising from historic land and water management practices
- assess feasible salinity management options available to address salinity risks and meet the objectives of both the Basin Salinity Management Strategy and the Basin Plan. Options investigated in detail are joint works and measures (salt interception and flow management), salinity targets, accountability arrangements and implementation capacity (inclusive of future institutional arrangements). Whilst the focus is on joint (inter-jurisdictional) programs, the review recognises the important contribution that state programs provide to achieving salinity outcomes
- provide advice on the cost-effectiveness, through quantitative or qualitative means, of the management options which require joint or inter-jurisdictional effort.

Key findings

Key findings from the review of the current salinity risk (to 2015) in the basin are that:

- all landscapes in the Basin (Mallee, Northern Basin, Riverine Plains and Southern Uplands) contribute to salinity in the shared water resources either through river regulation and diversion of water, or by exacerbating inflow of salt loads. Sources of salt from these landscapes include natural salt inflows, salt mobilised due to past actions and salt mobilised by recent developments
- the key Basin landscapes contributing more to the salinity hazard are the Mallee regions of South Australia, Victoria and New South Wales and parts of the Riverine Plains of New South Wales and Victoria
- the flow regime that dilutes salt loads is primarily sourced from the regulated and unregulated tributaries emerging from the Southern Uplands
- the suite of salinity controls implemented to date, including salt interception schemes, improved irrigation system and on-farm practices, have led to the achievement of the Basin Salinity Target since 2010 such that over the long term, there is likely to be fewer in-river peak salinities exceeding 800 EC at Morgan
- a key achievement of the Basin-scale partnership has been the implementation of salt interception schemes that:
    - contribute significantly to reductions in the magnitude and frequency of elevated salinity levels (i.e. long-term average and peak salinity outcomes)
    - are particularly beneficial during periods of prolonged drought when there is less dilution available for the river, and SIS operations preventing saline groundwater reaching the river are most effective during low flow periods in limiting increases in river salt concentration
- current salinity risks are being managed when outcomes are considered in terms of achievement of the Basin Salinity Target, however residual risks remain; specifically event-based elevated salt loads that from time to time may be mobilised during relatively low river flows leading to increased salinity levels over short time periods that may require an operational response.

Key findings on future salinity risks (beyond 2015):

- all landscapes will continue to export salt and there is an ongoing need to manage current salinity levels as well as future increases
- water recovery and use for environmental watering under the Basin Plan is estimated to have a net long-term salinity benefit to the shared water resources through restoration of dilution. This benefit will complement but not replace the substantial salinity outcomes achieved through joint investment in SIS
- salinity impacts are forecast to gradually increase over time due to the delayed arrival of salt from various landscapes into the river, and that states may choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits. There is also potential for salt to be mobilised from floodplain environmental watering. However, there are significant uncertainties about the projected extent and timing of salt load accessions and associated river salinity increases

- based upon the current available knowledge, the largest increases in salt loads are predicted to emanate from the lower reaches of the Mallee region arising from relatively recent irrigation development (post-1988) and the delayed salinity impact from past land and water management activities including clearing of native vegetation and historic irrigation development (pre-1988)
- for the most part, projected changes in salinity impacts to the shared water resources from the Northern Basin, Riverine Plains and Southern Uplands are relatively small, however this risk profile still warrants management and periodic review
- consistent with the current risk, short-term elevated salt load discharge events (previously experienced within the River Murray) are likely to arise from time to time
- risks to local assets arising from emerging threats should be considered during the development of Water Resource Plans to ensure that localised salinity impacts are understood and appropriate controls put in place. However, accountability for salinity impacts to the shared water resources is still required through Schedule B of the Murray–Darling Basin Agreement
- further work is required to address knowledge gaps, better understand risk and to provide a contemporary approach to future investments for salinity management. This work should focus on:
    - ways in which dilution effects of all water in the system (including both consumptive and environmental water), and river operations generally, could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities
    - understanding the potential for salt to be mobilised from floodplain environmental watering
    - scoping the future use of salinity credits that are currently available on the registers such as:
        - the extent to which states may require these credits to offset historic land and water management actions, and recent or future actions that are not currently on the register
        - options for alternative use of credits
    - pursuing opportunities to resolve the significant uncertainty in the projected increase in future salt loads from the Mallee.

In light of the future risks and uncertainties, a clear on-going collaborative commitment to future Basin-scale salinity management is required with salt interception playing a key role in meeting the salinity objectives for the shared water resources. The BSMS 2001–2015 has been successful and hence many of its key elements should be retained beyond 2015, but with refinements to reflect the contemporary understanding of risk and to accommodate complementary management arrangements under the Basin Plan.

Basin salinity management beyond 2015

This review has confirmed the need to maintain a dedicated joint salinity program post the BSMS to ensure that salinity risk continues to be managed effectively. The review proposes the development of an updated strategy, the ‘Basin Salinity Management 2030’ (BSM2030) to cover the period 2015 to 2030, along with preliminary work to inform the objectives and elements of the strategy.

Consistent with the regulatory role that Schedule B provides for accountabilities outlined by the BSMS, accountabilities agreed within BSM2030 will also require formal regulatory support. Both the current Schedule B and the BSMS can be expected to significantly contribute to the development of BSM2030, with the process of formulating the new strategy also informing necessary improvements to the Schedule. A coordinated and iterative approach will be necessary in undertaking the review of Schedule B (required under Clause 35) and the development of the proposed BSM2030 strategy. Collectively the required outcome is clear alignment between the strategy and regulatory arrangements.

Development of the proposed BSM2030 strategy and the review of, and proposed revisions to, Schedule B should be completed and available for consideration by Ministerial Council by June 2015 when the BSMS comes to the end of its term. This review notes that there is potential for cost savings associated with implementing an updated Basin salinity management program, while noting additional work is also required to address knowledge gaps, better understand the future salinity risks and develop improved management tools to realise some of these savings.

Considering the transition to full implementation of the Basin Plan and its dilution benefits and forecast salinity risks, there is potential to refine the approach to Basin-scale salinity management [1]. Additionally, there are opportunities to update elements of the salinity program and re-scale the administration of the accountability framework due to improved understanding of salinity processes and experience gained through the implementation of the BSMS. In light of the above, the review identified feasible management options that warrant consideration in the development of an updated Basin-wide salinity management program. These include:

- joint works and measures through:
  - an adaptive operational approach to the management of SIS
  - improved flow management to support in-river salinity outcomes
- salinity targets
- accountability arrangements
- improved capacity to implement a Basin-wide salinity management program.

Joint works and measures - an adaptive operational approach to the management of SIS

The approach to adaptive management for SIS is based on the premise that the current approach of operating all SIS continuously could be refined such that collectively schemes, or parts of schemes, are geared towards operational capacity commensurate with the forward outlook on risk over a time interval of perhaps two to five years.

Indicative estimates from modelling (see Figure 1) are that when taking into account the dilution benefits from Basin Plan implementation, salt interception capacity could be reduced to provide around 86% of the (95 percentile) salinity benefit at Morgan until 2030 whilst still meeting the Basin Salinity Target over this period. However as noted in this report, there are significant assumptions underpinning the modelling. The report also highlights risks and uncertainties that require further consideration prior to instigating such a major change to the SIS program. Given the need to balance the potential efficiencies of reduced SIS operations, and the need to manage the

[1] As a precautionary measure, for the purpose of salinity risk assessment, it has been assumed that 2400 GL would be available to meet the Basin Plan requirements after allowing for the operation of the Sustainable Diversion Limit adjustment mechanism.

associated risks, a key issue to progress the potential to reduce SIS operations is the development of an adaptive approach. Adaptability in this context requires SIS operations to be sufficiently flexible to enable transition back to a required capacity in response to an emerging Basin-scale salinity threat.

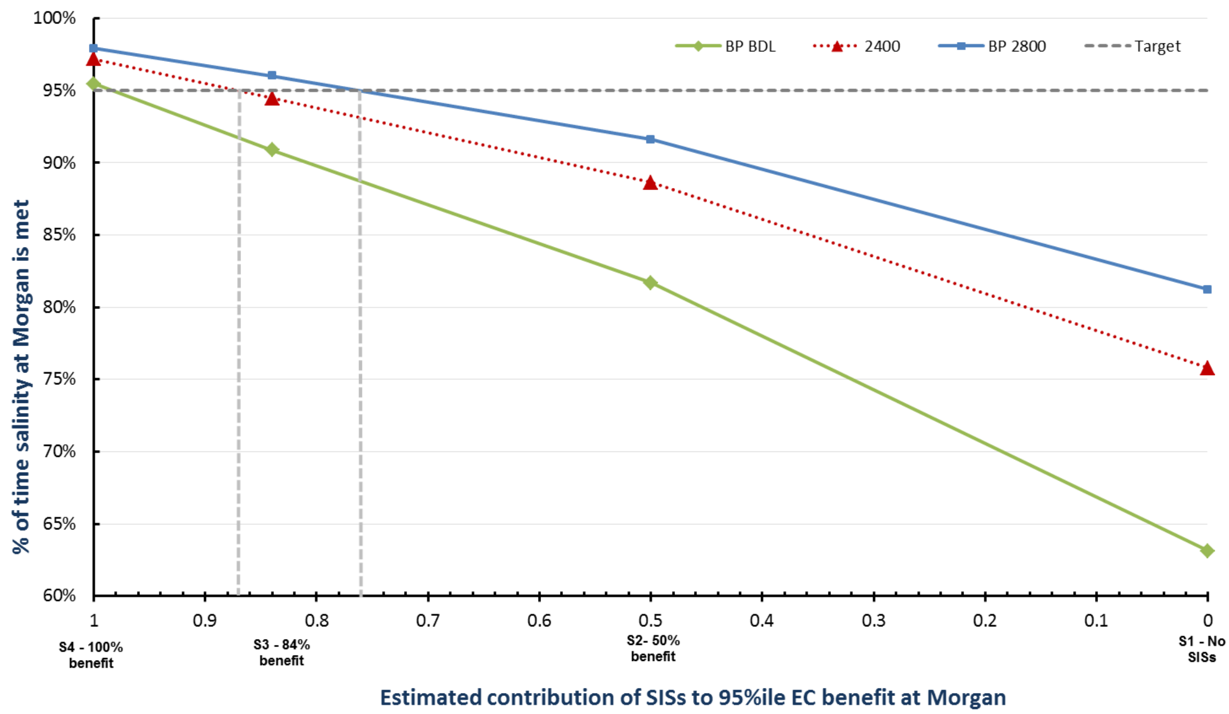

Figure 1 Impact of Salt Interception Schemes on 95%ile salinity at Morgan for BP BDL, BP 2400 and BP 2800 scenarios and 2030 salt accession level, 1975–2000 climatic period.

To progress an adaptive approach to SIS as part of the development of BSM2030, understanding will be required on:

- the extent to which particular SISs (or parts of SISs) may be operated adaptively to maintain the Basin Salinity Target at Morgan and commensurate with the level of salinity risk within the shared water resources of the Murray–Darling Basin
- the benefit cost implications of operating schemes differently, including the variability in the average cost per unit of salinity offset between schemes
- the extent to which SIS operations are expected to assist in contributing to the achievement of operational targets
- the implications of changed SIS operations for the register balance of each jurisdiction (EC impacts and salinity cost effects)
- management of risk within the face of uncertainties such as developments currently underway or new state actions that result in an adverse salinity impact with reliance on offset from existing credits, uncertainties in the time and magnitude of projected increases in salinity, and uncertainties in the net impact of environmental water recovery and use.

Given that adaptive SIS operations would align operations with the level of salinity risk, it is important that improved confidence is provided in risk evaluation, and hence progress be made towards reducing the uncertainties in the modelling undertaken to-date. Areas for improvement include:

- access to data regarding the net volume of environmental flows likely to be available
- understanding the scheduling of environmental flows to particular wetlands in wet and dry sequences
- understanding of salt loads that are likely to be mobilised from environmental watering
- reducing uncertainties in the likelihood, timing, and magnitude of delayed salinity impacts reaching the river
- timely advice on how and when states may plan to utilise salinity credits that are currently available on the register.

Joint works and measures - improved flow management to support in-river salinity outcomes

The changed flow regime under the Basin Plan suggests that flow management may provide a means of responding to episodic salinity events. However, if decisions on salt interception operations are based solely upon achievement of the Basin Salinity Target, exceedances of salinity operational targets are likely to be reported more regularly at some Basin Plan reporting sites. The extent to which improved flow management will provide a means of responding to these on-going occurrences is uncertain but warrants further consideration.

As part of the development of BSM2030, the application of flow management to support in-river salinity outcomes should be explored. Key matters for consideration include:

- capturing and analysing the experiences gained to date in managing peak salinity events investigating ways in which dilution effects of all water in the system (including both consumptive and environmental water), and river operations generally, could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities
- potential approaches to flow management that seek to pursue salinity management outcomes which could be incorporated into relevant planning documents and processes, if appropriate (such as the Basin-wide environmental watering strategy, annual environmental water prioritisation, environmental water delivery, objectives and outcomes for river operations and annual operating plans)
- the progressive review of current river operation rules within the context of a changed flow regime, as it emerges through water recovery and the use of environmental flows.

Salinity targets

Complementary salinity targets are provided for within the BSMS and the Basin Plan. The BSMS targets were intended as indicators of catchment salinity ‘health’ and condition with progress against these targets assessed on the basis of the frequency of exceedance over a threshold salinity for the modelled 1975–2000 Benchmark Period. Basin Plan operational targets, on the other hand, are intended to influence flow management decisions and hence support water quality outcomes measured in the river on a day-to-day basis.

Collectively, the BSMS and Basin Plan targets provide long-term benefits by supporting planning and management strategies that reduce the frequency of salinity threshold exceedance, and in having regard to salinity outcomes, consideration of a management response to individual events or potential events.

Whilst having an important role in supporting long-term planning and management as articulated within the Basin Plan, state end-of-valley targets for each of the tributary valleys under the BSMS were established at a time when there was considered to be a significant threat from dryland salinity. That perceived threat is no longer considered to pose a significant risk to the shared water resources. A recent review (SKM 2014) suggested that some state end-of-valley targets could be revised and their future role and application within the accountability framework be reviewed. In reviewing Schedule B and developing BSM2030, a key matter for consideration is to clarify the future role and application of state end-of-valley targets within the accountability framework.

Accountability arrangements

Given the highly evolved status of the current Basin-scale salinity program, there is potential to improve efficiencies in the management and administration of the accountability framework. In developing BSM2030, key matters for consideration include:

- a risk-based approach to operation of the salinity registers, reviews, modelling, reporting and audit. Such an approach would necessarily also consider the management and administration of salinity accountability elements of the Basin Plan, and would also require consideration in the review of Schedule B
- accountability arrangements to resolve how state and Commonwealth governments will be accountable for the impacts of environmental water use and associated impacts on jurisdictional salinity register balances, with the outcome potentially having implications for the review of Schedule B
- over the longer term, a comprehensive review of the Benchmark Period to establish whether it is appropriate to extend or replace the Benchmark Period with an alternative climatic sequence, noting that a review of the Benchmark Period is not considered to be a priority until the key aspects of the Basin Plan have been implemented by 2019
- developing clear direction on the future role of the salinity cost effect ($ million per year) in managing accountabilities under the salinity registers. Subject to this direction, it may be necessary to update the cost functions and agree upon a schedule for the review of cost function model parameters
- recognising the Basin-wide stream salinity monitoring program and that it be maintained as a mandatory requirement within the accountability framework. Consideration should also be given to the Independent Audit Group for Salinity suggestion that any rationalisation of monitoring programs be subject to a transparent review process based on an agreed risk assessment process
- investigating the potential for improved efficiencies in undertaking reporting and auditing functions taking into account the requirements for reporting on salinity under the Basin Plan.

Improved capacity to implement

Capacity to implement within the context of this review is considered to cover issues of governance and knowledge. Recognising the critical importance that the partnership approach to governance (particularly inter-jurisdictional advisory panels) has played in salinity management achievements to date, when developing BSM2030 key matters for consideration include:

- more effective coordination in implementation, such as integration with Basin Plan implementation (use of environmental flows and the Water Quality and Salinity Management Plan), and river operations
- providing efficiencies in program delivery and coordination which benefit from the policy and technical inputs provided by partner governments, but recognising the potential for rationalising some aspects of existing advisory panel and governance arrangements

- investing in an improved understanding of the future salinity hazard particularly with respect to the Mallee and floodplain environmental watering
- investing in information systems and predictive tools that provide a better understanding of salinity dynamics and the impact of operational decisions on in-river salinity outcomes including managing for operational targets, understanding floodplain salinity processes, and adaptive approaches to SIS operations.

Cost-effective ways to manage risk to meet salinity objectives

Key findings from the assessment of cost effectiveness of the implementation of the above management options indicate that there is a modest opportunity to streamline SIS operations and still achieve the Basin Salinity Target up to 2030 subject to managing the future risks and implications identified in this review. The most cost-effective option was SIS operating to deliver 86% of the (95 percentile) salinity benefits at Morgan dependent on the findings of further investigation into the optimal configuration of SIS operations.

For some other elements of the joint program, efficiencies in program management could be sought while still maintaining effective implementation. Such efficiencies may be gained by rationalising salinity register entry reviews, and re-scaling annual reporting and audit commensurate with the risk profile. However in seeking these efficiencies, it is critical that the robust technical attributes that underpin the program be retained, such as maintaining BSMS models which underpin the understanding of salinity processes, register entries and assessment of progress against targets.

To support a more risk-based approach and long-term efficiencies, investment will be required in an improved knowledge base and capacity to manage future risks including: (a) to better understand and manage new issues (e.g. salinity impacts of environmental watering); and (b) to enhance current capabilities that may enable savings to be achieved in operations by supporting a risk-based management approach (e.g. future salinity hazard studies and forecasting tools).

Recommendations

The recommendations from the review outlined below should be progressed during 2014-15 with the priority being to deliver a proposed BSM2030 strategy, a review of Schedule B, and any recommended changes to Schedule B to Ministerial Council by June 2015. A coordinated and iterative approach will be adopted when undertaking the review of Schedule B and development of the proposed BSM2030. This approach is required given the complex interdependencies between these activities and the need to ensure that any impacts arising from either activity on the other are assessed and the outcomes aligned.

Elements of the proposed BSM2030 will be progressed over the lifetime of the updated Basin salinity management program to 2030, and will be undertaken as required and according to relative priority.

To address the findings of this General Review of Salinity Management and to inform the development of the BSM2030, it is recommended that by June 2015 the MDBA and partner governments:

1. Further investigate the extent to which adaptive SIS operations could provide cost effective long-term and operational salinity outcomes including:
    - the potential to operate at approximately 86% of current SIS benefits to meet the future risk profile under Basin Plan flows

- a contemporary understanding of the salinity risks to the shared water resources associated with operating at below 100% of current SIS benefits and implications for:
    - salinity targets (the Basin Salinity Target and Basin Plan salinity operational targets)
    - the salinity register balance of jurisdictions
- the potential for operational arrangements being sufficiently flexible to transition back to a required capacity in response to an emerging salinity threat.

2. Develop the next and updated Basin-scale salinity management strategy (proposed to be termed 'Basin Salinity Management 2030' (BSM2030) that provides for:
    - investment in a contemporary understanding of future salinity hazard from key areas, with priority on the Mallee region and on salt mobilisation from various floodplain watering activities
    - the application of flow management planning and river operations to support in-river salinity outcomes, including ways in which dilution effects of all water in the system (including both consumptive and environmental water) could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities accountability for the salinity impacts of all environmental watering activities
    - continuation of improved land and water management practices consistent with the salinity accountability framework and the Basin Plan
    - the potential to adopt an adaptive management approach to SIS operations, including development of criteria and a decision framework for resuming SIS operational capacity in response to an emerging salinity threat (depending upon the outcome of Recommendation 1)
    - enhanced technical elements that better reflect climatic variability and tools that integrate new knowledge for contemporary operational salinity management. The technical elements that may be considered include predictive modelling tools, an appropriate Benchmark Period and cost functions
    - coordination and integration of BSM2030 with the complementary salinity management arrangements set out in the Basin Plan including flow management and broader water quality requirements
    - establishment of the future role of state end-of-valley targets within the accountability framework
    - a commitment to continued monitoring of accountability, and an improved knowledge base to support adaptive management and continuous improvement in program implementation
    - a major program review within 10 years of commencement with shorter term reappraisal as warranted.
3. Review the operation of Schedule B of the Murray–Darling Basin Agreement in conjunction with the development of BSM2030 and provide recommendations on changes to Schedule B that align with the accountability obligations under the proposed BSM2030.
4. Develop governance, systems and performance mechanisms that support efficient program delivery including the potential for:

- effective integration and coordination between Basin Plan and the BSM2030 implementation processes
- consideration of management arrangements for the efficient delivery of the proposed adaptive SIS program
- improving efficiencies in program delivery including a risk-based approach to operation of the salinity registers, reviews and modelling, a re-scaled frequency of audits and annual reporting and rationalising some aspects of existing advisory committee and governance arrangements.

5. Provide the proposed BSM2030 and recommendations on changes to Schedule B to Ministerial Council for consideration and agreement.

1. Introduction

Salinity, the presence of soluble salts in water and soil, is a natural characteristic of the Murray–Darling Basin (MDB). Problems can arise for the Basin's communities, environment and economy when salt concentrations are too high for the use of water and land for both development and the natural environment. Excessive salinity has serious implications for water quality, plant growth, biodiversity, land productivity, industry and the supply of water for critical human needs.

Salinity levels in rivers and streams are a function of both the salt load and the flow regime. Whilst surface and groundwater regimes have always provided a pathway for some salt to be transported to land or waterways, prior to European land management, much of the salts remained stored within the landscape. Land clearing and irrigation have led to increased quantities of salt being mobilised into river systems. At the same time, river flow has been regulated and diverted for irrigation, industrial and urban uses. The outcome is substantially less flow in which to dilute the prevailing salt loads.

Basin communities and governments have undertaken significant actions to address increasing levels of river salinity at a local and regional scale. Crucial to these efforts has been the partnership approach which recognises that downstream salt concentrations are a reflection of both the incremental salt contributions from different parts of the Basin, and that dilution has been reduced by upstream diversions for irrigation and other purposes.

The Murray–Darling Basin (MDB) Agreement, the Basin Salinity Management Strategy (BSMS) and its predecessor, the Salinity and Drainage Strategy have provided the policy framework under which jurisdictions have committed to shared and individual responsibilities and actions to address salinity impacts on the river. As a result, in-river salinity has been successfully managed by reducing the net amount of salt entering the river through both individual State and joint salinity management actions including salt interception schemes.

With the BSMS reaching the end of its term in 2015, and the recently approved Basin Plan providing complementary policy directions for the management of salinity, the Basin Officials Committee (BOC) requested a General Review of Salinity Management in the Basin. The review is conducted within the context of the shared water resources of the MDB and is intended to:

- assess salinity risks within the context of contemporary understandings of climatic variability, projected salinity impacts of historical developments, current salinity management activities, environmental watering and future development activities
- make recommendations on the most cost-effective ways to manage the long-term and operational salinity outcomes required by the BSMS, MDB Agreement and the Basin Plan, and the desired institutional arrangements to implement future management arrangements.

The scope of this review relates to the net salinity impact of the changing flow regime and salt loads upon the shared water resources. The structure and content of the review was guided by Terms of Reference provided by BOC (Appendix 1), with significant input from an inter-jurisdictional steering committee.

In addressing the key questions outlined in the Terms of Reference for the general review, this report provides:

- a contemporary understanding of the salinity risk to the shared water resources of the Murray–Darling Basin within the context of the recent flow regimes provided under the Murray–Darling Basin Agreement
- the future salinity risk under water management arrangements envisaged through the Basin Plan and future development activities
- feasible joint salinity management options that are available to address salinity risks and meet the objectives of both the Basin Salinity Management Strategy and the Basin Plan
- advice on cost-effective ways for managing the salinity risk to meet Basin Salinity Management Strategy and Basin Plan objectives
- advice on desired institutional arrangements required to deliver salinity management within the Basin.

2. Background

Salinity impacts are realised both locally, where salt is discharged to land, wetlands and streams, and downstream, when in-stream salinities exceed threshold levels with potentially adverse impacts upon the social, environmental and economic values of the shared water resources of the Murray–Darling Basin.

The Salinity and Drainage Strategy (S&DS) was initiated in 1988 to combat problems of river salinity, waterlogging and land salinisation in the Murray Valley, from development and river regulation in the river corridor and the large-scale irrigation districts in the riverine plain and the Mallee. The BSMS (2001 – 2015) and Schedule B of the Murray–Darling Basin Agreement were developed in the early 2000s as a further response to these problems and to also address the perceived salinity threats from upland catchments of the Basin. These two high level policy initiatives were the first coordinated inter-jurisdictional response to jointly manage the problems of salinity and waterlogging in the Basin (Figure 2). They provided a co-ordinated approach to historically high salinity events in the lower Murray where from the 1960s to the 1980s salinities were regularly recorded above 800 EC for considerable periods and reflected concern that such problems may be exacerbated in the future.

Building on the S&DS, the BSMS expanded the coordinated response beyond the irrigated areas of the southern Basin. This wider context was a response to the understanding that the salinity benefits achieved through programs under the S&DS could be overwhelmed by increased salt contributions from dryland areas and drainage systems built prior to the S&DS. This reflected the status of knowledge at the time; that if observed increases in groundwater levels and salt loads in streams continued, there would be substantial increases in land salinisation and an increasing downstream salinity impact.

The BSMS provided a framework for a coordinated inter-jurisdictional response to the Basin-scale extent of the salinity problem and included a joint works and measures investment program, adoption of Basin-wide salinity targets and an accountability framework which tracks river salinity impacts (increases and decreases) for each jurisdiction. Salinity targets provided by the BSMS include the Murray–Darling Basin Salinity Target at Morgan and other End-of-Valley targets for each of the tributary valleys.

Jurisdictional responsibilities outlined within the BSMS were prescribed within Schedule B to the Murray–Darling Basin Agreement including accountabilities for existing salinity impacts and future increases in river salinity, monitoring, evaluation, reporting, and the role of the MDBA in coordination, management and audit.

As a Basin-wide strategy, the BSMS introduced a suite of additional elements (in addition to those prescribed within Schedule B) aimed at addressing local salinity impacts where progress towards mitigating its effect is highly dependent upon local priorities and state specific obligations.

General review of salinity management in the MDB

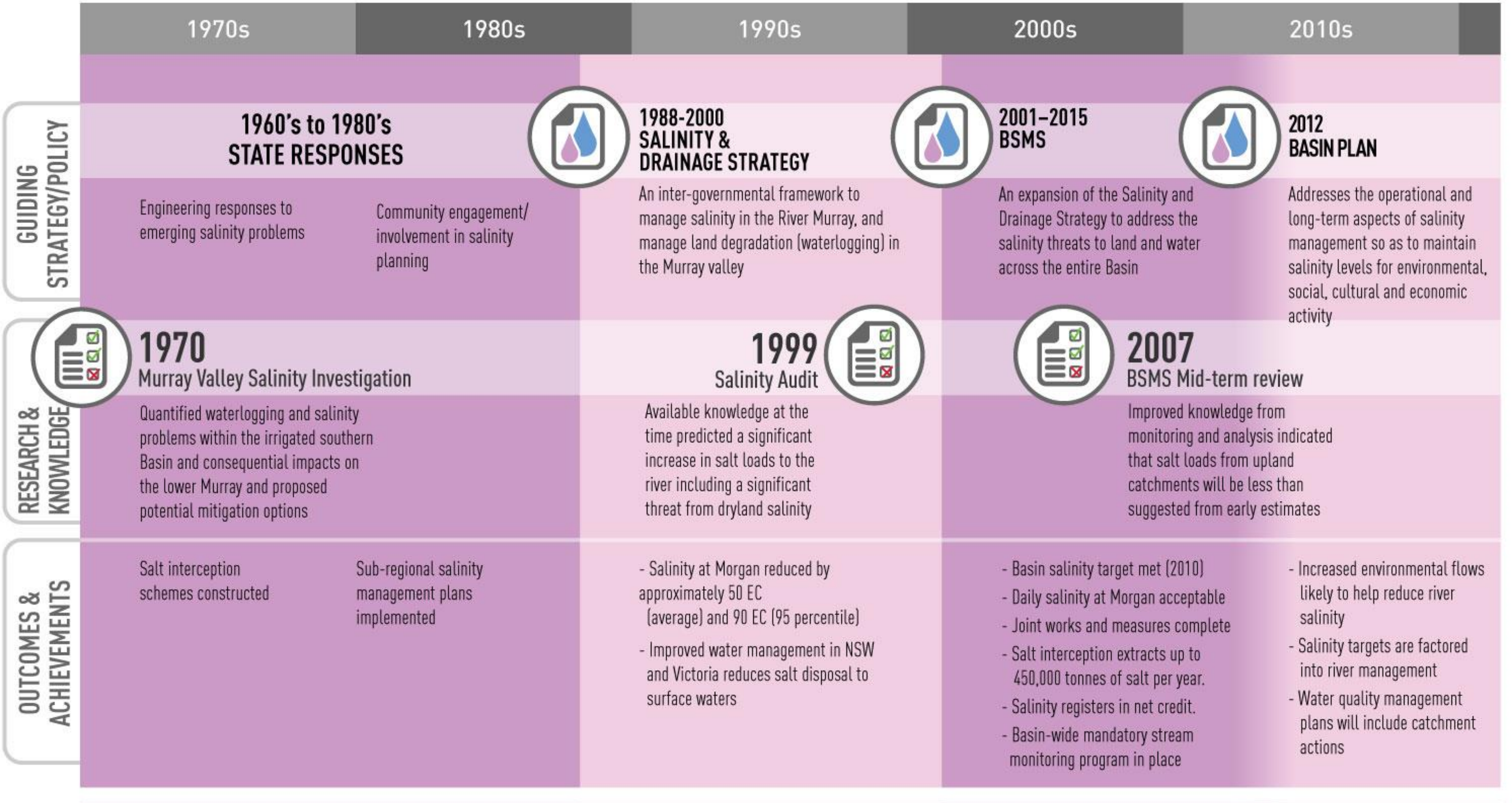

Figure 2 History timeline of important Murray–Darling Basin salinity investigations, policy responses and outcomes over the past 40 years

The major achievements of the BSMS and its predecessor (the S&DS) are a substantial reduction to in-river salinity, particularly in the lower Murray where the aggregate salinity impacts are most apparent and threshold salinities have been exceeded in the past. Such achievements cannot be concluded from observed day to day in-river salinity concentrations as short term outcomes are dominated by the prevailing climatic conditions which drive salt mobilisation and the dilution regime. Rather improvements in salinity are concluded from a combination of measurement and modelling which demonstrate that mitigation works and measures deliver salinity benefits over the long-term when considering both wet and dry periods.

Figure 3 illustrates the progressive improvement in the salinity outcome against the BSMS/Schedule B Basin Salinity Target of less than 800 EC for 95% of the time (over a standardised climate represented by the 1975 to 2000 hydrological regime) due to the joint works and measures undertaken by partner governments and individual state actions. It is noted however that this target would not have been met if the jurisdictions utilised all the available salinity credits for additional development activities.

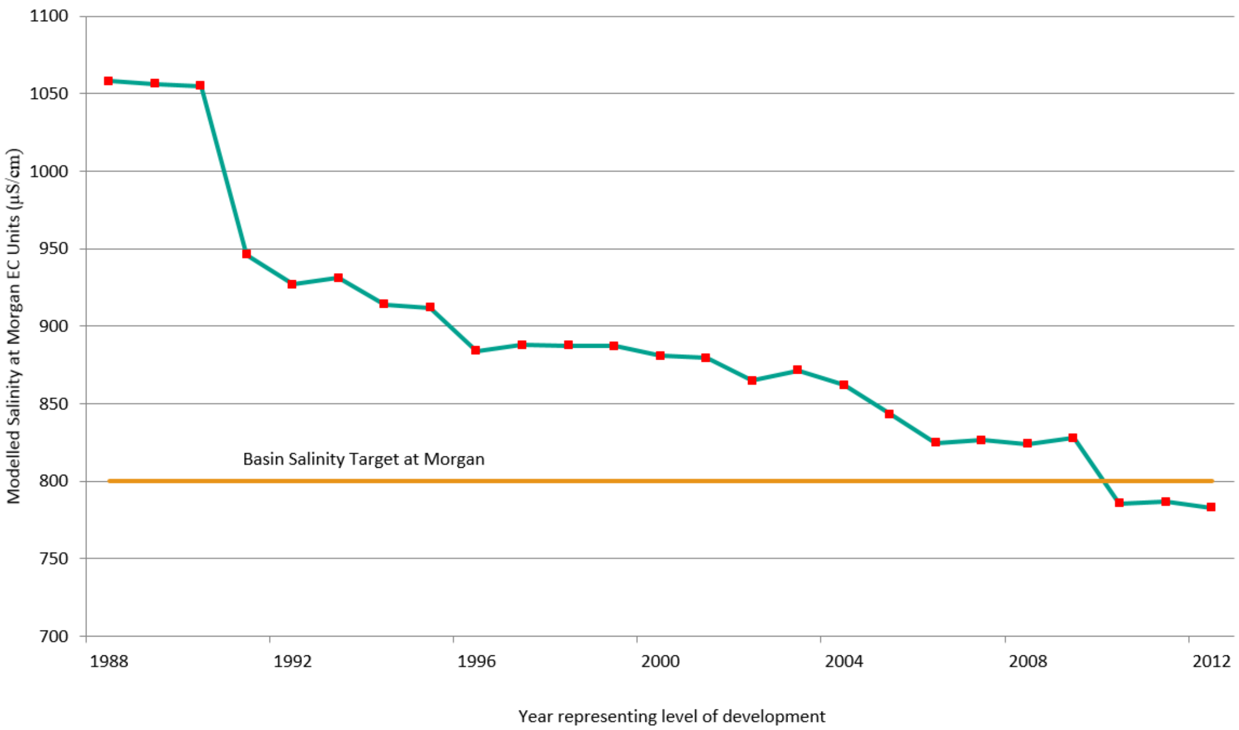

Figure 3 Modelled 95 percent of the time salinity outcome at Morgan in South Australia over a standardised 1975–2000 hydrological regime

Joint works and measures have primarily involved the construction and operation of salt interception schemes to reduce salt loads entering the river system, and improvements to river operating arrangements to achieve greater dilution benefits at critical times. Salt interception schemes (SIS) reduce salt loads to the river by intercepting and diverting saline groundwater that would otherwise have entered surface waters. For some schemes, additional local benefits are also provided (such as the protection of local environmental assets).

Individual state actions have also involved salt interception along with actions targeting reduced salt mobilisation. Examples include improved irrigation delivery infrastructure and on-farm irrigation efficiency programs both of which aim to reduce groundwater recharge that displaces large salt loads to the river system. In some areas such as the Mallee, complementary policies regulate new irrigation developments to zones of lower salinity risk.

Shared responsibility for delivering expected water quality outcomes extends beyond mitigation works and measures. Jurisdictional governments have committed to a coordinated Basin-wide monitoring program across all of the major tributary valleys, and the maintenance of an effective salinity accountability framework. This commitment is given effect through the MDBA salinity registers that record significant increases or decreases in salinity impacts on the river through a system of salinity credits or debits (MDBA 2014a). The registers allow a state to increase the salinity impact through an action, provided such an increase is offset by a reduced impact elsewhere, and the State's register balance is positive. The registers are supported by a governance arrangement that includes on-going monitoring, review and independent audit. These arrangements facilitate the acquisition and application of new knowledge needed for continuous improvement in salinity management and refinement to the contemporary understanding of salinity risk.

Benefits that can be directly attributable to mitigation measures are demonstrated by Figure 4 using measured and modelled data. It compares in-stream salinity outcomes at Morgan in South Australia with model predictions as to the salinity outcome if no mitigation actions had been undertaken since 1988. These results demonstrate the progressive improvement in salinity over time through implementation of mitigation works, measures and actions, noting that Figure 4 also demonstrates the significant influence that the flow regime has upon salinity and that the benefits of actions are most profound during periods of lower flow. Flow regime impacts are clearly illustrated in the 2007–2009 period (MDBA 2014a) corresponding to the latter stages of the recent extended drought whereby the difference between recorded salinity levels (blue line) and the model estimates of salinity outcomes from no further intervention (red dashed line) is greatest. During the high flow period of 2010–2012 there is minimal difference between recorded salinity levels and model estimates of salinity outcomes from no further intervention.

The achievements of the BSMS and S&DS described above, reflect in part the long-standing (25 years) partnership approach to salinity management that allocates responsibilities to partner governments within a clear accountability framework. The commitment to the partnership is implicit acknowledgement by all jurisdictions that development of the land and water resources across the Basin contributes to salinity outcomes of the shared water resources either through extraction and use of water or by actions that exacerbate salt mobilisation.

The Basin Plan, which commenced in 2012, provides complementary salinity management provisions through a water quality and salinity management plan which sets out water quality objectives and targets for Basin water resources, including for salt export. The plan also identifies agencies responsible for considering those targets as part of their operational roles, provides for inclusion of water quality measures in state water resource plans, and contributes to the Basin Plan's outcome that the Basin's water resources be fit-for-purpose. The flow regime within the Basin is changing as a result of environmental water recovery under the Basin Plan. It is therefore timely to review Basin salinity management in light of contemporary understanding of risk and management options.

