Acknowledgments

This report was compiled by Dr Shawan Dogramaci and Dr Brad Degens (Water and Rivers Commission) from the following reviews:

Dogramaci, S (2003), *Review of groundwater pumping to manage salinity in Western Australia,* Water and Rivers Commission, Perth, in prep.

Salama, R, Rutherford, J, Pollock, D, Ali, R & Baker V (2002), *Review of relief wells and siphons to reduce groundwater pressures and water levels in discharge areas to mange salinity*, CSIRO, in prep.

Chandler, KL & Coles, NA (2003), *Review of deep drains to manage salinity in Western Australia*, Department of Agriculture Western Australia, in prep.

Meney, K, Coleman, M & Carey, M (2003)), *Review of safe disposal in salinity management for engineering options*, Syrinx Environmental Pty Ltd in Prep

Farmer, DL, Chandler, K, Coles, N, Stanton, D & Cattlin T (2003), *Review of surface water management to manage salinity in Western Australia*, Department of Agriculture, In Prep.

These reports are available upon request from the Engineering Evaluation Initiative at the Water and Rivers Commission (Phone 9278 0300; email: eei@wrc.wa.gov.au)

Recommended Reference

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Cover photograph:

Drains in Belka Valley by

Tim Sparks

Contents

1 Introduction

1.1 Purpose

Engineering options such as deep drainage and groundwater pumping are increasingly being seen by many farmers and catchment groups as viable options to manage salinity. There are now over 11,000 kilometres of drains and banks installed and a significant number of groundwater pumping and siphon bore schemes established, with considerable interest in expanding the use of these across the Western Australian Wheatbelt.

There are widely differing opinions about the scale at which engineering should be implemented. Some consider that all water should be retained ‘on-farm’ while others suggest substantial arterial drainage schemes that include canals, feeder drains or groundwater pumping can be used to transport water to alternative disposal sites, including ocean discharge.

The Engineering Evaluation Initiative (EEI) being undertaken by the WA Government will encompass a range of on-ground projects to examine the performance of specific engineering options (Deep drains, groundwater pumping, siphon and relief, and surface water management), identify safe disposal options and plan for regional drainage.

This report presents a compilation of technical reviews and workshop discussion of current knowledge about salinity engineering and safe disposal options to determine the main technical problems in using these in WA. This report includes the outcomes of discussion at the Salinity Engineering seminar on the 4 March 2003 and the subsequent workshop with major interest groups on the 5 March 2003. The problems and technical gaps identified at these meetings will be used to determine priorities for investment by the EEI in on-ground works and form the basis for calls for expressions of interest in undertaking engineering evaluation projects.

1.2 Background

The use of engineering to manage salinity is limited by difficulties in choosing an approach that will work, siting the construction and dealing with the water that is produced. The assessment of major drainage schemes or other engineering options at catchment scales is complicated by landscape changes due to the delayed impacts of initial land clearing. These changes appear to be inevitable and any assessment of engineering options needs to take into account these longer-term impacts which may not be fully apparent for at least 20 to 50 years.

The drive for increased engineering has been matched by increasing concern about the potential downstream impacts and resulting social conflict. In particular, there is uncertainty about the cumulative

It is within this context that more information is required to both assist farmers and catchment groups to plan and design engineering solutions and take account of environmental and social concerns. The early stage of many engineering schemes and the timing of the Engineering Evaluation Initiative presents the ideal opportunity to influence and encourage the appropriate use of engineering through better information about siting, performance criteria and selecting disposal options that limit downstream risks. The initiative also provides a forum to address the needs for more understanding and leadership on the complex issue of regional drainage.

In July 2002 the Minister for Environment and Heritage established the following Steering Committee to set the direction for the Engineering Evaluation Initiative:

John Ruprecht (engineering and hydrology)

Garry English (farming, State and Local implementation of salinity management)

Gordon Davidson (farming, local government)

Kevin Lyon (drainage)

Neil Coles (agricultural water management)

Tom Hatton (water and ecology)

Greg Keighery (biodiversity and nature conservation)

David Pannell (resource economist)

In addition, Dr Richard George (Department of Agriculture) participated with the Steering Committee in developing the program for the Engineering Evaluation Initiative as chair of the Catchment Demonstration Initiative Steering Committee.

