



# Engineering our way forward through Australia's salinity challenge

By Thomas J. Hatton

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# ENGINEERING OUR WAY FORWARD THROUGH AUSTRALIA'S SALINITY CHALLENGE

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## Abstract

Salinisation of Australia's landscape has progressed at a rate and extent that significant built and natural assets are at immediate or imminent risk of damage or loss. The dominant national paradigm regarding our response to this challenge can be summarised as: if deforestation caused the problem, then reforestation (or new farming systems that behave hydrologically like forests) is the solution. This view underpins the majority of R&D and dryland salinity management investment, whether through community-based approaches such as Landcare or through the development and establishment of commercial silvicultural or agricultural alternatives. However, over the recent past a number of analyses have been published that reveal the general inadequacy of revegetation approaches for the protection of assets at risk to salinity, given the limitations of time, scale, economics, water yield tradeoffs and in some cases the hysteretic nature of the phenomenon.

While the revegetation paradigm apparently drives much of the public debate and intent, in practice there are a set of engineering approaches aimed at salinity control that have been developed and adopted, often extensively, that have not featured prominently in the sights of NRM agencies, NGO's or R&D providers. These approaches include surface water control, deep open groundwater drains, groundwater pumping, disposal basins, and regional arterial drainage and flood mitigation structures. It is apparent, at least in Western Australia (where the majority of Australia's secondary salinity is at present), that stakeholders with assets at immediate risk are electing engineering options to protect those assets. The collective failure of the technical community to direct adequate R&D and commercial investment in this direction has created a vacuum between need, intent and capacity. Expensive earthworks and pumping are going into the Australian landscape with highly uncertain on-site benefits and off-site impacts, largely without the participation of the engineering or scientific professions. Lack of adequate guidelines, design principles, and regional planning will likely lead to uneven performance, elevated risk, unexpected externalities and wasted resources. This paper argues that the technical community has a serious and pressing challenge to bring our minds to bear on the development and extension of proper engineering solutions to Australia's salinity problem. The commercial potential involved in some of these solutions is explored.

**Key Words:** salinity, Australia, engineering

## Introduction

*When one looks back over human existence however, it is very evident that all culture has developed through an initial resistance against adaptation to the reality in which man finds himself. – Carl Jung (1875 - 1961)*

The profound and enduring environmental changes wrought as a result of widespread land clearing for agriculture in Australia are due, in large part, to changes in underlying hydrological and hydrogeological processes on a grand scale

in space and time. These processes include rising groundwater levels, increased waterlogging and flooding, and salinisation.

The impacts of agricultural clearing (especially salinisation) extend across the continent, and are particularly severe and extensive in the southwest (the wheatbelt) of Western Australia, where over 1.8 million hectares is currently salt-affected (Anon, 1996) with up to 8.8 million hectares (33%) at risk by 2050. Associated with this risk is up to 1.8 million hectares of remnant vegetation, 80,000 hectares of important wetlands, 2665

kilometres of highway and main roads, 22,930 kilometres of minor roads, 2180 km of rail, and 29 townsites at risk of salinisation (National Land and Water Resources Audit, 2000). Some 450 species of plant are subject to extinction as a result (Keighery et al., 2001). All of the significant river systems in this region are in an advanced state of salinisation (Hatton and Ruprecht, 2001), with an associated elevated risk of extreme flooding (Bowman and Ruprecht, 2000). While to a large degree the generalities regarding preclearing and postclearing hydrology extend across southern Australia (c.f. Hatton and Nulsen, 1999), in fact the river systems of this region are quite distinctive and extrapolation eastward is problematic.

In this paper, the imperative for good engineering as the key to effective salinity management is established. The diverse engineering approaches available to address the impacts associated with rising watertables and salinisation are reviewed together with the current uncertainties associated with their design and implementation. A few examples of local and regional engineering schemes and their intent and effectiveness are reviewed. Current proposals for regional drainage schemes in Western Australia are discussed, as are commercial opportunities to exploit the saline effluent. Finally, the gulf between need and knowledge in engineering approaches to salinity management is underscored, as is the lack of R&D funding needed to close this gap. While the focus is mainly on Western Australia, the engineering imperative is national in scope and priority.