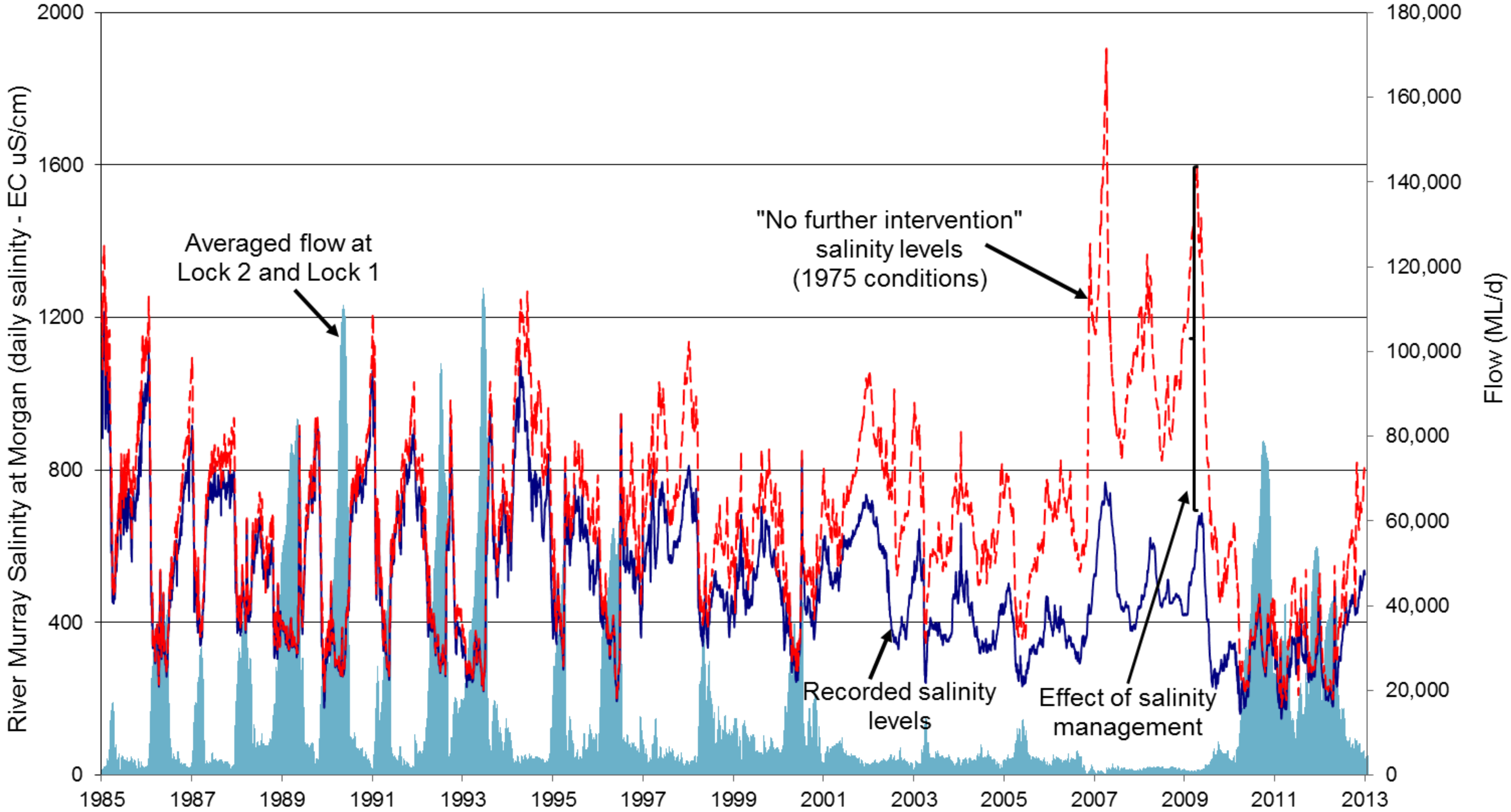

Figure 4 Effect of salinity management in the Murray–Darling Basin

2.1 A General Review of Salinity Management

The Basin Officials Committee requested a General Review of Salinity Management in the MDB; a review that provides insight into the risks posed by salinity within the context of:

- the completion of the BSMS salt interception program of works
- modelled salinity levels achieving the Basin Salinity Target since 2010
- the substantial improvement in the knowledge of the major sources of salt, the risks from dryland salinity and the relative role of climate and management in driving in-stream salinity outcomes
- the early stages of implementation of the Basin Plan which includes:
  - a Water Quality and Salinity Management Plan with salinity targets to have regard for when managing flows and using environmental water and a process for long-term State water resource planning that includes water quality management plans
  - the recovery of water for the environment which potentially provides substantially more water for salinity dilution
- future development activities including the expansion (and emergence) of significant industries in the Basin that have potential water quality implications, specifically coal mining and coal seam gas developments
- improved understanding of the effects of climate variability
- the scheduled review of Schedule B of the MDB Agreement.

This General Review of Salinity Management summarises the contemporary understanding of the salinity risk to the shared water resources as a basis to support implementation of the Basin Plan, the subsequent review of Schedule B and development of a future salinity management program.

Key drivers for the review

- *Salinity in the Basin has long been identified as a significant issue affecting all jurisdictions. Joint effort and investment made by governments of the Basin through the Salinity and Drainage Strategy (S&DS 1988–2000) and the Basin Salinity Management Strategy (BSMS 2001–2015) have made a significant contribution to reducing the salinity of the shared water resources.*
- *Salinity management actions (State Actions and Joint Works and Measures) have delivered significant salinity benefits over the long-term when considering both wet and dry periods allowing the modelled Basin Salinity Target established at Morgan in SA to be achieved in 2010. However this target would not have been met if the jurisdictions utilised all the available salinity credits for additional development activities.*
- *The flow regime in the Basin is changing significantly as water is recovered and used for environmental purposes and the Basin Plan 2012 is implemented, and this has implications for long-term and operational salinity outcomes, including substantial restoration of dilution, as well as increased salt mobilisation risk.*
- *The BSMS is close to the end of its 15 year term. This General Review of Salinity Management reflects the need to consider the future requirements for the management of salinity within the shared water resources including an understanding of current and future risks, cost effective management strategies and future institutional arrangements.*

3. Approach

The MDB Agreement, Basin Salinity Management Strategy and the Basin Plan collectively provide a suite of objectives for salinity management across the Basin. Within the context of this review which focuses upon the shared water resources, these objectives can be summarised as:

- maintenance of appropriate salinity levels for all beneficial uses - agricultural, environmental, social, cultural, urban, industrial and recreational, with the Basin Salinity Target at Morgan to be maintained at less than 800 EC for 95 % of the time
- maintenance of the ecological character of declared Ramsar wetlands, and the protection and restoration of the ecosystems and ecosystem functions of non-Ramsar wetlands, and ensuring that ecosystems are resilient to climate change and other risks and threats
- maintenance of good palatability and minimisation of adverse health and odour risks of water taken for treatment for human consumption (consistent with the need to protect critical human water needs) and achievement of low risk to human health during recreational use
- maintenance of water quality, that when used with best irrigation and crop management practice, will not result in crop yield loss or soil degradation
- to ensure adequate flushing of salt from the River Murray System into the Southern Ocean.

Both the BSMS and Basin Plan provide in-stream salinity targets to drive and assess progress against objectives. Such targets also provide a measure against which to assess catchment and Basin health and condition; and evaluate risk and cost effective management options to mitigate this risk.

Collectively the BSMS and Basin Plan provide a range of salinity targets captured in Appendix 2, which can be summarised as:

- targets for managing water flows
- targets for fresh water-dependent ecosystems
- targets for irrigation water
- targets for long-term planning and management e.g. the Basin Salinity Target and end-of-valley targets.

The Basin Plan also includes a salinity trigger point (Chapter 11 Part 2), for emergency responses to ensure water supply to meet Critical Human Water Needs (CHWN). The salinity trigger point is reached when the level of salinity is 1,400 EC or greater.

For the purpose of the General Review of Salinity Management, this report focuses on the targets covered under 1 and 4 above. The targets for managing flows are referred to as operational targets. Achievement against operational targets is based upon assessing monitored outcomes over a specified period of time and the need to have regard to these targets when planning and making decisions about managing flows. Targets covered under 4 above are referred to as long-term targets which are cross referenced within the Basin Plan to the BSMS targets. These targets inform water resource plans and long-term planning and management. These long-term targets are model based and hence are compared against a statistical assessment of salinity outcomes over a standard variable climatic regime represented by 1975–2000 (the Benchmark Period).

For the purpose of this review, risks are evaluated by considering aggregated risks within:

- An operational context – maintaining the average daily salinity at reporting sites at measured levels that are below the values provided in the Basin Plan for operational targets. The reporting sites are at Burtundy on the Darling River and the River Murray at Morgan, Lock 6 and Murray Bridge, and the Lower Lakes at Milang
- A long-term context – maintaining the modelled average daily salinity at Morgan at less than 800 EC for 95% of the time over the Benchmark Period.

3.1 Methods

Given the differences in landform and climate across the Basin, a landscape approach is used within this review to describe current salinity risks within the Basin focusing on the intrinsic threats, current controls and residual threats. This approach characterised the salinity contributions to the shared water resources in terms of the sources of salt, and the role of the flow regime in contributing to salinity outcomes. The temporal nature of the salinity threat is also described in recognition of the fact that groundwater processes within some areas are slow, and given that these processes are the primary means by which salt is transported to rivers and streams, in some areas it could be decades to over 100 years before the consequence of land or water management actions materialise within the river system.

Within this report, future risks from changes to known salinity threats are informed by quantitative modelling (MDBA 2014b) and qualitative assessment. The modelling compared aggregate salinity outcomes under different flow conditions (with and without Basin Plan water recovery and use) at levels of salt load accessions to the river for future time horizons consistent with the BSMS. Outcomes were provided over the Benchmark Period (1975–2000) and a longer climatic period (1975–2009) which included the recent extended drought. Qualitative descriptions were provided for any identified emerging or future salinity threats that are not incorporated into the models.

Just as achievements to date reflect a combination of joint works and measures, state actions and policy initiatives, management of future risks will be optimised through such a partnership approach. As the scope of this review relates mainly to the joint program, the identification of feasible management options has focused upon those options likely to be delivered as joint works or measures including SIS, flow management and the delivery of the salinity management program under Schedule B. Different SIS operational capacity scenarios were modelled under different flow conditions (with and without Basin Plan water recovery and use) at levels of salt load accessions to the river for future time horizons consistent with the BSMS to identify if there is potential to adaptively manage the SIS program commensurate with the salinity risk.

Cost effectiveness analysis was applied to support the future development of a salinity management strategy that appropriately balances the need to manage risks and meet regulatory obligations relating to salinity, and the long-term costs associated with implementing the strategy. Elements that were identified as potential opportunities to streamline existing management and operational arrangements have also been included as areas that require review or further investigation.

Current institutional arrangements were reviewed and matters to be considered in refining these arrangements to deliver the next generation salinity management program and improve cost effectiveness are discussed.

A high level conceptualisation of the various aspects of Basin-scale salinity management that were required to be considered in undertaking this review is illustrated within Figure 5.

An inter-jurisdictional steering committee was established to advise on the conduct of the review and to provide input to policy and technical issues. An independent chair was appointed to effectively progress and guide the review and to deliver clear recommendations arising from the review. Technical specialists supported and assisted the review, while independent peer review was undertaken of the supporting modelling work.

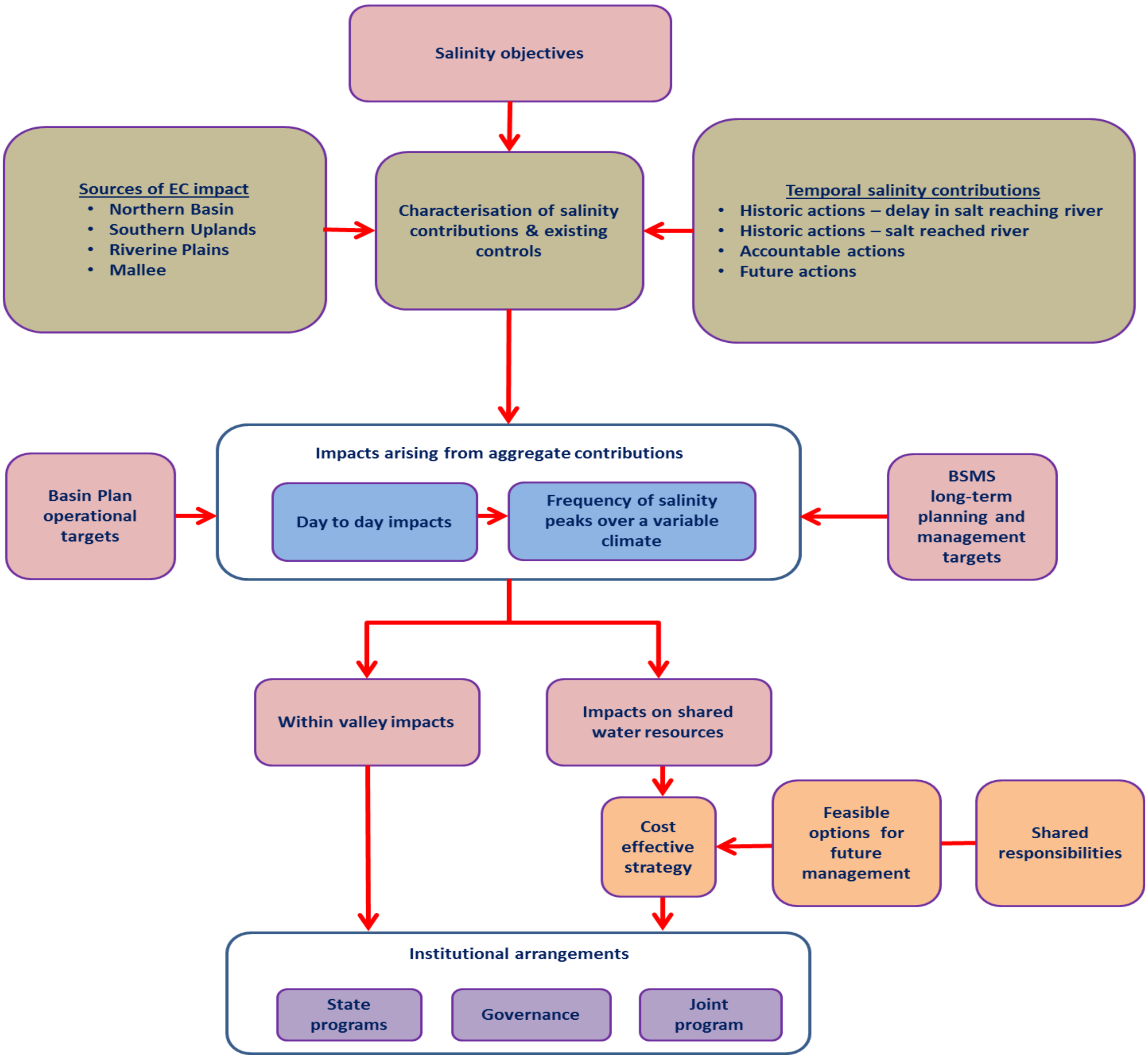

Figure 5 Linkages between the components considered through the General review of salinity management in the Basin

4. Current salinity risk

4.1 Context

For the purpose of this report, current salinity risk reflects the status of threats arising from flow conditions and salt load contributions to the River Murray that have the potential to adversely impact upon the River Murray by 2015; the final year of the BSMS 2001–2015. From time to time, these threats may materialise within the river through the combined effect of salt load accessions and water diversions across the Basin, and hence pose a Basin-scale risk to the shared water resources.

Landscapes across the Basin encapsulate both climate and landform and therefore provide a sound geographical basis upon which to consider current salinity risks. Accordingly, this chapter provides an overview of the sources of salt, the drivers of salt mobilisation, and salt transport and dilution within a landscape context. Threats from the various landscapes (comprising impacts from land and water management actions across the Basin) that contribute to the risk profile are informed by the BSMS salinity registers [2] (MDBA 2014a) as all states must report impacts of past and current actions to the MDBA, if they have a significant impact upon the River Murray.

The registers are underpinned by reports and models that are updated regularly in accordance with Schedule B accountability arrangements. This contemporary knowledge base was available for this assessment of current risks, enabling the review to be underpinned by the best available science and information.

4.2 A Basin-wide perspective

Climate varies across the Basin with increased aridity from the eastern highlands, to the west and south west (URS 2008), and a change in seasonal rainfall patterns from summer/autumn dominated episodic events in the north, to winter/spring dominated seasonal rainfall in the south.

The landforms representative of the Basin environment include uplands to the north, east and south with highland valleys grading to the sedimentary Riverine Plains within the central and western areas. Aeolian and marine deposits lie to the southwest. The Basin comprising these landforms has been described as *low lying, and saucer shaped* with the River Murray providing the primary conduit for groundwater and salt export from the Basin (Evans and Kellett 1989). Collectively the following provides an overall summary of the key drivers for the intrinsic salinity threat that characterises the Basin:

- groundwater recharge primarily within the higher rainfall areas to the east
- regional groundwater flow systems from east to west becoming increasingly saline as groundwater moves away from the primary recharge sources
- lower reaches of the River Murray incised below the highly saline regional watertable and flow paths within the regional aquifers being primarily towards this incised river trench; a generalised presentation of the primary flow paths for the watertable aquifers within the Mallee region are shown in Figure 6(a) and Figure 6(b).

[2] The salinity registers are described within Appendix 4 of this report.

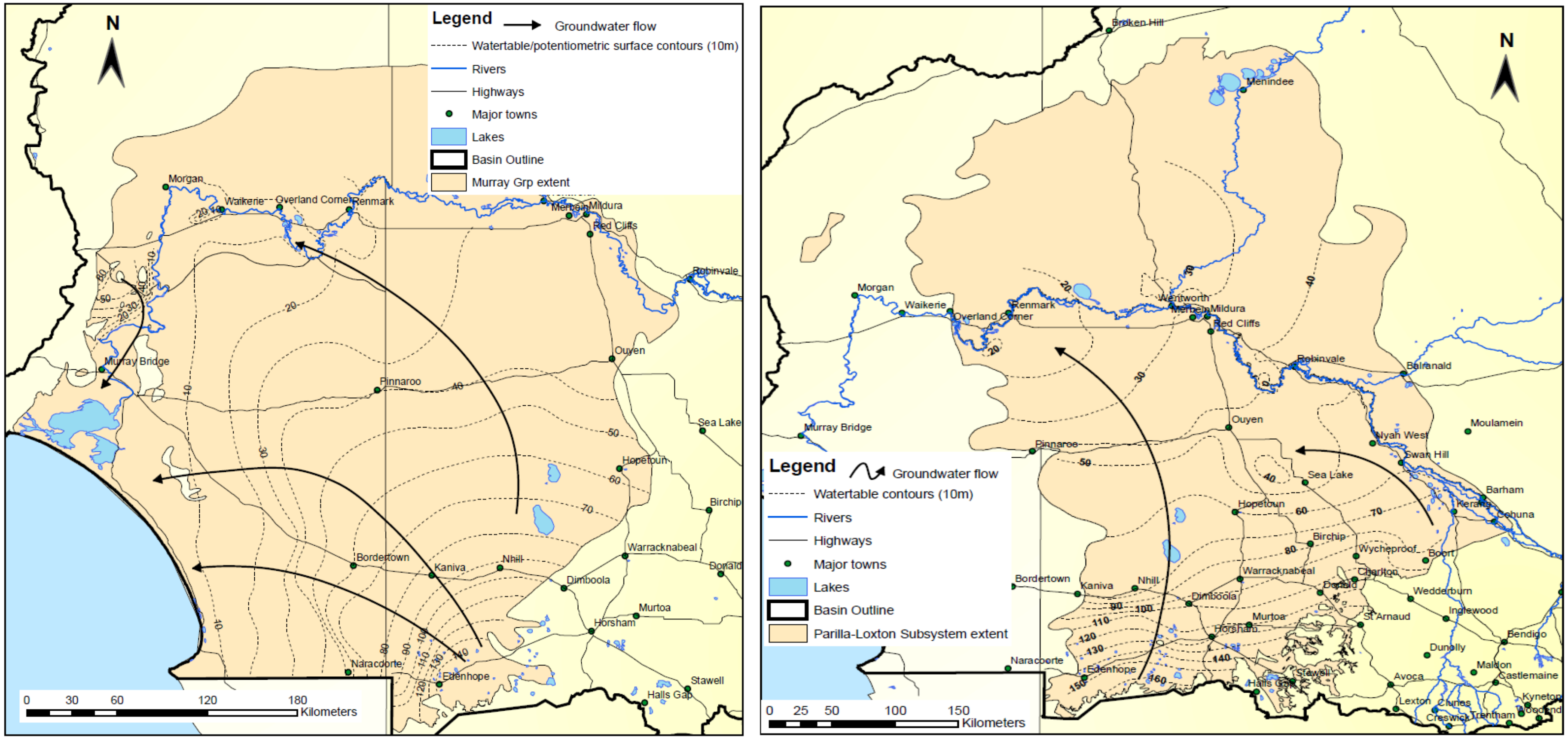

Figure 6 Groundwater flow directions within (a) the Murray Group aquifer and (b) the Parilla/Loxton sands aquifer; the primary regional aquifers underlying the River Murray in the western and eastern Mallee respectively (source: URS 2008).

Notes:

(a) Shows extent of Murray group aquifer relative to the River Murray (b) Shows extent of Parilla/Loxton sands aquifer relative to the River Murray

Whilst there are deeper aquifers which exhibit variations to these flow paths, the regional watertable aquifer is of primary importance because of its potential to significantly interact with the river.

These drivers of the salinity threat are compounded by land and water resource development which has increased salt mobilisation, and significantly altered the river flow regime.

To provide a greater understanding of the source of salts and characterise the trends in salt loads emanating from those sources (and hence the current risk profile), the intrinsic threats, development contributions to these threats, and controls in place to manage these threats are discussed in the following sections within a landscape context. These descriptions are based upon the following landscape categories illustrated within Figure 7:

- the Northern Basin - capturing the highlands and the northern plains within Queensland and New South Wales
- the Southern Uplands – including the A.C.T., eastern New South Wales and Victoria
- the Riverine Plains – encompassing the broad acre irrigated plains across northern Victoria and the Riverina of NSW
- the Mallee region – extending from western New South Wales and Victoria into South Australia.

The discussion of landscape categories includes the relative contribution of salt loads to EC impact at Morgan, and the flow contribution to the shared water resources that offsets salt load impacts (Figure 8). The location of the salt input is important as the further upstream the salt input occurs, depending on the base salinity level of the river reach, the greater the economic cost (from an increase) or benefit (from a decrease) per unit change in salinity. The contributions from each landscape to the progressive increase in river salinity along the River Murray (Figure 9) are also discussed.

Whilst these landscape categories provide a reasonable Basin-scale framework upon which to describe salinity contributions to the shared water resources of the Murray–Darling Basin, significant variations occur within each landscape with respect to salt storage, salt mobilisation and the flow regime that contributes to the dilution of salt loads.

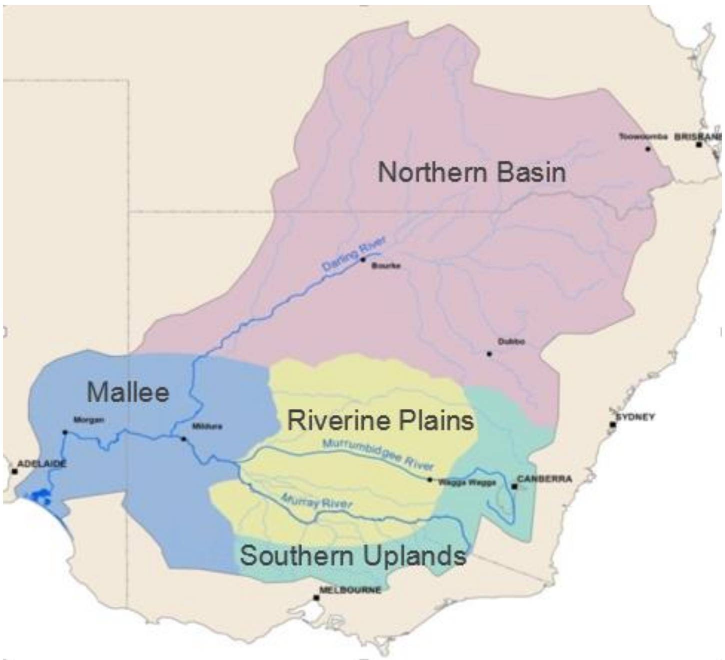

Figure 7 Landscape categories of the Murray–Darling Basin that have been adopted within this review

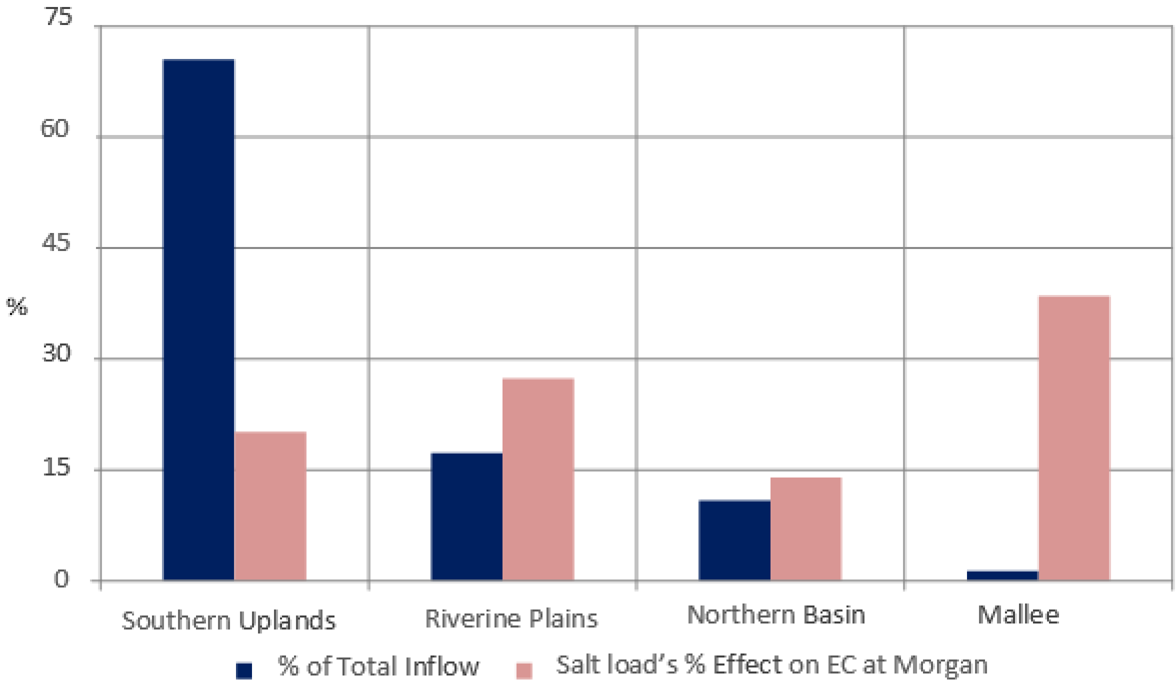

Figure 8 Relative average contributions of salt loads to river salinity at Morgan, and flow contributions to the shared water resources under 2015 conditions (but not including Basin Plan flows) [3]

[3] Average salt load/flow contributions from the various landscapes are illustrated within Figure 8. The data underpinning this graph is derived from the Morgan salinity study (MDBC 2003) adjusted to reflect impacts of changed land and water management development since that period (using the modelling scenario, BP BDL S4 2015 described within MDBA (2014b)). Figure 8 illustrates the relative impact that the tributaries, drains and groundwater within each landscape have on the average salinity at Morgan over the BSMS Benchmark Period (May 1975 to April 2000).

Within the MDBC (2003) study, multiple modelling runs were undertaken, with each run involving the turning off of selected salt loads/flows so as to derive the relative contributions from each source. Undertaking a comparable intensive modelling study to reflect contributions under current land and water management decisions was beyond the available time and resources for this General Review of Salinity Management. Hence results of 2003 were re-interpreted taking into account the latest estimates of salt load contributions from various sources. This interpretation was made by comparing MDBC (2003) estimates of salt load contributions and consequent EC impact at Morgan with those under current levels of development (MDBA 2014b; BP BDL S4 2015 scenario). The relative differences in salt load were used as a basis for pro-rata adjustments to the MDBC (2003) contributions, which are illustrated in Figure 8 as a percentage of salt load contributions at Morgan.

Flow contributions from the various tributaries, drains and groundwater were sourced from modelling undertaken for this General Review of Salinity Management (MDBA 2014b; BP BDL S4 2015 scenario) and hence reflect current levels of development. These flow estimates were attributed to the various landscapes and are illustrated within Figure 8 as a percentage of flow contribution at Morgan.

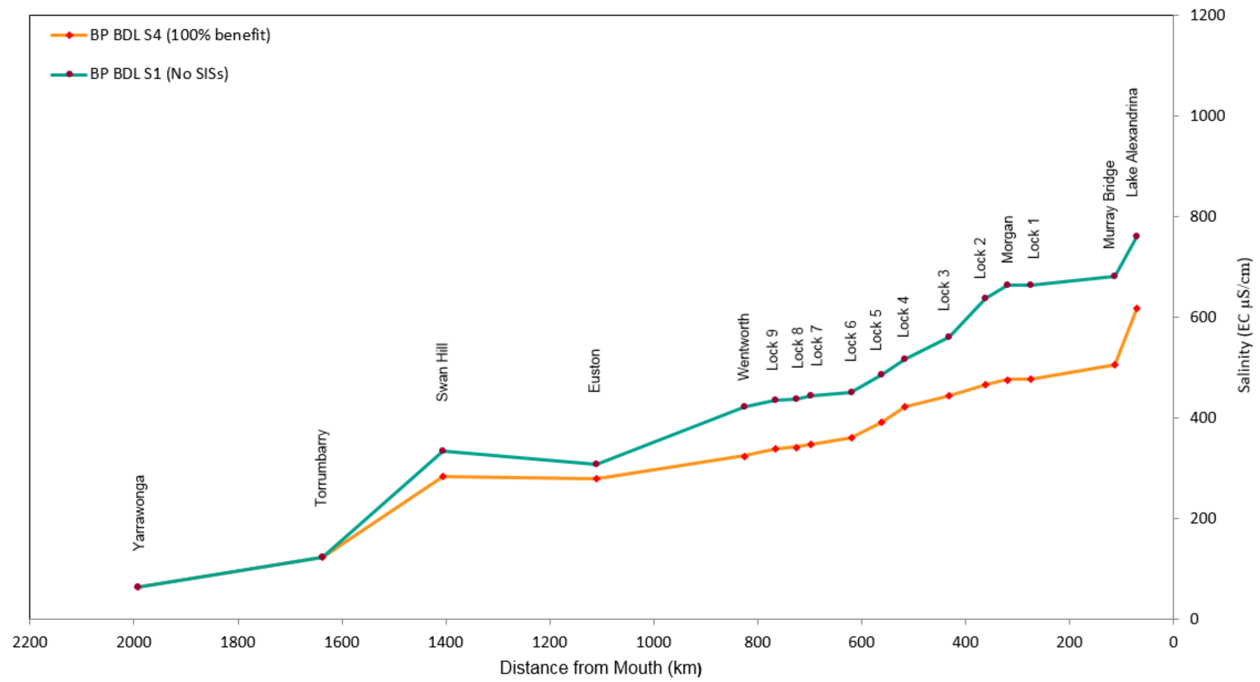

Figure 9 Average daily salinity along the River Murray over the 1975–2000 Benchmark Period with 2013 levels of development and salt interception

In considering the salinity threats posed by each landscape, it is also important to recognise that in many parts of the Basin, groundwater processes dominate salt mobilisation to the river. As sub-surface water movement is slow, impacts from the mobilisation of salt within the landscape will in some cases not materialise within surface water bodies for decades or possibly within 100 years. There are also significant uncertainties as to the likelihood and magnitude of these delayed impacts. In this report, delayed salinity impacts are considered to be future risks and hence are discussed in the Chapter 5.

Intrinsic threats, current controls and residual threats within MDB landscapes

4.3.1 Northern Basin

Intrinsic threats

The Northern Basin contributes salt and flows to the shared water resources via the Darling River (Figure 7). The Darling River system's highland valleys are generally home to ephemeral rivers which are primarily exporters of salt to the plains. Vast transit distances along the Darling River, and extensive overbank flow events on the northern plains leads to most of the salt exported from the highlands being deposited on the floodplain. Remobilisation of these salts to rivers is constrained by the relatively deep groundwater levels beneath the plains relative to river levels.

The Northern Basin contributes ~14% of the salt load impact at Morgan, which is diluted by providing ~11 % of the flow (Figure 8). Flow and salt load from the Northern Basin contribute to the increasing average salinity profile as the river flows downstream from where it enters the River Murray at its confluence with the Darling River (Figure 9).

Controls

While salt interception schemes located in the Mallee contribute to a level of control for salt inflows from some upstream landscapes, the Upper Darling salt interception scheme constructed south of Bourke is the only major control that has been put in place specifically to manage salt impacts from the Darling River on the shared water resources. Whilst not operational at the time that this report was prepared, it is expected to reduce salinity impacts at Morgan by ~2.2 EC (MDBA 2009). The emphasis on salinity control elsewhere within the Northern Basin is primarily towards the protection of local assets (for example, water quality, agricultural land, infrastructure and biodiversity in the Condamine Catchment (Searle *et al*. 2007)). There are few register entries for the Northern Basin (aggregating to a net debit of <1 EC) reflecting the relatively low impact that most land and water management actions within this landscape have upon the salinity of the shared water resources.

Residual threats

Under the current management conditions and with current rates of salt mobilisation to the Darling River, the Northern Basin can be expected to continue to contribute net average salt loads and flow regimes to the shared water resources, typical of the past (Figure 8). However the episodic nature of the flow regime from the Northern Basin means that elevated salt load discharge events will arise from time to time. Based on past experiences, such threats will arise as a consequence of the mobilisation of accumulated salt on either the “rising limb” of a flood hydrograph, or flow releases from Menindee Lakes to a saline lower Darling River. An example of the latter is captured within **Figure 10** where elevated salinities at Wentworth and Lock 9 can be tracked back to a salt mobilisation event identified at Burtundy.

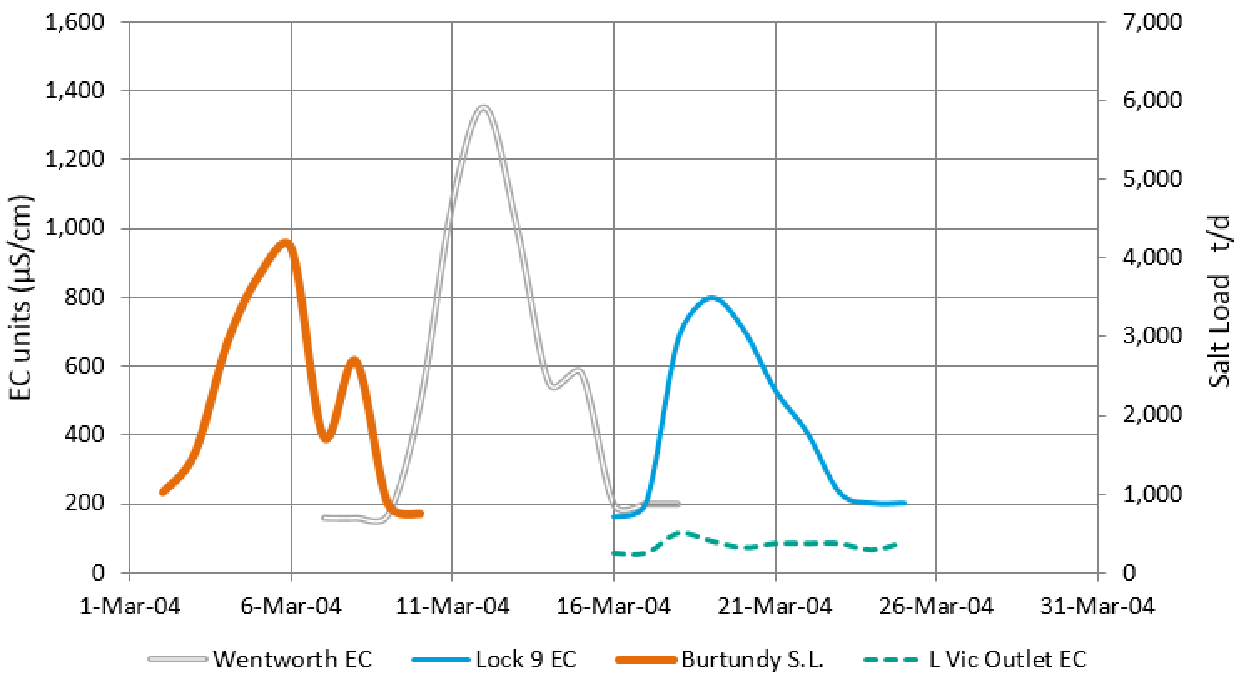

Figure 10 Salinity spike in the shared water resources emanating from the 7,000 ML released from Menindee Lakes into the Darling River that comprised saline pools

(data sourced from MDBA Weekly reports - March 2004)

The management response to such an event has been to monitor the downstream transport of the salt load, and diversion into Lake Victoria with releases back to the river during higher river flow events. Importantly, press releases are provided to ensure that the public is aware of the river salinity threat, and so ensure water users are sufficiently informed to manage their risks.

4.3.2 Southern Uplands

Intrinsic threats

The tributaries of the Southern Uplands contribute flows and salt loads at various locations within the southern Basin with the New South Wales contributions primarily being via the Murrumbidgee River, and the Victorian contributions via a series of north flowing tributaries. The tributaries of the Southern Uplands have in the past contributed approximately 20% of the salt load to the shared water resources which is significantly diluted through a contribution of around 70% of the flow (Figure 8). As the southern tributaries flow through the Riverine Plains and have a number of confluences with the River Murray, the net contributions of flow and salt load to River Murray salinity is not easily discernable in Figure 9. The rising trend in average salinity between Yarrawonga and Swan Hill (Figure 9) is the net effect of salt load/flow contributions from the Victorian tributaries, along with contributions from the Riverine Plains. Similarly, the combined effect from the Murrumbidgee uplands and parts of the NSW Riverine Plains is realised between Swan Hill and Euston, with no apparent increase in average salinity within the River Murray (Figure 9) likely to be a consequence of the high flow regime provided by the Murrumbidgee.