1.3 Scope of the EEI

This project is focused on improving the appropriate use of engineering options to manage dryland salinity for economic, social and environmental benefit through the following work areas:

improved siting and design of engineering options to maximise performance at farm scale

safe disposal of discharge waters

implementation of options within a planned regional drainage context.

1.4 Objectives

The following are the objectives for each work area.

Develop decision support system (DSS) tools to select what and where engineering options will perform best.

Provide guidelines and best management practices for groundwater pumping, deep drainage, relief bores, siphons, and surface water management.

Safe disposal options

Review options for the safe disposal of drainage water including the productive uses of saline waters.

Evaluate the characteristics of discharge waters from specific engineering options, analyse the

1.6 Setting priorities for investment

Reviews of the four engineering options commissioned by the EEI to identify technical gaps in understanding siting, installation and maintenance of the engineering work to provide greatest benefits. A review of options for safe disposal was also commissioned to highlight the gaps in understanding of how to identify safe natural sites or to construct engineered evaporation basins to deal with the discharge water.

The results of these reviews and case studies were presented to an audience of farmers, land managers, scientists, other stakeholders and interested community members (about 160 people altogether) at a public seminar held at the Burswood-on-Swan reception centre on 4 March 2003. These presentations will be available on the web at www.wrc.wa.gov.au/salinity /EEI.

On the following day a workshop was held to discuss and recommend priorities for the on-ground investment of funds. About 50 key stakeholders participated in the workshop representing a broad cross-section of farmers, drainage proponents, community members, land-care representatives, conservation organisations (WWF), regional NRM group representatives, local government and state agencies involved in NRM (Department of Conservation and Land Management, Department of Agriculture and Water and

2 Review of groundwater pumping

2.1 Introduction

Groundwater pumping is an effective method for lowering watertables in some areas within the Wheatbelt of WA. The response of groundwater to pumping is primarily dependent on the hydraulic properties of the water-bearing formations.

2.2 Current understanding

1. The effectiveness of pumping in lowering the watertable and recovering saline land depends on the

3 Review of siphon and relief bores

3.1 Introduction

A siphon bore is essentially a passive vacuum pump. The siphon bore is a closed pipe or conduit which conveys water from a point of higher hydraulic head to one of lower head after raising it to a higher intermediate elevation which is under negative pressure. Siphons have a maximum theoretical lift of 10.2 m (equivalent to atmospheric pressure) but a maximum practical lift of 8.3 m (the decreased lift is due to the vapour pressure of water and friction head loss).

Pressure relief bores, called artesian bores continuously discharge at or near the soil surface. The groundwater pressure enables water to passively discharge to the soil surface.

3.2 Current understanding

Siphon bores

8. Most of the siphon bores investigated in the Great Southern have been effective in lowering groundwater locally.

Relief bores

9. Relief bores can reduce pressure head in discharge areas. They are not, as such, effective in recovering saline land as they do not lower the water level below the surface at the discharge area (unless constructed with a sub-surface outlet). However they can halt salinity spread in the catchment if they are designed to remove the additional recharge and may reduce the severity of the salinity.

10. Relief bores can successfully be used to relieve hydrostatic pressure and to halt saline seepage from farm dams.

11. Relief bores are always constructed in the lower areas of the landscape which are the natural actual or potential groundwater discharge zones. Salt export to these sites will continue until all the mobile salt in the catchment is depleted. This can take from a few hundred to a few thousand years.

12. Relief bores may be more effective when installed at the base of a deep drain.

3.3 Recommended further work

1. Evaluate and communicate the results of the current investigation in the Great Southern to allow farmers to assess the suitability elsewhere.

2. Investigate the off-site impacts of siphon and relief bores in terms of chemistry, hydro-period, salinity other environmental effects compared with ‘do nothing’ option.

