River Murray salinity management and irrigation

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Background - the basin scale salt accumulation and mobilisation processes

Over recent geological time saline groundwater has accumulated across a vast area stretching from Shepparton to the Murray mouth. This is a natural process that results from low rainfall regimes and very high evaporation rates. It is not residual seawater as was once suggested; it is merely the concentration of salt from rainfall (typically 7mg/L) through evaporative processes over the past few hundred thousand years. Native vegetation extracts as much water as it can whilst leaving the drainage to flush the residual salt. The Mallee tree is particularly effective with its very deep rooting system, leaving less than 1% as regional groundwater recharge input but all of the rainfall salt. The exposure of groundwater to evaporative discharge in saline depressions (salt lakes) further concentrates salt in the groundwater which slowly migrates westwards across the basin. Groundwater regimes with salinity concentrations close to seawater (35,000mg/L[1]) and now prevail over much of the southern basin.

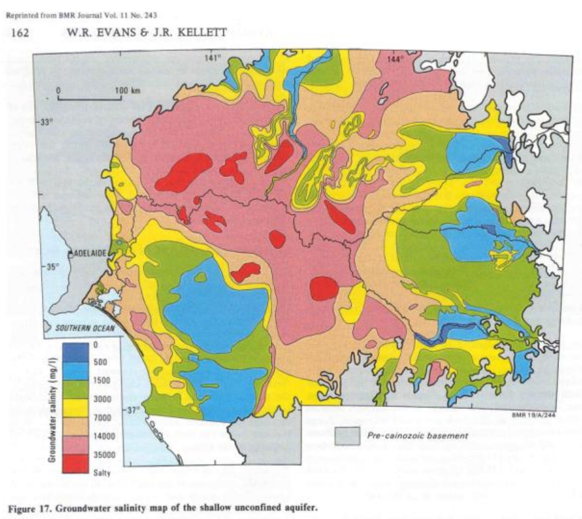

Figure 1 Groundwater salinity map of the shallow unconfined aquifers in the Murray Groundwater Basin

Source Evans and Kellett BMR 1988.

The Murray groundwater basin covers about a quarter of the Murray Darling Basin and extends from Echuca and Narrandera in the East, Wilcannia in the North, down to Goolwa at the Murray Mouth. The river confluence shown in the centre of the diagram is the junction of the Darling and Murray Rivers.

The Murray Darling groundwater basin is a natural trap for salt. Some 2,000,000 t/y arrives with the rainfall and about the same amount is exported, albeit erratically with the higher flows. This is probably a happy coincidence, as it is recognised that the northern portion of the Murray Darling Basin is accumulating salt whereas the southern basin is exporting salt. Almost zero salt was exported during the decade of drought!

Generally the river systems in the upper basin remain relatively fresh. However salinity in the lower Murray (the Mallee region), in particular below the South Australian border, can approach critical levels. The base salt load delivered from upstream of Swan Hill is exacerbated by natural and induced groundwater accessions further downstream. The salt accessions are erratic both temporally and spatially. There is a delicate balance in the interface between the groundwater regime and the river regime. The river varies between being a ‘losing stream’ and a ‘gaining stream’. There are occasionally significant freshwater lenses that have kept the more saline groundwater away from the river interface.

Irrigation and drainage development - mobilising additional salt!

Irrigated crops are sensitive to the build-up of salt in the root zone and it is essential for irrigators to leach the salts through over irrigation. Unfortunately, in the early days, very poor irrigation systems led to the build-up of groundwater mounds over the natural saline regional groundwater beneath irrigation areas which in turn mobilises salt towards the river and its floodplain.

Irrigated crops vary in their sensitivity to rootzone salt build up which is related to the salinity of the source water. High instream salinities prevail throughout Sunraysia and Riverland and down to the Lower Lakes. Production losses are dependent upon the short and long-term salinity regime. A

[1] Note 1EC unit (micro-siemen/cm electrical conductivity) approximates 0.6 mg/L

study undertaken on behalf of Land and Water Australia in 2005 to 2007 suggested the relationship in fig 2, which illustrates the potential annual cost of lost production over a growing season for the current range of plantings in the Mallee region from Swan Hill to Wellington in SA. The actual value of lost production is dependent upon the leaching efficiency i.e. how effectively salt is removed from the whole of the root zone.