The source of these salt loads within the upland tributaries is primarily groundwater discharge to streams as a result of clearing of deep-rooted vegetation. These impacts were apparent from rising in-stream salinities that were a major point of concern during the 1980s and 1990s. Concern arising from the potential impact of these threats (MDBC 1999) led to substantial investment in monitoring and capacity to better understand the dryland salinity risk.

The knowledge accumulated from various studies over the last 15 years from this investment (reviewed and summarised in SKM 2013) indicates that rising groundwater trends and stream salinity increases during the latter half of the twentieth century were largely a function of a prevailing wetter period. Rather than having a long-term upward trend, many upland groundwater systems are in dynamic equilibrium with periodic wet and dry sequences. Projected increases in salt exports from upland catchments are therefore significantly less than was the previous understanding although some NSW sub-catchments still do have increasing salinity trends (DECC 2009) as does the Loddon River in Victoria (Cheng *et al.* 2012).

Controls

Under the BSMS, the focus of land and water management initiatives to combat dryland salinity within the southern tributary valleys has primarily been on redesigning farming systems, reforestation and vegetation management, with the primary strategy being for cropping systems and other vegetation to maximise the transpiration of soil moisture and so reduce groundwater recharge. However evidence supporting valley scale in-stream benefits from these controls has not been forthcoming. The ANAO (2008) found that "*the ability of regions to quantify what investments achieve against program outcomes is constrained by the absence and general nature of some targets and the lack of relevant monitoring and/or modelling systems*". Cook (2008) notes that the evolution of dryland farming systems are impacted by a range of factors including climate, technology and markets, and that whilst incentives may be helpful in providing direction on programs (such as salinity initiatives), in the absence of a regulatory framework, they cannot be relied upon to counter external influences.

Whilst there are potentially other sound reasons for investment in these elements of the BSMS (such as the protection of local assets, or improved ecological values), their potential to mitigate risks to the shared water resources have not been proven.

In addition to the management initiatives to combat dryland salinity, salt interception schemes located in the Mallee contribute to a level of control for salt inflows from the Southern Uplands.

Residual threats

The Southern Uplands will continue to export salt, along with a flow regime that provides dilution benefits. Whilst studies over the last 15 years suggest a reduced risk profile from the uplands, there remain a number of valleys where salinities may increase in the future and hence warrant more investigation (DECC 2009). In the short term, the primary residual risk is likely to be salts accumulated during drier periods being mobilised on the "rising limb" of a flood hydrograph. An example of such an event for the Loddon River is illustrated within Figure 11 where rising river levels mobilised significant salt loads leading to a salinity spike above 1,500 EC for several months and at one point, almost reaching 3,000 EC at Kerang Weir. The implications of such events on the River Murray are dependent upon the river flow regime, but has the potential to compromise downstream Basin Plan targets for irrigation water (at 833 EC), or the more likely outcome of exceeding the Basin Plan Lock 6 operational target (580 EC).

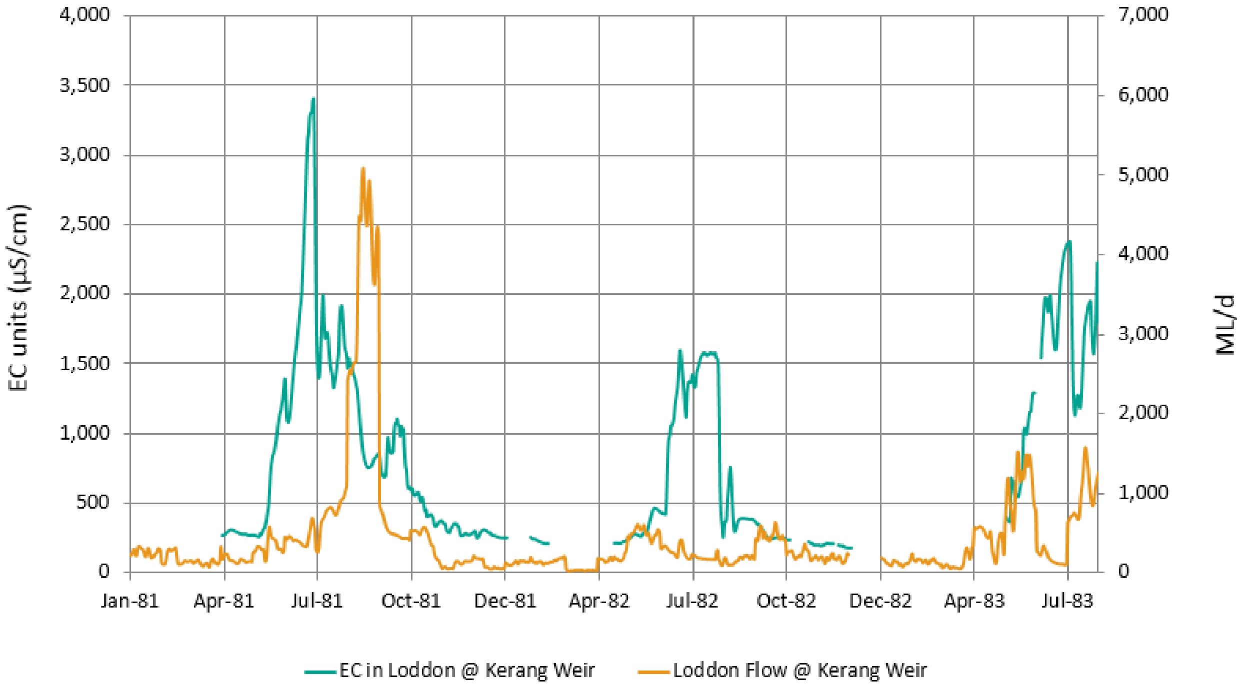

Figure 11 Salinity spike on the rising limb of a flood hydrograph downstream of the Loddon uplands.

Note: while monitoring provides evidence that such an event occurred, the data is sourced from MDBA (2014) modelling and so represents pre-Basin Plan flows and 2015 salt load inflows.

As for the Northern Basin, the primary management option currently available to respond to such an event is to divert such flows into Lake Victoria with releases during higher river flow events.

4.3.3 Riverine Plains

Intrinsic threats

Salt mobilisation from the Riverine Plains is primarily sourced from the irrigated landscape from areas with high salt storage and relatively deep incised surface drainage systems that provide a conduit for salt wash-off and direct groundwater discharge to the river system. Prior to the millennium drought when drainage flows reduced substantially, the Riverine Plains contributed approximately 27% of the salt load contributions to the salinity at Morgan (Figure 8). Through their meandering streams and drainage networks, the Riverine Plains also contribute dilution benefits comprising approximately 17% of the flow to the shared water resources (Figure 8).

Intrinsic threats from the Riverine Plains primarily arise in areas where these deep drains incise areas of significant salt storage and so provide a ready conduit for saline groundwater to reach the river.

Barr Creek near Kerang has for decades provided a substantial salinity impact upon the river (GHD 1970) being a significant contributor to the average river salinity increase between Torrumbarry and Swan Hill (Figure 9) with its contribution being in the order of 760 t/day over the Benchmark Period but contributing flows of just 160 ML/day (RPS and RMCG 2013). Whilst GHD (1970) identified other areas with a history of salinity/waterlogging, such as the Edward-Wakool River system which delivers an average salt load of 800 t/day to the River Murray (RPS and RMCG 2013), this system provides average dilution benefits of in excess of 4,000 ML/day (MDBA 2014a) [4]. It does not have the deep drainage network as does the Barr Creek Catchment, and much of the salt load is sourced from fairly fresh river water from the River Murray (via the Mulwala Canal or from overbank flows from River Murray flooding events).

Controls

Significant investment has been undertaken towards salinity mitigation within the irrigated plains, although many of the initiatives seek to control the productivity losses from waterlogging and land salinisation rather than being to provide downstream benefits. However within the Barr Creek Catchment, termed a high impact zone (RPS and RMCG 2013), saline drainage flows have been targeted for control. The Barr Creek Drainage Diversion Scheme was constructed in 1968 in response to complaints from downstream irrigators about saline slugs passing down the river (GHD 1970) and has been enhanced through a commitment to reduce drainage flows within the creek, so as to contribute to improved efficiencies of the drainage diversion scheme. These improved efficiencies are referred to as the Barr Creek Catchment Strategy on the salinity registers. In more recent years, controls include programs to reduce groundwater recharge by reducing irrigation system losses, and other efficiency measures noting that the primary drivers for these more recent programs relate to water recovery initiatives.

Salt interception schemes located in the Mallee also contribute to a level of control for salt inflows from the Riverine Plains.

Residual threats

The combined impact of rainfall and broad acre irrigation in the Riverine Plains has the potential to maintain a shallow watertable mound within areas of high hydrological loading (GBCMA 2012). However at the regional scale, a range of policy and investment initiatives are driving landscape change across the Riverine Plains including improved on-farm efficiencies (Australian and State government investments), modernisation of irrigation infrastructure, the Victorian 80:20 sales deal which was effectively an entitlement transfer from irrigation to the River Murray environment under The Living Murray water recovery program, and the net impact of water trade upon entitlements and allocations held (and used) within the region (GBCMA 2012; RPS and RMCG 2013). The residual salinity risk is substantially reduced where these initiatives reduce the hydrological loading which plays a significant role in salt exports.

[4] Sourced from modelling runs underpinning the MDBA (2014b) report

RPS and RMCG (2013) identified the Torrumbarry Irrigation Area near Kerang as highest priority salinity threat (inclusive of the Barr Creek Catchment). The risk status attributed to the Barr Creek catchment reflects the high salt store/deep drainage network described earlier; a combination of salt mobilisation drivers that largely set it apart from the other parts of the irrigated Riverine Plains. The intrinsic threat from this catchment is already partially offset by the Barr Creek Drainage Diversion Scheme, however drainage flows during extended wet periods or storm events have historically exceeded the capacity of the drainage diversion scheme to divert salt away from the river. At the other extreme, the dry conditions of the recent extended drought led to Barr Creek ceasing to flow (SKM 2011), with these two climatic extremities illustrating that the residual risk is highly sensitive to the net impact of irrigation intensity and prevailing climatic conditions. Hence, the transition towards less use of irrigation water within the Torrumbarry Irrigation Area is expected to reduce the residual risk (RPS and RMCG 2013).

In providing an overall statement as to the residual risks associated with the Riverine Plains, the extent of land and water use change underway (i.e. reduced irrigation intensity) strongly suggests a reduced impact in the future, compared with that experienced in the past. However whilst irrigation continues to take place within the “high impact” Barr Creek catchment there is potential for occasional episodic salt discharge events to occur from time to time. Modelling of such an event in 1994 indicates a correlation between incidences of high salt load discharge from Barr Creek, and a delayed salinity impact downstream at Swan Hill (Figure 12).

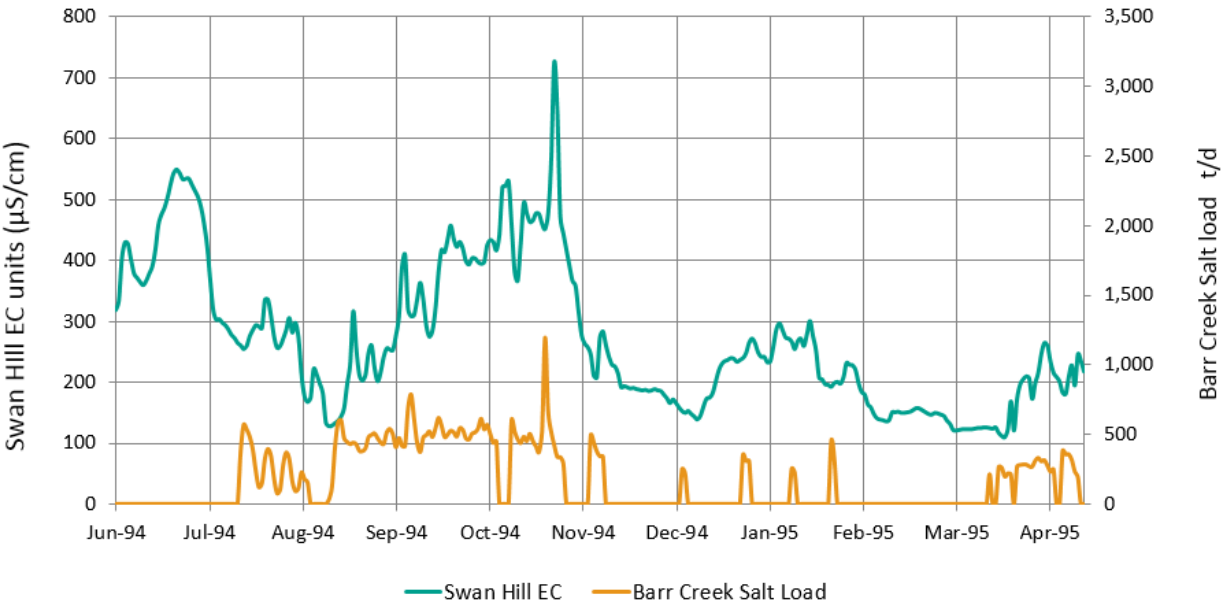

Figure 12 Salt load impacts from Barr Creek on River Murray salinity at Swan Hill in 1994.

Note: while monitoring provides evidence that such an event occurred, the data is sourced from MDBA (2014) modelling and so represents pre-Basin Plan flows and 2015 salt load inflows.

Upon reaching the river, the primary management option for river operators is to divert peak salt loads into Lake Victoria as discussed in relation to the tributaries (including the Darling River). However for the Barr Creek catchment, there is also an opportunity to review the operation of the pumps so as to improve their effectiveness in the diversion of water to Lake Tutchewop. These pumps are currently operated according to rules established to optimise the average salinity outcome at Morgan delivering an EC credit of approximately 5 EC (MDBA 2014a). However if future drainage flows are likely to be substantially reduced due to changed land and water management (see discussion above), there may be a lesser need for diversions to achieve the average salinity outcome sought for Morgan and hence potential to capture salt loads not currently being intercepted under existing operational rules. To this end, a future review of the operation of the Barr Creek pumps scheduled for 2016 (MDBA 2014a), may seek to improve both the average EC outcome at Morgan (i.e. the register entry), and minimise the impact of discharges on the Basin Plan Lock 6 operational target.

4.3.4 Mallee region

Intrinsic threats

The Mallee contributes ~38% of the salt load contribution to the salinity impact at Morgan with a very low volumetric flow contribution for dilution of less than 2% of the shared water resources (Figure 8).

Regional and local groundwater flows, and floodplain processes, play an important role in the transport of this salt from groundwater to the river with water movement and salt mobilisation processes being variable and complex. The flow paths of water are dependent on the topography, geomorphology, groundwater flow into the floodplain, and river height. Due to their low elevation, saline groundwater flows into the floodplain from adjacent higher elevation landscapes. When river levels are low, this groundwater can discharge into the river. During times of high river flow the direction of discharge is reversed, so that river water flows into the floodplain aquifer. However, increased water levels in the floodplain due to river regulation have complicated this general picture. River regulation, irrigation adjacent to the floodplain, and clearing native vegetation from higher elevations collectively contribute to higher groundwater levels beneath the floodplain. This both increases the volume of saline groundwater discharging to rivers, and allows evaporation and salt enrichment close to the surface of the floodplain (SKM 2014).

Salt accumulation impacts the health of the floodplain and also has the potential to be washed to the river and so increasing in-stream salinity but direct groundwater flow is thought to be the dominant transport process delivering salt direct to the river. A key factor is whether the floodplain is gaining or otherwise. Salt transport direct to the river from groundwater tends to occur where regional groundwater gradients are strongest, where the floodplain is narrow, and where the floodplain salinity is high (AWE 2012). The groundwater flow direction and flux rate can change over short distances, and in some locations, the river can be gaining on one side and losing on the other (AWE 2012).

Salt load contributions along the river are illustrated by the gradual rising trend in the historic average salinity apparent from Euston to Murray Bridge, noting that the increase in salinity downstream of Murray Bridge (Figure 9) is dominated by reduced flows and salt concentration factors other than groundwater processes and salt load accessions. AWE (2012) identified the key reaches, not protected by SIS, with most risk of contributing salt loads to the river as being from Mallee Cliffs to Red Cliffs, between Lock 5 and Berri at Pike, and from Loxton to Lock 3.

Controls

Mitigation strategies undertaken in the Mallee include improvements in irrigation efficiencies, reductions in losses from irrigation delivery infrastructure, new irrigation developments being directed to low impact zones and the construction and operation of salt interception schemes. River channel operational capacity limits and sustainable diversion limits established under the Basin Plan also provides an upper limit on the scale of development within the Mallee Region, and hence irrigation impacts.

Whilst most of the salt interception schemes operated within the MDB are located in the Mallee region due to efficiency with which significant sources of saline groundwater can be identified and diverted, these controls are commonly offsets for actions that cause salinity increases elsewhere within Basin and hence operations are collectively funded by Victoria, New South Wales and South Australia.

Residual threats

Whilst significant works have been undertaken to offset the high salinity risk within the Mallee region, the extensive salt stores within the landscape and strong connectivity between groundwater and the River Murray means continued salt accessions will take place in those reaches of the river not protected by salt interception. These residual threats emanate from rain fed dryland agricultural areas, from beneath irrigation areas, and from the saline floodplain. Whilst continued improvements in irrigation efficiencies will assist in reducing these residual threats, 100% irrigation efficiency is not achievable and is in fact undesirable given the need to apply excess water to leach salts from the rootzone (Newman *et al.* 2009).

These residual threats are apparent as diffuse long-term groundwater base flows that contribute to the salinity increase from Swan Hill to Lock 9, and are the primary source of the average salinity increase from Lock 9 to Murray Bridge (Figure 9).

Event-based mobilisation of local salt stores as a consequence of short term changes to river hydrology also pose an on-going risk. The extent to which such events contribute to adverse outcomes depend upon the sequence of hydrological events. Typically within the Mallee, the impacts are realised when floods initiate the mobilisation of salt, followed by a low flow regime. If salts mobilised by the event continue to enter the river as the flood recedes and enters a low flow period, elevated salinities may result. An example of such an event was the elevated river salinity that resulted from backflow from Lake Bonney in the aftermath of the 1981 flood. This was followed by an elevated (albeit lesser peak) salinity most likely driven from floodplain accessions (Figure 13).

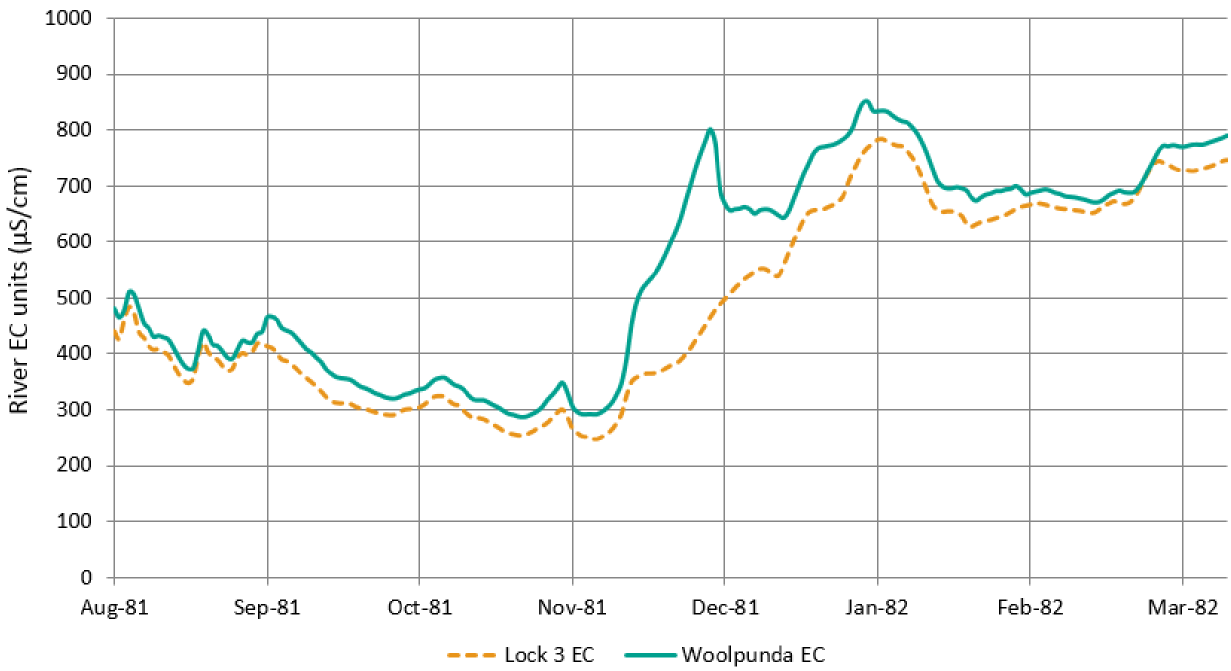

Figure 13 Salinity spike in the River Murray with the difference between salinity outcomes between Lock 3 and Woolpunda, evidence of salt mobilisation from Lake Bonney and Chowilla during a flood event.

Note: while monitoring provides evidence that such an event occurred, the data is sourced from MDBA (2014) modelling and so represents pre-Basin Plan flows and 2015 salt load inflows.

4.4 Summary of the current salinity risk

All landscapes contribute salt to the river and progressive salinity increases along the River Murray (Figure 9) reflect the aggregate impact of the salt load and flows from the various landscapes. The most significant source of salt load is the Mallee region (~38%) followed by the Riverine Plains (~27%). The Southern Uplands contributes about 20% and the Northern Basin about 14% of the salt load, with the Southern Uplands providing the major flow regimes (around 70%) to dilute the salt loads (Figure 8). Salinity concentrations in the river are also a reflection of river regulation and upstream diversions that have reduced the substantial dilution and flushing of the river that would have occurred prior to development of the land and water resources of the Basin.

Achievement of the Basin Salinity Target in 2010 (as illustrated within Figure 3) suggests that controls implemented across the Basin have been effective in mitigating the aggregate salinity impact of each of the landscapes described above. The effectiveness of the salinity mitigation works under (and prior to) the BSMS is demonstrated by the progressive decline in the 95 percentile salinity at Morgan modelled over the climatic period of 1975 to 2000. This decline in peak salinity indicates that whilst day to day salinity outcomes will in part be in response to climatic conditions, over the long-term, there will be fewer in-river peak salinities exceeding 800 EC at Morgan.

While the exceedance of long-term targets is reduced, salt is a natural part of the MDB landscape and elevated salinity levels will continue to occur from time to time. When such events occur, they do have social, economic and environmental impacts and hence pose a current salinity risk. Such events have occurred within each landscape in the past and examples are documented above for each of the Basin landscapes. The extent to which salt mobilisation events impact the river is dependent upon the flow regime in the river at the time.

Where salt loads emanate upstream of Lake Victoria and salinity impacts are deemed significant, diversion of flows into the lake (and subsequent release to a higher river flow) have provided the primary means of mitigating such events. Downstream of the lake, there are fewer options for management of salinity events other than, in some cases, the manipulation of regulators to control the release of saline water to the river.

4.4.1 Summary of the current salinity risk

The summary of the current salinity risk is as follows:

- Landform and climate determine the intrinsic nature of the salinity threat as it is these characteristics that determine the sources of salt, the extent to which salt sources are readily transported to the river, and the time lag for the emergence of this salt within the river.
- For the purpose of this review, the landscapes representing landform and climate have been categorised regionally as the Northern Basin, the Southern Uplands of Victoria and NSW, the Riverine Plains, and the Mallee of NSW, Victoria and South Australia. There is significant variability within each of these landscape categories; however they provide a reasonable framework upon which to describe the scale and type of salinity contributions to the shared water resources of the Murray–Darling Basin.
- All landscapes in the Basin contribute to salinity in the shared water resources either through river regulation and diversion of water, or by exacerbating inflow of salt loads. Sources of salt from these landscapes include natural salt inflows, impacts of salt mobilised due to past actions and salt mobilised by recent developments.
- The key Basin landscapes contributing more to the salinity hazard are the Mallee regions of South Australia, Victoria and New South Wales and parts of the Riverine Plains of New South Wales and Victoria.
- The flow regime that dilutes salt loads is primarily sourced from the regulated and unregulated tributaries emerging from the Southern Uplands.
- The suite of salinity controls implemented to date, including salt interception schemes, improved irrigation system and on-farm practices, have led to the achievement of the Basin Salinity Target since 2010 such that over the long-term, there is likely to be fewer in-river peak salinities exceeding 800 EC at Morgan.
- Current salinity risks are being managed when outcomes are considered in terms of achievement of the Basin Salinity Target, however residual risks remain; specifically event-based elevated salt loads that from time to time may be mobilised during relatively low river flows leading to increased salinity levels over short time periods that may require an operational response.

5. Future salinity risks and implications from the Basin Plan

5.1 Context

As previously outlined, in-river salinity outcomes are a function of both salt load and the flow regime. An increased risk will therefore arise if the aggregate increase in salt loads mobilised through past actions that are yet to reach the river (delayed salinity impacts) and future land and water management actions, are substantial and not adequately buffered by an increased flow regime.

This chapter explores this potential increase in the salinity risk profile, taking into account the progression towards a substantially higher flow regime arising from the delivery of environmental water associated with Basin Plan implementation. Uncertainties are also discussed both in terms of projected increases in salt loads, and the long-term flow regime which could be more variable under future climate. While the discussion of future risks assumes current levels of salt interception, the implications of reduced salt interception operations on future risks are noted. Modelling to support the General Review of Salinity Management included scenarios for reduced levels of salt interception scheme operations, and these are included in discussions of the feasible management options (Chapter 6).

5.2 Future risks

5.2.1 Projected salinity impacts and salt loads

As discussed when considering the current salinity risk profile, the salinity registers provide a list of the accountable actions that have been brought forward to the registers and so provide a comprehensive list of current threats. However, the salinity threats listed in the registers also include estimates of delayed salinity impacts (due to Legacy of History and delayed impacts of more recent actions), which refer to salt that was (or will be) mobilised by past actions, but will not reach the river for decades or perhaps even 100 years.

> *Salinity increases over time as a result of delayed salinity impacts are due to a relatively small number of actions identified within the registers.*

Table 1 provides a list of register entries with significant projected salinity increases over time. The largest increases are predicted to emanate from the Mallee region of South Australia and will arise from relatively recent irrigation development (since 1988 - Register A) and the Legacy of History impacts from past land and water management activities including dryland clearing and historic irrigation development (prior to 1988 – Register B). Smaller increases over time are forecast from the Legacy of History impacts from past land and water management activities in the eastern Mallee region within NSW and Victoria, and in the Goulburn and Loddon catchments in the Victorian Southern Uplands. Projected change in delayed salinity impacts from the Northern Basin and the Riverine Plains are comparatively low.

The projected salinity increases are currently offset by state actions, for example through improvements to irrigation efficiency and also by salt interception scheme operations, and up to 2050 the overall net salinity effect at Morgan in the registers is predicted to be in balance.

Table 1 Register entries with significant projected salinity increases over time (extracted from the 2013 Salinity Register - MDBA, 2014a)

Accountable Action	Salinity Effect [5] (average EC at Morgan) in 2000	Salinity Effect [5] (average EC at Morgan) in 2015	Salinity Effect [5] (average EC at Morgan) in 2050	Salinity Effect [5] (average EC at Morgan) in 2100
NSW Sunraysia Irrigation Development 1997 to 2006	0	0.9	4.5	6.1
SA Irrigation Development Based on Footprint Data	-3.6	5.8	33.9	72.8
SA Irrigation Development due to Water Trade	0.1	0.5	16.2	32.2
SA Irrigation Development Based on Site Use Approvals	-0.1	0.3	14.9	66.2
NSW Mallee – dryland	0	0.3	1.3	3.6
NSW Mallee – pre 88 irrigation	0	0.4	1.2	2.3
Goulburn Catchment Legacy of History	0	0.5	1.1	1.6
Loddon Catchment Legacy of History	0	1.0	1.5	2.3
Victorian Mallee – dryland	0	0.6	2.2	5.9
Victorian Mallee – pre 88 irrigation	0	1.4	4.7	8.3
SA Mallee Legacy of History – dryland	0	4.1	14.5	32.8
SA Mallee Legacy of History – pre 88 irrigation	0	46.6	86.9	113.3

Table 2 shows indicative salt load accessions to the River Murray in the Nyah to Wellington river reach. The Legacy of History impacts (dryland clearing and pre-1988 irrigation) in this river reach are estimated to increase from 185 tonnes/day at 2010 levels to 278 tonnes/day at 2015 levels, 573 tonnes/day at 2050 levels and 862 tonnes/day at 2100 levels (MDBA 2014b). In addition, estimates of salt load accessions from more recent (current) irrigation development also increase over time (Table 2). However, the increases are offset by improved irrigation practices, salt interception scheme operations and other state actions, such that the net outcome of total salt load going to the river does not exceed the 1988 baseline until beyond 2050.

[5] These accountable actions are offset by salt interception and improved land and water management, and up to 2050 the overall net salinity effect at Morgan in the registers is predicted to be in balance.

There are significant uncertainties in the salt load estimates that underpin this projected increase in salinity. Key areas contributing to the uncertainty noted by Middlemis (2014) (Appendix 3) are:

- the extent to which increased recharge rates arising from historic clearing within the Mallee are yet to influence salt load accessions to the river
- unidentified sources of measured increased salt loads along the river (referred to as unaccounted salt loads in the river model)
- the dynamic nature of river-groundwater interaction (depending on the river and groundwater levels) particularly in relation to the floodplain which, post flood recession, is a significant source of salt.

Table 2 Changes in salt loads (t/day) in the Nyah to Wellington reach from the 1988 Baseline based on the 2013 salinity register [6]

Scenario	Baseline salt loads	Dryland + pre-1988 irrigation (Legacy of History - Register B)	Current (post-1988) irrigation development (Register A)	Improved irrigation practices (Register A & B)	SISs and other State actions (Register A)	Total salt load going to the river
2000	3092	0	75	-122	-737	2307
2015	3092	278	158	-413	-799	2315
2050	3092	573	547	-646	-877	2689
2100	3092	863	1098	-721	-893	3438

The outcome from the projected salinity increases over time for all landscapes is that the combined salinity registers balance moves from an average salinity credit in 2015 of 165 EC to an average salinity debit in 2100 of 50 EC (MDBA 2014a). However, as noted, there are significant uncertainties in the salt load estimates and variations in flow that underpin this projected increase in salinity.

While existing levels of control adequately deal with the current salinity risk profile (indicated by achievement of the Basin Salinity Target in 2010), the predicted increased impacts to the river over time will require monitoring and management. Implications for future salinity management are that the forecast increases will require additional mitigation activities to maintain the Basin Salinity Target. Modelling completed to support this review (MDBA 2014b) estimates that under pre-Basin Plan flow regimes and assuming current levels of controls, that the Basin Salinity

[6] The salt loads presented in this table are for the Nyah to Wellington river reach. These numbers are indicative and exclude the register entries that have salt load implications for this reach which are based on changes to river operating rules (i.e. Revised Hume-Dartmouth pre-releases rules, Barmah-Millewa Forest operating rules, Tandou Pumps from Lower Darling, Changes to Edward-Wakool and Escapes, Permanent water trade) and entries that are based on time series of flow and salinity data (i.e. Boggabilla enlargement, Pindari Dam, NSW MIL LWMP's, Tragowel Plains Drains, Shepparton SMP, Kerang Lakes/Swan Hill SMP, Nangiloc-Colignan SMP, Campaspe West SMP, Woorinen Irrigation Excision, Sunraysia Drains Drying up, Lambert Swamp). Barr Creek operating rules, Woolpunda SIS, Waikerie SIS, Pyramid Creek SIS, Barr Creek CMP, Upper Darling and Mildura-Merbein SIS were included in the estimate even though they are not based on constant salt loads. Negative values indicate salt loads prevented from reaching the river while positive values show salt loads entering the river.

Target would be met until about 2035. Model estimates with 2800 GL of Basin Plan flows extend this timeframe beyond 2050 until about 2080. However, the modelling does not include a number of future salinity impacts that would either increase salt mobilisation to the river or reduce dilution benefit. These future risks are discussed in subsequent sections of this chapter.

5.2.2 Future accountable actions

The process prescribed within Schedule B for bringing forward accountable actions contributes to the management of future salinity risk, as actions that increase salinity (i.e. a debit) must be offset by an equivalent reduction in salinity (i.e. a credit). However the achievement of the Basin Salinity Target in recent years (Figure 3) is in part a consequence of jurisdictions undertaking mitigation actions (termed state actions) that either reduce debits or generate credits, but not yet exercising their rights under Schedule B to initiate development activities that would cause a corresponding debit.

A detailed description of the salinity registers is provided in Appendix 4 including a summary of the status for each state's position with respect to credits and debits on Register A and B. The aggregate outcome from the 2013 salinity register (average salinity at Morgan) for all three states is estimated to be a 165 EC credit (MDBA 2014a). These credits are assigned to NSW (~37 EC), Victoria (~27 EC) and South Australia (~45 EC) and remaining credits (~56 EC) generated though the Salinity and Drainage Strategy are committed to the River (Appendix 4).

Not all credits are available to offset future development and a proportion of the credits are required to offset projected increases from the delayed salinity impacts from past land and water management and existing accountable actions on the salinity registers (approximately 60 EC by 2050). However, given that the ' are entitled to utilise the remaining credits in the future to offset development activities that would have otherwise resulted in a debit, this would increase salinity levels and the in-river outcomes illustrated within Figure 3 and Figure 4 cannot be guaranteed into the future.

An example of the utilisation of available salinity credits is where Victoria has recently identified some existing debit claims not currently on the registers and a number of future debit claims, related to development activities currently underway, which would lead to the uptake of part of its available credits in the near future (MDBA 2014b). Uptake of these salinity credits by Victoria and any future debit claims by the other states that are not offset would result in higher river salinities. An assessment of the need for states to utilise these credits in light of the water extraction regimes under Basin Plan should be considered in future management strategies.

The Independent Audit Group for Salinity (MDBA 2012) noted that maintaining the salinity registers in credit balance as outlined in Appendix 4 and required under Schedule B will not ensure that the 800 EC target at Morgan will be achieved. They compared the outcome from the 2011 salinity register for the 95th percentile salinity at Morgan with a balanced 2011 salinity register and noted a difference of 47 EC and concluded that the Basin Salinity Target would not have been achieved in 2011 if states had chosen to utilise all available net salinity credits. The implications are that future predictions of salinity outcomes should include the potential uptake of salinity credits, as utilisation of available net salinity credits substantially increases the risk profile and reduces the headroom that is currently available to meet the Basin Salinity Target at Morgan.

5.2.3 Coal seam gas and other extractive industries

Development of coal seam gas and coal mining within the Northern Basin will co-produce large quantities of saline water as a by-product of capturing these energy sources. In the Queensland portion of the MDB, the salt content of co-produced water is estimated to be 35 million tonnes by 2040, which equates to an average of 1.3 million tonnes per year (Klohn, Crippen, Berger 2012). In response to the scale of mining expansion, both the Queensland and New South Wales governments have developed regulatory arrangements including prohibiting the use of evaporation basins as a means of managing co-produced water (EHP 2012; NSW Office of Water 2013).

Measures are required under Environmental Impact Assessment processes to mitigate the potential escape of co-produced water or associated brine, as well as to promote effective disposal, storage or management options. Implementation of these measures reduces the risk of large scale spills of co-produced water, however it has the potential to become a distributed source of salt in the Northern Basin and may contribute, over a long period of time, to the salinity of the Darling River system. Given the episodic nature of flood events dominated by overbank/overland flow, much of the salt is likely to be lost to the floodplain rather than being successfully transported down the Darling River.

In light of the regulatory arrangements and the constraints on the hydrological regime to physically transport salt to the River Murray, salinity impacts to the shared water resources from extractive industry development in the Northern Basin are likely to be immaterial. However future risks associated with the management of co-produced water could apply at the valley scale. These risks warrant consideration during the development of Water Resource Plans to ensure that any more localised salinity impacts for within valley assets are fully assessed and appropriate controls put in place.

5.2.4 Climate variability

The importance of the prevailing climatic conditions to salinity outcomes within the shared water resources is well recognised, and is the reason for long-term salinity outcomes to be considered within the context of a consistent hydrological regime currently considered under Schedule B as being the 25 year period (Benchmark Period) from 1 May 1975 to 30 April 2000.

However discussion around the extent to which the 1975 to 2000 climatic period adequately represents current or future climatic variability has been raised, and investigation of the adequacy of the Benchmark Period has been identified as a component of the future salinity management program. Studies of future rainfall projections have led to conclusions that changes may occur in the future prevalence of wet or dry periods. In addition, there is some evidence to suggest there will be different outcomes between the north and south of the Basin (CSIRO 2008). Hence future salinity threats and the need for controls must be considered within the context of a range of future climate scenarios and outcomes including the potential for longer dry or wet sequences than have been experienced to date.

Experience to date has demonstrated that extended wet periods will lead to greater salt mobilisation, but will be offset by greater dilution regimes. Extended dry periods will lead to reduced salt mobilisation from floodplains, but groundwater inflows will continue to deliver relatively high salt loads in some parts of the Basin, in situations where there is less flow available for dilution.

Hence, salt interception schemes are critical during such periods as was clearly demonstrated during the recent extended drought. Towards the end of this prolonged drought sequence, when system dilution was no longer available, salt interception schemes were critical in reducing river salinity as illustrated in Figure 4.

Ultimately, salinity outcomes will remain dynamic with the net outcome subject to the temporal patterns of salt load discharge and the prevailing flow conditions. It is the sequence and duration of salt mobilisation/flow regime events that determines whether a threat is realised. The greatest impacts will emerge if wet periods initiate salt mobilisation to the river, and these salt loads are maintained for an extended period during a low flow period of less than 5,000 ML/day flow to South Australia (AWE 2012).

5.2.5 Floodplain salt mobilisation due to environmental watering

Potential for floodplain salt mobilisation

Significant areas of floodplain wetlands with high ecological value are underlain by highly saline groundwater. Environmental watering of these sites has the potential to mobilise these salts to the river with some preliminary estimates on impacts provided for a range of river reaches/wetlands summarised within Table 3.