## **Why the Imperative for Engineering?**

The dominant paradigm regarding our best response to salinisation can be summarised as: if deforestation caused the problem, then reforestation (or new farming systems that behave hydrologically like forests) is the solution. This view underpins the vast majority of R&D and dryland salinity management investment, whether through community-based approaches such as Landcare or through the development and establishment of commercial silvicultural or agricultural alternatives. However, over the recent past a number of analyses have been published that reveal the general inadequacy of revegetation approaches for the protection of assets at risk to salinity, given the limitations of time, scale, economics, water yield tradeoffs and in some cases the hysteretic nature of the phenomenon (Hatton and Salama, 1999; Hatton and Nulsen, 1999; Salama and Hatton, 1999; Hatton and George, 2000; George et al., 2001; Hatton, 2001).

It is worth noting, however, that to the author's knowledge, only two Australian catchments have ever been recovered from secondary (dryland) salinisation, and that was with reforestation. The first of these is the Mundaring catchment, in which 8,100 ha of trees were ringbarked in 1903 to increase catchment water yield for supply to Perth and the eastern goldfields. The resulting salinisation of the catchment was recognised by 1909 and the deforested area was allowed to recover naturally with additional trees planted. The water quality improved thereafter. The other apparently recovering catchment is the Denmark, which had 18% of its vegetation cleared in the 1970's, with stream salinity doubling by 1985. Since about that time, over 60% of the cleared area was reforested with commercial plantations, and there is some indication that stream salinity may be declining (Hatton and Ruprecht 2001). The key features of these examples are (a) only a small fraction of the catchments were ever cleared, and (b) most or all of the cleared area was planted back to trees, and (c) these are coastal catchments with relatively high rainfall and reasonable hydraulic gradients. For the vast majority of Australia's salinity-affected land, these features do not or will not likely hold.

At the local scale, the re-introduction of woody perennials with summer activity is clearly effective in reducing groundwater recharge to pre-clearing levels. There is ample evidence that putting trees or shrubs (native and non-native) back into the landscape can achieve this result (Nulsen et al., 1986; Bell et al., 1990; Greenwood et al., 1992; Walker et al., in press). At the catchment scale, arguments based on the results of Hatton and Wu (1995) and Ellis et al. (1999) suggest that however trees are put back into the landscape, effective control of recharge will be achieved only at a leaf area index approaching that of the natural state, implying revegetation of most or all parts of the catchment. Hatton and Salama (1999) concluded that revegetation was unlikely to recover the Wheatbelt rivers from salinity. George et al. (2001) reached similar conclusions. Empirical work by George et al. (1999) indicated that the effect of tree plantations on groundwater levels is quite localised in most cases (i.e., the downslope impacts on watertables rarely extends more than a few tens of metres away from the plantation). In fact, Salama and Bartle (1995) point out that in such flat landscapes, the groundwater sink that can develop under a plantation (or remnant woodland) can cause a reversal of flow towards the trees with the potential to impact on their health through localised salinisation, and there is

evidence of rising watertables under remnant vegetation by this phenomenon.

In stating the above, it is important to recognise that each individual hydrological system has an inherent capacity to discharge groundwater without significantly raising watertables. Thus, there may be some sub-optimal leaf area index associated with a sustainable level of groundwater recharge (e.g., Salama et al., 1993). In general, however, the discharge capacity of salinisation-prone catchments is quite low (Hatton and Nulsen, 1999).

Revegetation of saline discharge areas is common, and commonly thought to enhance the discharge rate. The key features of the discharge enhancement strategy are the placement of trees in landscape positions in which (a) the groundwater is reasonably fresh, (b) the groundwater is reasonably close to the surface (< 3 m (Thorburn, 1997), (c) the aquifer has reasonable transmissivity and gradient, and (d) the saturated thickness of the unconfined aquifer is limited (<10 m). This generally precludes the planting of trees on saline discharge areas *per se* and restricts application to a limited fraction of affected landscapes in southern Australia (generally sand country). The lack of sustainability of trees at saline sites without sufficient periodic leaching of salts which otherwise accumulate in the root zone is well documented and modelled (Thorburn et al., 1995).