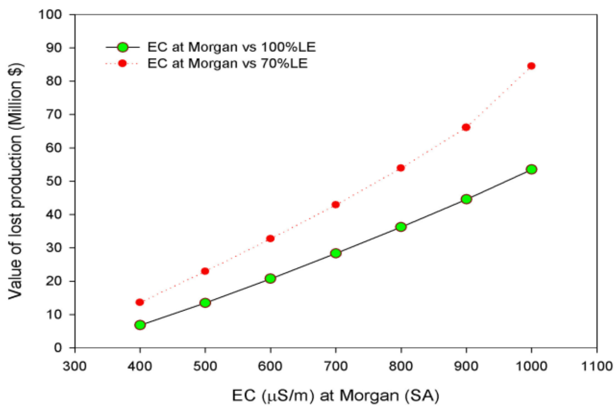

Figure 2 Value of combined Mallee region horticultural crops lost production at increasing river salinities - Source Dr Tapas Biswas

Leaching and root zone drainage is essential but generates increased recharge to the groundwater system and consequently mobilisation of salt to the river.

However, in the early years of irrigation, excessive leaching generated shallow water tables which were ameliorated with subsurface drainage systems which often discharged to floodplain evaporation basins. These were sources of salt mobilisation due to being held above local river levels.

In addition, these poor irrigation practices resulted in the build-up of groundwater mounds adjacent to the Murray Valley, which in turn mobilise the natural salt to the floodplain and the river. Furthermore, the pattern of irrigation development since the introduction of water trade resulted in ribbon developments along the river corridor which further exacerbates this aspect of salt mobilisation and floodplain and wetland degradation.

Institutional Responses - public policy

Salinity in the lower Murray was first recognised at the time of negotiation of the River Murray Water Agreement (1914). The water sharing arrangements included an allowance for maintaining water quality for downstream users through dilution. Water quality was formally introduced into the River Murray Waters Agreement in 1982 (Meacham 1984).

It was the sensitivity of irrigation to high saline groundwater tables and high salinity source water that triggered the next institutional responses. In the Riverine Plains (Shepparton Tragowel Plains, Kerang) saline water tables rose 10 to 20 m eventually affecting crop production. Several hundred thousand hectares of low-lying pasture production was affected with estimates that this could rise to 1,000,000 ha over 20 to 30 years. (GHD 1985)

In the lower Murray (in particular the South Australian Riverland) crop yields were greatly affected by high salinity of the source water. In 1967, during drought, some 30% of the permanent plantings were lost due to excess salt. This brought the salinity issue into focus and resulted in intensive hydrogeologic investigations to better understand the salt mobilising processes and to identify opportunities for mitigating salinity. This led to a program of works to mitigate salinity. In particular, drainage diversion schemes (eg the Noora scheme) and many salt interception schemes.

Initially, these works and measures were undertaken at the state level; however, with the initiation of the Murray Darling Basin Ministerial Council (MDBMC) in 1985, a more collaborative arrangement was established through the Salinity and Drainage Strategy (S&DS1989). This generated a ‘pollution trading’ regime whereby the states became accountable for future decisions that increased salt mobilisation to the river, whilst jointly contributing to a program of works that more than offset such increases including those from natural sources and past actions.

A salinity audit for the whole of the Murray Darling Basin (MDBMC 1999) suggested that the salinity regime is likely to deteriorate further over the next 20 to 100 years. This resulted in the Basin Salinity Management Strategy (BSMS2001 to 2015) and triggered the Federal Government National Action Plan for Salinity and Water Quality (NAPS&WQ 2001 to 2008).

An important feature of both the S&DS1989 and the BSMS2001 is the emphasis on economically rational decision-making. Investments in salinity mitigation are only made when they are economically justified based on the costs of salinity to downstream water users.

Salinity target and registers

The S&DS1989 instituted a set of salinity registers which accounted in detail for the individual actions that either reduce salinity or increase it. In the context of achieving a salinity target at Morgan of less than 800EC for 95% of the time[2], it was agreed to pursue a program of works to reduce average salinity (at Morgan) by 80 EC, whilst accommodating actions which would exacerbate salinity by +30EC. It is important to observe that the salinity registers actually record the dollar value of cost effects to downstream users. The salinity strategies are driven by economics. The use of average EC reduction at Morgan is only an indicator.

In 2001, the MDBMC in recognising that the target had still to be achieved whilst additional salt mobilisation was acknowledged, agreed to a further program of works generating 46 EC of salinity credits whilst accommodating a further 30 EC of exacerbating actions.

Since 1989, there are now some 93 entries on the salinity registers 57of which record actions that exacerbate salinity and 38 of which record actions that mitigate salinity. By 2010, a 61 EC salinity mitigation program was completed and the Morgan salinity target was achieved.

Analysis tools - surface and groundwater modelling

With the improved conceptual understanding and the need to quantify the salt mobilising processes to support the salinity registers, there has been a very significant effort to develop analytical tools to assess the impacts of actions which affects salinity, including both hydrologic and hydrogeologic numerical models.

The MDBA MSMBigMod hydrologic model now effectively synthesises flow and salinity and the associated cost to water users over the period 1971 to 2011 and is used as the basis of the registers. This hydrologic model is informed by more locally based irrigation drainage or groundwater models which simulate the effect of irrigation development or salt interception schemes on a reach by reach basis.