Improved knowledge is required to refine these estimates however based upon the current status of knowledge, the best estimate of salt mobilisation impacts from watering events (excluding TLM watering) extending from the confluence of the Loddon and Murray Rivers, to the lower Murray, is an approximate 33 EC increase in average salinity (over the Benchmark Period) with a potential range of 16 to 96 EC. This was based on the use of 1,600 GL of environmental water under drought conditions, with no consideration of active flow management to have regard for salinity targets in the Basin Plan. Modelling (MDBA 2014b) completed to support this review suggests that the dilution benefit from 2800 GL in 2015 is around 58 EC. The preliminary modelling of net salinity benefits of TLM program is estimated to be around 19 EC. However this benefit may be reduced when the salinity impacts from Victorian mid-Murray storages under the TLM program are fully understood.

These preliminary estimates suggest that as a direct result of environmental watering, the average salinity outcome over the long-term will improve as a result of the Basin Plan flow regime, noting that more detailed discussion of the dilution benefits of the Basin Plan flows are provided in the next section. However on a site by site basis, the short-term impacts of environmental flows may be important and hence require consideration. Under the Basin Plan, river operators and environmental water holders and managers must have regard to the salinity operational targets, and hence planning will be required prior to water delivery so as to effectively manage short term risks.

Table 3 Preliminary estimates of salt mobilisation impacts from environmental watering [7] [8]

Study	Areas targeted for environmental flows	Average salinity impacts at Morgan from salt mobilisation over the Benchmark Period
Use of 1600 GL of CEWH environmental water (RPS Aquaterra 2011)	Darling to Lock 1	21 EC (12-62 EC)
Use of 1600 GL of CEWH environmental water (RPS Aquaterra 2011)	Murrumbidgee to Darling	7 EC (4 – 20 EC)
Use of 1600 GL of CEWH environmental water (RPS Aquaterra 2011)	Loddon	5 EC (1 -14 EC)
Use of 1600 GL of CEWH environmental water (RPS Aquaterra 2011)	Above reaches combined	33 EC (16 – 96 EC)
Use of TLM entitlements (preliminary modelling MDBA 2011)	Chowilla	3. 5 EC
Use of TLM entitlements (preliminary modelling MDBA 2011)	Mulcra and Hattah	1.1 EC

Management of environmental watering risks

Flow regimes associated with the delivery of environmental water under the Basin Plan are managed to mitigate any associated operational salinity risks. Environmental water holders, including the states, TLM and the Commonwealth Environmental Water Office (CEWO), conduct a rigorous risk assessment when designing watering options. Potential risks are discussed with delivery partners (e.g. states, Commonwealth, river operators, catchment management authorities, local groups, landholders etc.) and scientific experts as required. Like other entitlement-based water, environmental water must be managed by river operators consistently within existing rules while seeking to address water quality, taking into account all relevant information.

Where a potential risk to the achievement of Basin Plan salinity operational targets is identified but information is lacking, environmental water holders work with delivery partners to commission modelling, monitoring or further research to better understand the nature of the risk and possible mitigation options. For example, in 2013 CEWO, in collaboration with the Mallee Catchment Management Authority, worked with the MDBA to model the potential salinity impacts of providing water to a number of Mallee wetlands so as to be able to plan the mitigation of any impacts.

Proposed environmental watering actions may be altered to avoid or mitigate identified sources of risk and ultimately to manage any impacts. This might involve modifying the timing, duration,

[7] Preliminary estimates of salt mobilisation impacts which do not consider any dilution benefits or active management of environmental water to have regard to Basin Plan targets. The estimates for the use of Commonwealth environmental water were based on drought conditions. Figures in brackets indicate the possible ranges of modelled estimates

[8] The high-end range of average salinity impacts at Morgan represent a worst case scenario which is extremely unlikely to eventuate simultaneously in all of the above reaches

peak magnitude or recession rate for the flow event, seeking particular management of regulating structures during and after watering, and/or providing dilution flows. Delivery partners also adaptively manage environmental water to respond to changing circumstances during watering events. An example of how controls are applied to mitigate salinity risks is provided by the case study of environmental watering in the Werai State Forest in Appendix 5.

5.3 Dilution implications from environmental water under the Basin Plan

River flow is an important consideration in the evaluation of future salinity risk given the progression towards the delivery of environmental water under the Basin Plan which will have large implications for the dilution regime. Substantial volumes of environmental water have already been recovered under the Basin Plan, although the full impact of water recovery under the Basin Plan will not be realised until 2019. As at 31 March 2014, total water recovery in the Murray–Darling Basin that contributes to 'bridging the gap' is 1,900 GL (long-term diversion limit equivalence).

The Basin Plan includes provisions for the Sustainable Diversion Limits (SDL) to be increased or decreased by up to 5% of total surface water SDL. The surface water SDLs can be adjusted due to supply measures or efficiency measures undertaken as per Chapter 7 of the Basin Plan. Hence it is likely that the final volume of actual water recovery will differ from the benchmark of 2750 GL in the Basin Plan. For example, supply measures may potentially reduce the SDL reduction amount by up to 650 GL. There is also potential to increase water recovery by 450 GL through implementation of efficiency measures.

Two flow scenarios were modelled to represent how river salinity may change with water recovery and use. Full details of the modelling are provided in the report '*Modelling to support the general review of salinity management*' (MDBA 2014b). The scenarios modelled were a 'without Basin Plan' scenario (referred to as BP BDL) which reflects water management arrangements that were in place in June 2010 and does not include any water recovered under the Basin Plan; and a 'with Basin Plan' scenario (referred to as BP 2800) that represents changes in flow regimes that can be achieved through the recovery and use of 2800 GL of water for the environment under the Basin Plan.

In addition to the two modelled flow scenarios, and as a precautionary measure given the uncertainty of the total volume of Basin Plan water to be recovered due to SDL adjustment, some modelling results were interpolated for a third scenario to represent recovery and use of 2400 GL of water for the environment under the Basin Plan (referred to as BP 2400). This level of water recovery and use was selected based on existing model runs for 2400 GL of water recovery from previous Basin Plan modelling exercises. Results for the BP 2400 GL flow scenario are discussed in the assessment of feasible management options in Chapter 6 to provide additional context for the salinity benefits provided by reduced levels of salt interception.

Modelling results are reported over four time horizons against long-term Schedule B targets and Basin Plan salinity operational targets. These time horizons are for conditions as at 2010, 2015, 2050 and 2100. These conditions are not projections of likely salinity in those years but indicators of river salinities that would have been experienced during the 1975–2000 Benchmark Period with salt load accessions to the river as per projections for these time horizons.

Modelling results for the Basin Salinity Target at Morgan

Compared to the 'without Basin Plan' scenario, water recovery and use under the Basin Plan (BP 2800 scenario) is estimated to have a long-term salinity benefit (64 and 58 EC reduction of the 2015 95th percentile and average salinity at Morgan respectively over the Benchmark Period) with all SIS in operation (MDBA 2014b). This level of benefit reduces to about 50 EC (average salinity at Morgan) with the BP 2400 GL scenario. These benefits and the net benefits of the TLM program will complement but not replace the estimated salinity outcomes achieved by SIS (361 and 195 EC reduction of 95th percentile and average salinity at Morgan in 2015) through joint investment and governance.

Comparison of the outcomes for the Basin Salinity Target under the BP BDL and BP 2800 flow scenarios are shown in Table 4. This shows that the additional Basin Plan environmental flows have the effect of extending the period over which the Basin Salinity Target can be met into the future, assuming projections of delayed salinity impacts and current levels of salt interception scheme operations. The Basin Salinity Target would be exceeded before 2050 (at about 2035) without any water recovered under the Basin Plan. With 2800 GL of water recovery, the Basin Salinity Target could be met beyond 2050 (until about 2080).

It should be noted that the modelling did not include potential future salinity increases not currently recorded on the registers. These include issues already discussed in earlier sections relating to advice from the states that there are development activities currently underway for which the salinity impacts will be offset against available credits and also the possibility that states may choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits, and any long-term impacts of salt mobilisation from floodplain environmental watering. These effects may moderate the estimated dilution benefit provided by Basin Plan water recovery and use.

Table 4 Summary of the 95%ile salinity at Morgan for modelled flow scenarios using the climatic period 1975 to 2000

Year salt impacts realised	BP BDL (95%ile EC at Morgan)	BP 2800 (95%ile EC at Morgan)
2010	746	690
2015	767	703
2030 [9]	791	727
2050	823	758
2100	901	827

Modelling results for the Basin Plan salinity operational targets

The modelling also highlights the effect of changed flow regimes associated with the delivery of environmental water under the Basin Plan on the achievement of the Basin Plan salinity operational targets, noting that there is no 'have regard to' consideration captured in the modelling, as per the Basin Plan requirements. In addition, this analysis is based on modelled data, whereas the Basin Plan operational targets apply and are assessed using observed data. Furthermore, the Basin Plan stipulates that these targets are for having regard to when managing

[9] Ninety five percentile salinity values at 2030 are derived from simple linear interpolation between the modelled outcomes for 2015 and 2050

water flows and making decisions about the use of environmental water. As such there is no mandatory requirement to meet these targets.

While section 9.14 of the Basin Plan does not specify the timeframe over which a target is to be achieved, it requires that an assessment of whether the target values are met or not must be reported annually over successive five-year reporting periods. There is a need to develop an agreed protocol for assessing these targets and guidelines consistent with Basin Plan obligations to clarify the application of these 'have regard' targets under section 9.14.

Modelling outcomes for assessment against targets have been expressed in terms of salinity levels using daily results over the period 1975–2009 (Table 5) to investigate longer-term outcomes. The modelling has also explored outcomes over a series of five-year rolling reporting periods between 1975 and 2009 (MDBA 2014b) to investigate potential trends over operational timeframes.

The modelling results indicate that the additional dilution provided by 2800 GL of Basin Plan flows reduces the salinity levels (95% of time non exceedance) and so increases the likelihood of meeting these targets in the short-term. However as the projected salt loads increase to 2050, levels of achievement of the Basin Plan operational targets decrease. Table 5 shows these trends based on modelling outcomes expressed in terms of the salinity levels (95% of time non exceedance) over the period from 1975–2009. The same trends are observed when analysing data over the series of five-yearly rolling reporting periods which shows an increased likelihood that target values would be reported as being exceeded as the projected salt loads increase from 2015. The analysis of five-yearly rolling reporting periods also highlights the potential for exceedances of these targets during periods of low flows even with the water recovery and use under the Basin Plan.

In addition, modelling of options for reduced levels of salt interception operations (results provided in Table 9 of Chapter 6 on feasible management options) show diminished achievement of the Basin Plan operational targets with reduced levels of salt interception.

The modelled data may also provide insight into the sequence of flows and salt loads that pose the highest risk for exceeding operational targets. Further interrogation of the modelling data would be useful to ascertain the relationship between additional salt loads, flow regime and changes to SIS operation and the timing, duration and magnitude of exceedances of these targets. This could help understand the situations that pose a high risk and hence inform future planning and management approaches.

Salinity management under the Basin Plan requires the states/MDBA and environmental water holders and managers to have regard to Basin Plan salinity operational targets. Whilst there was no requirement to have regard for any salinity operational targets prior to the Basin Plan, day-to-day river operations practically managed the river within the river operating rules to limit adverse salinity impacts. This involved, for example, capturing salinity spikes in storages or releasing flows to dilute anticipated salinity spikes.

The modelling undertaken for this review (MDBA 2014b) did not investigate any options for active use of river flows (including the dilution effects from environmental water) to manage salinity nor did it reflect the requirement to have regard to Basin Plan salinity operational targets. It may be possible to coordinate the use of environmental water and river operations generally to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities. The implications of the changed flow regimes for future salinity management are that improved modelling tools for forecasting salinity and a degree of flexibility may be required to adjust salinity management responses depending on salinity impacts. This may include the flexible operation of SIS which is discussed as a feasible management option in Chapter 6.

Table 5 Model estimates of salinity levels at the Basin Plan reporting sites for the BP BDL and BP 2800 GL flow scenarios

* Table entries with an asterisk indicate that the Basin Plan salinity flow management target has been exceeded.

Reporting site and target value	2010 salinity levels 95% of the time modelled on 1975–2009 data – BP BDL	2010 salinity levels 95% of the time modelled on 1975–2009 data – BP 2800	2015 salinity levels 95% of the time modelled on 1975–2009 data – BP BDL	2015 salinity levels 95% of the time modelled on 1975–2009 data – BP 2800	2050 salinity levels 95% of the time modelled on 1975–2009 data – BP BDL	2050 salinity levels 95% of the time modelled on 1975–2009 data – BP 2800	2100 salinity levels 95% of the time modelled on 1975–2009 data – BP BDL	2100 salinity levels 95% of the time modelled on 1975–2009 data – BP 2800
Murray Bridge (830 EC)	749	723	770	738	840 *	806	951 *	878 *
Morgan (800 EC)	712	671	735	686	787	741	866 *	808 *
Lock 6 (580 EC)	516	494	517	493	542	532	556	543
Burtundy [10] (830 EC)	826	-	824	-	824	-	824	-
Milang (1000 EC)	1162 *	846	1257 *	865	1358 *	954	1520 *	1045 *

5.4 Summary of future risk and implications for management

Predictions of future salinity impacts from known actions on the salinity registers point to an increasing future salinity risk even with the dilution benefits provided by increased flows under the Basin Plan. Much of the projected increase in salt loads arise from both relatively recent irrigation development (post-1988) and delayed salinity impacts from past land and water management in the Mallee region, while noting that considerable uncertainty exists about the extent to which increased recharge rates arising from historic clearing within the Mallee are yet to influence salt load accessions to the river. While projected increases from other landscapes are lower these will still require management in the future given the overall cumulative impact on river salinity.

The existing levels of control generally deal with the current salinity risk profile, while noting that the potential for shorter-term elevated salinity levels (e.g. salinity spikes) remains. Over time, the predicted increased salt load accessions to the river diminish the outcome provided by the existing levels of control, and this will require monitoring and management.

The restoration of dilution to the river system through water recovery and use under the Basin Plan will provide a long-term dilution benefit, however this will complement and not replace the level of control provided by salt interception. Changed flow regimes associated with the delivery of environmental water under the Basin Plan will have the effect of extending the time horizon

[10] The modelling has limited capacity to estimate salinity outcomes at Burtundy under Basin Plan flow regimes in the Northern Basin tributary valleys.

over which the Basin Salinity Target at Morgan can be met into the future for a given level of SIS operation and also improve the frequency of achieving the Basin Plan salinity operational targets. However the overall dilution benefits provided by changed flow regimes associated with the delivery of environmental water under the Basin Plan may be less than expected due to the potential for salt to be mobilised from floodplain environmental watering. In addition, the final volume of water recovered to meet the Basin Plan requirements may vary due to the Sustainable Diversion Limit adjustment mechanism, with a reduction in dilution benefits if less water is recovered.

Other future salinity risks that are not reflected in the modelling outcomes which may increase river salinity over time and have implications for future salinity management include:

- the possibility that states may choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits
- future climate variability beyond that represented by the Benchmark Period.

The major implication for future salinity management identified in the review is the potential for the progressive reduction in the available ‘headroom’ due to the combined effect of some or all of the future risks. As a result, any proposed changes to future salinity management arrangements should take a precautionary approach given the uncertainty associated with potential increased salt mobilisation to the river and the overall dilution benefits from water recovery and use under the Basin Plan.

In light of the need to continue to manage current risk and these future risks, and noting that the BSMS is reaching the end of its 15 year life, an updated Basin-scale salinity strategy is required to provide the policy framework to deliver Basin-scale salinity management to 2030. It is proposed that this future strategy would be termed Basin Salinity Management 2030 (BSM2030).

Given the contribution that formal accountability requirements have provided to the success of the BSMS, it is anticipated that there will be a continued role for Schedule B beyond 2015. As the operation of the Schedule requires review under Clause 35, it is proposed that development of BSM2030 coincide with this operational review so that any revisions to Schedule B can be undertaken if necessary. This will ensure that the Schedule is aligned with the accountability requirements of BSM2030.

5.4.1 Summary of the future salinity risk

The summary of the future salinity risk is that:

- All landscapes will continue to export salt and there is an ongoing need to manage current salinity levels as well as future increases
- The net benefits of salinity mitigation options implemented so far have reduced river salinity impacts, and the Basin Plan, when fully implemented, will help further reduce such salinity impacts. However, salinity impacts are forecast to gradually increase with time due to delayed arrival of salt from various landscapes into the river and the possibility that states may choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits. There is also potential for salt to be mobilised from floodplain environmental watering. However, there are significant uncertainties about the projected rate of salt load accessions and the associated river salinity increases

- The largest increases in salinity impacts are predicted to emanate from the lower reaches of the Mallee region and will arise from relatively recent irrigation development and the delayed salinity impacts from past land and water management activities including dryland clearing and historic irrigation development
- For the most part, projected changes in salinity impacts to the shared water resources from the Northern Basin, Riverine Plains and Southern Uplands are relatively small, however this risk profile still warrants management and periodic review
- Short-term elevated salt load discharge events will continue to be a residual risk for river salinity that require consideration for future flow management and river operations
- Risks to local assets arising from emerging threats should be considered during the development of Water Resource Plans to ensure that localised salinity impacts are understood and appropriate controls put in place. However, accountability for salinity impacts to the shared water resources is still required through Schedule B
- Water recovery and use under the Basin Plan is estimated to have a net long-term salinity benefit to the shared water resources through restoration of dilution. This benefit will complement but not replace the substantial salinity outcomes achieved through joint investment in salt interception schemes (SIS) and governance
- A key feature of existing salinity management activities is the ability of SIS to mitigate river salinity over the long-term as well as protect the river during prolonged drought sequences when system dilution is no longer available, a characteristic that will be essential to manage salinity when environmental water is not practically available
- Decisions on salinity management are largely made within the context of our current understanding of climate variability and projections on future salt loads. In considering future risks, it is important to recognise that further work is required to address knowledge gaps and better understand risk and to provide a contemporary approach to future investments for salinity management. This work should focus on:
    - ways in which dilution effects of all water in the system (including both consumptive and environmental water), and river operations generally, could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities
    - the potential for salt to be mobilised from floodplain environmental watering
    - scoping the future use of salinity credits that are currently available on the registers such as:
        - the extent to which states may require these credits to offset historic land and water management actions, and recent or future actions that are not currently on the register
        - options for alternative use of credits
    - the significant uncertainty as to projections of future salt loads from the Mallee
- Given the future salinity risks, an updated Basin-scale salinity strategy, termed Basin Salinity Management 2030 (BSM2030), is required to provide the policy framework to deliver Basin-scale salinity management to 2030.

6. Feasible management options

6.1 Context

The BSM2030 strategy (proposed in the preceding section) will provide the policy framework that sets out a salinity management approach that is commensurate with the contemporary understanding of the Basin-scale salinity risk. Elements of the policy framework will necessarily include physical mitigation measures, as well as other program components such as governance arrangements, systems and performance measures that are also necessary to achieve salinity objectives.

This chapter is intended to provide guidance on the key directions for BSM2030 which will also be informed by the upcoming review of the operation of Schedule B. This guidance is based on the premise that when considering the Basin Salinity Target as the primary indicator for evaluating the status of Basin-scale salinity risk:

- current salinity risks are generally being managed over the long-term but there are risks relating to event-based elevated salinity levels
- environmental water recovery provides improved salinity outcomes and dilution benefits will arise from the regular use of environmental flows.

BSM2030 should therefore continue to appropriately manage current risk while focusing on ways to manage emerging future risks at the Basin-scale. As identified within the preceding chapters, these risks arise from:

- a projected increase in river salinity through delayed salinity impacts
- the possibility that states may choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits
- event-based elevated salinity levels that may occur from time to time
- additional salt mobilisation due to floodplain environmental watering.

Either collectively or individually, these current and future risks have the potential to reduce the headroom that currently exists below the Basin Salinity Target and may result in exceedance of the Basin Salinity Target at some point in the future. There is also the potential that Basin Plan operational targets will be exceeded more frequently in the future.

6.2 Elements of the BSMS and salinity elements of the Basin Plan

To support an understanding of the scope of an updated Basin-wide program, the suite of elements provided by the BSMS and salinity related aspects of the Basin Plan are listed within Table 6. Basin-scale salinity management requires policy direction and action relating to these elements to be provided by each jurisdiction, as well as an inter-jurisdictional co-operative approach to ensure that administrative boundaries are not an impediment to effective salinity management. Hence the elements listed within Table 6 are identified as either individual jurisdictional responsibilities or joint (inter-jurisdictional) program responsibilities or both.

Within the following sections, the elements are discussed within the context of the respective responsibilities. Whilst it is recognised that jurisdictional management arrangements are a key to the future success in the effort to manage salinity within the Murray–Darling Basin, the discussion on state/territory responsibilities is relatively brief and consistent with the focus upon a future joint program.

Table 6 Joint and jurisdictional responsibilities under the BSMS and the Basin Plan

Instrument	Elements of the BSMS [11] & salinity elements of the Basin Plan	Joint responsibilities	Individual jurisdictional responsibilities
BSMS	Constructing salt interception works	Yes	No
BSMS	Setting salinity targets	Yes	Yes
BSMS	Ensuring Basin-wide accountability: monitoring, evaluating and reporting	Yes	Yes
BSMS	Developing capacity to implement the strategy	Yes	Yes
BSMS	Identifying values and assets at risk	No	Yes
BSMS	Managing trade-offs with the available within-valley options	No	Yes
BSMS	Implementing salinity and catchment management plans	No	Yes
BSMS	Redesigning farming systems	No	Yes
BSMS	Targeting reforestation and vegetation management	No	Yes
Basin Plan	Developing operational targets in Water Resource Plans	No	Yes
Basin Plan	Water Resource Plan measures to contribute to the achievement of objectives and having regard to targets	No	Yes
Basin Plan	Having regard to operational targets	Yes	Yes
Basin Plan	Monitoring, evaluation and reporting	Yes	Yes
Basin Plan	Salt export objective	Yes	No

[11] BSMS elements are presented here as identified in MDBMC (2001a)

6.3 Jurisdictional responsibility

As indicated within Table 6, jurisdictional programs include a suite of policy and physical measures that contribute to the management of the Basin-scale salinity threat. Examples of policy and physical programs covered by the elements for which jurisdictions have responsibilities include:

- redesigning farming systems through on-farm works programs that reduce land salinisation (which may also provide water savings, improved agricultural productivity and ecological outcomes)
- implementing salinity and catchment management plans including regulatory measures to prevent actions that would cause future mobilisation of salt. Examples include planning provisions to manage the impacts of new irrigation developments in high salinity impact zones in the Mallee region, and those that restrict widespread clearing of endemic vegetation
- developing capacity to implement the strategy through extension support for best management practices in the use of irrigation water to reduce the impacts on production of periodic increases in river salinity
- salt interception or flow management activities that are funded by a jurisdictional government separate to the joint works and measures program
- ensuring Basin-wide accountability by undertaking the key accountability responsibilities of the jurisdictional government, including the development of in-stream salinity targets, putting forward accountable actions (and reviews of actions) as an input to the salinity registers, and reporting as required under Schedule B.

Notwithstanding the fact that jurisdictions must comply with statutory accountability obligations (i.e. Schedule B and the Basin Plan), within a local context, state programs will evolve depending upon the regional priorities of jurisdictional governments. Regional priorities will necessarily consider the requirements of Water Resource Plans under the Basin Plan. As outlined by the Basin Plan, a Water Resource Plan must:

- include a water quality management plan
- identify key causes of water quality degradation
- identify risks and strategies for addressing the risks
- explain why measures addressing risks from elevated salinity or other types of water quality degradation have or have not been included in the water resource plan
- identify the water quality target values, using the water quality targets as specified in Chapter 9 Part 4 Division 2, however a different or more stringent target can be specified if deemed applicable and in accordance with the water quality objectives
- specify measures to be undertaken to contribute to the achievement of the water quality objectives, however there is no requirement to set out measures to meet the targets
- consider impacts on other Basin states.

Collectively, the existing catchment strategies along with development of the Water Resource Plans will provide a means of collating the necessary data so as to identify salinity risks to local assets and implementation of any cost-effective measures to address those risks. As Basin Plan-consistent Water Resource Plans are yet to be fully developed, and are to be progressively implemented through to 2019, BSM2030 will be likely to support refinements to the elements of a

Basin-wide strategy framework that integrates the salinity components of Water Resource Plans and regional strategies within a Basin-wide context.

6.4 Joint responsibility

As indicated within Table 8, essential elements of the joint program under the BSMS has included the construction of salt interception schemes, the development and maintenance of program implementation capacity covering areas of governance and coordination roles (including the operation and maintenance of the SIS), the setting of salinity targets, and accountability arrangements. Under the BSMS, the commitment to the elements covered by the joint program, are given effect through Schedule B of the Murray Darling Basin Agreement.

When considering the responsibilities required of the MDBA under the Basin Plan, relevant areas (within a salinity context) include having regard to operational targets in operating the River Murray System, and monitoring, evaluation and reporting specifically in relation to operational targets and on the salt export objective. These 'Basin Plan elements' align with 'BSMS elements' as follows:

- having regard to operational targets when performing functions – not explicitly covered by the existing nine BSMS elements but consistent with the definition of Joint Works and Measures (MDBC 2005) which within a salinity context under Schedule B refers primarily to salt interception, but also includes changes to flow operations (e.g. changed operations to Menindee and Lower Darling, and changed MDBC River operations are included as Joint Works and Measures in the Salinity Registers)
- monitoring, evaluation and reporting – consistent with the BSMS element on Basin-wide accountability.

In light of the existing BSMS elements for which there are joint responsibilities, and the complementary salinity related requirements under the Basin Plan, it is anticipated that in the development of BSM2030, the following four elements will effectively underpin the joint program:

- joint works and measures (incorporating both salt interception and flow management);
- salinity targets
- accountability
- capacity to implement.

The following subsections describe the potential options to progress each of these elements given the discussions on current and future risks. Key matters for consideration are summarised so as to provide directions for BSM2030.

6.5 Joint works and measures

Physical works and measures within this report relate to joint works and measures rather than state actions. Joint works and measures are actions that require decision making and cost sharing between partner governments, with the responsibility shared on the basis that substantial current and future salinity impacts are an outcome of the historic development of the Basin's land and water resources. They are generally physical works and measures that reduce in-stream salinity by either reducing salt loads, or managing flows for improved salinity outcomes through dilution. To date, joint works and measures have primarily involved SIS, but as demonstrated by the Salinity Registers, also include changes to river operational rules (MDBA 2014a).

The following sub-sections therefore focus upon joint works and measures that have the potential to efficiently manage current and future salinity risks to shared water resources described in previous chapters in terms of salt interception and flow management.

6.5.1 Salt interception

Overview

The feasibility of salt interception has been demonstrated over many years through the program's significant contribution to achieving the Basin Salinity Target as assessed by the modelled long-term average salinity outcome of less than 800 EC for 95% of the time at Morgan over both wet and dry periods (Figure 3). Approval for the construction of schemes has been subject to benefit cost analysis to ensure an adequate return on significant investment. These benefit cost analyses are underpinned by cost functions described within section 6.7 on accountability, although the recreational, amenity and ecosystem service benefits of SIS were not included in the economic analysis.

The outcome of achieving the Basin Salinity Target is a reduction in the frequency of high river salinity events over an extended period that includes both wet and dry years. Modelling estimates that the aggregate salinity benefit arising from all SIS approved as joint works under the Salinity and Drainage Strategy and the BSMS is a ~150 EC reduction in the average daily salinity at Morgan (MDBA 2014a) prior to the introduction of a changed flow regime under the Basin Plan. If benefits of schemes constructed prior to the Salinity and Drainage Strategy are included, the full benefit of SIS is a 195 EC reduction in the average daily salinity at Morgan (MDBA 2014a). Schemes funded as state actions are estimated to contribute an average daily salinity reduction of 12 EC at Morgan.

As salt interception reduces base salt loads in the river, salt interception also contributes to the likelihood that operational targets will be met during episodic salt mobilisation events illustrated by Figures 10 through 13 in the discussion on current risks (Chapter 4). The benefits of salt interception are greatest during low flow periods because at these times the diversion of highly saline surface and groundwater away from the river by salt interception schemes provides a greater reduction to in-river salt concentration (Figure 4). During high flow periods, the impact of the saline surface and groundwater diverted by SIS is very small due to the large volumes of low salinity water in the river system; hence the net salinity benefit from the operation of SIS during high flow periods is less.

Given the salinity risks discussed within preceding chapters and the benefits provided by the joint works program to date, salt interception clearly has an ongoing role in salinity mitigation. Key issues for future salinity management include the feasibility of expanding the SIS program, and the feasibility of more adaptive operational arrangements.

Feasibility of an expanded joint SIS program

In addition to the current achievement of the Basin Salinity Target discussed above, the discussion of future salinity risks in Chapter 5 highlights that further improvements in River Murray salinity are anticipated from changed flow regimes under the Basin Plan. This achievement and prospect suggest that there is no need at this time for additional joint salt interception works to support further reductions in the frequency of high salinity events. Modelling (MDBA 2014b) suggests that in the event of a water recovery of 2,400GL under the Basin Plan, further joint investment in SIS is unlikely to be required until after 2030, with the actual timing of the requirement for a decision being subject to the magnitude and timing of increased salt loads to the river; a timeline which is currently highly uncertain.

Expansion in SIS could involve either increasing the extraction rate of existing schemes (through the installation of larger pumps in bores that are capable of higher yields) or the identification and installation of new schemes. Within the available salt interception infrastructure, there is some unutilised capacity in existing pipelines to salt management basins, however an expanded program in other areas would require new pipelines to be installed.

The potential for an expanded program was considered by SKM (2005a; 2005b) identifying a number of sites for which benefit cost ratios were likely to be greater than 1. Subsequent to these reports, some new schemes (and extensions to existing schemes) have been constructed. Others such as Pike, upgrade to Mildura Merbein and the extension to Woolpunda have been put on hold. Whilst this indicates that there is still potential for an economically viable expanded SIS program, over the longer term, it is anticipated that new schemes will become increasingly expensive (GHD and Ernst & Young 2006). This conclusion is based on the premise that investigations to-date will have identified the most cost effective schemes (highest salt load outputs and least cost schemes would have been identified during the earlier part of the program) and hence a higher average cost per unit of salinity offset (i.e. the marginal cost) can be anticipated into the future (Conner 2008).

Whilst it is unlikely that an expansion of SIS will be required under the joint works and measures program during the proposed 15 year lifetime of the BSM2030, the broader Basin-scale salinity objectives and targets summarised within Appendix 2 (i.e. aside from achieving the Basin Salinity Target) may provide the impetus for further investigations as to the merits of expanding SIS. These may include SIS as a:

- contribution to the achievement of Basin Plan operational targets
- state action to offset salinity impacts of actions that impose a debit on the salinity register
- contribution to groundwater management schemes that seek benefits to both the river and floodplain condition through elements of both SIS (highland or floodplain) and floodplain aquifer freshening.

Key matters for consideration

> *The Basin Salinity Target is likely to continue to be achieved over the next 15 years without the need for an expanded salt interception program, and hence the feasibility (and cost effectiveness) of providing additional capacity requires consideration of its potential to contribute to other outcomes such as the achievement of operational targets, the requirement of states for additional salinity credits (which Appendix 4 indicates is not currently required), and as a contribution to improved floodplain condition. These are unlikely to be priority issues for BSM2030, but may be matters to be considered under jurisdictional programs.*

Feasibility of a more adaptive approach to SIS operations

The existing salinity management framework provided by the BSMS and Schedule B reflects the principles of adaptive management and continuous improvement through the process of monitoring, review and reporting and audit. To date, these principles apply broadly to the Basin-wide salinity program, including to the operation of salt interception schemes in seeking to minimise running costs and shutting down operations in response to flooding events (MDBA 2013). This option investigates whether there is potential for further advances in adaptive management in SIS operations within the context of the risk profile discussed within the preceding chapter.

In recognising the likelihood of increasing frequency of high salinity events over time, this option explores whether the current approach of operating all SIS continuously, could be refined such that collectively, schemes or parts of schemes, are geared towards operational capacity commensurate with the forward outlook on risk over a time interval of perhaps two to five years. An optimum outcome would be for schemes to operate, subject to operational limitations, at full capacity during periods when the salinity risk is high, whereas during periods of reduced risk, efficiencies would be gained by operating at lower levels of interception.

Approach

In order to explore salinity benefits from different levels of salt interception operations, river modelling (MDBA 2014b) was undertaken to provide an indication as to how salinity outcomes vary in response to a range of SIS operating scenarios. These scenarios were as follows:

- S1 – BP BDL (Baseline conditions scenario for the Basin Plan) scenario with all schemes turned off except State schemes (these schemes are operational in all scenarios)
- S2 (50%) – S1 scenario plus a combination of SISs to achieve approximately 50% of the current estimated contribution (353 EC) to 95%ile EC benefit at Morgan
- S3 (84%) – S2 scenario plus a combination of SISs to achieve approximately 84% of the current estimated contribution (353 EC) to 95%ile EC benefit at Morgan
- S4 (100%) – S3 scenario plus all SISs to achieve 100% of estimated contribution (353 EC) to 95%ile EC benefit at Morgan.

Results for each scenario are reported over four time horizons against long-term Schedule B targets and Basin Plan operational targets. These time horizons are for conditions as at 2010, 2015, 2050 and 2100. These conditions are not projections of likely salinity in those years, but indicators of river salinities that would have been experienced during the 1975–2000 Benchmark Period with salt load accessions to the river as per projections for these time horizons. A fifth time horizon of 2030 has been included by interpolating model results (see Figure 14) to represent the timeframe for BSM2030.

Salinity outcomes under the various flow / SIS operational scenarios are discussed below in terms of:

- BSMS Basin Salinity Target of <800 EC 95% of the time at Morgan over the 1975–2000 Benchmark Period
- Basin Plan operational targets over the 1975–2009 period.

Implications of scenarios for the achievement of the Basin Salinity Target

Under a 2,800 GL water recovery scenario, modelling results suggest that an estimate of the proportion of 95th percentile salinity benefits provided by SIS required to meet the Basin Salinity Target at Morgan will be 64% in 2015, 77% in 2030, 89% in 2050, and >100% by 2100 (MDBA 2014b).

This required increase in salinity benefit provided through SIS operations by 2100 reflects the projected increase in salt loads to the river. In the short term, the increase is expected to be buffered through the use of environmental water, but over the longer term it is projected to exceed the protection provided by the SIS program implemented to date.

Recognising that the full water recovery may not be needed to achieve equivalent outcomes under the Basin Plan after allowing for the operation of the SDL adjustment (Basin Plan Chapter 7), modelling outputs have been interpolated to understand the salinity implications for 2030 with 2,400 GL (Table 8). The year 2030 has been targeted for this assessment as it is the proposed end date for the updated salinity management program BSM2030.

A summary of the results of this interpolation as they relate to achieving the Basin Salinity Target at Morgan under the various SIS scenarios is provided in Table 8. With 2,400 GL of water recovery and use, the modelling estimates that the Basin Salinity Target at Morgan is likely to be maintained in 2030 when SIS operates at either 100% or 86% of the current provision of 95th percentile salinity benefit, but not at lesser salinity benefit levels (77% and 50%).

It is important to note that modelling predictions are based on the following assumptions that have implications for the reliability of the predicted salinity outcomes:

- states will not choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits
- Environmental watering actions will not mobilise additional salt into the river
- The timing and magnitude of projected salt loads are comparable to current estimates.

Hence the modelling results should be taken as indicative as it is likely that there will be accountable actions by some states that are offset by existing credits rather than new mitigation works, and salt load exports from environmental watering actions. There is also uncertainty regarding the timing and magnitude of projected salt loads.

In conclusion, the scenario modelling suggests that subject to clarification of the implications from the underlying assumptions, over the 2015–2030 period proposed to be covered by BSM2030, the Basin Salinity Target can be achieved at a lower level of salt interception scheme operational capacity, and hence there is potential to further explore an adaptive approach to SIS operations to deliver upon salinity objectives more efficiently.