## Engineering Options

In discussing options to significantly improve the state of salinising catchments, it is useful to distinguish among the goals of reducing flooding, reducing waterlogging, and reducing salinity. The breadth of these approaches was identified in George et al. (1997) and George and Coleman (2001).

Davies et al. (1988) examined the potential options for flood mitigation including retarding basins, levees, road crossings and drainage to reduce or increase peak flows. These authors concluded that most soil conservation structures and treatments only have a mitigating effect on small to moderate floods and are less effective in controlling major flood events. There was no inexpensive control method identified for major flooding in wheatbelt catchments, although retarding basins located on main drainage lines can be effective in controlling major floods. There is the potential to create detention basins by raising the outlets of natural lakes and thus effectively mitigate risk, but this is untested in

practice. These basins may create a temporary impoundment, which releases water in times of "diluting high flows", but not floodflows.

The options for reducing inundation and waterlogging are similar to flood mitigation, although the emphasis is more likely to be on surface water management, water harvesting, and options to increase discharge. The installation of shallow interceptor drains has been promoted to accelerate the removal of surface waters and to some extent drain shallow perched aquifers (McFarlane and Cox, 1990; McFarlane et al., 1990; Cox and McFarlane, 1995). In a more regional sense, surface water control aimed at keeping runoff off the valley floors where it would otherwise provide localised recharge to saline groundwater systems is crucial for salinity management now that the valley floor sediments have extensive saline watertables at or near the surface (Coles and Ali, 2000). When successful, these drains reduce (perched) waterlogging and thus lead indirectly to recharge control, however they can serve as points of localised recharge to deeper aquifer systems (Hatton et al., 2001).

Engineering options addressing salinity *per se* need first to distinguish between recovering *land* versus *streams* from salinisation. Where the objective is the latter, often due to water resource or instream biodiversity values, the struggle is generally to keep accessions of salt out of the stream. Where the object is the former, engineering focuses on the protection of terrestrial assets (infrastructure, agricultural land, biodiversity) and may not have the additional constraint of minimising salt loads in stream. In either case, salinity engineering involves (a) a form of enhanced discharge (drainage) and (b) a form of disposal of the effluent.

The protection of river water quality usually involves the interception of saline groundwater discharge (surface or subterranean) and its diversion to disposal (storage) basins, or the limitation of upstream withdrawals that would otherwise dilute downstream waters. The most notable Australian example is the Salinity and Drainage Strategy of the Murray-Darling Basin Commission. This Strategy involved the construction of four salt interception schemes and upgraded two State schemes, resulting in a net reduction in average salinity at Morgan of 61 EC units (Murray-Darling Basin Commission, 1999). Management of flows to increase dilution in low flow periods provided an additional 35 EC reduction. A new joint program of salt interception schemes, costing an estimated \$60 million, commenced in 2001 to deliver at least 46 EC at Morgan, and potentially up to 61 EC, over

the first seven years. Disposal of drainage effluent associated with these large interception schemes, and the numerous smaller drainage schemes associated with irrigation areas, is into storage basins; there are some 270 such basins of various scales in the Basin. The design criteria (Walker et al., 2000) for these structures are aimed at minimising the return flow of salt into the underlying groundwater systems and thence back into the river. In Western Australia, in the only significant water resource catchment earmarked for salinity recovery, the Collie, salt interception pumping and the diversion of surface saline discharges have been identified as part of a necessary combination of methods aimed at achieving a mean inflow salinity of less than 500 mg/L into Wellington Dam by 2015 (Mauger et al., 2001)

In most of Western Australia, however, the main assets at risk are associated with land salinisation, with the stream systems and their salinity a much lesser concern. This had led to a wide variety of approaches proposed and adopted that enhance discharge of saline groundwaters to locally lower watertables and reduce such impacts, with disposal generally into natural playas or directly into natural streamlines. Groundwater pumping and deep open groundwater drains to reduce land salinisation is widely practised at scales from managing local discharges (Bettenay, 1978; George and Frantom, 1990; Salama et al., 1994) to regional systems (Otto and Salama, 1994; Ali and Coles, 2001).