3. Systematic analysis of cost and benefits for relief and siphon bores has not been carried out, but there are several studies associated with groundwater pumping for mitigation of salinity that might be relevant to cost-benefit analysis of siphon and relief bores.

4. Conduct a trial of combined relief and siphon bores.

4 Review of deep drainage

4.1 Introduction

Deep drains collect and transport groundwater and, at times, surface water across the landscape.

Deep drains are typically used where the natural drainage system is inadequate to remove the inflow of water and salts in rainfall and irrigation water. In these areas, accumulated water and salts in the soil profile decrease land capability such as agricultural production. An artificial or man-made drainage system increases discharge by removing water. Draining saline agricultural land can significantly improve crop production because it prevents waterlogging and may lower the soil salinity in mid to long term.

The main types of deep drainage include:

- Deep open drains
- Deep closed (leveed) drains
- French drains
- Pipe drains
- Mole drains

French, pipe and mole drains can be classified as deep subsurface drains.

Deep surface drains (open and leveed) remove land from production; restrict the use of machines and

3. It is difficult to transfer results from studied drains to other areas because the Wheatbelt soils and landforms are so varied. There have also been large variations in maintenance problems with drains that can greatly influence the functional life and impacts of drains on down-stream farms/environments.

Chemistry of drainage waters

4. The geochemical processes occurring in deep drains in the southwest are poorly understood. The presence of iron oxides, other indurates and low pH drainage waters in many deep drains in WA has been noted but their significance for drain function is not yet well understood. There is conflicting evidence concerning the drainage of sodic soils. While sodic soils require pre-drainage treatment, this is rarely adequately done, if done at all. If sodic soils are to be treated, then the types of pre- and post-drainage treatments available and application rates to avoid loss of soil structure and land capability must be determined. Furthermore, the rehabilitation time for sodic soils using drainage and treatments is unclear. It is also necessary to alter the design of deep drains constructed in sodic soils to ensure stability. Shallower batters are suggested, but this has not been quantified.

Financial aspects

5. A generic economic evaluation concluded that to break even it would be necessary to reclaim/protect a strip extending between 25 and 90 metres on either side of a drain (depending on assumptions as to the frequency of drain maintenance and the applicable gross margins). The two most recent studies, Narembeen and Dumbleyung, exceed this criterion. A critical limitation of this analysis is the availability of crop yield responses that can be attributed to the impact of drainage.

4.3 Recommended further work

Priority

1. Develop an appropriate site test to assist with effective drain planning and design. The site test can be used to estimate the permeability of soil at a site, and possibly to detect the presence and connectivity of preferred pathway flow.

2. Construct a series of deep drains in different soil and landscape types, with pre-drainage watertable data. Conduct a thorough site investigation, including permeability estimates via auger hole method at each site and design the drain accordingly. Measure the flow and watertable drop at the site, and compare with those predicted using standard drainage theory with estimated soil permeability. Monitor the decay of the drainage structure and determine whether the auger hole method was an

4. From the existing and future data, develop a list of standard methods that should be used to monitor deep drains and determine the minimum necessary controls for WA conditions. Develop simple monitoring techniques (for example, the extent of sedimentation and the quality of drainage water) for landholders to use to improve the success and maintenance of their deep drains.

5. Quantify transmission losses along the constructed drains compared to evaporation loss, and their impacts downstream.

6. Improve the prediction of potential drainage discharge quality from pre-construction measurements of water chemistry, pH and EC. Investigate pH and EC of existing deep drains in the Wheatbelt, determine whether there is a spatial relationship, and whether it can be used as an indicator of drainage performance or potential discharge quality problems.

7. Develop and promote field tools for determining the level of sodicity of soil and required treatment.

8. Investigate the process of acid water generation in drains, impacts on sub-soils and drainage function and solutions to neutralise acid waters (capacity for soils to neutralise water in drains, downstream or with addition of amendments to drains).