MODFLOW style numeric groundwater models are now commonly used and replace an earlier rapid assessment tool (SimRAT). Nevertheless there is still a disconnect between the groundwater models and the observed local dynamic salt accessions driven by the transient interface with the floodplain and river. Floodplain salt processes are very complex.

Further information on the groundwater models is available through many publications and technical reports available on the MDBA and agency websites.

Salinity mitigation

Salinity mitigation is currently achieved through the diversion of irrigation drainage waters or groundwater interception. It necessarily involves the transport and disposal of saline waste water. This is a topic worthy of a whole discussion paper. In the context of this current paper and the limited space available the following points are worth noting:

- ***Drainage Diversion:*** Schemes such as the Noora scheme in SA which diverts drainage water from Berri and Renmark; to the out of valley basin at Noora Similar schemes occur throughout Sunraysia and upstream in the Riverine Plains around Shepparton and Tragowel Plains, Barr Creek downstream of Kerang and in the Murrumbidgee and Murray irrigation areas in NSW.
- ***Salt Interception:*** Some 13 salt interception schemes have now been constructed which collectively divert more than 500,000t/y; the first were at Mildura Merbein and Buronga, followed by schemes at Rufus River (Lake Victoria), Woolpunda and Waikerie, Mallee Cliffs, Loxton, Bookpurnong. There is even one on the Darling upstream of Bourke.

Irrigation development and practices

The investigations under the S&DS1989 identified poor irrigation practices combined with poor location of new irrigation developments as a major contributor of additional salt to the river. In particular, throughout the Mallee region, groundwater mounds have built up above the saline regional groundwater and by 1999 (MDBMC Basin Salinity Audit) had doubled the Mallee region

[2] The target "<800EC for 95% of the time" refers to the 1975 – 2000 hydrologic Benchmark Sequence after taking account of agreed actions as defined in the MDBA hydrologic models). It is not a 'real time' target!

natural local salt loads to the river from around 800t/d to 1600t/d with a potential for further increases to 2400t/d over the coming decades.

Fortunately, improved irrigation practices offer a win-win opportunity for both the irrigator and the natural resource manager. Over the past 15 years a very significant effort has been made to foster improved irrigation practices through research and practical on-farm education. Irrigators have been able to reduce water consumption by 25 to 50% releasing water for further development through the water trade market. This has resulted in a reduced recharge (root zone drainage) to the groundwater system ranging from 50 mm per year to 250 mm per year. The groundwater mounds are starting to recede. The groundwater modelling suggests that the irrigation induced salt accessions throughout the Mallee region would reduce very substantially putting off the need for further sanity mitigation investments possibly indefinitely!

The validity of those modelling predictions will be very interesting to observe.

Future Salinity Management

In the context of undertaking a mid-term review of the whole basin salinity management strategy, studies were undertaken to identify the need and opportunities for future salinity management action. As mentioned above, the need for validation of the benefits of improved irrigation practices was one of the major outcomes. In addition, the recognition of the value of increasing and better managing dilution flows is also a priority. In fact, it was essentially a no-brainer! However, until there is a resolution of how best to manage environmental flows such a debate has been placed on the backburner. The key issue is the timing of environmental flow management to achieve a compromise between improving the ecology whilst maintaining optimum water quality for human use. Remember, the current philosophy of salinity management is driven by economic priorities.

The Basin Plan, Salinity and Water Quality Plan

Increasing salinity regimes are one of the triggers for the federal takeover of the Murray Darling Basin and the development of a Draft Basin Plan.

In 2007, the previous collaborative arrangements for the management of the Murray Darling Basin were abandoned and the Australian Government Water Act 2007 established the Murray Darling Basin Authority. At the time of writing this paper a draft Basin Plan is open for public comment. The plan includes provision for a Basin Salinity and Water Quality Plan that appears to adopt the strengths of the earlier arrangements including the continuation of the salinity registers and the adoption of salinity targets. In addition, the draft plan suggests a salt export target of 2MT/a averaged over a ten-year period.

Conclusion

The focus of this paper is on the relationship between irrigation and salinity. Over the past several decades salinity management has resulted in greatly improved salinity regimes within the lower Murray which has very substantial benefits to the irrigation sector. At the same time, irrigators have greatly improved their irrigation practices resulting in less sensitivity to salinity, significant water savings and reductions of groundwater accessions to the river and its floodplain. Transparent public policy has been particularly successful, through the collaborative inter-jurisdictional arrangements to address the salt mobilisation potential and mitigation opportunities. The salinity target at Morgan of <800 EC for 95% of the time has been achieved. The future basin plan will include water quality as a priority.

The foreseeable downside arises from the likely consequences of climate warming and drying. The current predictions would suggest that, even with an aggressive basin plan, it will be very difficult to maintain salinity regimes at the current tolerable levels.

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