Table 7 Summary of the 95%ile salinity at Morgan with BP 2800 and different levels of SIS operations

Year of salinity projection	SIS operational scenario	800 EC 95% of time over a climatic period comparable to 1975–2000
2010	S4 – 100%	690
2010	S3 – 84%	730
2010	S2 – 50%	800
2010	S1 – 0%	952
2015	S4 – 100%	703
2015	S3 – 84%	750
2015	S2 – 50%	827
2015	S1 – 0%	989
2050	S4 – 100%	758
2050	S3 – 84%	814
2050	S2 – 50%	910
2050	S1 – 0%	1074
2100	S4 – 100%	827
2100	S3 – 84%	888
2100	S2 – 50%	984
2100	S1 – 0%	1159

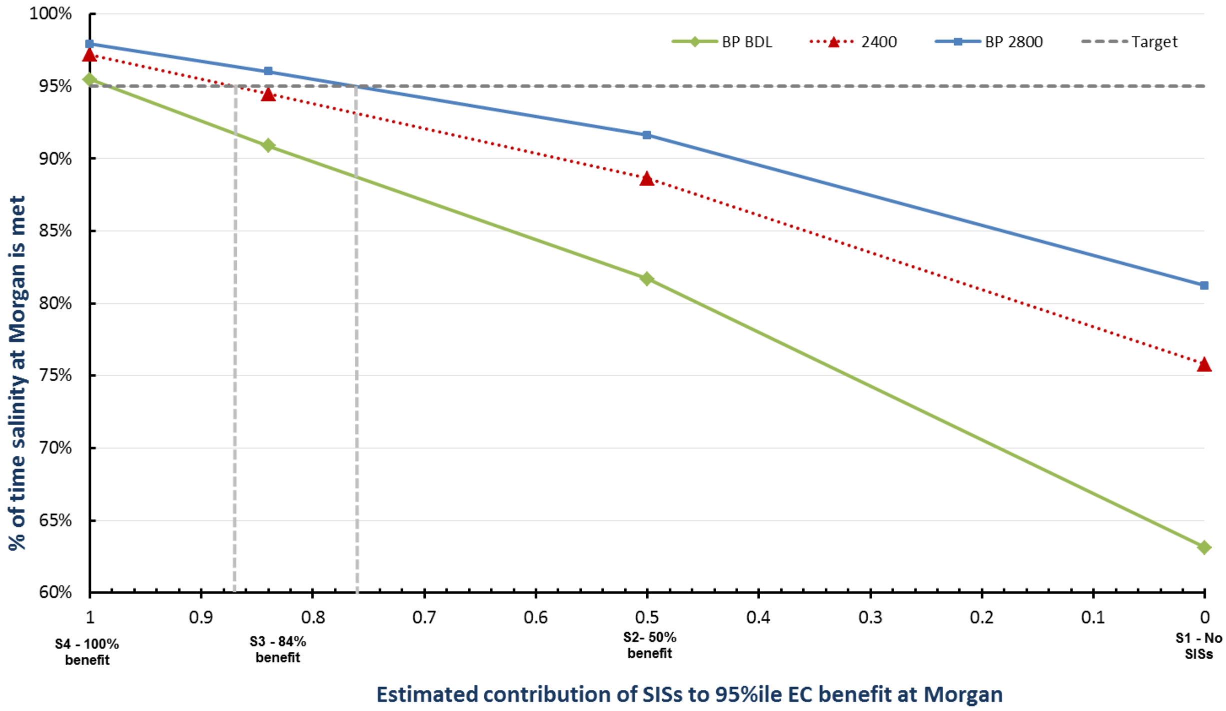

Figure 14 Impact of Salt Interception Schemes on 95%ile salinity at Morgan for BP BDL, BP 2400 and BP 2800 scenarios and 2030 salt accession level, 1975–2000 climatic period

Table 8 Progress against the Basin Salinity Target in 2030 based on varying operations of SIS for 2400 GL

Level of salt interception relative to 100% of the current 95 percentile salinity benefits	Percentage of time salinity at Morgan <800 EC over the Benchmark Period	Basin Salinity Target Maintained
100%	98%	Yes
86%	95%	Yes
77%	93%	No
50%	89%	No

Implications of scenarios for the achievement of Basin Plan operational targets

As discussed earlier, the Basin Plan includes salinity targets for the management of water flows (s9.14) which are referred to in this report as operational targets. Modelling undertaken by MDBA (2014b) indicates that:

- The likelihood of more frequent exceedance of operational targets under reduced SIS operations due to higher base level salinity and hence less buffering of the peak salinity during episodic salt mobilisation events (i.e. less headroom)
- River operators will be faced with further challenges in having regard to these targets if projected increases in salt loads to the river are realised.

Modelling results analysed over the period 1975–2009 are shown in Table 9. When results were further analysed over a series of five year rolling reporting periods, for most sites, the percentage of periods where a target value was likely to be reported as exceeded increased for all reduced SIS options (S3 to S1) in all time periods (MDBA 2014b).

Table 9 Salinity outcome (95% of the time) compared with BP operational targets [12] for the BP 2800 GL flow scenario over the period 1975–2009

*Table entries with an asterisk indicate that the Basin Plan salinity flow management target has been exceeded.

Year	Scenario	2010	2015	2050	2100
Murray Bridge (target 830 EC)	S4	723	738	806	878 *
Murray Bridge (target 830 EC)	S3	754	772	855 *	938 *
Murray Bridge (target 830 EC)	S2	834 *	853 *	950 *	1032 *
Murray Bridge (target 830 EC)	S1	979 *	1011 *	1116 *	1233 *
Morgan (target 800 EC)	S4	671	686	741	808 *
Morgan (target 800 EC)	S3	709	727	790	851 *
Morgan (target 800 EC)	S2	787	805 *	875 *	952 *
Morgan (target 800 EC)	S1	931 *	973 *	1075 *	1182 *
Lock 6 (target 580 EC)	S4	494	493	532	543
Lock 6 (target 580 EC)	S3	505	504	540	552
Lock 6 (target 580 EC)	S2	564	563	605 *	616 *
Lock 6 (target 580 EC)	S1	592 *	591 *	634 *	647 *
Milang (target 1000 EC)	S4	846	865	954	1045 *
Milang (target 1000 EC)	S3	883	903	996	1099 *
Milang (target 1000 EC)	S2	981	1009 *	1123 *	1229 *
Milang (target 1000 EC)	S1	1161 *	1202 *	1319 *	1446 *

Whilst it is envisaged that under a more adaptive management model, reductions in SIS operations would apply during periods of diminished Basin-scale salinity risk, salt mobilisation from local sources (e.g. environmental watering of saline floodplains) and tributaries, are likely to occur from time to time, requiring a response that has regard to operational targets. Opportunities

[12] Modelling results for the Burtundy reporting site (target 830 EC) are not included here as the model has limited capacity to estimate salinity outcomes under Basin Plan flow regimes in the Northern Basin tributary valleys.

for adaptive management of SIS will therefore be required to be integrated with improvements in river flow management. Opportunities for river operation contributions to the management of salinity are discussed later in this chapter in sections on “Flow management” and “Capacity to implement”.

Implications for the salinity registers

Salt interception schemes not only assist in maintaining the Basin Salinity Target, they also contribute significantly to each state maintaining their salinity registers in credit (Appendix 4). Hence, whilst the Basin Salinity Target may be achieved with less than 100% of the salinity benefit currently provided by SIS, it will also be important to understand whether each State remains in credit under an adaptive approach to the management of SIS.

A review of the status of the salinity registers (Appendix 4) indicates that South Australia currently has a net credit of ~45 EC, while New South Wales and Victoria have fewer credits at ~37 and ~27 EC respectively. A decision to operate the SIS differently (either a reduction in operations or an increase in operations), therefore requires a full understanding of the implications for each of the southern Basin states’ net credits on the register (and hence their current and future rights to drainage works or actions that increase salinity). It must also be recognised that the sharing arrangements for SIS benefits on the registers vary, depending upon whether the SIS was constructed under the S&DS or the BSMS as explained within Appendix 4.

Furthermore, whilst salinity debits and credits are commonly referred to in terms of EC impacts, Schedule B defines debits and credits in terms of average salinity costs, which varies between schemes depending upon the location of the interception works (MDBC 2005).

Given the complexity of sharing arrangements of credits and debits, future arrangements will need to be developed and agreed to resolve the sharing of debits and credits between New South Wales, Victoria and South Australia should schemes be operated on an adaptive basis.

Changes to SIS operations may also require changes to the computational approaches that track accountability. Extensive modelling underpins many of the register entries, which in the case of SIS includes an assumed extraction rate. It will be impractical to adjust the registers in a single year in response to a changed operational status. The accountability arrangements would therefore require adjustment to ensure continued practical operation of the registers.

For example, consideration may be given to:

- reconciling the registers less frequently than the annual reconciliation currently required by Schedule B
- infrequent but significant changes in the operational capacity of some schemes may require debits and credits to be reconciled as averages over the medium term, e.g. credits attributable to the states from SIS may be based upon the average salinity benefit provided by SIS over the preceding five to ten years.

A return to more saline conditions can be expected to occur in the future although the timing of such a reoccurrence is highly uncertain. In light of the identified future salinity risks, an adaptive approach which provides operational flexibility, the capability of ‘gearing up’ and ‘gearing down’ in response to the changes to the risk profile, is desirable.

However the extent to which such flexibility can be achieved requires further investigation. Such investigations will necessarily pursue an understanding of the physical capabilities of schemes (or bores within a scheme), including the varying levels of performance, and the time lag from start-up to full interception capability.

A possible approach would be to categorise schemes (or components of schemes) as:

- *Core* – schemes that are cost-effective but have a significantly long lead time to achieve effective interception (typically months and years) or have local/regional/social and/or economic benefits
- *Standby* – schemes that are cost-effective and provide a relatively rapid in-river water quality response (within 2 to 4 weeks of start-up), so can be operated at relatively short notice in response to a predicted increase in salinity
- *Mothballed* – schemes that could be classified as either core or standby schemes, but are not required within the context of the current risk profile. With respect to mothballing, a decision support framework would be required with clear understanding as to the timeframes necessary, and costs involved to recommission and achieve full benefits to the river. Depending upon the scheme, a time period of between two to five years may be required to recommission (i.e. reinstall pumps; rebuild switchboards; reconnect power
- some reconditioning (of headworks and bores) and achieve full operational effectiveness
- *Decommissioned* – schemes which are not considered to provide cost effective salinity mitigation.

Categorising each SIS (or components of SISs) will require considerable resources and therefore would only be undertaken if a decision was made to pursue a more adaptive operational approach to SIS. Such a decision would also require the development of criteria and a decision support framework to provide a clear basis to guide the operation of schemes e.g. triggers for equipping mothballed schemes, and turning on/turning off, standby schemes.

Key matters for consideration:

Further investigation into the potential for a more adaptive approach to the operation of SIS is proposed as a priority issue for BSM2030 including understanding:

- the extent to which particular SISs (or parts of SISs) may be operated adaptively to maintain Basin Salinity Target at Morgan and commensurate with the level of salinity risk within the shared water resources of the MDB
- the benefit cost implications of operating schemes differently, including the variability in the average cost per unit of salinity offset between schemes
- the extent to which SIS operations are expected to assist in contributing to the achievement of operational targets
- the implications of changed SIS operations for the register balance of each jurisdiction (EC impacts and salinity cost effects), and ensuring that any unintended consequences for the operation of registers are resolved and able to be practically implemented
- The risk profile within the face of uncertainties such as:
    - developments currently underway or new state actions that result in an adverse salinity impact with reliance on offset from existing credits (rather than new mitigation actions)
    - uncertainties in the time and magnitude of projected increases in salinity
    - uncertainties in the net impact of water recovery and environmental use of water.

Subject to the outcomes of these investigations, it is proposed that the development of BSM2030 consider the potential to adopt an adaptive approach to SIS operations, including development of criteria and a decision framework for resuming SIS operational capacity in response to emerging salinity threat.

6.5.2 Flow management

Overview

Flow management under the historic flow regime has been regulated under well-established river management rules that have contributed to the salinity outcomes noted earlier in this report (including the meeting of the Basin Salinity Target). Under these arrangements, the priority has been to operate the River Murray system efficiently and effectively in order to deliver state water entitlements. Matters considered in operating the river include conserving water and minimising undesirable losses, and maximising the water available to the southern Basin states, after providing for operating commitments in the River Murray System. With the additional flows to be provided through the Basin Plan, this option explores the potential to further improve in-stream salinity outcomes achieved by operators whilst also achieving the broader objectives required of river regulation and environmental watering.

Modelling of river flow and salinity (MDBA 2014b) has shown that in-river salinity will be reduced through the dilution benefits of an estimated 2,800 GL used for environmental purposes. However it should be noted that the actual outcome will vary depending upon the timing and destination of water delivery and any additional salt mobilised from floodplain environmental watering.

Higher net flows from the use of environmental water will also increase the likelihood of meeting Basin Plan operational targets, as average base level salinities will be lower with Basin Plan flows, reducing the net salinity outcome when climatic events or management decisions mobilise salt to the river. Whilst modelling completed to date suggests that the net impact of environmental water recovery and use for river salinity will be positive, the size of the net benefit is not clear and the potential to proactively manage flows so as to improve river salinity outcomes whilst achieving the primary purpose of the flow regime has not yet been fully considered.

Notwithstanding expected improvements in salinity outcomes arising from the Basin Plan, episodic events that increase salt loads to the river can cause elevated in-river salinity levels over time with periods ranging from days to years, even though the frequency of such events may remain within agreed targets. Evidence of historic peak salinity events is provided within the description of current salinity risks discussed earlier in this report (see Figures 10, 11, 12 and 13).

Historically, river operators have considered such peak salinity events within the broader context of river management objectives. This means that they balance salinity outcomes along with the range of other river management objectives and outcomes. Under the Basin Plan, the Authority, Basin Officials Committee, and agencies of Basin states must ‘have regard to’ the salinity operational targets when performing functions relating to the management of water flow. Holders of environmental water (including the Commonwealth) must also have regard to the targets when making decisions about the use of environmental water.

However the management of water flows may in some circumstances lead to trade-offs between competing Basin Plan objectives. For example, a decision to provide water for dilution of a salinity peak may be at the expense of other objectives. The challenge for river management is therefore to balance competing Basin Plan objectives within the constraints provided by operating rules and the broader river operations objectives and outcomes.

Given adverse salinity impacts to the shared water resources are most likely to arise within the middle and lower reaches of the river, opportunities to buffer elevated salt loads are relatively limited. To support salinity management into the future, flow management arrangements will necessarily build upon past experiences. Depending upon the reach of river, elevated river salinity outcomes can be reduced in some circumstances through weir manipulation, diversion to Lake Victoria or Menindee Lakes, or the provision of additional flows from Menindee Lakes that provide dilution benefits. Such actions seek to reduce the salinity by modifying the timing, duration, peak magnitude, or recession rate.

Importantly, a key to improved decision making will be to advance the knowledge base (discussed within the Section of this report on the “Capacity to Implement” and the development of guidelines to provide guidance and transparency to the decision making process.

Key matters for consideration

> *The application of flow management to support in-river salinity outcomes requires further exploration through the development of BSM2030. Areas requiring further work include:*

- Capturing and analysing the experiences gained to date in managing peak salinity events
- Investigating ways in which dilution effects of all water in the system (including both consumptive and environmental water), and river operations generally, could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities
- Developing potential approaches to flow management that seek to pursue salinity management outcomes which could be incorporated into relevant planning documents and processes, if appropriate, such as the Basin-wide environmental watering strategy, annual environmental water prioritisation, environmental water delivery, objectives and outcomes for river operations and annual operating plans
- The progressive review of current river operation rules within the context of a changed flow regime, as it emerges through water recovery and the use of environmental flows.

6.6 Salinity targets

Salinity targets provided within the BSMS were intended as indicators of catchment salinity ‘health’ and condition (MDBMC 2001a). As progress against the BSMS targets are required to be assessed on the basis of the frequency of exceedance over a threshold salinity for the modelled 1975–2000 Benchmark Period, they are described within the Basin Plan as targets for long-term salinity planning and management. They are intended to achieve this by managing the frequency of peak salinity events.

These BSMS targets complement the Basin Plan operational targets. Collectively, they provide long-term benefits in supporting planning and management strategies that will reduce the frequency of salinity threshold exceedance, and day-to-day benefits in having regard to river salinity outcomes in flow management decisions.

Operational targets have already been set under the Basin Plan and are not due for review until 2017. BSMS end-of-valley targets have also been set with some suggested amendments recommended under a review of these targets (SKM 2013).

An issue for BSM2030 is to clarify the future role of state end-of-valley targets within the accountability framework. Inclusion of end-of-valley targets within the BSMS was largely a response to a projected increased threat from dryland salinity highlighted by the 1999 Salinity Audit (MDBMC 1999). However, improved knowledge since that time indicates that future salt loads emerging from these dryland catchments will not (for most valleys) be substantially worse than that following the wet sequence of the mid to late 1990s. Jurisdictions responded to this contemporary understanding of risk, by prioritising their efforts towards accountabilities associated with the most highly effective salinity reduction programs (i.e. salt interception schemes, programs to reduce irrigation drainage, and comprehensive planning arrangements to ensure that new irrigation developments occurred only within low salinity impact zones). The relatively intensive modelling required to assess progress against most end-of-valley targets has therefore not been undertaken over the life of the BSMS raising questions as to whether some of the state end-of-valley targets provide a practical and effective contribution to the accountability framework, or are best used to maintain a watching brief on the relative downstream salt contribution from tributary valleys.

Key matters for consideration

> *In developing the BSM2030 strategy, the future role and application of state end-of-valley targets within the accountability framework should be clarified taking into consideration the findings and recommendations provided by SKM (2014). Any decision to change these accountability arrangements would require amendments to Schedule B and would also require consideration as to any implications for the Basin Plan which explicitly refers to these targets.*

6.7 Accountability

Principles underpinning accountability include: transparency, monitoring, evaluation and reporting on salinity outcomes and the benefits that they provide.

Under the BSMS, Schedule B has provided the foundation for these attributes of accountability through the salinity registers, the annual reporting and audit requirements, and rolling reviews of register entries, models and tributary valley contributions.

6.7.1 Management and administration of the accountability framework

As outlined within the Background section of this report, the registers capture actions that affect river salinity by providing a record of the debit and credit balance of accountable actions that significantly affect salinity at Morgan (i.e. that would result in a change of average daily salinity by at least 0.1 EC within 100 years). This environmental accounting system provides a transparent basis for making decisions on Basin-wide trade-offs on salinity management actions and investments in joint works and measures. It provides an effective framework to support Basin-wide salinity management while providing states with flexibility in the salinity management actions they will employ.

Accountable actions recorded on the Registers are required to be reviewed within every 5 years with models underpinning the register entries required to be reviewed within every seven years; a process that is consistent with the principle of continuous improvement. The BSMS operational protocols support the concept of the level of effort being commensurate with the level of risk. Schedule B is definitive on the required frequency of the reviews and the necessity for a peer review process to apply to model updates.

Whilst this process has delivered rigour to the salinity management framework, it incurs implementation costs and there are opportunities to improve cost effectiveness.

Given that the knowledge base and level of confidence underpinning the registers and model updates does not change rapidly, and that there have been significant improvements to the understanding of salinity risk since the 1999 Salinity Audit (MDBMC 1999), there is potential to review the frequency of technical reviews currently required under Schedule B.

For instance, providing flexibility through a risk-based approach to the review requirements with reviews being triggered by:

- the emergence of new data and hence the potential for a review to provide a significantly changed understanding of the risk
- the relative contribution that the accountable action has upon the river (i.e. the relative magnitude, immediacy and uncertainty of the register entry).

Key matters for consideration

> *Given the highly evolved status of the current Basin-scale salinity program, there is potential to improve efficiencies in the management and administration of the accountability framework. In developing BSM2030, a risk-based approach to operation of the salinity registers, reviews, modelling, reporting and audit should be considered. Such an approach would necessarily also consider the management and administration of salinity accountability elements of the Basin Plan, and would also require consideration in the review of Schedule B.*

6.7.2 Accountability for environmental flows

Use of environmental flows within some wetlands along the River Murray is expected to increase salt load exports (RPS Aquaterra 2011) however the dilution benefits anticipated from the use of environmental water is predicted to provide a net improvement in river salinity when assessed over the Benchmark Period. Not-withstanding these anticipated improvements in salinity, environmental flows are identified as being a likely accountable action under the BSMS Operational Protocols (MDBC 2005), yet the accountability requirements of Schedule B does not currently cover the Commonwealth Government and MDBA who are the largest holders of environmental water entitlement.

The policy framework to provide direction on management of salinity accountabilities associated with the use of environmental water (the approach and assignment of institutional responsibilities) has been identified as a priority action by the Independent Audit Group for Salinity for a number of years (e.g. MDBA 2013). Without a firm policy framework, the understanding of the implications of environmental watering on meeting targets (for long-term planning and management, and for flow management) remains highly uncertain. This uncertainty has implications in understanding the residual risk associated with implementing feasible joint works and measures options discussed within this report.

Key matters for consideration

In developing BSM2030, accountability arrangements are required to resolve how state and Commonwealth governments will be accountable for the impacts of environmental water use. It is proposed that this matter is a priority for consideration in developing BSM2030 and the review of Schedule B.

6.7.3 Modelling supporting accountability

Models have played a significant role in supporting the BSMS/Schedule B accountability framework. Consultation with jurisdictional agencies undertaken as part of the review of end-of-valley targets (SKM 2013) indicated that this modelling approach is supported as the only means of providing a consistent standardised approach to long-term salinity planning and management within the context of a variable climatic regime. These benefits of the modelling approach, complement operational approaches that rely upon field based measurements under the Basin Plan where the outcome is reported as a comparison of the target value with a metric that enables the reporting of outcomes over a specified period of time.

However the modelling platform is underpinned by assumptions and data sets that warrant periodic review and potential updates. Key components of the existing modelling platform are the Benchmark Period and the cost functions which are discussed below.

The Benchmark Period

The Benchmark Period defines a climatic sequence that is used consistently in models to predict the effects of various combinations of actions at specified times. The period is currently defined as 1 May 1975 to 30 April 2000 on the basis that it was considered to adequately cover the typical range of climate variability that can be expected (MDBC 2005). The recent extended drought demonstrated a substantial dry period in excess of that covered by the defined Benchmark Period (1975–2000), a matter that was raised within the Mid-Term Review of the BSMS (MDBC 2008). Since the establishment of the Benchmark Period at the commencement of the BSMS, there are now substantially longer flow/salinity data sets available for the River Murray and its tributaries and so providing the basis for an extension to the existing Benchmark Period. Provision of an extended Benchmark Period would have implications for evaluating in-river salinity outcome achievements against long-term salinity and planning targets, and upon salinity register outcomes.

Key matters for consideration

Over the longer term, there is a need to comprehensively review the Benchmark period to establish whether it is appropriate to extend or replace the Benchmark Period with an alternative climatic sequence. However there are potentially significant implications in undertaking such a review. This includes the resources required to undertake River Murray and tributary modelling, and the implications for the states' register balance (i.e. debts and credits). While the review of the Benchmark Period is proposed for consideration as an element of BSM2030, it is not considered to be a priority until the key aspects of the Basin Plan have been implemented by 2019.

Cost functions

Cost functions are used in modelling to relate levels of river salinity to the economic impact on the various River Murray water users. They provide the economic basis for calculating the salinity cost effect ($ millions/year) from salinity on agricultural, household, commercial and industrial consumers and government instrumentalities (MDBC 2005) based upon studies by GHD (1999) and Allen Consulting Group (2004). A review of the agricultural attributes of the cost functions has been completed (RMCG 2009) and noted that the costings are sound, however the recommendations have not been implemented and so the salinity cost effect on the current salinity registers (MDBA 2014a) reflect the earlier work.

To date, the cost functions have been useful in providing the basis for understanding the relative cost benefit analysis of accountable actions, particularly in the salt interception program, enabling the costs and benefits to all water users to be assessed along the whole of the River Murray, rather than just the biophysical salinity effects as expressed in the salinity levels at Morgan (Newman and Sakadevan 2006). If only the modelled biophysical salinity impacts on Basin Salinity Target at Morgan were used for comparing between different options to manage river salinity, it would have put a greater emphasis on actions that prevent salt inflows closer to Morgan without considering the overall economic benefits of using better quality water by all users throughout the River Murray System. The location of the use is important relative to actions that cause an increase or decrease in river salinity. The further upstream an action occurs, depending on the base salinity level of the river at various river reaches, the greater the economic cost (from an increase) or benefit (from a decrease) per unit change in salinity.

The cost functions provide a standardised ‘common currency’ for determining the relative economic impact of changes in river salinity caused by various actions regardless where they occur in the River Murray System. For this reason, they are used as the basis, in accordance with Schedule B, for determining credit and debit balances in salinity registers in $ millions per year. They may also have a role in choosing between various options available to manage SIS more adaptively as part of the BSM2030.

While the current cost functions broadly provide the role as ‘common currency’ to relatively compare benefits between salinity management options, the cost functions require update if they were to be used for understanding the absolute economic benefits of various management actions. However, maintaining the currency of the cost functions for estimating absolute economic benefit is a challenge because:

- they are required to be supported by data sets that indicate the location of the use, salinity costs to the various uses of water which may change substantially over time. Such data sets must include the type of use by household, commercial, industrial and agricultural users (including crop type and areas) and assumptions on soil type, irrigation methods, leaching requirements, and average applied water salinity
- cost-effective technologies have emerged such as de-salinisation of urban supplies that may require consideration in applying in-river salinity costs associated with some domestic and industrial uses.

Maintaining the currency of such extensive data requires significant resources and hence would require funding commitments by the jurisdictional partner governments (MDBA 2013).

Key matters for consideration

An important consideration for BSM2030 is to develop clear direction on the future role of the salinity cost effect ($ million per year) in managing accountabilities under the salinity registers. Subject to this direction, it may be necessary to update the cost functions and agree upon a schedule for the review of cost function model parameters as recommended by RMCG (2009).

6.7.4 An updated accountability framework

As stated previously within this report, the Basin Plan is complementary to the BSMS for which accountability obligations are prescribed within Schedule B. Beyond 2015, it is therefore essential that BSM2030 provide a contemporary policy framework that incorporates complementary elements of the BSMS and Basin Plan underpinned, where relevant, by an updated Schedule B.

In reviewing Schedule B (consistent with clause 35 of the schedule) and considering any revisions, it will be necessary to consider:

- requirements to support the implementation of BSM2030
- the review of the operation of Schedule B already undertaken by the MDBA in accordance with Clause 152 of the Murray–Darling Basin Agreement to assess the extent to which the Schedule is consistent with the Basin Plan.

Areas for consideration in a revised accountability framework that have already been identified under the clause 152 review include:

- the potential inconsistency in relation to salt load values included in targets specified under Schedule B and the salt export objective in the Basin Plan although the review noted that it was difficult to identify any circumstances in which the inconsistency will have a practical effect
- the accountability arrangements for environmental watering discussed previously, specifically how state and Commonwealth governments will be accountable for the salinity impacts of environmental water use and associated impacts on jurisdictional salinity register balances.

Another potential anomaly between the Basin Plan and Schedule B documented within SKM (2014) relate to measures' to assist in achieving operational targets (under the Basin Plan) and 'programs of actions' under Schedule B to achieve long term planning and management targets. The primary differentiator is the greater expectation and obligation upon jurisdictions under Schedule B programs of actions, than are envisaged for Water Quality Management Plans under the Basin Plan. In requiring a program of actions, there is an implicit expectation that Schedule B programs of actions will enable end-of-valley targets to be met, with comparable outcomes not a requirement for the design of measures within Water Resource Plans.

Key matters for consideration:

> *To support the implementation of BSM2030, revisions to Schedule B may be required. These should incorporate findings from the review of the operation of the Schedule (required under Clause 35 of the Schedule), address potential inconsistencies between the Schedule and the Basin Plan (identified under the review conducted under Clause 152 of the MDB Agreement), and align and integrate the accountability framework with policy directions consistent with the development of the BSM2030.*

6.7.5 Monitoring

A significant achievement of the BSMS and Schedule B has been a jurisdictional commitment to meet their respective obligations to monitor flow and salinity at all end-of-valley target sites (SKM 2013). Valley-scale datasets support an understanding of within catchment processes, but also enable a Basin-wide perspective of in-stream salinity and the sources (and timing) of salt load and flow that combine to determine salinity outcomes.

This achievement of a Basin-scale stream monitoring network is supported by the mandatory requirements for monitoring at end-of-valley sites within Schedule B. Continuity of this program is critical to the understanding of the sources and contributions of salt from the tributary valleys over the long-term including the implications of extended wet and dry climate sequences (i.e. the establishment of long-term data sets).

However the Basin-wide knowledge base underpinning the success of the salinity program relies upon a wider surface and groundwater monitoring network. The Independent Audit Group for Salinity (MDBA 2014c) reported that in recent years, all jurisdictions have rationalised their monitoring networks leading to a reduction in both surface water and groundwater sites (noting that none of the end-of-valley target sites have been affected). The Independent Audit Group for Salinity expressed concern as to whether there are implications for the future understanding of catchment processes, particularly in high salinity threat areas and at environmental watering sites (MDBA 2014c).

Key matters for consideration

> *Under BSM2030, the value of the Basin-wide end-of-valley stream salinity monitoring program should be recognised and maintained as a mandatory requirement within the accountability framework. Consideration should also be given to the Independent Audit Group for Salinity suggestion that any rationalisation of monitoring programs be subject to a transparent review process based on an agreed risk assessment process (MDBA 2014c).*

6.7.6 Reporting and auditing

Commonwealth, State and Territory governments report annually to the MDBA on the delivery of the various obligations under Schedule B. The MDBA also prepares a comparable report on how it has fulfilled its obligations under the Schedule. The MDBA report includes the salinity registers and is accompanied by a report of the Independent Audit Group for Salinity. The Independent Audit Group for Salinity assesses the performance of each State Contracting Government in implementing provisions of the schedule, and the MDBA's maintenance of the salinity registers.

The level of audit and governance applied through these processes has been a significant contributing factor towards the achievements of the strategy as identified within the Background section of this report.

Delivery of the program has now reached a level of maturity whereby principles of transparency and accountability may continue to be achievable with less intensive reporting (potentially in terms of detail and/or frequency). On-going reporting, review and auditing arrangements will be a necessary component of the development of BSM2030, and for efficiency reasons, can reasonably be expected to be integrated with salinity reporting requirements of the Basin Plan. Given the maturity of the current program, there may be opportunities to re-scale the frequency of audit and reporting arrangements currently required under the BSMS, so as to provide efficient delivery of salinity reporting under both BSM2030 and the Basin Plan.

Key matters for consideration

In the development of BSM2030, potential for improved efficiencies should be pursued in the reporting and auditing functions taking into account the requirements for reporting on salinity under the Basin Plan.

6.8 Capacity to implement

Capacity covers a range of areas including legal, institutional, planning, management, financial, technical and information skills and capacities, and leadership skills (MDBMC 2001b). Within this chapter they are collectively considered under the headings of governance (covering legal, institutional, planning and management aspects) and knowledge (covering technical and information aspects). Financial aspects are dealt with in the subsequent chapter that considers the potential costs of pursuing the recommendations arising from this consideration of feasible management options.

6.8.1 Governance

Governance arrangements reflect the processes and systems in place to manage and oversight a program. Under existing governance arrangements within the MDBA, partner governments play a role in advising on the core functions of the joint programs managed and coordinated by the MDBA. For the purpose of implementation of the Basin Plan, the MDBA seeks advice through the Basin Plan Implementation Committee which includes several subcommittees including a proposed Water Quality Taskforce. The function of this taskforce is related to implementation of water quality (including salinity) matters in the Basin Plan Implementation Agreement.

Governance arrangements that currently play an important role in the implementation of the BSMS and will therefore be important to successful implementation of the BSM2030 include:

- Jurisdictional policy advice
- Salt interception program management and technical advice
- The role of Construction Authorities.

Aspects to these governance roles are discussed below.

Jurisdictional policy advice

At the highest level the BSMS program is overseen by the Murray–Darling Basin Ministerial Council supported by the Basin's Officials Committee. Currently, the MDBA seeks advice from the Basin Salinity Management Advisory Panel (BSMAP) on matters related to the implementation of Schedule B including the MDBA's role in the co-ordination and management of the reporting and accountability arrangements.

The BSMAP provides necessary co-ordination, quality assurance, and policy advice in implementing the accountability framework and Basin-wide salinity management.

This attribute of the existing governance model gives effect to the principles of partnership that lie at the heart of the Basin-scale approach to salinity management. The application of this principle underpins the successes of joint and state programs to date. It is therefore an appropriate foundation upon which to manage the Basin program into the future.

However, within the context of the relative maturity of salinity management at the completion of the BSMS in 2015, and the necessity to efficiently integrate the Basin Plan within the proposed BSM2030 strategy, there may be opportunities to make refinements to the BSMS governance model to more efficiently engage with partner governments to develop and effectively implement a Basin-wide salinity program. Such refinements may include changes to existing advisory panel arrangements and functions to ensure effective jurisdictional input and reporting structures that are aligned and coordinated.

Jurisdictional technical advice on salt interception

In addition to facilitating and coordinating jurisdictional input, the current governance model also provides the MDBA with a lead role (on behalf of the Partner Governments) in SIS planning, construction, operation, maintenance, review and management roles (with support from Construction Authorities). Given the broader arrangements for the management of the shared water resources (i.e. management of dams, weirs, locks) and the MDBA's operational role in river management, its on-going responsibility for managing joint works and measures is expected to be the most appropriate model under a BSM2030 strategy.

A formal approach to ensure technical input to the salt interception program is also required which in recent years has been provided by the Technical Working Group for Salt Interception comprising technical agency personnel from New South Wales, Victoria and South Australia. On-going technical input from partner governments on SIS is anticipated to be required in the future with the past focus on investigating and constructing new salt interception schemes shifting towards a greater focus upon operations and maintenance, potentially including adaptive management arrangements proposed within this review.

The role of Construction Authorities

Under the Water Act 2007 (which incorporates the Murray Darling Basin Agreement) Construction Authorities are appointed by State Contracting Governments to construct, operate and maintain relevant assets including SIS that have been approved as joint works.

A full review of this delivery model is beyond the scope of this review (and has implications beyond the salt interception program) however in seeking future efficiencies, a range of options may be warrant exploration. For example, Construction Authorities currently provide SIS construction and operational services to the MDBA based primarily upon the jurisdictional location of works. Efficiencies could be potentially achieved by taking a 'no-borders' approach to the management of SIS; an approach that could consider the benefits of contracting some responsibilities across jurisdictional boundaries to a single agency such as:

- for the management of Victorian and NSW SIS in the Sunraysia region so as to improve efficiencies within a single geographic location
- for all schemes across the Mallee region (NSW, Victorian and South Australia).

Such an approach may enable consolidation of the current distribution of skills within a 'centre of excellence'. Advantages to program delivery may be a reduction in overheads in terms of project management and a requirement for specialised field equipment. With the larger scale of operations, a single agency may also deliver efficiencies through a dedicated and highly specialised workforce that could focus solely upon salt interception for construction, operation and maintenance. Informally elements of this approach are already being undertaken with SA Water specialists assisting NSW and Victoria with some maintenance programs where specialty skills and equipment is required. Hence existing arrangements may already be achieving efficient outcomes.

Key matters for consideration

In the development of BSM2030, implementation arrangements will be an important consideration including a governance model commensurate with the maturity of the delivery of the salinity program and integration of salinity elements of the Basin Plan into the BSM2030. Considerations as to the most appropriate governance arrangements may include reviewing:

- the inter-jurisdictional committee structures to explore opportunities to streamline arrangements while supporting effective jurisdictional input and reporting structures that are aligned and coordinated
- the contracting government delivery model for efficient construction, operation and maintenance of salt interception assets.

6.8.2 Knowledge

The BSMS recognised the importance of knowledge to understand salinity processes and risks, and so as to support continuous improvement in the management response. Improvement in the knowledge base has played an important role in understanding current and future risks as captured within this report through monitoring programs, the development of assessment tools including models, and associated investigations and analysis.

Technical studies and modelling

Modelling, knowledge and decision tools have been critical to the success of the BSMS contributing to the design and management of the Basin salinity management actions, and design and operation of accountability arrangements (MDBMC 2001a).

Future risks

The future risks chapter highlights for the Mallee region the uncertainty associated with projected salt loads particularly with respect to the delayed salinity impacts, floodplain processes and significant salt loads which are able to be measured in the river. It also highlights uncertainties regarding salt mobilisation from floodplain environmental watering.

The contemporary understanding of the current risk profile within the Basin owes much to the investment in monitoring and investigations that took place following the release of the 1999 Salinity audit, including technical studies that provide a more informed understanding of the risks from dryland salinity. Given current landscape priorities suggest that future risks are from the Mallee region and the floodplain, and consistent with the conclusions from the peer review (Middlemis 2014; Appendix 3) of the modelling that supported the review, monitoring and investigations should focus upon the following areas:

- further investigation to develop an integrated approach to reducing model uncertainties relating to dynamic floodplain processes
- understanding of the impacts of environmental watering upon in-river salinity outcomes and established targets, to confirm the degree to which operational management can mitigate potential impacts from floodplain watering and salt mobilisation
- a detailed monitoring data and science review of dryland and pre-1988 irrigation processes to validate groundwater models and so reduce uncertainty on long-term projections.

It may also be timely to undertake a simple review of the assumptions that underlie jurisdictional models.

Key matters for consideration

> *There is significant uncertainty in projections of future salt accessions and hence investment is warranted to improve confidence in the assessment of risks. BSM2030 should prioritise investment in a contemporary understanding of future salinity hazard from key areas with priority given to the Mallee region and on salt mobilisation from various floodplain watering activities. Evidence-based understandings should be pursued such as that provided by long-term in-river salinity observations and groundwater level trends.*

Having regard to operational targets

River managers consider a broad suite of management issues when making operating decisions as discussed within the flow management section of this chapter, but are often constrained in their capacity to significantly influence river salinity outcomes. These constraints include an absence of flow management options, and an inadequate knowledge base upon which reliable forecasting can be provided on the salinity response to specific actions (such as an environmental watering event). Given the improvement in modelling platforms and the understanding of salinity processes, there is potential to provide improved tools which would benefit day to day river management decisions, enabling operators to plan an effective response to an event or a likely event. This would also enable an adaptive approach to managing SIS.

Improvements in decision support tools could also be achieved through capturing monitoring data within a database so as to enable evidence-based predictions on salt load exports from high risk floodplain watering scenarios. Collectively such datasets and tools would enable operators to more accurately forecast the:

- risk of a salt load mobilisation event
- the location and magnitude of an event as it progresses along the river
- the likely implications for the magnitude and duration of the salinity spike under different management decisions.

The transition to the new river model “Source” (inclusive of both flow and water quality functionality) will enable operational data to be integrated within the river modelling platform, forming the basis for the development of such forecasting tools. In addition to operational benefits, the use of such tools will support operators having regard to salinity operational targets as per the Basin Plan requirements.

Additional decision support tools may enable operators to demonstrate that they are having regard to operational targets and so provide transparency to the decision making process. Further, such tools may assist river operators and environmental water holders and managers to coordinate delivery of environmental and consumptive flows to further enhance salinity mitigation while still achieving the primary purpose of the entitlements. Documenting intent in the annual operating plans, environmental watering plans and ensuring the process for managing salinity and ‘having regard for’ is documented and agreed will also facilitate confidence that targets are being considered in the process.