These methods include surface diversions of saline surface water around natural assets like Lake Toolibin, siphons and relief wells, and large-scale groundwater pumping exercises such as those associated with the Rural Towns Program. Above all other approaches, however, is the adoption of hundreds of kilometres of deep, open groundwater drains, often in linked networks that accrete significant discharges into the natural drainage lines (e.g., Ali and Coles, 2001). For instance, the linked drainage system in the Wakeman catchment, consisting of over 80 kilometres of groundwater drains, discharges some 400 tonnes of salt and over 6 ML of groundwater each day (Ali and Coles, 2001). Significant proposals for other regional-scale drainage systems ("arterial drainage") are currently before the community and government, including schemes for the Mortlock, Beacon River, and the upper Blackwood River.

## **The Gap between Practice and Knowledge**

The technical community in Western Australia is trying to catch up with knowledge and advice required to underpin the evaluation and design of drainage. This is driven by the widespread perception that such works are both effective and necessary for those stakeholders unfortunate enough to have their assets located in saline discharge areas (Drainage Taskforce, 2000). This situation was recognised by a recent review of salinity commissioned by the WA State Government, which acknowledged the increasingly important and urgent contribution to salinity management that engineering options need to make (Frost et al., 2001). This Task Force also acknowledged that there is much community criticism over the lack of government leadership and support for engineering approaches, as well as a serious dearth of technical knowledge that should underpin the debate.

The reluctance to support or advance engineering approaches to salinity management is based on a set of perceptions that included (a) negative economic evaluations of the costs and benefits, (b) limited expectations for the area treated based on presumed low regolith permeabilities, (c) anticipated serious environmental impacts of effluent disposal. However, the current rate of adoption of salinity-oriented engineering works by individual landholders, regional groupings of landholders and by government suggests that either economic foolishness is widespread or that early cost-benefit analyses under-valued the assets at risk and the worth of protecting them.

The second of these perceptions (the limited extent of influence) may be based on presumed hydraulic conductivities based on bulk texture of the regolith. It is only relatively recently that understanding has developed of the extent and character of relatively conductive paleochannels under the western Wheatbelt. The near-surface material in saline discharge areas is often quite heavy, and the usual experience with such material is that saturated hydraulic conductivities are very low, resulting in only a limited radius of impact away from drains. This is, at times, the case. Equally so, however, the effective conductivity can be remarkably high and the effective zone of drainage can apparently extend hundreds of metres; this is due to the presence of extensive, highly conductive and connected soil features that allow water under saturated conditions to effectively by-pass the bulk soil (Ali and Coles, 2001). Identification of those situations where such conductivities offer

significant benefits to drainage schemes is currently beyond our technical understanding or powers of prediction.

Above all other uncertainties are those associated with the impacts of disposal. In Western Australia it is likely that, for many, concerns are based on transference of information on impacts from elsewhere, not on any local investigation or analysis. In the case of the Wheatbelt, confusion can arise over a concern for instream water quality more properly associated with streams with either a water resource potential or a downstream aquatic environment that will receive, and be significantly salinised as a result of, effluent discharge upstream (e.g., the Murray River). Natural or enhanced flows arising in the bulk of the eastern and central Wheatbelt of Western Australia do not regularly reach the lower, fresher portions of the river except at times of great floods (when dilution is high); the upper, highly affected portions of the catchments are largely disconnected from the reaches for which instream ecological concerns are properly held (Hatton and Ruprecht 2001). The flatness of the bulk of the wheatbelt river systems leads to historic, and amusing, arguments regarding catchment boundaries, the putative connections between systems, and even which way water flows. It is essential to appreciate that these river systems do not all flow as one linked system except in the most extreme events. The smaller rivers may not flow for many years, and then either a major summer event or a wet winter will lead to flow events. The larger rivers cease flowing in the wheatbelt regions during summer, except when extreme tropical cyclonic events or severe thunderstorm activity lead to heavy, intense summer rainfall. In "normal" years, winter rainfall is not enough to move water continuously through the catchment from the extreme eastern and southern boundaries to the coast. In the Blackwood catchment, the Coblinine River and Dongolocking Creek are two headwater streams draining to Lake Dumbleyung. This section of the river has very low grades, approximately 0.17 m/km. The combined drainage enters Lake Dumbleyung, thought to have overflowed into the Lower Blackwood only three times since the 1870s. The chains of (mostly dry) lakes form a series of local storages that in most years are not overtopped by the surface flows from upstream.