Financial aspects

9. Evaluate costs and benefits of drainage systems. This must include intangible (non-market) factors, such as social and environmental costs, as well as opportunity costs. Compare case studies using standardised units, such as $/km or $/ha.

10. Compile an up-to-date list of costs for constructing and maintaining deep drains of different designs in different landscapes.

Lower-priority

6. Investigate existing deep drains with stepped batters for benefits and limitations in different soils and landscapes. Determine where stepped batters are most effective and develop preliminary best-practice design and maintenance. Construct a deep drain with stepped batters to test the best-practice guidelines and compare with a drain with straight batters.

7. Investigate existing drains constructed in sodic soils (high in sodium) for suitability of the drainage design and soil type. Develop best practice guidelines for drains constructed in sodic soils and construct a drain to test the design.

8. Develop a tool for contractors and landholders, which calculates design aspects such as drain spacing, width, and batter slope, from inputs such as soil type, permeability, depth, grade, depth to watertable.

9. Investigate the current best-practice design and maintenance of deep drains and see whether there is scope for modifications that reduce the risk of downstream impacts of the drains. The modified best practice would need to be field tested with deep drains constructed and managed in a range of soil landscapes.

2. *Poor understanding of the long-term hydrological and geochemical risks of disposal to natural sites:* The long-term on-site and off-site risk associated with sacrificial disposal sites beyond impacts on ecology (lakes, wetlands and drainage lines) is unknown. This gap relates to risks of disposing to sites where protection of the ecology is not an issue (degraded sites).

3. *Impacts of transmission losses from drainage system:* The effect of transmission losses from drainage systems on natural vegetation, particularly the effects on ecosystems where drainage/disposal channels traverse areas where the ground-water is below the channels. These losses need to be considered in relation to evaporative losses that would result in hypersaline recharge.

4. *Impacts of changes in surface water volumes and quality on estuaries.* The impacts of the "do nothing" scenario vs changes in discharge from engineering landscapes on estuaries is not known. Engineering may result in changes in the hydroperiod of the estuaries and interaction with coastal

Specific technical recommendations	Relevant engineering options
Determine range of impacts of acidic waters on streams/waterways How does the impact of discharge from engineering intervention compare with the impacts of acidic saline run-off and discharge from areas in similar sub-catchments with no intervention? What are the long-term consequences of disposing of acidic groundwater to natural disposal basins? How does this differ compared with the acidic saline run-off and discharge from areas in similar sub-catchments with no intervention?	Deep drains with acid flows (during base-flow) Groundwater pumping Deep drainage with significant base-flows, groundwater pumping schemes
Investigate impacts of non-acidic water disposal on natural sites Are the effects of non-acidic discharge to low-value natural disposal basins constrained to the basins? What are the long-term on-site factors that contribute to off-site problems? How do these factors compare with drainage from similar saline areas with no engineering intervention?	Deep drainage with constant baseflows, deep drainage with seasonal flows, pumping schemes
Improve decision tools to identify potential safe natural disposal sites Can a rapid appraisal system be developed to broadly determine the possible suitability of sites for safe disposal? Can this include a system to classify rivers, wetlands and lakes on the basis of sensitivity to change with further disposal (accounting for the trends in degradation pressures within the catchment)?	All

Specific technical recommendations	Relevant engineering options
Determine what sites would be suitable for disposal to modified natural basins and evaluate costs vs benefits. Can modified natural disposal basins be used to provide productive uses for salt water? What are the benefits relative to any short-term costs and long-term impacts? Can discharge be stored and released at opportune times from constructed evaporation basins?	Deep drainage and groundwater pumping
Audit characteristics of discharge water to provide better information on what alternative uses might be suitable for different parts of the wheatbelt..	

8. There are problems with the design and implementation of purpose designed surface water management systems for catchments using simplified methods. Traditional methodology for farm-based management of surface water is based upon rule of thumb and flow assessment methods that are not applicable to catchment-scale systems. In many cases the theory and physical basis that originally lay behind the numbers used in conventional designs have been lost in the act of simplification.

9. The functional basis of various engineering structures to manage water is not clearly established, which presents problems for pre-construction evaluation of designs within integrated management systems.