However the degree to which such knowledge will support the achievement of operational targets should not be overstated. River operators are required to consider a range of objectives and in doing so, must 'have regard to' operational salinity targets, meaning that the targets must be given "proper, genuine and realistic consideration" (clause 1.07). There may be situations when they are obliged to place a greater emphasis upon other water management objectives when carrying out their functions. Salinity impacts are likely to take precedence if the salinity trigger point is exceeded under section 11.05 of the Basin Plan. In this case, river managers may be directed to instigate an appropriate flow management response to ensure that water is of a suitable quality to meet critical human water needs.

Key matters for consideration

> *Investment in information systems and predictive tools that provide river operators with a better understanding of salinity dynamics and the impact of decisions on in-river salinity outcomes is considered important to contemporary salinity management including managing for operational targets, understanding floodplain salinity processes, and adaptive approaches to SIS operations.*

6.9 Summary of key matters for consideration

BSM2030 will provide the strategy for salinity management of the shared water resources between 2015 and 2030, and will therefore underpin and direct future investment to mitigate future salinity risks. This chapter has identified a number of key areas that support recommendations in relation to the development of BSM2030 and a review of Schedule B. Key matters for consideration are summarised below in, and considered more broadly within the following chapter on cost effectiveness.

Table 10 Summary of key matters for consideration in the development of BSM2030 and review of Schedule B

Matters for consideration	Implications for recommendations
Joint works and measures – A more adaptive approach to SIS operations	As part of the development of BSM2030, a more adaptive approach to the operation of SIS should be considered. Understanding will be required on: • the extent to which particular SISs (or parts of SISs) may be operated adaptively to maintain Basin Salinity Target at Morgan and commensurate with the level of salinity risk within the shared water resources of the MDB • the benefit cost implications of operating schemes differently, including the variability in the average cost per unit of salinity offset between schemes; • the extent to which SIS operations are expected to assist in contributing to the achievement of operational targets • the implications of changed SIS operations for the register balance of each jurisdiction (EC impacts and salinity cost effects), and ensuring that any unintended consequences for the operation of registers are resolved and able to be practically implemented • management of risk within the face of uncertainties such as developments currently underway or new state actions that result in an adverse salinity impact with reliance on offset from existing credits, uncertainties in the time and magnitude of projected increases in salinity and uncertainties in the net impact of environmental water recovery and use.

Matters for consideration	Implications for recommendations
	Subject to the outcomes of these investigations, it is proposed that the development of BSM2030 consider the potential to adopt an adaptive approach to SIS operations, including development of criteria and a decision framework for resuming SIS operational capacity in response to emerging salinity threat.
Joint works and measures – Flow management	As part of the development of BSM2030, the application of flow management to support in-river salinity outcomes should be explored. This may involve: • capturing and analysing the experiences gained to date in managing peak salinity events • investigating ways in which dilution effects of all water in the system (including both consumptive and environmental water), and river operations generally, could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities • developing potential approaches to flow management that seek to pursue salinity management outcomes which could be incorporated into relevant planning documents and processes, if appropriate, such as the Basin-wide environmental watering strategy, annual environmental water prioritisation, environmental water delivery, objectives and outcomes for river operations and annual operating plans • the progressive review of current river operation rules within the context of a changed flow regime, as it emerges through water recovery and the use of environmental flows.
Salinity targets	In developing the BSM2030 strategy, the future role and application of state end-of-valley targets within the accountability framework should be clarified taking into account the findings and recommendations provided by SKM (2014). Any decision to change these accountability arrangements would require amendments to Schedule B.
Accountability – Management and administration of the accountability framework.	Given the highly evolved status of the current Basin-scale salinity program, there is potential to improve efficiencies in the management and administration of the accountability framework. In developing BSM2030, a risk-based approach to operation of the salinity registers, reviews, modelling, reporting and audit should be considered. Such an approach would necessarily also consider the management and administration of salinity accountability elements of the Basin Plan, and would also require consideration in the review of Schedule B.
Accountability – Accountability for environmental flows	In developing BSM2030, accountability arrangements are required to resolve how state and Commonwealth governments will be accountable for the impacts of environmental water use. It is proposed that this matter is a priority for consideration in developing BSM2030 and the review of Schedule B.
Accountability – Modelling - the benchmark period	Over the longer term, there is a need to comprehensively review the Benchmark Period to establish whether it is appropriate to extend or replace the Benchmark Period with an alternative climatic sequence. However there are potentially significant implications in terms of the resources required to undertake the appropriate modelling, and the implications for the states' register balance (i.e. debts and credits). While the review of the Benchmark Period is proposed for consideration as an element of BSM2030, it is not considered to be a priority until the key aspects of the Basin Plan have been implemented by 2019.

Matters for consideration	Implications for recommendations
Accountability – Modelling - the cost functions	An important consideration for BSM2030 is to develop clear direction on the future role of the salinity cost effect ($ million per year) in managing accountabilities under the salinity registers. Subject to this direction, it may be necessary to update the cost functions and agree upon a schedule for the review of cost function model parameters as recommended by RMCG (2009).
Accountability – An updated accountability framework	To support the implementation of BSM2030, revisions to Schedule B may be required. Any required revisions to the Schedule should include any findings from the review of the operation of the Schedule (required under Clause 35 of the Schedule), address potential inconsistencies between the Schedule and the Basin Plan (identified under the review conducted under Clause 152 of the MDB Agreement), and any additional amendments to effectively align and integrate the accountability framework with policy directions arising from BSM2030.
Accountability – Monitoring	Under BSM2030, the value of the Basin-wide stream salinity monitoring program should be recognised and maintained as a mandatory requirement within the accountability framework. Consideration should also be given to the Independent Audit Group for Salinity suggestion that any rationalisation of monitoring programs be subject to a transparent review process based on an agreed risk assessment process.
Accountability – Reporting and auditing	In the development of BSM2030, potential for improved efficiencies should be pursued in the reporting and auditing functions taking into account the requirements for reporting on salinity under the Basin Plan.
Capacity to Implement -– Governance	In the development of BSM2030, implementation arrangements will be an important consideration including a governance model commensurate with the maturity of the delivery of the salinity program and integration of salinity elements of the Basin Plan into the BSM2030. Considerations as to the most appropriate governance arrangements may include reviewing: • the inter-jurisdictional committee structures to explore opportunities to streamline arrangements while supporting effective jurisdictional input and reporting structures that are aligned and coordinated • the contracting government delivery model for efficient construction, operation and maintenance of salt interception assets.
Capacity to Implement – Technical studies and modelling	There is significant uncertainty in projections of future salt accessions and hence investment is warranted to improve confidence in the assessment of risks. BSM2030 should prioritise investment in a contemporary understanding of future salinity hazard from key areas with priority given to the Mallee region and on salt mobilisation from various floodplain watering activities. Evidence based understandings should be pursued such as that provided by long-term in-river salinity observations and groundwater level trends.

Matters for consideration	Implications for recommendations
Capacity to Implement – Having regard to operational targets	Investment in information systems and predictive tools that provide river operators with a better understanding of salinity dynamics and the impact of decisions on in-river salinity outcomes is considered important to contemporary salinity management including managing for operational targets, understanding floodplain salinity processes, and adaptive approaches to SIS operations.

7. Cost effective management strategies

A cost effective management strategy will be one that appropriately balances: (a) the need to manage risks and meet regulatory obligations relating to salinity in the shared water resources of the MDB, and (b) the long-term costs associated with implementing the strategy.

Based on the feasibility assessment of management options in the previous chapter, varying levels of investment could be made within each of the four elements identified (refer Figure 15). However most of these elements and their components are unable to be packaged and costed at this point because:

- there are strong linkages and dependencies between the components (e.g. if a more risk-based approach to management and administration is determined to be appropriate, this will affect how monitoring, reporting, and auditing is undertaken)
- many of the components involve several steps, the first of which will determine the direction and level of investment required in the following steps
- the timing of activities over 2014/15 to 2029/30 will depend on a number of external constraints which are difficult to predict (e.g. budgetary constraints, climatic events, rate at which future risks emerge etc.), so a high level of flexibility needs to be provided for in BSM2030 to enable timely and efficient responses.

Consequently, this chapter focuses on assessing the cost-effectiveness of different levels of adaptive SIS operations, as this accounts for the majority of costs associated with the joint program, and considers the other elements of a future joint program in terms of their priority and development within BSM2030.

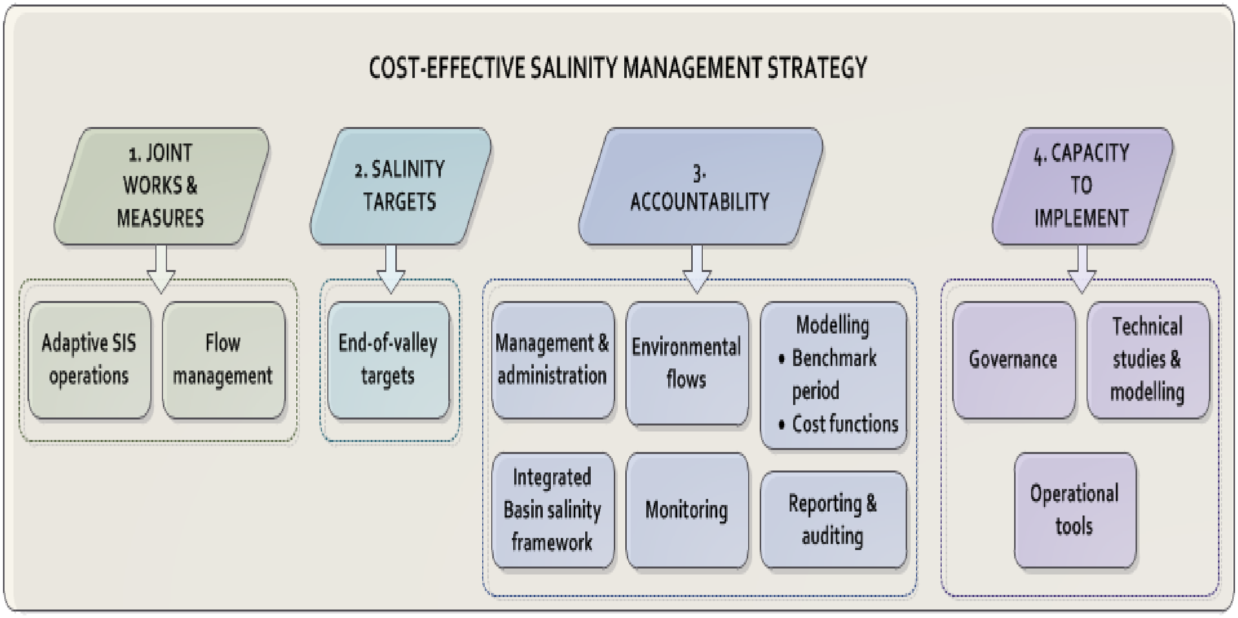

Figure 15 Developing a cost effective management strategy

It is important to note that the cost effectiveness assessment focuses on the comparison of options over the period 2014/15 to 2029/30. Real dollars (2013/14) have been used to compare costs and should not be used as proposed budget estimates for BSM2030. Furthermore, benefits and risks have not been quantified due to their complexity and a lack of suitable data. There are also multiple objectives and targets spanning different timeframes to be considered in assessing management options (e.g. operational targets, Basin Salinity Target), so a single and consistent “unit” of effectiveness could not be used to measure effectiveness.

Consequently, both the relative costs and qualitative discussion on the effectiveness of each option (which includes its impact on both risks and benefits) should be used to inform the overall assessment and any associated decisions.

7.1 Adaptive SIS operations

There may be opportunity to modify the current operations of SIS to be more adaptive in order to achieve cost savings, whilst still managing salinity levels so that they do not exceed the Basin Salinity Target at Morgan as defined in Schedule B. Currently, SISs are operating at 100 percent of available capacity to provide an agreed level of salinity benefit, but operations could be modified by decommissioning, mothballing, and / or putting schemes or components of schemes on standby.

To assess the cost effectiveness of operating SIS to provide varying levels of salinity benefit, a base case is required. This is often referred to as the ‘do nothing’ option or the ‘Business as Usual’ scenario, and allows us to measure the *relative* cost effectiveness of each option. For this assessment, the base case assumes that:

- SIS continues to deliver 100 percent of current salinity benefits
- the SDL adjustment mechanism will provide 2,400 GL of water through the Basin Plan
- the accountability framework is retained and state actions will continue to be implemented
- the estimated 95th percentile salinity impact at 2030 (over a variable 25 year climate experienced over 1975 –2000) is a suitable assessment period for the cost effective strategies.

Options for reducing SIS operations and the basis for including each option in this assessment are outlined in Table 11 (noting that it is assumed that the SDL adjustment mechanism will provide 2,400 GL of water through the Basin Plan).

Table 11 Overview of options for more adaptive SIS operations selected for further assessment

Option	Basis for selecting percentage of SIS benefits (refer to Figure 14)	Basis for reinstating SIS within the 16 year period
Option 1 - Business as usual (SIS operating to deliver 100% of the benefits) *(base case)*	100% SIS represents the business as usual scenario, i.e. continue operating SIS at its current level of effectiveness.	No reinstatement required, SIS already operating at 100% capacity.
Option 2 - SIS operating to deliver 86% of the benefits	86% SIS reflects the point at which the Basin Salinity Target at Morgan is exceeded in 2030 under the 2,400 GL scenario, noting that the figures for 2,400 GL have been interpolated from the actual model runs.	No reinstatement required as Basin Salinity Target at Morgan is not exceeded until 2030 under the 2,400 GL scenario.
Option 3 - SIS operating to deliver 77% of the benefits until 2023/24, and then requiring reinstatement to 100% SIS from 2024/25 to 2029/30	77% SIS reflects the point at which the Basin Salinity Target at Morgan is exceeded in 2030 under the 2,800 GL scenario but will not be maintained under the 2,400 GL scenario.	Reinstatement to 100% of salinity benefit provided by SIS, as Basin Salinity Target is not maintained under the 2,400 GL scenario.
Option 4 - SIS operating to deliver 50% of the benefits (50% SIS), and then requiring reinstatement to 100% SIS from 2024/25 to 2029/30	50% SIS could provide significant cost savings for a number of years, noting that the Basin Salinity Target at Morgan will not be maintained under both the 2,400 GL and 2,800 GL scenarios.	Reinstatement to 100% of salinity benefit provided by SIS, as Basin Salinity Target is not maintained under the 2,400 GL scenario.

Costing options for adaptive SIS operations

The optimal configuration of modified SIS operations would need to be determined through an in-depth investigation, which would assess which schemes or components of schemes could be decommissioned, mothballed, or put on standby. For the purpose of this cost-effectiveness assessment, the following costs have been considered for each option: [13]

- investigation of SIS operating adjustments (included for options 2 to 4)
- operation and maintenance of SIS continuing to operate to deliver 100 percent of current salinity benefits (included for all options, but to varying degrees)
- operation and maintenance of mothballed SIS schemes (included for options 2 to 4);
- capital works to mothball schemes (included for options 2 to 4)
- capital works to reinstate mothballed schemes (included for options 3 and 4).

Details about the assumptions and limitations associated with this costing approach are provided in Appendix 6. A summary of the assessment is provided in Table 12.

[13] Reducing SIS operations for each option has been based on rough estimates of the percentage of mothballing schemes required.

Costs were considered over the BSM2030 period (i.e. 2014–15 to 2029–30), and found that the greatest annualised savings are likely to be achieved through Option 2. This is because reducing the salinity benefits delivered by SIS beyond that proposed under Option 2 is likely to require reinstatement of mothballed schemes within the BSM2030 period to maintain the Basin Salinity Target. It is estimated that it could take two to five years to reinstate mothballed schemes depending on the attributes of the particular scheme.

Sensitivity analysis was also conducted for these options to test the uncertainties associated with reinstating mothballed schemes (refer Appendix 6 for further detail). This recognises the high uncertainties regarding timing and magnitude of future salinity risk and the need to be able to respond to changing or emerging risks (e.g. extended drought). This could require reinstatement of mothballed schemes at any point between 2014–15 and 2029–30.

The costing implications of reinstating mothballed schemes earlier or later (2019/20 and 2024/25), and to varying degrees of capacity (100% and 86% of the benefits) were all tested through this analysis. This analysis found that:

- generally, Option 1 is significantly more expensive, except in the case where SIS is reinstated to 100% in 2019/20
- if reinstatement of mothballed schemes is required earlier, there is very little difference in total costs and savings between Options 2, 3 and 4. However, the likelihood of Option 4 requiring reinstatement is significantly higher than Option 2.

Analysis of the risks and issues of reducing SIS operations

Whilst cost savings can be achieved by reducing SIS operations, SIS is critical to managing the salinity of the shared water resources. Any reduction from the current level of operating effectiveness will impact the ability to maintain the Basin Salinity Target and to manage salinities within Basin Plan operational targets, and reduces the broader environmental and economic benefits gained across the Murray–Darling Basin. Issues to be considered include:

- uncertainties around the timing and magnitude of impact of future risks with potential for a worse outcome if jurisdictions choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits or if there is a more rapid emergence of delayed salinity impacts
- potentially reduced capacity to protect river from salinity threats during extended drought when there are minimal options for mitigation with flows
- potential for more frequent exceedance of operational targets under reduced SIS operations due to less headroom for buffering against peak salinity events
- economic impacts on industrial, urban and agricultural water users and environmental impacts (including impacts on environmental benefits to some floodplains gained by scheme operation).

As summarised within Chapter 5 on future risks, the implications that reduced SIS operation may have for achieving targets has been assessed (MDBA 2014b), noting that these modelling results are indicative only and are based on a suite of assumptions. For example, key gaps in the modelling that affect the reliability of the predicted salinity outcomes include:

- lack of data regarding the net volume of environmental flows likely to be available;
- limited understanding of the scheduling of environmental flows to particular wetlands in wet and dry years

- exclusion of the salt loads likely to be mobilised from environmental watering
- limited understanding and exclusion of the timing and likelihood that current surplus salinity credits will be utilised
- uncertainties in the likelihood, timing, and magnitude of delayed salinity impacts reaching the river.

Further detail on the risks and issues analysis is provided in Appendix 7 with a summary presented in Table 12.

7.1.1 Summary

Table 12 provides a description of the qualitative scoring used for the assessment of the options for SIS operations.

Each option and the component of its assessment (i.e. total costs, annualised savings, impact on targets, risks / issues) has been given a qualitative score based on the scale in Table 12.

Table 12 Description of the qualitative scoring for SIS operations

Score	Assessment
+4	Much better than base case
+2	Moderately better than base case
0	Base case
-1	Moderately worse than base case
-2	Much worse than base case

In preparing an overall qualitative assessment score for each option, fifty percent of the weighting has been placed on costs (twenty-five percent for each of total and annualised savings), twenty-five percent of the weighting on the impact on targets to 2030, and twenty-five percent of the weighting on other risks and issues.

The overall qualitative assessment scores suggest that from a cost-effectiveness perspective:

- option 2 (86%) provides a slightly more cost-effective approach than the base case
- options 3 (77%) and 4 (50%) are slightly less cost-effective approaches than the base case.

When considering this assessment, it is important to note that further work is required to develop more accurate costs associated with reducing SIS operations, as these costs depend on the outcome of the investigation to determine the optimal configuration of SISs.

Furthermore, there is significant uncertainty associated with the predicted impact on targets and timing and magnitude of risks examined. This assessment does not account for development activities currently underway and further new accountable actions by jurisdictions that create a debit on the register and that are offset by existing credits, uncertainties of delayed salinity impacts, climate variability, or floodplain salt mobilisation due to environmental watering.

Thus, further work should be considered to better understand the costs, risks, and impact on targets before any transformative changes are made to current SIS operations, and in the meantime a more precautionary approach may be appropriate. As highlighted in the Chapter 6 on feasible management options, future SIS operations are likely to require a dynamic and adaptive mode of management, allowing SISs to be mothballed and reinstated to respond to emerging risks and events within the associated time constraints

Table 13 Summary of analysis of options for more adaptive SIS operations (all dollars are in real 2013/14 $, present value) and qualitative scoring outcomes

Option	Total costs until 2030	Annualised savings compared to business as usual	Impact on targets to 2030 (under 2,400 GL scenario)	Other risk / issues
Option 1 – Business as usual (SIS 100%)	$ 85,052,279	-	• Basin Salinity Target readily maintained (<800 EC 98% of time) • Significant capacity to buffer jurisdictional use of register credits and the potential emergence of delayed salinity impacts • Substantially reduces baseflow salt loads improving the likelihood of achieving Basin Plan operational targets • Maintains the current 'headroom' available to have regard for Basin Plan operational targets.	• Maintains existing economic benefits • Maintains complementary social and environmental benefits from SIS that are not explicitly considered in the approvals process for SIS.
Qualitative scoring of Option 1	0	0	• 0	• 0
Total Score Option 1 = 0				

Option	Total costs until 2030	Annualised savings compared to business as usual	Impact on targets to 2030 (under 2,400 GL scenario)	Other risk / issues
Option 2 – SIS 86%	$ 66,010,039	$ 1,190,140	• Basin Salinity Target maintained (<800 EC 95% of the time) • No capacity to buffer jurisdictional use of register credits and the potential emergence of delayed salinity impacts • Reduced capacity to protect river from salinity threat during extended drought when there are minimal options for mitigation with flows • Some reduction in 'headroom' and hence some reduction in the frequency of meeting Basin Plan operational targets.	• Reduction of economic benefits depending upon location of schemes targeted for reduced operations • Depending upon the sites targeted for reduced operation potential loss of some environmental benefits of SIS.
Qualitative scoring of Option 2	3	3	• -1	• -1
Total Score Option 2 = +1				

Option	Total costs until 2030	Annualised savings compared to business as usual	Impact on targets to 2030 (under 2,400 GL scenario)	Other risk / issues
Option 3 – SIS 77%	$ 72,241,170	$ 800,694	• Basin Salinity Target exceeded (<800 EC 93% of time). • Potential for a worse outcome if jurisdictions utilise their register credits or if there is a more rapid emergence of delayed salinity impacts • Further reductions in capacity to protect river from salinity threat during extended drought when there are minimal options for mitigation with flows • Reduces 'headroom' leading to a further reduction in the frequency of meeting Basin Plan operational targets	• Further reduction of economic benefits depending upon location of schemes targeted for reduced operations • Depending upon the sites targeted for reduced operation potential loss of some environmental benefits of SIS
Qualitative scoring of Option 3	+2	+2	• -3	• -3
Total Score option 3 = -0.5				

Option	Total costs until 2030	Annualised savings compared to business as usual	Impact on targets to 2030 (under 2,400 GL scenario)	Other risk / issues
Option 4 – SIS 50%	$ 67,551,405	$ 1,093,805	• Basin Salinity Target exceeded (<800 EC 89% of time). • Significant reduction in capacity to protect river from salinity threat during extended drought when there are minimal options for mitigation with flows • High incidence of not achieving Basin Plan operational targets	• Potentially a large reduction in economic benefits depending upon location of schemes targeted for reduced operations • Depending upon the sites targeted for reduced operation potential loss of some environmental benefits of SIS
Qualitative scoring of Option 4	+3	+3	• -4	• -4
Total Score option 4 = -0.5				

7.2 All other elements to be considered for BSM2030

Based on the consideration of other elements likely to be included within a Joint Program (Chapter 6), the following items are proposed as key opportunities to be considered in the development of BSM2030. Some of these elements will inform future work and direction, and may result in more efficient management and operational arrangements, and / or more cost effective management of salinity risk based on an enhanced understanding or capability.

Some elements presented in Table 14 involve reviewing current arrangements for implementing Schedule B. While making changes to the current arrangements may incur a one-off cost, implementing revised arrangements will require ongoing investment. A high level qualitative assessment of the indicative importance and investment options (optimal or reduced) for each of the components is also provided in Table 14.

This review recommends a program of activities for the 2014–15 year which include a review of operation of Schedule B of the Murray–Darling Basin Agreement that should be carried out in conjunction with the development of BSM2030. Until Schedule B is revised, the core obligations of the current Schedule will continue to be progressed. Any efficiencies or cost savings associated with implementation of an updated salinity management program are expected after the BSM2030 is developed and Schedule B is revised. The cost savings achieved by implementing an updated salinity management program compared to the current cost of BSMS and Schedule B implementation (the current program cost is approximately $2 million a year excluding the SIS operation and maintenance) are expected to be modest, but should be determined through the corporate planning process considering the level of investment required according to priorities and commensurate with risk.

Table 14 Joint program components (other elements)

ID	Joint program components	Indicative importance and investment options	Notes / other considerations
Element 1: Flow management component of joint works and measures			
1.1	Capture and analyse experiences in managing peak salinity events.	*Optimal:* Assessment will be at a key site level using updated modelling. *Reduced*: Assessment will provide less detail (i.e. either at a sample of key sites or regional level) using updated modelling.	This activity may be included as part of another major activity such as 1.2 or 4.2
1.2	Investigate ways in which dilution effects of all water in the system (including both consumptive and environmental water) could be used to enhance salinity mitigation benefits.	*Optimal*: Assessment will be at a key site level using updated modelling. *Reduced:* Assessment will provide less detail (i.e. either at a sample of key sites or regional level) using updated modelling.	As the environmental watering activities progress and their impacts are better understood, ways in which dilution effects to enhance salinity mitigation benefits may be developed over several years and are likely to be ongoing over the life of the BSM2030.
1.3	Develop potential approaches to flow management that seek to pursue salinity management outcomes which could be incorporated into relevant planning documents and processes.	These costs are fixed as they are to be incorporated into existing planning and operational processes. However their effectiveness and robustness will be enhanced by implementation of components 1.1 and 1.2.	Environmental watering strategies, priorities and schedules are expected to evolve over time. The development of approaches that provide complementary salinity outcomes will therefore also be ongoing.
1.4	Progressive review of river operation rules.	These costs are fixed as they are to be incorporated into existing planning and operational processes. However their effectiveness and robustness will be enhanced by implementation of components 1.1 and 1.2.	This activity may require more effort in the first years of BSM2030. However, a scaled-down ongoing effort may apply depending on future flow management decisions.

ID	Joint program components	Indicative importance and investment options	Notes / other considerations
Element 2: Salinity targets			
2.1	Review the role of state end-of-valley targets and amend Schedule B if necessary.	*Optimal:* Targets are reviewed as suggested by this report and previous work (SKM, 2014). *Reduced:* Targets are not reviewed and current arrangements are retained.	Relevant to Schedule B review and for consideration by mid-2015.
Element 3:			
3.1	Management and administration of the accountability framework.	*Optimal:* All components suggested by the Review are considered / implemented. *Reduced:* Some components suggested by the Review are implemented, depending on the priorities.	Relevant to Schedule B review. Initially, additional effort will be required for development of a risk-based approach to managing the accountability framework within the timeframes of the review of Schedule B. The majority of the investment will be ongoing for implementation of the revised accountability framework.
3.2	Accountability for environmental flows.	*Optimal:* This cost should be fixed as it is critical to consider under existing accountability arrangements. However implementation of components 1.1 and 1.2 will help inform this component. *Reduced:* not applicable	Depending on the outcome of the resolution of this issue, simplified accountability approaches that minimise transaction costs should be included in the Schedule B review. There will be ongoing costs associated with improving the assessment of salinity impacts of environmental watering actions into the future.

ID	Joint program components	Indicative importance and investment options	Notes / other considerations
3.3	Modelling – review the Benchmark Period.	*Optimal:* Review of the Benchmark Period is progressed around 2019 when key aspects of the Basin Plan are implemented. *Reduced:* The existing Benchmark Period remains in place and is reviewed at a later stage.	The effort required for this activity may be significant as there are implications on changes to the salinity registers.
3.4	Modelling – review and update of the cost functions.	*Optimal:* A clear direction for the future role of cost functions is established during the development of the BSM2030 and they are updated if necessary. *Reduced:* Use of cost functions continue in current form.	The value of such a review will depend upon the BSM2030 defining a clear future role for the salinity cost effect in managing accountabilities under the salinity registers. The resources required to maintain parameters behind the cost functions and to update them regularly is high, and there may be implications from an update for the register balance of jurisdictions.
3.5	An updated accountability framework.	*Optimal:* The BSM2030 is developed consistent with the revised Schedule B and salinity aspects of the Basin Plan. *Reduced:* not applicable	Relevant to Schedule B review and for consideration by mid-2015.

7.3 Proposed cost-effective salinity management strategy

This section summarises the key findings from the discussion and analysis of each option's feasibility and cost-effectiveness in previous sections. Any future cost-effective salinity management strategy is expected to comprise varying levels of investment in the following elements:

1. Joint works and measures (incorporating both salt interception and flow management);
2. Salinity targets
3. Accountability
4. Capacity to implement.

Under joint works and measures, key findings indicate that there is a modest opportunity to provide adaptive management to SIS operations commensurate with the contemporary understanding of the salinity risk, whilst still achieve the Basin Salinity Target up to 2030. The most cost effective option for SIS operations of those analysed was [14]:

- SIS operating to deliver 86% of the (95 percentile) salinity benefits at Morgan (Option 2) dependent on the findings of the investigation into the optimal configuration of SIS operations.

However as discussed in previous sections, further investigations into feasibility and risk are required in order to more closely examine the costs and benefits and determine whether the risk can be acceptably managed or not.

For the other elements, a risk-based management approach is proposed which considers opportunities for integration and improving cost effectiveness. It is considered there are opportunities to streamline or reduce current efforts in a number of areas (e.g. governance arrangements, reporting, auditing etc.) while still delivering an effective and integrated program. In other areas greater investment is required initially in order to support a more risk-based approach and cost savings over the longer term. This involves investment to: (a) better understand and manage new issues (e.g. salinity impacts of environmental watering); and (b) enhance current capabilities that may enable savings to be achieved in operations (e.g. future salinity hazard studies and forecasting tool).

There is substantial uncertainty regarding many of the salinity risks highlighted in this review, so it is critical that future management and operational arrangements are able to adequately, and within the associated time constraints, respond to unexpected increases in average salinity levels and the frequency of in-river salinity spikes; events that will require a management response.

[14] Costs are estimated across the period 2014/15 to 2029/30 and are in real 2013/14 dollars, PV

8. Key findings

Salinity in the Basin has long been identified as a significant issue affecting all jurisdictions with the aggregate impact most apparent as higher river salinities within the mid and lower reaches of the River Murray. Jurisdictions have recognised a shared responsibility in responding to this threat through a partnership response with joint and state investment reflected in the Salinity and Drainage Strategy 1988–2000 and Basin Salinity Management Strategy 2001–2015. The benefit of a collaborative inter-jurisdictional approach has seen collective actions reducing salinity impacts as demonstrated by achievement of the Basin Salinity Target (modelled salinity assessed as being less than 800 EC 95% of the time) at Morgan, South Australia, since 2010. Through cooperative management and governance, major salinity related consequences have been avoided, providing substantial social and economic benefits to the Basin's communities while protecting environmental assets and values.

8.1 Key findings from the review of the current salinity risk (to 2015) in the Basin

The key findings of from the review of the current salinity risk (to 2015) in the Basin are that:

- all landscapes in the Basin (Mallee, Northern Basin, Riverine Plains and Southern Uplands) contribute to salinity in the shared water resources either through river regulation and diversion of water, or by exacerbating inflow of salt loads. Sources of salt from these landscapes include natural salt inflows, salt mobilised due to past actions and salt mobilised by recent developments
- the key Basin landscapes contributing more to the salinity hazard are the Mallee regions of South Australia, Victoria and New South Wales and parts of the Riverine Plains of New South Wales and Victoria
- the flow regime that dilutes salt loads is primarily sourced from the regulated and unregulated tributaries emerging from the Southern Uplands
- the suite of salinity controls implemented to date, including salt interception schemes, improved irrigation system and on-farm practices, have led to the achievement of the Basin Salinity Target since 2010 such that over the long term, there is likely to be fewer in-river peak salinities exceeding 800 EC at Morgan
- a key achievement of the Basin-scale partnership has been the implementation of salt interception schemes that:
    - contribute significantly to reductions in the magnitude and frequency of elevated salinity levels (i.e. long-term average and peak salinity outcomes)
    - are particularly beneficial during periods of prolonged drought when there is less dilution available for the river, and SIS operations preventing saline groundwater reaching the river are most effective during low flow periods in limiting increases in river salt concentration
- current salinity risks are being managed when outcomes are considered in terms of achievement of the Basin Salinity Target, however residual risks remain; specifically event-based elevated salt loads that from time to time may be mobilised during relatively low river flows leading to increased salinity levels over short time periods that may require an operational response

- Key findings on future salinity risks (beyond 2015)
- The key findings on future salinity risks (beyond 2015) are that:
- all landscapes will continue to export salt and there is an ongoing need to manage current salinity levels as well as future increases
- water recovery and use for environmental watering under the Basin Plan is estimated to have a net long-term salinity benefit to the shared water resources through restoration of dilution. This benefit will complement but not replace the substantial salinity outcomes achieved through joint investment in SIS
- salinity impacts are forecast to gradually increase over time due to the delayed arrival of salt from various landscapes into the river, and that states may choose to offset future development activities that have adverse salinity impacts by utilising available salinity credits. There is also potential for salt to be mobilised from floodplain environmental watering. However, there are significant uncertainties about the projected extent and timing of salt load accessions and associated river salinity increases
- based upon the current available knowledge, the largest increases in salt loads are predicted to emanate from the lower reaches of the Mallee region arising from relatively recent irrigation development (post-1988) and the delayed salinity impact from past land and water management activities including clearing of native vegetation and historic irrigation development (pre-1988)
- for the most part, projected changes in salinity impacts to the shared water resources from the Northern Basin, Riverine Plains and Southern Uplands are relatively small, however this risk profile still warrants management and periodic review
- consistent with the current risk, short-term elevated salt load discharge events (previously experienced within the River Murray) are likely to arise from time to time
- risks to local assets arising from emerging threats should be considered during the development of Water Resource Plans to ensure that localised salinity impacts are understood and appropriate controls put in place. However, accountability for salinity impacts to the shared water resources is still required through Schedule B of the Murray–Darling Basin Agreement
- further work is required to address knowledge gaps, better understand risk and to provide a contemporary approach to future investments for salinity management. This work should focus on:
    - ways in which dilution effects of all water in the system (including both consumptive and environmental water), and river operations generally, could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities
    - understanding the potential for salt to be mobilised from floodplain environmental watering
    - scoping the future use of salinity credits that are currently available on the registers such as:
        - the extent to which states may require these credits to offset historic land and water management actions, and recent or future actions that are not currently on the register
        - options for alternative use of credits

- pursuing opportunities to resolve the significant uncertainty in the projected increase in future salt loads from the Mallee.

In light of the future risks and uncertainties, a clear on-going collaborative commitment to future Basin-scale salinity management is required with salt interception playing a key role in meeting the salinity objectives for the shared water resources. The BSMS 2001–2015 has been successful and hence many of its key elements should be retained beyond 2015, but with refinements to reflect the contemporary understanding of risk and to accommodate complementary management arrangements under the Basin Plan.

Basin salinity management beyond 2015

This review has confirmed the need to maintain a dedicated joint salinity program post the BSMS to ensure that salinity risk continues to be managed effectively. The review proposes the development of an updated strategy, the 'Basin Salinity Management 2030' (BSM2030) to cover the period 2015 to 2030, along with preliminary work to inform the objectives and elements of the strategy.

Consistent with the regulatory role that Schedule B provides for accountabilities outlined by the BSMS, accountabilities agreed within BSM2030 will also require formal regulatory support. Both the current Schedule B and the BSMS can be expected to significantly contribute to the development of BSM2030, with the process of formulating the new strategy also informing necessary improvements to the Schedule. A coordinated and iterative approach will be necessary in undertaking the review of Schedule B (required under Clause 35) and the development of the proposed BSM2030 strategy. Collectively the required outcome is clear alignment between strategy and regulatory arrangements.

Development of the BSM2030 strategy and the review of, and proposed revisions to, Schedule B should be completed and available for consideration by Ministerial Council by June 2015 when the BSMS comes to the end of its term. This review notes that there is potential for cost savings associated with implementing an updated Basin salinity management program, while noting additional work is also required to address knowledge gaps, better understand the future salinity risks and develop improved management tools to realise some of these savings.

Considering the transition to full implementation of the Basin Plan and its dilution benefits and forecast salinity risks, there is potential to refine the approach to Basin-scale salinity management [15]. Additionally, there are opportunities to update elements of the salinity program and re-scale the administration of the accountability framework due to improved understanding of salinity processes and experience gained through the implementation of the BSMS. In light of the above, the review identified feasible management options that warrant consideration in the development of an updated Basin-wide salinity management program. These include:

- joint works and measures through:
    - an adaptive operational approach to the management of SIS
    - improved flow management to support in-river salinity outcomes
- salinity targets
- accountability arrangements

[15] As a precautionary measure, for the purpose of salinity risk assessment, it has been assumed that 2400 GL would be available to meet the Basin Plan requirements after allowing for the operation of the Sustainable Diversion Limit adjustment mechanism.

- improved capacity to implement a Basin-wide salinity management program.

Joint works and measures – an adaptive operational approach to the management of SIS
The approach to adaptive management for SIS is based on the premise that the current approach of operating all SIS continuously could be refined such that collectively schemes, or parts of schemes, are geared towards operational capacity commensurate with the forward outlook on risk over a time interval of perhaps two to five years.

Indicative estimates from modelling (see Figure 16) are that when taking into account the dilution benefits from Basin Plan implementation, salt interception capacity could be reduced to provide around 86% of the salinity benefit at Morgan until 2030 whilst still meeting the Basin Salinity Target over this period. However as noted in this report, there are significant assumptions underpinning the modelling. The report also highlights risks and uncertainties that require further consideration prior to instigating such a major change to the SIS program. Given the need to balance the potential efficiencies of reduced SIS operations, and the need to manage the associated risks, a key issue to progress the potential to reduce SIS operations is the development of an adaptive approach. Adaptability in this context requires SIS operations to be sufficiently flexible to enable transition back to a required capacity in response to an emerging Basin-scale salinity threat.