A recent example (from Hatton and Ruprecht 2001) highlights this feature of Wheatbelt hydrological discontinuity. Following significant rainfall in the Avon River catchment on 21-22 January 2000 (remnants of Cyclone Steve), high river levels were experienced from Lake King to Perth. The rainfall was in excess of 100 mm in a

large area from east of Hyden to Beverley, with the highest reading being 172 mm east of Corrigin. Much of the mainstream Avon River upstream of Northam and the Salt River upstream of Yenyenning had flows in excess of 150 m<sup>3</sup>/s and below Northam in excess of 200 m<sup>3</sup>/s. Peak flow in the Swan River at the Great Northern Highway was 312 m<sup>3</sup>/s. The flood had an average recurrence interval of 1 in 20 years for summer events. The volume of water reaching the Swan River during the event was 270 GL (the approximate Swan-Canning estuary volume is 50 GL). Downstream tributaries of the Swan River like Ellen Brook and the Canning River had contributed almost nothing. The Avon River carried 1,200 kT of salt, 800 T of nitrogen and 35 T of phosphorus from 23 January 2000 to 1 March 2000 (Muirden 2000). The flow-weighted salinity in the Avon at Walyunga averaged 4,500 mg/L TDS, total nitrogen 3.0 mg/L and total phosphorus 0.12 mg/L. The salinity of the Swan River at the Narrows Bridge *reduced* from its normal 24,000 mg/L TDS prior to the event to 4,400 mg/L at peak flow. Note that the salt load over these five weeks was almost equivalent to the mean annual load in more normal years estimated by Viney and Sivapalan (2001). This event was the first time that the Lockhart subcatchment had flowed significantly in summer for forty years; even during winter, this system does not usually generate any flow that reaches the Avon.

The key point that follows from this example is the fact that effluent accumulated in the normally disconnected chains of lakes in the extensive salt-affected headwaters will likely only reach the lower reaches of Wheatbelt rivers under circumstances that hugely dilute their salt load. The presumed serious impact of enhanced drainage would seem to vanish under these circumstances. Ultimately, however, such determinations need to be based on technical knowledge and analyses that are, at present, lacking.

Progress in providing technical support is being made, but slowly. A few *dryland* drainage projects have been reviewed, mostly in Western Australia (George, 1985; George and Nulsen, 1985; Speed and Simons, 1992; Otto and Salama, 1994; Salama et al., 1994; Ferdowsian et al., 1997; Coles et al., 1999). General guidelines are now available from the Department of Agriculture at:

<http://www.agric.wa.gov.au/environment/land/drainwise/options/index.htm#eng>.

Guidelines such as these are not yet underpinned by sound and local analysis and monitoring, and can at this stage only provide the broadest advice. The WA Salinity R&D Technical Committee has identified engineering research along these lines among its highest priorities, and the WA State Government has set aside some \$4M toward evaluating and demonstrating engineering approaches to salinity management, although that program's launch has been postponed indefinitely at the time of writing.