6.3 Recommended further work

1. *Develop WA specific design guidelines.* Guidelines for a range of scales (10 km^2, 100 km^2 and 1000 km^2) and catchment systems (eg Northern vs Eastern and South Eastern Agricultural Zones). Develop a tool box of approaches with implementation guidelines conforming with principles of Environmental Management Systems.

2. *Conduct detailed economic cost-benefit analyses of existing evaluation sites.* Improve financial justification for implementing surface water management within integrated systems by analysis of water management components and whole systems. Analyse total costs of catchment-scale deep drainage and surface water management systems and off-site impacts of each system.

3. *Evaluate integrated systems at catchment scales.*

    Evaluate systems in the context of farm practices. Carry out an audit of surface water management systems to provide base information on the long-term costs and benefits. Review and conduct a rudimentary assessment of the original 1950s soil conservation sites (where appropriate), Department of Agriculture sites and data, WISALT sites and of sites of recent work. Establish anecdotal links between surface water management, increases in productivity and reduction in degradation. Link this to recovery at catchment scales.

    Evaluate integration of water management in isolation and integrated with large-scale deep drainage systems.

    Improve information on runoff regimes for various landscapes and understanding of changes to these as a result of engineering intervention. This should include the influence of landscape heterogeneity on runoff-run-on characteristics of catchments.

    Evaluate systems in the context of Environmental Management Systems.

    Investigate the links between infrastructure protection, waterlogging and salinity. Infrastructure such as roads act as flow impediments that can increase salinity risk. Evaluate options for

4. *Improve modelling of catchment responses*

    Increase predictive power of existing models for at paddock, farm and catchment scales. Improve modelling capability at single bank scale for various slopes, treatments, and characteristic events.

    Integrate evaluations of surface water management systems to improve modelling of water balance in catchments. Provides capacity to evaluate the benefits of water management at catchment scales to ground-water recharge and salinity.

5. *Develop better economic, education and extension tools to demonstrate the economic benefits of integrated farm management and water harvesting systems.*

6. *Develop approaches to improve the adoption of surface water management systems*

    Accreditation

    Regulation and legislative tools

7 Concluding remarks

The reviews and discussions at the seminar and workshop highlighted the following critical points.

Site-specific investigation is needed to make decisions about engineering work and safe disposal sites.

1. It is not considered possible to compile maps to guide implementation of engineering works for use at farm-scales. Additional projects to characterise the different hydrogeological provinces in terms of the effectiveness of engineering work in managing salinity at farm scale will not substitute for the detailed site-specific studies and will only be a waste of resources. This is due to the variability of the hydraulic properties of the soil and the underlying water bearing formations in the Wheatbelt The wide range of values obtained from these studies for the water yield from groundwater via bores or drainage limits the transferability of data from existing sites to other parts of the landscape.

2. As with engineering options, it is not considered possible to compile maps of suitable safe disposal sites for use at farm and sub-catchment scales. Regional characterisation of safe disposal sites in natural rivers, lakes and wetlands is no substitute for detailed site-specific assessments which will be necessary to finalise whether a site can safely handle discharge water from engineering options. This is due to the variability of the eco-hydrological properties of natural systems, with is a consequence of the vegetation composition and the underlying variations in water bearing formations in the Wheatbelt (as highlighted above). The variety of natural ecosystems and current condition of these limits transfer of safe disposal criteria defined for specific sites to other parts of the landscape.

7.1 Beyond the scope of farm-scale engineering options

The following issues raised at the seminar or the workshop were beyond the scope of the reviews and investment planning for farm-scale engineering or safe disposal. In some cases these will be dealt within the regional drainage planning program or are beyond the scope of the Engineering Evaluation Initiative. In the latter case, they are recorded here in the expectation that there will be opportunities to address these in other initiatives.

Issues relevant to the regional drainage planning program

- Consequences of flow conveyance and linking of small systems between small systems.
- Connecting local scale drainage to regional drainage. What are the requirements for doing this?

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