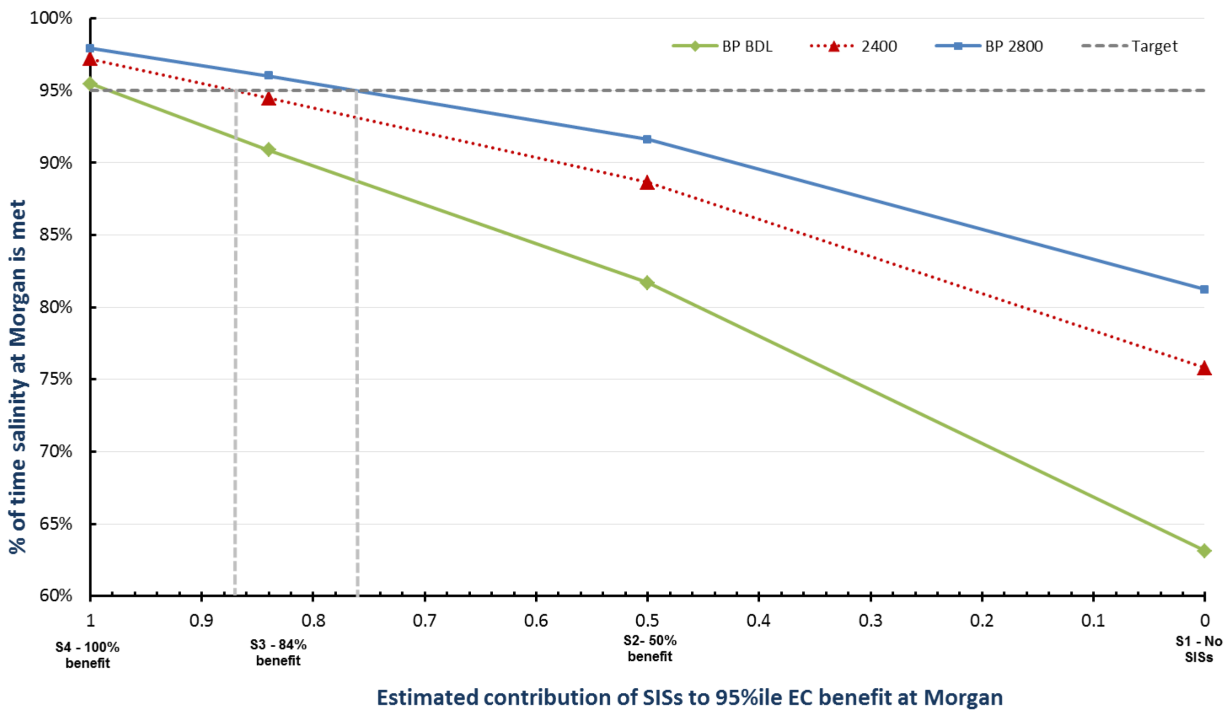

Figure 16 Impact of Salt Interception Schemes on 95%ile salinity at Morgan for BP BDL, BP 2400 and BP 2800 scenarios and 2030 salt accession level, 1975–2000 climatic period

To progress an adaptive approach to SIS as part of the development of BSM2030, understanding will be required on:

- the extent to which particular SISs (or parts of SISs) may be operated adaptively to maintain the Basin Salinity Target at Morgan and commensurate with the level of salinity risk within the shared water resources of the Murray–Darling Basin

- the benefit cost implications of operating schemes differently, including the variability in the average cost per unit of salinity offset between schemes
- the extent to which SIS operations are expected to assist in contributing to the achievement of operational targets
- the implications of changed SIS operations for the register balance of each jurisdiction (EC impacts and salinity cost effects)
- management of risk within the face of uncertainties such as developments currently underway or new state actions that result in an adverse salinity impact with reliance on offset from existing credits, uncertainties in the time and magnitude of projected increases in salinity, and uncertainties in the net impact of environmental water recovery and use.

Given that adaptive SIS operations would align operations with the level of salinity risk, it is important that improved confidence is provided in risk evaluation, and hence progress be made towards reducing the uncertainties in the modelling undertaken to-date. Areas for improvement include:

- access to data regarding the net volume of environmental flows likely to be available;
- understanding the scheduling of environmental flows to particular wetlands in wet and dry sequences
- understanding of salt loads that are likely to be mobilised from environmental watering
- reducing uncertainties in the likelihood, timing, and magnitude of delayed salinity impacts reaching the river
- timely advice on how and when states may plan to utilise salinity credits that are currently available on the register.

Joint works and measures - improved flow management to support in-river salinity outcomes

The changed flow regime under the Basin Plan suggests that flow management may provide a means of responding to episodic salinity events. However, if decisions on salt interception operations are based solely upon achievement of the Basin Salinity Target, exceedances of salinity operational targets are likely to be reported more regularly at some Basin Plan reporting sites. The extent to which improved flow management will provide a means of responding to these on-going occurrences is uncertain but warrants further consideration.

As part of the development of BSM2030, the application of flow management to support in-river salinity outcomes should be explored. Key matters for consideration include:

- capturing and analysing the experiences gained to date in managing peak salinity events
- investigating ways in which dilution effects of all water in the system (including both consumptive and environmental water), and river operations generally, could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities
- potential approaches to flow management that seek to pursue salinity management outcomes which could be incorporated into relevant planning documents and processes, if appropriate (such as the Basin-wide environmental watering strategy, annual environmental water prioritisation, environmental water delivery, objectives and outcomes for river operations and annual operating plans)
- the progressive review of current river operation rules within the context of a changed flow regime, as it emerges through water recovery and the use of environmental flows.

Salinity targets

Complementary salinity targets are provided for within the BSMS and the Basin Plan. The BSMS targets were intended as indicators of catchment salinity 'health' and condition with progress against these targets assessed on the basis of the frequency of exceedance over a threshold salinity for the modelled 1975–2000 Benchmark Period. Basin Plan operational targets, on the other hand, are intended to influence flow management decisions and hence support water quality outcomes measured in the river on a day-to-day basis.

Collectively, the BSMS and Basin Plan targets provide long-term benefits by supporting planning and management strategies that reduce the frequency of salinity threshold exceedance, and in having regard to salinity outcomes, consideration of a management response to individual events or potential events.

Whilst having an important role in supporting long-term planning and management as articulated within the Basin Plan, state end-of-valley targets for each of the tributary valleys under the BSMS were established at a time when there was considered to be a significant threat from dryland salinity. That perceived threat is no longer considered to pose a significant risk to the shared water resources. A recent review (SKM 2014) suggested that some state end-of-valley targets could be revised and their future role and application within the accountability framework be reviewed. In reviewing Schedule B and developing BSM2030, a key matter for consideration is to clarify the future role and application of state end-of-valley targets within the accountability framework.

Accountability arrangements

Given the highly evolved status of the current Basin-scale salinity program, there is potential to improve efficiencies in the management and administration of the accountability framework. In developing BSM2030, key matters for consideration include:

- a risk-based approach to operation of the salinity registers, reviews, modelling, reporting and audit. Such an approach would necessarily also consider the management and administration of salinity accountability elements of the Basin Plan, and would also require consideration in the review of Schedule B
- accountability arrangements to resolve how state and Commonwealth governments will be accountable for the impacts of environmental water use and associated impacts on jurisdictional salinity register balances, with the outcome potentially having implications for the review of Schedule B
- over the longer term, a comprehensive review of the Benchmark Period to establish whether it is appropriate to extend or replace the Benchmark Period with an alternative climatic sequence, noting that a review of the Benchmark Period is not considered to be a priority until the key aspects of the Basin Plan have been implemented by 2019
- developing clear direction on the future role of the salinity cost effect ($ million per year) in managing accountabilities under the salinity registers. Subject to this direction, it may be necessary to update the cost functions and agree upon a schedule for the review of cost function model parameters
- recognising the Basin-wide stream salinity monitoring program and that it be maintained as a mandatory requirement within the accountability framework. Consideration should also be given to the Independent Audit Group for Salinity suggestion that any rationalisation of monitoring programs be subject to a transparent review process based on an agreed risk assessment process

- investigating the potential for improved efficiencies in undertaking reporting and auditing functions taking into account the requirements for reporting on salinity under the Basin Plan.

Improved capacity to implement

Capacity to implement within the context of this review is considered to cover issues of governance and knowledge. Recognising the critical importance that the partnership approach to governance (particularly inter-jurisdictional advisory panels) has played in salinity management achievements to date, when developing BSM2030 key matters for consideration include:

- more effective coordination in implementation, such as integration with Basin Plan implementation (use of environmental flows and the Water Quality and Salinity Management Plan), and river operations
- providing efficiencies in program delivery and coordination which benefit from the policy and technical inputs provided by partner governments, but recognising the potential for rationalising some aspects of existing advisory panel and governance arrangements
- investing in an improved understanding of the future salinity hazard particularly with respect to the Mallee and floodplain environmental watering
- investing in information systems and predictive tools that provide a better understanding of salinity dynamics and the impact of operational decisions on in-river salinity outcomes including managing for operational targets, understanding floodplain salinity processes, and adaptive approaches to SIS operations.

Cost effective ways to manage risk to meet salinity objectives

Key findings from the assessment of cost effectiveness of the implementation of the above management options indicate that there is a modest opportunity to streamline SIS operations and still achieve the Basin Salinity Target up to 2030 subject to managing the future risks and implications identified in this review. The most cost-effective option was SIS operating to deliver 86% of the (95 percentile) salinity benefits at Morgan dependent on the findings of further investigation into the optimal configuration of SIS operations.

For some other elements of the joint program, efficiencies in program management could be sought while still maintaining effective implementation. Such efficiencies may be gained by rationalising salinity register entry reviews, and re-scaling annual reporting and audit commensurate with the risk profile. However in seeking these efficiencies, it is critical that the robust technical attributes that underpin the program be retained, such as maintaining BSMS models which underpin the understanding of salinity processes, register entries and assessment of progress against targets.

To support a more risk based approach and long-term efficiencies, investment will be required in an improved knowledge base and capacity to manage future risks including: (a) to better understand and manage new issues (e.g. salinity impacts of environmental watering); and (b) to enhance current capabilities that may enable savings to be achieved in operations by supporting a risk-based management approach (e.g. future salinity hazard studies and forecasting tools).

9. Recommendations

The recommendations from the review outlined below should be progressed during 2014-15 with the priority being to deliver a proposed BSM2030 strategy, a review of Schedule B, and any recommended changes to Schedule B to Ministerial Council by June 2015. A coordinated and iterative approach will be adopted when undertaking the review of Schedule B and development of the proposed BSM2030. This approach is required given the complex interdependencies between these activities and the need to ensure that any impacts arising from either activity on the other are assessed and the outcomes aligned.

Elements of the proposed BSM2030 will be progressed over the lifetime of the updated Basin salinity management program to 2030, and will be undertaken as required and according to relative priority.

To address the findings of this General Review of Salinity Management and to inform the development of the BSM2030, it is recommended that by June 2015 the MDBA and partner governments:

1. Further investigate the extent to which adaptive SIS operations could provide cost effective long-term and operational salinity outcomes including:

    - the potential to operate at approximately 86% of current SIS benefits to meet the future risk profile under Basin Plan flows
    - a contemporary understanding of the salinity risks to the shared water resources associated with operating at below 100% of current SIS benefits and implications for:
    - salinity targets (the Basin Salinity Target and Basin Plan salinity operational targets)
    - the salinity register balance of jurisdictions
    - the potential for operational arrangements being sufficiently flexible to transition back to a required capacity in response to an emerging salinity threat.

2. Develop the next and updated Basin-scale salinity management strategy (proposed to be termed 'Basin Salinity Management 2030' (BSM2030) that provides for:

    - investment in a contemporary understanding of future salinity hazard from key areas, with priority on the Mallee region and on salt mobilisation from various floodplain watering activities
    - the application of flow management planning and river operations to support in-river salinity outcomes, including ways in which dilution effects of all water in the system (including both consumptive and environmental water) could be used to further enhance salinity mitigation and offset adverse impacts while still achieving the primary purpose of these activities
    - accountability for the salinity impacts of all environmental watering activities;
    - continuation of improved land and water management practices consistent with the salinity accountability framework and the Basin Plan
    - the potential to adopt an adaptive management approach to SIS operations, including development of criteria and a decision framework for resuming SIS operational capacity in response to an emerging salinity threat (depending upon the outcome of Recommendation 1)
    - enhanced technical elements that better reflect climatic variability and tools that integrate new knowledge for contemporary operational salinity management. The technical

elements that may be considered include predictive modelling tools, an appropriate Benchmark Period and cost functions

- coordination and integration of BSM2030 with the complementary salinity management arrangements set out in the Basin Plan including flow management and broader water quality requirements
- establishment of the future role of state end-of-valley targets within the accountability framework
- a commitment to continued monitoring of accountability, and an improved knowledge base to support adaptive management and continuous improvement in program implementation
- a major program review within 10 years of commencement with shorter term reappraisal as warranted.

3. Review the operation of Schedule B of the Murray–Darling Basin Agreement in conjunction with the development of BSM2030 and provide recommendations on changes to Schedule B that align with the accountability obligations under the proposed BSM2030.
4. Develop governance, systems and performance mechanisms that support efficient program delivery including the potential for:

- effective integration and coordination between Basin Plan and the BSM2030 implementation processes
- consideration of management arrangements for the efficient delivery of the proposed adaptive SIS program
- improving efficiencies in program delivery including a risk-based approach to operation of the salinity registers, reviews and modelling, a re-scaled frequency of audits and annual reporting and rationalising some aspects of existing advisory committee and governance arrangements.

5. Provide the proposed BSM2030 and recommendations on changes to Schedule B to Ministerial Council for consideration and agreement.

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12. Glossary of terms

Accountable Action means a land or water management action that is expected to have a *Significant Effect*.

Baseline Conditions are the conditions that govern the movement of salt through the land and water within the Basin on 1 January 2000. It includes the salinity impacts of land and water management actions that took place prior to 1988 that have materialised within the river by 2000, but does not include the impact of management actions that took place after 1988.

Basin Salinity Target is the average river salinity target at Morgan, South Australia which is to maintain the simulated salinity below 800 EC for at least 95 per cent of the time; modelled over the 1975 to 2000 *Benchmark Period*.

Benchmark Period is an observed climatic sequence over a defined period (at the time of this review, determined to be the period 1 May 1975 to 30 April 2000) that is representative of hydrological variability across the Basin.

BSMS is the Basin Salinity Management Strategy 2001–2015 (MDBMC 2001a).

BSM2030 is the title for a proposed Basin-wide salinity strategy to replace the BSMS strategy in 2015.

Cost effectiveness is a comparison of the relative costs of a package of measures aimed at achieving the *Basin Salinity Target* at Morgan.

Delayed salinity impacts are salinity impacts that result from a pre-1988 action but for which the impact does not begin to occur until after 1 January 2000.

EC is a unit of measurement for electrical conductivity (1 EC = 1 µS/cm), measured at 25 degrees Celsius, commonly used as an indicator of water *Salinity* (salt concentration).

Intrinsic Threat refers to the aggregate salinity impacts from a landscape that are captured in the *Baseline Conditions* or as *Accountable Actions* recorded in the *Salinity Registers.*

Joint work or measure means physical works or measures that reduce in-stream salinity, either through a reduction in salt loads or through a changed flow management regime, for which partner governments have formally agreed to cost sharing.

Residual Threat refers to the current salinity impacts from a landscape remaining after salinity management controls have been applied.

Salinity (or salt concentration) is the concentration of sodium chloride or dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).

Salinity Cost Effect is a change in average salinity costs resulting from an action.

Salinity Credit is a reduction in average *Salinity Cost Effect*.

Salinity Debit is an increase in average *Salinity Cost Effect*.

Salinity Effect means a change in river salinity that leads to a *Salinity Cost Effect*.

Salinity Registers are a credit and debit based salinity accounting system which tracks all actions that are assessed to have a *Significant Effect* on river salinity, being a change in average daily salinity at Morgan which will be at least +/-0.1 EC within 100 years. The *Salinity Registers* provide a primary record of jurisdictional accountability for actions that affect river salinity. More detailed information on the *Salinity Registers* is provided in Appendix 4.

Register A contains details of any actions after the baseline date (1st January 1988) that are considered to have a *Significant Effect*, excluding those actions that have the express purpose of offsetting *Delayed Salinity Impacts*. *Register A* also brings forward information about works carried out under the former Salinity and Drainage Strategy.

Register B records *Delayed Salinity Impacts* due to actions taken before the baseline date applicable to each state (the 'legacy of history' for which the Contracting Governments accept joint responsibility). It also contains details of the predicted future effects of actions aimed at addressing *Delayed Salinity Impacts*, including contributions from *Joint Works or Measures*, and their salinity costs.

Salinity Threat refers to a source of a salinity impact that may arise from the aggregate impact of salt mobilisation and the flow regime of the receiving waters.

Salt load is the amount of salt carried in rivers, streams, groundwater or surface run-off, in a given time period. The salt load is calculated from data on *Salinity* and stream flow and is often expressed in kg/day, tonnes/day or tonnes/year.

S&DS is the Salinity and Drainage Strategy (MDBMC 1989).

Schedule B is a schedule to the Murray–Darling Basin Agreement that provides the accountability framework for implementation of the BSMS by the participating jurisdictions.

Shared water resources refer to the River Murray System.

Significant Effect is a change in average daily salinity at Morgan which the Authority estimates will be at least 0.1 EC within 100 years after the estimate is made, or a salinity impact the Authority estimates will be significant.

SIS refers to salt interception schemes.

Appendix 1 – Terms of Reference

Background

The Basin Salinity Management Strategy (BSMS) has been in place since 2001 and its current term is scheduled to end in 2015. The mandatory elements of the BSMS are implemented through Schedule B which provides for joint action by Contracting Governments to reduce or limit the rate at which salinity increases in the Murray–Darling Basin through measures such as building salt interception schemes and improving land and water management practices. It also includes an accountability framework (Salinity Registers, audit and reporting) for managing long-term salinity trade-offs resulting from development activities.

The Basin Plan 2012 includes a Water Quality and Salinity Management Plan (WQSMP) which sets out objectives and targets that contribute to water quality in the Basin that is 'fit for purpose'. The WQSMP sets additional 'operational' salinity targets for managing flows (Basin Plan section 9.14) whilst adopting the long-term salinity targets contained in Schedule B (and referred to in section 9.19 of the Basin Plan). The Basin Plan also includes (in Chapter 11 section 11.05) a salinity trigger point at which water in the River Murray System becomes unsuitable for meeting critical human water needs.

The Review of Joint Activities Taskforce (RoJAT) and Basin Officials Committee (BOC) requested a review of joint salinity management activities in light of the emerging and expected significant changes in Basin salinity risks associated with water recovery and use under the Basin Plan and future development activities. This General Review will help inform the Schedule B (Clause 35) review of the BSMS that is to occur before December 2014.

Context for the General Review

Documentation of the current salinity management objectives established by the Murray–Darling Basin Agreement and the Basin Plan will be conducted to provide context for the review. This analysis will consider:

- objectives and legacy of BSMS and previous joint efforts
- Basin Plan salinity objectives
- River Murray System vs Basin-wide objectives for managing both long-term and operational salinity issues.

Key questions for the General Review

The General Review will address the following five questions:

Q1. What is our understanding of the current salinity risk in the Basin?

The answer to this question is expected to provide evidence-based context for the answers to the other four key questions. It will:

- describe known salt sources (what is in the baseline and what is entered on the salinity registers) and characterise the trends in salt loads emanating from those sources
- provide explicit statements of the knowledge gaps, uncertainties and assumptions underpinning the current understanding of the various salinity risks
- explain the current salinity management activities being implemented to:
    - offset the delayed salinity impacts of past land and water management activities

  - offset current salinity impacts including salt interception works and improvements to land and water management practices
- adjust flow regimes in ways that affect salinity impacts (river operations, environmental watering and other policy initiatives)
- offset any future development activities that may impact on salinity.

Q2. What is our understanding of the future salinity risk as we progress implementation of the Basin Plan and take account of emerging risks?

The answer to this question will, to the extent possible in the timeframes of the review, be informed by modelling and qualitative assessment of the overall future salinity risk and integrated impacts of risk mitigation activities during high, medium, and low flow periods.

Q3. What feasible salinity management options are available to meet the objectives of both the BSMS and Basin Plan given the future salinity risk?

The feasible management options will include, but need not be limited to, dilution flows, salt interception schemes and regulation of the salinity impacts of changes to land or water use. The answer to this question will consider the effectiveness of management options during high, medium and low flow periods.

Q4. What is the most cost-effective strategy for managing the salinity risk to meet BSMS and Basin Plan objectives?

The answer to this question will provide a recommended suite of management options. The cost effectiveness assessment will be applied in the broad sense to consider both the direct and indirect cost of the management options using both qualitative and quantitative approaches where necessary.

Q5. What institutional arrangements are required to deliver the proposed strategy efficiently and effectively?

General Review process

The General Review will include four phases:

1. Identification of key salinity issues / risks in consultation with the jurisdictions
2. execution of salinity risk assessment and any technical projects required for risk assessment
3. Identification and analysis of management options
4. Synthesis of review findings to answer the key questions and provide recommendations.

General Review delivery model

The general review will be overseen by a jurisdictional steering committee supported by:

- An independent Chair
- An independent technical expert
- MDBA staff.

Workshops required for the review will be facilitated if necessary. Any external experts required for the review will be invited to participate in the workshops as appropriate. Technical aspects of the review will be subject to an independent peer review.

Review progress and outcomes will be reported at critical stages to BOC, RoJAT, Basin Plan Implementation Committee (BPIC) and the MDBA Executive.

General Review reporting arrangements

A draft final report from the General Review will be completed by mid-April 2014 ahead of distribution to BOC at their next meeting and subsequently to Ministerial Council.

The General Review will provide recommendations on:

- the most cost-effective ways to achieve the long-term and operational salinity outcomes called for by the BSMS and the Basin Plan
- desired future institutional arrangements, including where possible transitional arrangements and timeframes.

Appendix 2 – BSMS and Basin Plan salinity objectives and targets

Murray–Darling Basin Agreement, Schedule B

BSMS objectives:

- maintain water quality of shared water resources of the Murray and Darling rivers for all beneficial
- uses - agricultural, environmental, urban, industrial and recreational
- control the rise in salt loads in all tributary rivers of the Basin and, through that control, protect their water resources and aquatic ecosystems at agreed levels
- control land degradation and protect important terrestrial ecosystems, productive farm land, cultural heritage, and built infrastructure at agreed levels Basin-wide
- maximise net benefits from salinity control across the Basin.

Schedule B Clause 6 Meeting End-of-Valley Targets

- Each State Contracting Government must, by 31 March 2004 and thereafter at intervals of not more than five years; give the Authority its proposed Program of actions to meet End-of-Valley Targets adopted for that site.

Schedule B Clause 7 Basin Salinity Target

- The Basin Salinity Target is to maintain the average daily salinity at Morgan at a simulated level of less than 800 EC for at least 95% of the time, during the Benchmark Period.

Schedule B Clause 16 Obligations of State Contracting Governments

- A State Contracting Government must take whatever action may be necessary:

  a. To keep the total of any salinity credits in excess of, or equal to, the total of any salinity debits, attributed to it in Register A
  b. To keep the cumulative total of all salinity credits in excess of, or equal to, the cumulative total of all salinity debits, attributed to it in both Register A and Register B.

Basin Plan

Basin Plan objectives related to salinity

s5.04 Objective and outcome in relation to water quality and salinity:

1) The objective in relation to water quality and salinity is to maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Murray–Darling Basin
2) The outcome in relation to water quality and salinity is that Basin water resources remain fit for purpose.

For ecosystems - maintenance of the ecological character of declared Ramsar wetlands, and the protection and restoration of the ecosystems and ecosystem functions of non-Ramsar wetlands, and ensuring that ecosystems are resilient to climate change and other risks and threats.

- s8.05 Protection and restoration of water-dependent ecosystems
- s8.06 Protection and restoration of ecosystem functions of water-dependent ecosystems
- s9.04 Objectives for water-dependent ecosystems

For human consumption – maintenance of the palatability of water taken for consumption

- s9.05 Objectives for raw water for treatment for human consumption

For irrigation use – when used in accordance, with best irrigation and crop management practice, will not result in crop yield loss or soil degradation.

- s9.06 Objective for irrigation water
- s9.07 Objective for recreational water quality
- s9.08 Objective to maintain good levels of water quality
- s9.09 Salt export objective.

Basin Plan targets/triggers relating to salinity

- s9.14 Targets for managing water flows set out in the table, 95% of the time:

Table 15 Reporting sites for salinity in the Basin Plan

Item	Reporting site	Target value (EC) (us/cm)
1	River Murray at Murray Bridge	830
2	River Murray at Morgan	800
3	River Murray at Lock 6	580
4	Darling River downstream of Menindee Lakes at Burtundy	830
5	Lower Lakes at Milang	1000

- s9.16 Water quality targets for fresh water-dependent ecosystems
- End-of-Valley targets in appendix 1 of Schedule B to the Agreement
- s9.17 Water quality targets for irrigation water
- 95% of the time over 10 year period (ending with current water accounting period)

Applies at site in the MDB where water is extracted by an irrigation infrastructure operator for the purpose of irrigation.

- Southern Basin (Murray River and tributaries) – 833 EC
- Northern Basin (Barwon River and Darling River and their tributaries)
    - Paroo and Warrego rivers – 838 EC
    - Generally – 957 EC.

- s9.19 Salinity targets (to be applied in performing long-term salinity planning and management functions)

End of Valley targets in appendix 1 of Schedule B to the Agreement

- s11.05 Water quality and salinity trigger points

(2) A salinity trigger point is reached if a member of the Basin Officials Committee advises the Authority that:

a. a water supply authority has taken raw water from the River Murray System, at any site at or upstream from Wellington, for the purpose of treatment and supply for human consumption
b. The level of salinity in that water is 1,400 EC or greater.

Appendix 3 – Peer review report

Table 16 Memorandum

Attention:	Denis Flett, Independent Chair, General Review of Salinity Management
From:	Hugh Middlemis, Director, Hydrogeologic Pty Ltd.
CC:	Asitha Katupitiya, Director, Water Quality and Salinity Management, Murray–Darling Basin Authority
Date:	21 June 2014
HGL Job Number	61.003
DOC	GRoSm_modelling_risks_e
Subject	MDBA General Review of Salinity Management (GRoSM) – Review of model related risks

Summary

This review has concluded that the best available model tools have been applied to GRoSM Basin Plan scenario analysis, with inputs from BSMS accredited groundwater model salt loads. The approach should be considered fit for the GRoSM purpose, noting the limitations applying (MDBA, 2014), principally that it is not ideal for floodplain watering purposes. The key model limitations in a BP context are the poor dynamic response to floodplain watering and the (related) large accession or "unaccounted" salt loads.

Introduction

As described in detail in MDBA documents, the General Review of Salinity Management (GRoSM) is being undertaken into joint salinity management activities in light of the emerging and expected significant changes in Basin salinity risks associated with water recovery and use under the Basin Plan and future development activities.

The GRoSM process involves the consideration of MSM-BigMod model scenarios to estimate the salinity effects on the River Murray due to land and water management actions, which are evaluated in relation to a range of target salinity values ("BP targets"). MSM-BigMod simulates salt loads and salinity from known hydrological and hydrogeological processes, based on measurements of flow and salinity, as well as from unaccounted/unassigned salt loads (these terms are also used in relation to BSMS "accountability" and "unassigned salinity credits", and are replaced herein by the term accession salt loads or "accessions"). Accession salt loads include salt inflow contributions that are difficult or impossible to measure, such as drains and tributaries/wetlands with no monitoring, and it also includes errors in the basic river flow and salinity input data. Accession salt loads notably include groundwater inflows.

This brief peer review report identifies some key model risk issues relating to MSM-BigMod and groundwater model inputs to it. This review was completed in a short time frame, and it was not possible to evaluate the entire range of data, modelling methods and scenarios. While this review does not consider or address all such issues and risks, it attempts to identify key uncertainties and aims to provide some understanding of some of the risks to support decision-making by MDBA and other stakeholders in the context of the GRoSM. The key technical document provided by MDBA for review purposes was MDBA (2014; version 17).

Overview

There are key areas where data uncertainties and model uncertainties can potentially affect the judgement of model/results fitness for purpose and where the risk context needs to be understood. This review suggests that some of the key risks are low, but there remains a key risk in that little objective evidence has been provided that operational management can mitigate potential impacts from floodplain watering (although there have been assertions during the GRoSM project that it can and does). The key risks include (but are not limited to):

- *Saline groundwater accessions* – low risk implications relating to long term salinity impacts (accredited BSMS models with steady salt loads to river); the potentially high risk for short term operations (due to no modelled dynamic response to floodplain watering) is accounted for in MSM–Bigmod by saline accessions inputs (with acknowledged limitations; MDBA, 2014)
- *Operational management risks with no headroom from SIS to help manage effects of environmental watering* – there have been low to medium risk assertions in GRoSM technical report drafts, but the notable absence in MSM-BigMod of floodplain salt mobilisation from environmental watering invokes limitations on the BigMod application to GRoSM, which requires careful risk management
- *Legacy of History (Mallee clearing and pre-1988 irrigation)* – low risk of major short term impacts, and while long term predictions have uncertain timing, there is high potential for adaptive management to treat the risk.

Saline Groundwater Accessions

As explored in Section 3, the MSM-BigMod scenarios assume long term average groundwater-driven salt inflows that are steady across the benchmark period for any given scenario (e.g. reflecting 2015, 2050 or 2100 conditions). As groundwater flow systems are known to be slow-moving, it is arguably a reasonable approach to specify these inputs as steady background groundwater inflows, even under dynamic flood conditions (i.e. the salt inflows would be over-estimated during the flood period). While this approach also means that the groundwater salt inflows would be under-estimated post-flood, this is arguably reasonable given that, during the post-flood recession, there are a range of approaches applied in MSM-BigMod to achieve a match to the measured flows and salinities (i.e. in addition to the saline groundwater inputs, the accession salt loads include other inputs (e.g. from tributaries and wetlands) that are designed to cover for any under-estimates in the adoption of long term average groundwater salt inflows).

The accession salt load data set is variable monthly across the benchmark period and is variable spatially across reaches in MSM-BigMod, but is fixed for any one scenario (i.e. the model cannot dynamically adjust all accessions due to environmental watering, for example). **Despite this limitation (poor dynamic response to floodplain watering of all BSMS models (MSM-BigMod and groundwater), the best available model tools are being used, with accredited groundwater model salt load inputs, and thus the approach should be considered fit for the GRoSM purpose.**

There is identified potential for operational management methods to achieve dilution flows to offset environmental watering impacts, with previous assessments identifying a potential 33 EC benefit, that were considered broadly adequate to offset salinity impacts (RPS Aquaterra, 2011). The RPS Aquaterra (2011) study had acknowledged limitations as it was done (with no input from operational experts) by making use of available MSM- BigMod results that are not specifically accredited as fit for the environmental watering purpose (hence the results are indicative only). The final version (17) technical report (MDBA, 2014) simply quotes the potential 33 EC benefit “headline” without clarifying that the estimate is subject to uncertainty (e.g. it was itself was based on scaling MSM-BigMod scenarios (with similar limitations to those applying to the GRoSM application of MSM-BigMod), and without the benefit of operational inputs).

Operational Management and Risk Context

There is a range of uncertainties affecting these model results (key points considered in Sections 3 and 4), and yet the model results need to be used for decision-making. “Operational management” factors are invoked in the GRoSM analysis to suggest that the risks can be managed. In that context, it is worth noting that risk is defined in the new risk management standard (ISO 31000) as “the effect of uncertainty on project objectives” (but is still quantified as the product of probability and consequence). Apart from the key uncertainties identified herein, it can be argued that **there are significant further uncertainties invoked by adoption of the no-SIS scenario, as it tends to "load the dice" towards higher in-stream salinities** (compared to the historical context of SIS operations to date that have demonstrably reduced salt loads to the river and enabled substantial achievement of Morgan salinity targets, even during the high risk, low flow drought period).

If no SIS were available, the operational/management action headroom would be substantially reduced in the short term in the event that we find that some process (such as environmental watering mobilising floodplain salt, which is not considered in the modelling work) is tending towards exceeding BP targets. This could be considered to apply "consequence pressure" to the risk of unwanted outcomes, and to reduce the scope we have for effective/responsive management action (SIS take at least 1–2 years to begin to achieve targets, and in some cases five years).

In very simple terms, this review suggests that the modelling scenarios undertaken are arguably the best we can do at the present time, although the consequent decision-making context is not without risk, and consideration (by others) of suitable operational management actions under uncertainty is critical.

> ***It is recommended that objective evidence be identified to confirm the degree to which operational management can mitigate potential impacts from floodplain watering and salt mobilisation.***

Legacy of History

It is understood that Mallee clearing is in the order of 10% to 30% of the total predicted salinity impact (depending on where and when it is considered). MDBA (2014) indicated that “The projected salt load accessions due to dryland Mallee clearing, when it eventuates, would lead to most of the salinity targets being exceeded under a hydrologic regime of 1975 to 2009 period, even with all SIS’s working and with Basin Plan water recovery”. The uncertainty is that, while the groundwater models include this process, we cannot be sure whether we are still waiting for the potentially significant salt load source from the Mallee clearing recharge pulse to arrive (as the science indicates), or whether the pulse has already occurred (before the start of monitoring) and the groundwater system has re-equilibrated. Pre-1988 irrigation is much less subject to uncertainty (reasons discussed later).

Brief reviews undertaken for this task of selected bore monitoring data in SA, NSW and Victoria, along with discussions with key researchers, failed to identify any trend of rising groundwater levels and salinity due to Mallee clearing. Similarly, a report on Victorian dryland salinity risk (Gill et al, 2012) concluded that "The previous assumption of continuously rising groundwater levels (SKM 1999, 2004) is not valid across most [Riverine Plains] landscapes". This is interpreted to mean that there is a low risk of a high salt load in future from Riverine Plains dryland processes. The data in the Mallee was less definitive and such a conclusion was not reached there. However, the brief data review undertaken for this task did not identify rising trends in the Mallee.

This is essentially a data/science uncertainty (not a modelling uncertainty). In fact, groundwater modelling studies over the last 10 years have led to substantial reductions in the predictions of Legacy of History salt loads, primarily due to improved data (e.g. LiDAR on the floodplain and airborne EM geophysics, with some model parameter refinements; Passfield *et al*, 2009 – see abstract appended to this report).

> ***In summary, the risks to the shared water resources from dryland processes appears to be substantially less than was envisaged at the inception of the BSMS.***

Despite the uncertainties, adaptive management is likely to work here. For example, if the Mallee clearance pulse has already passed, then there is a low risk of greatly increased salt loads in the future. If there is indeed a Mallee clearance recharge pulse still coming through, then monitoring should pick up when it encounters the water table (as increased level and salinity), and there should be time to take appropriate action such as re-commission SIS to mitigate the salt load effect.

> ***While a detailed monitoring data and science review is warranted before the BSMS review by 2015, Legacy of History can be assigned a low risk, as the fit for purpose modelling (under current guidelines) has likely adopted an over-estimation approach.***

MSM–BigMod, Accession Salt Loads and Floodplain Recession

For GRoSM purposes, MSM-BigMod is being used to model the salinity effects of selectively decommissioning Salt Interception Schemes (SIS). MSM-BigMod uses a benchmark period (1975–2000, more recently extended to 2009) that arguably encompasses more climate variability than is predicted under climate change scenarios. Along with a range of other inputs, MSM-BigMod uses as input data the results from (BSMS-accredited) groundwater model predictions of the long term average salt inflows to the River from groundwater. The groundwater model scenarios provide the ability to unpack processes including recharge from dryland Mallee clearing and irrigation development, plus SIS discharge, but otherwise assume a steady hydrological background (e.g. steady river weir pool level and long term average rainfall and evapotranspiration), consistent with BSMS requirements for input to MSM-BigMod. While this is not consistent with predicting the effects of floodplain watering, which are important for a Basin Plan and TLM context, groundwater models can be developed with these processes (Passfield et al 2009).

Accession ("unassigned") salt loads represent a significant source of salt to BigMod: an average of 3,315 tonnes per day, with 37% of this salt entering the river between Lock 5 and Morgan (SKM 2013). These accession salt loads also allow the MSM-BigMod model to be calibrated to the measured flows and salinities (the model is well-constrained to measurements); however the accession salt loads are unable to change with changes to the flow regime. In simple terms, this means that any single MSM-BigMod scenario assumes a specific set of long term average salt load inputs that are a combination of output from (accredited) groundwater models, and additional accessions to match measured flows and salinities per reach. These inputs represent the predicted salt accessions at the key years of 2015, 2030, 2050 and 2100, and they are applied as steady inputs to the entire benchmark period for that run, and notably do not change to represent floodplain watering salt mobilisation. While MSM-BigMod is well-calibrated to flow and salinity measurements, the accession salt loads within it are a major source of uncertainty (and therefore risk) in the BP/TLM context. Some key elements of uncertainty are due to the groundwater model setup and results (see above), while others relate to the MSM-BigMod modelling framework, as discussed below.

Some recent studies by AWE (2013), in conjunction with MDBA (cited in SKM, 2013) have identified the potential for mining information from the accession salt load elements of MSM-BigMod. The aim is to identify relationships that improve its ability to model more dynamic salt loads with changes to the flow regime. As the study noted, an average of 37% of the accessions enter the river between Lock 5 and Morgan (or 1213 t/d within an average total of 3315 t/d). After detailed investigations, this was reduced by an average of 365 t/d, with another 59 t/d improvement relating to the Chowilla recession process (above Lock 5). Combined, these improvements amount to 423 t/d, or just 13% of the total average 3315 t/d accessions, which itself is understood to be in the order of 30% of the total salt load (all processes). While this is an improvement, there remains a substantial accession salt load that by definition contains significant uncertainties. **Further investigation is warranted**.