It is worth noting the current phase (1998-2003) of the National Dryland Salinity Program has some 45 projects in which R&D investments have been made; only two of these are related to engineering approaches (NDSP, 2001). One of these projects (*Evaluating the efficacy of engineering options*), had the aims of collating and assessing information, literature and guidelines on engineering techniques to manage dryland salinity, documenting and analysing Australian case studies to identify in which regions engineering options may have potential (Sinclair Knight Merz 2001). This project did not generate design criteria, but rather it identified the considerations needed in electing an engineering approach. This project also produced an extensive review of engineering options and their use for salinity management in Australia and overseas. The second project (*Evaluating impacts of deep drains on crop productivity and the environment*) aims to evaluate surface drainage impacts on crop yield, surface salinity and waterlogging and assess catchment scale impacts of drainage, including changes in timing and amount of salt loads/concentrations as well as flood peaks. The project intends to deliver design recommendations and policy for surface drainage in salt-affected landscapes.

The lack of sound technical underpinning to salinity management through engineering extends beyond the knowledge gap. Few such endeavours, at least in Western Australia, engage the services of the engineering fraternity in the design and implementation of works using *current* knowledge and best practice. Generally, this onus falls to drainage contractors outside of this fraternity or remains with the landholder. The risk inherent in such an approach is compounded by the current lack of a comprehensive vision for Western Australia's major drainage basins and their management. As drainage proposals are put forward and as drainage goes in (often *ex officio*), there is no regional design or constraint to which the community is expected to adhere or consider. The cumulative impacts downstream are not currently considered by government, at least not in a form underpinned by any technical

analysis or model. The onus of liability, maintenance, and management of drainage systems is remarkably unclear.

## Some Commercial Opportunities

To date, engineering designs have been aimed at disposal of an unwanted resource. As George and Coleman (2001) pointed out, agricultural clearing has resulted in a potential water resource of some 1000 GL/yr of saline (>30,000 mg/L) groundwater in the WA Wheatbelt. Aquaculture, salt (and mineral) harvesting, desalination and energy production are all large-scale possibilities, although there remain technical and economic challenges in the full exploitation of the resource. PPK (2001) reviewed a variety of these saline resource options in the NDSP OPUS project.

Beyond those options listed above, three examples of the potential commercial use of saline effluent are currently topical in WA. The first of these, already under development, is the disposal of groundwater pumped from under the town of Merredin via a desalination plant, with the concentrated brines disposed of in a lined evaporation basin. This project is significant in that the pumping was necessary and justified on the basis of infrastructure protection in its own right. Further justification arises from the fact that Merredin is supplied with fresh water from distant coastal catchments at great expense; desalinated water can compete on an economic basis under these circumstances.

Recently, CSIRO announced a plan to develop the means to extract a wide variety of minerals from saline groundwater (<http://www.csiro.au>). The proposal involves the creation of new industries to extract valuable raw materials from the groundwater, using natural evaporation and solar energy. For instance, ordinary salt can be crystallised out of groundwater by evaporation, then used to make chlorine, hydrochloric acid, sodium hydroxide, sodium metal, soda ash, sodium bicarbonate and table salt. Among these are substances that can be used in the processing of titanium and zirconia. Once the salt is removed the water, known as "bittern", still contains magnesium, potassium, sulphates, boron, strontium, bromine, iodine and other useful compounds. These range from epsom salts, worth \$400-800 a tonne, to fertiliser ingredients, cement ingredients and many other chemicals more valuable still. Bittern can be directly used in the mining industry as a dust suppressant.

The CSIRO plan envisions the widespread recovery of salts from saline evaporation ponds. A network of solar-powered desalination plants

and energy-storage ponds across the Murray-Darling Basin could then convert highly saline waters to fresh water for local communities and value-added chemicals for industry. The plan also links into the development of major titanium and mineral sands industries in the Basin, based on the existing \$13 billion resource and using value-added salts in the processing. Titanium, in turn, can be used to make corrosion-resistant parts for desalination plants. CSIRO estimates that an early stage industry adding value to Murray-Darling salt could be worth \$200 million a year.

Another grand proposal to commercially exploit large quantities of saline drainage water involves its collection and transport by pipe to the eastern Goldfields (Kalgoorlie), where the demand for water (even saline water) for mineral processing is great and currently unsatisfied. This idea must compete with alternative proposals to bring seawater up from the southern ocean, which would bring with it none of the environmental and economic benefits that using Wheatbelt drainage water would bring.

These commercial opportunities to exploit saline groundwater have not received the same degree of prefeasibility investment that innovation in more traditional regional primary industries has enjoyed. Given the imperative to drain for asset protection from salinity, the investment in developing this resource should have a much higher priority than it currently enjoys.

## Discussion

Hatton and Salama (1999) concluded that neither revegetation nor engineering was likely to recover the *rivers* of the Western Australia Wheatbelt from salinity. However, it is now widely recognised that engineering can be effective in reducing the impacts and extent of *land* salinisation on infrastructure and natural assets, as well as in keeping land under crops. It is also generally acknowledged that even if the long-term strategy is to revegetate, the immediate protection of land and assets can require engineering. Government and dozens of private landholders are already employing such practices across Australia.

There is a lot of groundwater drainage being constructed in Western Australia's wheatbelt, mainly on private land with private funds. The on-farm effectiveness of these engineering works varies, but to date has been subject only to modest research and development efforts to improve effectiveness and efficiency. There are serious concerns expressed by some downstream

stakeholders regarding the negative impacts of disposal waters. In the absence of the evaluation of these broader aspects, it is difficult to advance a serious debate on the winners and losers, and who pays, associated with engineering.

It is unlikely that the full complement of hydrological functions can ever be restored with revegetation, even using the original genetic material established at the fullest possible scale. Some hydraulic and hydrochemical characteristics of the system may be irreversibly changed. The most pessimistic assessment suggests that Australia's southern landscape will not be renewed until the next geologic orogeny or a large change in climate. Nevertheless, there is an ethical and practical compulsion to bring to our landscape as much of the original ecohydrologic function as possible. In this regard, we can only wish those pushing forward the development of effective silvicultural and farming alternatives (e.g., the CRC for Plant Based Management of Salinity) the best of luck.

Where we cannot do so, then we are similarly compelled to develop and use appropriate technology to protect assets at risk under the changed ecohydrological regime, and to exploit this new regime to our advantage. In this regard, the role of good engineering design and practice is central. Substantial and urgent investment in the requisite R&D is needed to underpin such engineering. Perhaps the most important first step along this path is to get governments and the wider community to accept that our salinising landscapes cannot be put back to what they were, and that to a great degree our way forward involves a large measure of managing, and exploiting, salty water.

It is a cruel irony that we have salinity problems in these catchments precisely because they are in the process (in the most global sense) of *freshening*. More salt is coming out of the landscapes than is now going into them from the atmosphere, and if we take the longest possible view, at least the stream salinity will eventually (in thousands of years perhaps) self correct even if we do nothing. But in the process, we would be leaving behind much of the natural and human heritage we value.

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## Author Biography

Dr Tom Hatton is a Senior Principal Research Scientist with CSIRO. His research focuses on issues of land management from the perspective of providing water to people and the environment. Dr Hatton's research has ranged across bushfire science, mining reclamation, ecohydrology, environmental water allocation, and salinity. Dr Hatton obtained his Ph.D. from Utah State University shortly before immigrating to Australia in 1986. Following a post-doctoral position in mathematics with the University of New South Wales, he joined what is now the CSIRO Division of Land and Water in 1988. He served on the Board of the CRC for Catchment Hydrology 1998-1999. He is Officer-in-Charge of the CSIRO Land and Water Floreat (Western Australia) Laboratories and serves on the Operations Committee of the National Dryland Salinity Program. Dr Hatton has made significant advances in the measurement and modelling of transpiration, catchment hydrological modelling, the understanding of ecosystem dependence on groundwater, and the management and future of our salinising landscapes. He serves on the Editorial Review Boards of *Tree Physiology* and *Land Use and Water Resources Research*. In 1999, he received the Inaugural W.E. Wood Award for

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