It is understood that the MSM-BigMod version used for the GRoSM and Basin Plan scenarios does not include the large (365 t/d) Lock 5 to Morgan floodplain recession relationship improvements identified by AWE (2013) (as they were considered too weak), but does include the 59 t/d Chowilla flood recession dynamic relationships (C. Diaconu, pers. comm. and MDBA, 2014). There is an ongoing program of work to further improve MSM-BigMod by including these floodplain recession relationships wherever the data and model performance improvement supports their inclusion. While this will require substantial investigation, it should eventually further reduce the accession salt loads and improve the dynamic response of MSM-BigMod. However, for GRoSM purposes, **the end result of the attempt to improve MSM-BigMod by targeting the "low hanging fruit" of "unassigned" accessions only achieved a modest reduction in MSM-BigMod uncertainty** ("unassigned" accession salt load data reduced by about 13%, as outlined above).

> ***This means that there are no significant dynamic floodplain recession relationships coded into the BP version of MSM-BigMod that is used for the GRoSM scenarios, and thus the fundamental MSM- BigMod uncertainties remain in relation to Basin Plan and TLM prediction capability (i.e. poor dynamic response to floodplain/watering processes).***

Similarly to the floodplain recession processes investigated above, groundwater modelling studies have identified that their major water balance term is evapotranspiration, which occurs almost entirely on the floodplain, and is responsible for most of the salt accumulation process. Yet there is no discussion of this effect in the MSM-BigMod reports reviewed. Similarly, there have been some significant advances in recent years to understand and model the dynamic floodplain processes of recharge, discharge and salt load effects in groundwater models (e.g. at Lindsay-Wallpolla; Passfield et al, 2009), using airborne EM geophysical and other data. The strength in using process-driven groundwater models is that they can change dynamically with the hydrological stresses applied, and they can help inform this weakness within MSM-BigMod. However, the BSMS requirements do not currently allow such an approach (rather, they require steady river and climate settings for application to BSMS long term predictions).

It is recommended that further investigation of model uncertainties should be undertaken by a multi-disciplinary team of surface water and groundwater modellers, to develop an integrated approach to reducing these model uncertainties relating to dynamic floodplain processes.

Mallee Clearing Recharge Uncertainties

A major uncertainty in the groundwater model results relate to simulations of pre-1988 Legacy of History actions, notably including Mallee clearing, but also including pre-1988 irrigation. The main uncertainty here is the recharge rate due to Mallee clearing and the lag time applied to it, as this drives some big increases in salt loads from about 2050, and thus is a major cause of the failure to achieve future BP targets. As MDBA (2014) states: the projected salt load accessions due to dryland Mallee clearing, when it eventuates, would lead to most of the salinity targets being exceeded under a hydrologic regime of 1975 to 2009 period, even with all SIS's working and with Basin Plan water recovery.

The irrigation recharge elements in the groundwater models are much less subject to uncertainty (measurement of water table mound build-up, and geophysical techniques (e.g. nanoTEM) provide direct measurements of the irrigation salinity effect.

While clearing of the Mallee occurred from the early to mid-1900s, chloride mass balance methods indicate that there will be lag times of many decades to hundreds of years before increased rainfall (dryland) recharge reaches the water table (Cook et al, 2004). The dryland recharge rates (and time lags) used in the groundwater models are calculated by the unsaturated zone analytical equation within SIMRAT, with rates usually reaching a maximum of about 10–15 mm/year for dryland clearing. While 10 mm/yr is not high in itself, where it is applied to a large area, the volumes (and thus salt inflows to the river) can be high. In some areas of sandy soils (e.g. east of Mildura), the recharge rate can reach 30 mm/year, which is itself high when compared to typical irrigation recharge rates which of 50 to 150 mm/year.

However, according to the best knowledge available, there have been no recent studies or monitoring reviews that have definitively identified the water level and salinity pulse reaching the water table under areas of Mallee clearing. The brief reviews undertaken for this task included consideration of selected groundwater monitoring data and discussion with key researchers involved in the original research (Prof. Peter Cook, Flinders University; and Steve Barnett, DEWNR), as well as discussions with SA modellers who have reviewed the monitoring data, and consideration of previous reports that considered this issue; Aquaterra, 2009, 2010). For example, a brief review of bore monitoring data in the high recharge and short time lag area east of Mildura did not identify a rising trend (a more comprehensive review is warranted). Another example is a monitoring review report (Barnett, 2007) on Mindarie (middle of SA Mallee, 50 km from river) which suggested an early trend (apparent in 2007) that was attributed to clearing. However, review of the latest data from those bores shows that the levels and salinities are effectively steady and have not continued the rising trend (some have decreased). Hence, what in 2007 was plausibly the early signal of a rising trend due to clearing is not confirmed at 2014. Finally, a report on Victorian dryland salinity risk (Gill et al, 2012) concluded that "The previous assumption of continuously rising groundwater levels (SKM 1999, 2004) is not valid across most (Riverine Plains) landscapes". This is interpreted to mean that there is a low risk of a high salt load future from dryland processes, although the data in the Mallee was less definitive and such a conclusion could not be made there.

> ***We cannot be sure whether we are still waiting for the potentially major salt load source from the Mallee clearing recharge pulse to arrive (as the science indicates), or whether the pulse has already occurred (before the start of monitoring) and the groundwater system has re-equilibrated.***

Despite these uncertainties, there is an opportunity for adaptive management to work here, in the context of the General Review. If the Mallee clearance pulse has already passed, and the latest monitoring shows either recent steady levels or perhaps a recession during the Millennium drought, then there is a low risk of greatly increased salt loads in the future. If there is indeed a Mallee clearance recharge pulse still coming through, then monitoring should pick up when it encounters the water table (as increased level and salinity), and there should be time to take appropriate action such as re-commission SIS to mitigate the salt load effect. Further and more detailed investigation is warranted before the BSMS review by 2015.

Conclusions and recommendations

Model Limitations re Floodplain Watering and Salt Mobilisation: This review concludes that the modelling approaches and scenarios are arguably the best we can do at the present time, although the consequent decision-making context is not without risk (mainly due to uncertainties relating to floodplain watering and salt mobilisation). Thus, consideration (by others) of suitable operational management actions under these risks is critical. The key limitation is that there are no significant dynamic floodplain watering and salt mobilisation relationships coded into the BP version of MSM-BigMod model used for the GRoSM scenarios, and there are no floodplain watering scenarios applied to the groundwater models (as required under the BSMS purpose).

It is recommended that further investigation of model uncertainties should be undertaken by a multi- disciplinary team of surface water and groundwater modellers, to develop an integrated approach to reducing these model uncertainties relating to dynamic floodplain processes

(this will require months to years of effort and thus improvements will not be available for GRoSM purposes).

Operational management action headroom would be substantially reduced in the short term under scaled down SIS operations in the event that we find that some process (such as environmental watering mobilising floodplain salt, which is not considered in the modelling work) is tending towards exceeding BP targets. This could be considered to apply "consequence pressure" to the risk of unwanted outcomes, and to reduce the scope we have for effective/responsive management action (SIS take at least 1–2 years to begin to achieve targets, and in some cases five years).

It is recommended that objective evidence be identified to confirm the degree to which operational management can mitigate potential impacts from floodplain watering and salt mobilisation.

Legacy of history: We cannot be sure whether we are still waiting for the potentially major salt load source from the Mallee clearing recharge pulse to arrive (as the science indicates), or whether the pulse has already occurred (before the start of monitoring) and the groundwater system has re-equilibrated. The pre-1988 irrigation recharge elements in the groundwater models are much less subject to uncertainty. In any event, given the lack of identified rising groundwater trends, the Legacy of History risks to shared water resources from dryland processes appears to be substantially less than was envisaged at the inception of the BSMS. Legacy of History can thus be assigned as low risk, as the fit for purpose modelling (under current guidelines) has likely over-estimated salt loads. Thus adaptive management potential is high, as monitoring should pick up when the dryland clearing recharge pulse encounters the water table (as increased level and salinity), and there should be time to take appropriate action such as re-commission SIS to mitigate the salt load effect.

It is recommended that a detailed monitoring data and science review of dryland and pre-1988 irrigation processes be completed before the BSMS review by 2015 to rationalise the above interpretations.

In conclusion, despite the key limitation (poor dynamic response to floodplain watering in all BSMS models), **the best available model tools are being used,** with BSMS accredited groundwater model salt load inputs, and thus the approach should be considered **fit for the GRoSM purpose, noting the limitations applying** (MDBA, 2014), principally that it is not ideal for floodplain watering purposes.

Reference list of the peer reviewed report

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Passfield G, Weatherill D, Middlemis H and Sutherland G, 2009, *Advances in groundwater modelling of floodplain inundation recharge and evapotranspiration, with application of AEM data (Lindsay–Wallpolla, Victoria and NSW)*, 3rd Australasian Hydrogeology Research Conference, 1–3 December 2009, Perth, WA. *See abstract appended to this report.*

Appendix 4 – Status of the Salinity Registers

History of the salinity registers

Under the BSMS (MDBMC 2001a) and its predecessor the Salinity and Drainage Strategy or S&DS (MDBMC 1989), partner governments have recognised the collective responsibility for the salinity problems of the shared water resources either through mobilisation of salt loads or diversion of water from the river. Hence, all states should be responsible for actions significantly affecting River Murray salinity with impacts categorised as either baseline, legacy of history, or post 1988 actions. These salinity impacts (historic, current and projected) are tracked within the MDBA Salinity Registers.

The Salinity Registers is a credit and debit based accounting system which tracks all actions that are assessed to have a significant effect on river salinity, being a change in average daily salinity at Morgan which will be at least +/-0.1 EC within 100 years. A significant effect can result from a change in the magnitude or timing of either or both of salt loads and water flows. So as to separate the salinity impact of offsetting new accountable actions and the impact of past actions, the Salinity Registers comprise two components - Register A and Register B (Wright *et al.* 2008).

The accounting metric within the registers is both physical salinity effect (EC), and the salinity cost effect ($ millions/year). The cost effects in $ millions/year are accounted as credits and debits and used for determination of net position of states in accordance with Schedule B of the Murray–Darling Basin Agreement. The decision to include both economic and physical salinity arose because of concerns from mid-Murray irrigators as to the adverse economic effects to water users from drainage schemes upstream of salt interception schemes. However this description of the registers draws significantly upon the BSMS Operational Protocols (MDBC 2005), the focus is upon physical salinity effect or debits and credits based on EC as it presents a clearer picture of the situation which is more easily understood. The most recent version of the salinity registers is provided within the BSMS 2012-13 Annual Implementation Report (MDBA 2014a) which includes the details of salinity effects and salinity cost effects (credits and debits) of individual actions.

Register A contains details of any actions after a nominated baseline date (1st January 1988) that are considered to have a significant effect, excluding those actions that have the express purpose of offsetting delayed salinity impacts. Register A also brings forward information about works carried out under the former Salinity and Drainage Strategy. Entries in Register A will include actions taken after 1988 and the impacts resulting from those actions. Salinity effects of states' through their contribution to the joint program for offsetting future delayed salinity impacts are also entered in Register A. However, the salinity effects (credits or debits) of these contributions offsetting 'Legacy of History' are transferred to Register B and not included in calculating the credit/debit balance ($ millions/year) of Register A.

Register B records delayed salinity or 'Legacy of History' impacts due to actions taken before the baseline date applicable to each state (the 'legacy of history' for which the Contracting Governments accept joint responsibility). It also contains details of the predicted future salinity effects of actions aimed at addressing delayed salinity impacts, including contributions from joint works and measures, and their salinity cost effects. Delayed salinity impacts that result from a pre-1988 action but for which the impact does not begin to occur until after 1988 should be entered in Register B, but only for that part of the impact that occurs after 1 January 2000. That part of the impact which occurs before 1 January 2000 is incorporated into baseline conditions. Salinity and cost effects of relevant management actions undertaken specifically for offsetting 'Legacy of History' salinity impacts after 1 January 2000 are also entered in Register B.

The joint works and measures program

Due to concerns over rising river salinity levels, and the needs of states to provide on-going drainage particularly within irrigation regions, the joint works and measures program was a key element of the Salinity and Drainage Strategy (MDBMC 1989). This strategy provided for NSW, Victoria, South Australia and the Commonwealth to jointly contribute to SIS that would reduce Morgan average daily salinity by 80 EC. Of this 80 EC, 15 EC were allocated to each of NSW and Victoria to offset the impacts of future drainage works or development in irrigation areas (MDBC 1999). The "80 EC", the "15 EC" and the ratio "15/80" was derived as the optimum economic outcome that could be achieved through a mix of SIS that created 80 EC, combined with drainage and salinity control work in the upper states that impacted the River to the extent of around 15 EC.

Accordingly, the 80 EC salinity effect delivered by the S&DS SIS program was allocated within the Registers as follows:

- NSW received 18.75% (15/80) of the total (80 EC)
- Victoria received 18.75% (15/80) of the total
- The River received 62.5% (50/80) of the total [16].

A further joint works and measures program was instigated as part of the BSMS in response to a Salinity Audit (MDBMC 1999) that predicted large increases in river salinity, mainly due to dryland salinity in the tributary catchments. That is, the "gradual deterioration" was quantified and came to be known as the 'Legacy of History' or the delayed salinity impacts of past actions.

A major part of the BSMS was the decision to address the 'Legacy of History', and that the parties that had caused these increasing effects (the states) would be responsible for offsetting them. Register B was created to bring to account these 'Legacy of History' salinity impacts, assigned to the states of NSW, Victoria and SA, from each of the major tributary valley and the Mallee landscape. Under the BSMS, South Australia was included on the Registers and its actions from 1988 to 2000 were retrospectively included on Register A.

Agreement for the joint works and measures program under the BSMS involved sharing of 61 EC (reduction in daily average salinity at Morgan) program by allocating 25% to each of NSW, Victoria, SA and the Commonwealth who allocated their share to offset the 'Legacy of History' impacts. These sharing arrangements are documented within MDBC (2005:33) and the Schedule B (Clause 11). The states' 25% shares are allocated to Registers A and B as 16.39% and 8.61% respectively. Whilst not explicitly stated, this separate allocation to the two registers was presumably to ensure that states had sufficient credits set aside to offset 'Legacy of History' salinity impacts, rather than allocating the states' entire share of reduced salinity effects of joint

[16] "When the Strategy was formulated, South Australia decided to allocate its share of the credits from joint works to improve River Murray salinity. This highlighted the importance to South Australia of actually achieving a net reduction in salinity in the river. At this time it was envisaged that South Australia would manage its new irrigation developments to ensure that it would remain salinity neutral." In light of this it was thought at the time to be unnecessary for SA to be on the Register (MDBC 1999).

works and measures to offset new salinity impacts of state actions (i.e. drainage works and irrigation developments).

An interim agreement (MDBC 2005:95) assigned the Commonwealth's 25% share of the 61 EC program to Register B in the proportions NSW (15%), Victoria (5%) and SA (80%). The implications to the states allocation of credits from this allocation of the Commonwealth's share of the BSMS Joint Works and Measures is as follows:

- NSW gets — 16.39% (Reg A) + 8.61% + (0.15 x 25%) (Reg B) = 28.75% of the total (61 EC)
- Vic gets —16.39% (Reg A) + 8.61% + (0.05 x 25%) (Reg B) = 26.25% of the total
- SA gets —16.39% (Reg A) + 8.61% + (0.80 x 25%) (Reg B) = 45.00% of the total.

Summary of the registers and the status of each state

A summary of the 2013 Register's position in terms of salinity effect at Morgan for each of the southern Basin states is provided within Table 17 including allocation of the joint works and measures from the S&DS and the BSMS as described above. Table 17 also categorises and delineates assignment of salinity effects at Morgan to each of the three states and the River. The net position of each state apparent from this tabulation are NSW – 36.92 EC, Victoria -26.67 EC and SA -44.79 EC all of which indicate a reduction of salinity at Morgan. From the S&DS, the river received -56.12 EC at Morgan.

Table 17 Position of states on the salinity registers (2013) [17]

Joint Shared and State Programs	Average Salinity effect in 2013 at Morgan	Assignment of salinity effects to NSW	Assignment of salinity effects to Vic	Assignment of salinity effects to SA	Assignment of salinity effects to The River
Salinity & Drainage Strategy	-89.8	-16.84	-16.84	-	-56.12
Basin Salinity Management Strategy (Register A component) [18]	-18.69	-6.23	-6.23	-6.23	-
Shared NSW and Victorian actions	-2.1	-1.05	-1.05	-	-
Net NSW state actions (Register A)	-9	-9	-	-	-
Net Victoria state actions (Register A)	-2.9	-	-2.9	-	-
Net SA state actions (Register A)	-28.7	-	-	-28.7	-

[17] Negative and positive numbers indicate a decrease and increase respectively of river salinity

[18] Balance represents salinity effect (EC) at Morgan. However, for compliance with Schedule B requirements, register balance is determined based on salinity cost effect ($ millions/year). The salinity effects and the salinity cost effects are not linearly related

Joint Shared and State Programs	Average Salinity effect in 2013 at Morgan	Assignment of salinity effects to NSW	Assignment of salinity effects to Vic	Assignment of salinity effects to SA	Assignment of salinity effects to The River
Total Register A Balance [19]	*-151.2*	*-33.12*	*-27.03*	*-34.93*	*- 56.12*
Basin Salinity Management Strategy (Register B component) [19] [20]	-19.31	-4.7	-3.75	-10.86	-
Net 'Legacy of History' Impacts (Register B)	+5.3	+0.9	+3.4	+1	-
Total Register B Balance [20]	*-14.01*	*-3.8*	*+0.35*	*-9.86*	-
Total Register Balance [20]– All states and the River	**-165.2**	**-36.92**	**-26.68**	**-44.79**	**-56.12**

[19] 50.83% of the total BSMS joint works salinity effects are transferred to Register B for offsetting 'Legacy of History' impacts.

[20] Some joint works and measures of BSMS (approximately -23 EC to be delivered by the Murtho and Upper Darling schemes) are yet to be included in the Registers

Appendix 5 – Werai state forest environmental watering – case study

In 2009, the Commonwealth sought to provide 4.5 GL of environmental water to the Werai State Forest (NSW). The area was affected by the presence of the hypersaline Mallen Mallen Creek although, due to the extended period of time the region had been in drought, the creek was at that time disconnected from the main river channel. If the Mallen Mallen Creek were to be reconnected to the main river channel by the watering action, it was considered likely to cause a salinity spike at the Werai Forest site and possibly cause poor quality water downstream.

Following the risk analysis and further investigation, including advice from on-ground advisors such as the then NSW Department of Environment, Climate Change and Water (DECCW), CEWO designed the environmental flow with a slow-release hydrograph to address the salinity risk. This was intended to ensure the main river channel would peak below a height that could connect the channel with Mallen Mallen Creek.

As well as designing the hydrograph to mitigate the potential for a salinity spike, CEWO took additional precautionary measures, including:

- deploying comprehensive compliance monitoring that focused on water quality for the duration of the action. This would have provided CEWO and river operators with an early warning should any negative water quality outcomes have arisen during the event;
- only partially opening the regulating structures along the river channel, which served a dual purpose:
    - to slow the flow of water and ensure there was enough time to obtain water quality information from the on-ground monitoring, before a significant amount of water passed through the system
    - to ensure flow regulators could be closed quickly to prevent poor water quality entering the main channel and impacting the sensitive ecological systems, such as the Colligen-Niemur system, further downstream.

The environmental flow for this action was released into the Edward River, directed through Werai State Forest and considered a success in meeting its objectives. The NSW DECCW report on the operational monitoring undertaken by the Murray CMA (working with NSW Industry & Investment) and environmental consultants Ecosurveys Pty Ltd (on behalf of NSW DECCW) noted that:

- the water quality was regularly checked throughout the event and did not cause any concerns
- vegetation such as river red gum (Eucalyptus camaldulensis), as well as waterbirds, small fish, frogs and turtles, had a positive ecological response to the watering event.

Appendix 6 – Costs and risks associated with more adaptive SIS operations

Costing options for adaptive SIS operations

The optimal configuration of such modified operations would be determined by conducting an in-depth investigation (costed at approximately $150,000) to identify the least cost-effective SIS, which would inform which schemes or components of schemes could be decommissioned, mothballed, or put on standby.

Savings and issues associated with reducing current SIS operations include:

- *Decommissioning schemes* – an initial investment in decommissioning would be required, which includes the cost of removing pumps and above ground infrastructure, and grouting/capping of bores. Ongoing costs may also be required for land management, which could cost around $25,000 per bore over the 2014/15 to 2029/30 period
- *Mothballing schemes* – an initial investment in mothballing bores and removing pumps would be required (approximately $10,000 to $20,000 per bore), and ongoing maintenance of mothballed bores and above ground infrastructure would still be required (approximately $12,500 per bore per annum). Furthermore, the cost of reinstating a mothballed bore is between $100,000 and $120,000. Savings to be realised by mothballing schemes (compared to current costs) include:
    - Power – around 100% of power costs could be saved due to pump removal
    - Operations and maintenance – approximately 75%
- *Putting schemes on standby* – schemes would need to remain operational, requiring active pumping at around 10% of full operations. Savings to be realised include:
    - Power – around 80%
    - Operations and maintenance – approximately 25%.

The annual operations and maintenance costs associated with operating SIS from 0% to 100% of its current capacity are shown in Figure 17, with each option highlighted.

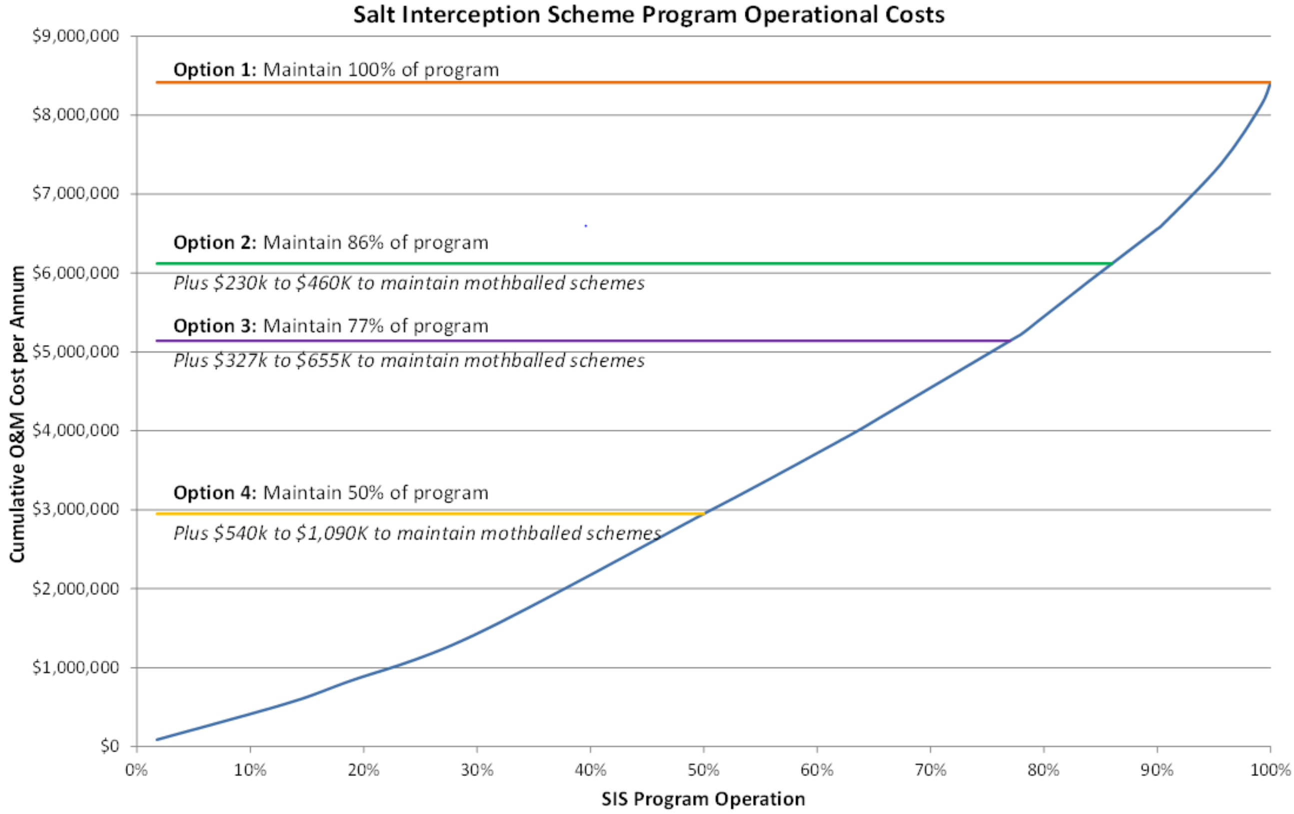

Figure 17 SIS operational costs

The costs associated with each of the options have been based on the following assumptions and limitations:

- Costs are considered over a 16 year period (2014/15 to 2029/2030)
- All dollars are in real present values terms (2013/14) and a discount rate of 7% has been applied
- An estimate of the number of bores associated with the current SIS operations is approximately 300 bores
- As there is further analysis required to identify the configuration of modified operations, cost estimates have been based on potential costs associated with mothballing schemes only (although some bores might be able to be decommissioned). Rough estimates of the percentage of mothballing schemes required are as follows:
    - Option 2 (SIS 86%) – bores mothballed to reduce benefits by 14%, no reinstatement required before 2029/30
    - Option 3 (SIS 77%) – bores mothballed to reduce benefits by 23%, reinstatement to 100% of SIS capacity required in 2024/25
    - Option 4 (SIS 50%) – bores mothballed to reduce benefits by 50%, reinstatement to 100% of SIS capacity required in 2024/25.

The costing of each option for reduced SIS operations is provided in Table 18.

Table 18 Overview of costs associated with options for reduced SIS operations from 2014/15 to 2029/30 (real 2013/14 dollars, PV)

Costs	Option 1 – Business as usual (SIS 100%)	Option 2 – SIS 86% of the benefits	Option 3 – SIS 77% of the benefits	Option 4 – SIS 50% of the benefits
O&M – operational SIS	$ 85,052,279	$ 61,847,809	$ 60,445,233	$ 43,980,930
Investigation of SIS operating adjustments	-	$ 150,000	$ 150,000	$ 150,000
CAPEX – mothballing schemes	-	$ 525,000	$ 862,500	$ 1,875,000
O&M – mothballed schemes	-	$ 3,487,230	$ 3,689,979	$ 6,124,914
CAPEX – reinstating mothballed schemes	-	-	$ 7,093,458	$ 15,420,561
TOTAL	**$ 85,052,279**	**$ 66,010,039**	**$ 72,241,170**	**$ 67,551,405**

Annualised cost savings to be realised through more adaptive SIS operations

Table 19 provides an overview of the annualised costs and savings associated with each option (based on total costs in real dollars over the sixteen year period 2014/15 to 2029/30). This includes annual operational and maintenance costs, as well as capital expenditure required to reduce the current capacity of operational SIS and then reinstate it in 2024/25). Each option appears to provide cost savings compared to the base case (Option 1 – SIS 100%), with the greatest savings to be achieved through Option 2 (SIS 86%) as it does not include the SIS reinstatement costs associated with Options 3 and 4.

Table 19 Annualised costs and savings associated with each option compared to the base case (option 1) (based on period 2014/15 to 2029/30)

Costs	Option 1 – Business as usual (SIS 100%)	Option 2 – SIS 86% of the benefits	Option 3 – SIS 77% of the benefits	Option 4 – SIS 50% of the benefits
OPEX (O&M)				
• Operational SIS costs • Maintenance of mothballed schemes	$ 5,315,767	$ 4,083,440	$ 4,008,451	$ 3,131,615
CAPEX				
• Investigation of SIS operating adjustments • Mothballing schemes • Reinstating mothballed schemes (options 3 and 4 only)	-	$ 42,188	$ 506,622	$ 1,090,348
TOTAL	**$ 5,315,767**	**$ 4,125,627**	**$ 4,515,073**	**$ 4,221,963**
TOTAL savings compared to Option 1	**-**	***$ 1,190,140***	***$ 800,694***	***$ 1,093,805***

Testing uncertainties associated with reinstating mothballed schemes

As outlined in previous chapters, the uncertainty regarding the timing and magnitude of future salinity impacts is high. For instance, jurisdictions may use all of their available credits, and / or delayed salinity impacts could occur faster than expected. Such events would cause salinity in the shared water resources to increase at a much faster rate than predicted, threatening the ability of MDBA and jurisdictions to meet their salinity management obligations.

Therefore, over the next sixteen years it is critical that salinity levels are maintained to a level that provides a sufficient buffer to respond to both unknown and known risks within the required time constraints. This could require reinstatement of mothballed schemes at any point between 2014/15 and 2029/30, and it is estimated that it could take two to five years to reinstate them depending on the particular scheme.

To test the costing implications of reinstating mothballed schemes earlier or later and to varying degrees of capacity in the sixteen year period, a number of reinstatement situations were examined. These include different combinations of timing (i.e. reinstatement occurs either six (2019/20) or eleven (2024/25) years into the BSM2030 period) and SIS capacity (i.e. whether reinstatement is required to 86% or 100% of current SIS capacity). Thus, the combinations considered are:

A. Reinstatement to 100% of the benefits in 2019/20 (including reinstatement for Option 2)
B. Reinstatement to 100% of the benefits in 2024/25 (including reinstatement for Option 2)
C. Reinstatement to 86% of the benefits in 2019/20
D. Reinstatement to 86% of the benefits in 2024/25.

The results of testing these reinstatement situations are provided in Table 20. They suggest that:

- Generally, the business as usual option (Option 1) is significantly more expensive except in the case where SIS is reinstated to 100% in 2019/20 (Scenario A), which achieves total savings of only $3 million (Option 4) to $4.6 million (Option 2) across the whole sixteen year period
  - If reinstatement of mothballed schemes is required earlier (i.e. 2019/20), there is very little difference in total costs and savings between Options 2, 3, and 4. However if schemes do not need to be reinstated until later (i.e. 2024/25), Option 4 does present more significant savings. However it is critical to understand that the likelihood of Option 4 requiring reinstatement of mothballed schemes within the BSM2030 period is significantly higher compared to Option 2 (as modelling estimates that the Basin Salinity Target will be exceeded before 2030 with 50% SIS).

Table 20 Sensitivity testing (real 2013/14 dollars, PV), 2014/15 – 2029/30

Estimated total costs to 2030	Option 1 – Business as usual (SIS 100%)	Option 2 – SIS 86% of the benefits	Option 3 – SIS 77% of the benefits	Option 4 – SIS 50% of the benefits
Original assessment:	$ 85,052,279	$ 66,010,039	$ 72,241,170	$ 67,551,405
Annualised savings compared to Option 1	-	*$1,190,140*	*$800,694*	*$1,093,805*
A: Reinstatement to 100% of the benefits in 2019/20 (including Option 2)	$ 85,052,279 *No change*	$ 80,463,259	$ 80,947,358	$ 82,096,955
Annualised savings compared to Option 1	-	*$286,814*	*$256,558*	*$184,708*
B: Reinstatement to 100% of the benefits in 2024/25 (including Option 2)	$ 85,052,279 *No change*	$ 73,416,089	$ 72,241,170	$ 67,551,405
Annualised savings compared to Option 1	-	*$727,262*	*$800,694*	*$1,093,805*
C: Reinstatement to 86% of the benefits in 2019/20	$ 85,052,279 *No change*	$ 66,010,039 No change	$ 63,496,735	$ 64,646,332
Annualised savings compared to Option 1	-	*$1,190,140*	*$1,347,222*	*$1,275,372*
D: Reinstatement to 86% of the benefits in 2024/25	$ 85,052,279 *No change*	$ 66,010,039 No change	$ 61,971,462	$ 57,281,697
Annualised savings compared to Option 1	-	*$1,190,140*	*$1,442,551*	*$1,735,661*

Appendix 7 – Analysis of the risks and issues of reducing SIS operations

Whilst cost savings can be achieved by reducing SIS operations, SIS is critical to managing the salinity of the shared water resources. Any reduction from the current level of operating effectiveness (i.e. without sufficient responsive/adaptive management capability) will impact the ability to maintain the Basin Salinity Target and have regard to operational targets, and so reduce the broader environmental and economic benefits gained across the Murray–Darling Basin.

In recent years, SISs and other controls have adequately dealt with the current salinity risk profile (indicated by achievement of the Basin Salinity Target since 2010). However as outlined in the Chapter 5 on future risks, over the longer-term it is expected that threats could lead to more regular exceedance of 800 EC at Morgan, potentially eroding this outcome.

There is also significant uncertainty around the timing and magnitude of impact of future risks which needs to be considered when examining options for an adaptive operational approach. For instance, a decision to reduce SIS operations is expected to have implications for state salinity credits, but this has not yet been assessed and assigned to the appropriate state. If states were to utilise and substantially reduce their current credit balance by undertaking actions that increase their salinity contributions, reliance on SIS to maintain the Basin Salinity Target would actually increase.

There is also a risk that reduced SIS operations will increase the likelihood of exceeding operational targets. This is because SIS, whilst not intended to mitigate upstream short term episodic salt mobilisation events, do assist in mitigating the net salinity impact by providing lower base level salinity within the river. This could be expected to reduce the frequency with which higher upstream salt loads contribute to exceedance of thresholds downstream (i.e. by providing ‘headroom’ below the target salinity at critical times).

Table 21 provides a summary of the implications that reduced SIS operations will have for achieving targets based on recent modelling (MDBA 2014b). However the modelling results should be regarded as indicative only, given that they are based on a significant suite of assumptions. For example, key gaps in the modelling that affect the reliability of the predicted salinity outcomes include:

- Lack of data regarding the net volume of environmental flows likely to be available
- Limited understanding of the scheduling of environmental flows to particular wetlands in wet and dry years
- Exclusion of the salt loads likely to be mobilised from environmental watering
- Limited understanding and exclusion of the timing and likelihood that current surplus salinity credits will be utilised
- Uncertainties in the likelihood, timing and magnitude of delayed salinity impacts reaching the river.

Table 21 Overview of risks and issues associated with options for modifying SIS operations (real 2013/14 dollars, PV)

Risks / issues	Option 1 – Business as usual (SIS 100%)	Option 2 – SIS 86%	Option 3 – SIS 77%	Option 4 – SIS 50%
Risk of exceeding Basin Salinity Target at Morgan	Target expected to be readily maintained up to 2030 (<800 EC for 98% of time), and significant capacity to buffer jurisdictional use of register credits and the potential emergence of delayed salinity impacts.	• Target expected to be maintained up to 2030 (<800 EC for 95% of time), but no capacity to buffer jurisdictional use of register credits and the potential emergence of delayed salinity impacts. • While no allowance has been provided for mothballed wells to be reinstated, an unexpected elevation in salinity risk could require such action. • Reduced capacity to protect river from salinity threat during extended drought when there are minimal options for mitigation with flows.	• Target will be exceeded (i.e. not achieved) before 2030 (<800 EC for ~93% of time in 2030) and potential for a worse outcome if jurisdictions utilise their register credits or if there is a more rapid emergence of delayed salinity impacts. • Highly likely that mothballed wells will need to be recommissioned before 2030, noting that mothballing costs are greater than operational costs if recommissioning of a mothballed bore is required within five years. • Further reductions in capacity to protect river from salinity threat during extended drought when there are minimal options for mitigation with flows.	• Target will be exceeded (i.e. not achieved) before 2030 (<800 EC for ~89% of time in 2030). • Almost certain that mothballed wells will need to be recommissioned before 2030 noting that mothballing costs are greater than operational costs if recommissioning of a mothballed bore is required within five years. • Significant reduction in capacity to protect river from salinity threat during extended drought when there are minimal options for mitigation with flows.
Capacity to have regard to BP operational targets	• Within the constraints imposed by the climatic conditions, and the available knowledge base, the full SIS program substantially reduces baseflow salt loads improving the likelihood of achieving Basin Plan operational targets • Maintains the current ‘headroom’ available to have regard for Basin Plan operational targets.	• Within the constraints imposed by the climatic conditions, and the available knowledge base, a reduction in the SIS program will lead to some reduction in ‘headroom’ and hence some reduction in the frequency of meeting Basin Plan operational targets	• Within the constraints imposed by the climatic conditions, and the available knowledge base, a further reduction in the SIS program will further reduce ‘headroom’ leading to a further reduction in the frequency of meeting Basin Plan operational targets.	• Within the constraints imposed by the climatic conditions, and the available knowledge base, a reduction in the SIS program to this level will lead to a high incidence of not achieving Basin Plan operational targets.

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Risks / issues	Option 1 – Business as usual (SIS 100%)	Option 2 – SIS 86%	Option 3 – SIS 77%	Option 4 – SIS 50%
Social, environmental, or economic impacts	• Maintain existing economic benefits • Maintain complementary social and environmental benefits from SIS that are not explicitly considered in the approvals process for SIS.	• Reduction of economic benefits depending upon location of schemes (could be in the order of ~$5m/year or a 4% reduction from Option 1 [21]) • Depending upon the sites targeted for reduced operation potential loss of some environmental benefits of SIS.	• Further reduction of economic benefits depending upon location of schemes (could be a reduction of between $5m and $18m/year or a 4%-17% reduction from Option 1 [22]) • Depending upon the sites targeted for reduced operation potential loss of some environmental benefits of SIS.	• Potentially a large reduction in economic benefits depending upon location of schemes (could be in the order of ~$18m/year or a 17% reduction from Option 1 [23]) • Depending upon the sites targeted for reduced operation potential loss of some environmental benefits of SIS.

[21] This is a rough estimate only, as the figure is based on 2005 cost functions and 84% benefit with BP 2,800 GL (MDBA 2014b). Dollars are 2012 CPI.
[22] This is a rough estimate only, as the figure is based on 2005 cost functions and 84% and 50% benefit with BP 2,800 GL (MDBA 2014b). Dollars are 2012 CPI.
[23] This is a rough estimate only, as the figure is based on 2005 cost functions and 50% benefit with BP 2,800 GL (MDBA 2014b). Dollars are 2012 CPI.