Evaluating impacts of drainage discharge from engineering salinity schemes on water and soil chemistry of downstream river systems of the wheat belt of Western Australia

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Introduction

Reduced evapotranspiration and increased recharge to shallow and deep groundwater occurred as a direct consequence of clearing (Allison and Hughes, 1983) causing the watertables to rise continuously. The remobilisation of salts stored within the regolith as a result of rising watertables, and the development of localised perched systems, has resulted in extensive areas of the wheatbelt being affected by seasonal waterlogging and secondary salinity (McFarlane *et al*., 1992). To date some 1.8 million ha in the wheatbelt have been impacted by primary or secondary salinity (Ferdowsian *et al.,* 1996). The problem of soil salinity and waterlogging threatens both the productive agricultural land and the rural infrastructure that support it. The annual cost of the consequences of dryland salinity in the wheatbelt of WA is up to several hundred million dollars.

The relatively rapid spread of salinity over the last 20 years has re-focused attention on the use of deep drainage and other engineering interventions for the mitigation of dryland salinity and waterlogging. The total length of these drains in the wheatbelt now exceeds 15,000 km, and they now exist in almost every catchment but are generally scattered, isolated, and without extensive regional linkages. Most have been constructed without any engineering design or construction principles nor with any formal evaluation of their on-site and off-site impacts. A recent study evaluated the on-site impacts of a deep open drain near Narembeen, WA, on groundwater levels (Ali *et al*., 2004a), soil salinity (Ali *et al*., 2004b), crop productivity (Hodgson *et al*., 2004), and quality and quantity of flow (Ali *et al*., 2004c). Most of the drainage systems in the wheatbelt, discharge into natural creeks and rivers. The off-site impacts of drainage discharge on the downstream ecology and hydrology of creeks and rivers were largely unknown and had not been previously studied. This study, the first of its kind in the wheatbelt of WA, evaluated the impacts of drainage discharge from engineering interventions on the water quality and soil chemistry of downstream natural streams and rivers. The objectives were to:

- evaluate the impacts of drainage discharge on water quality of downstream natural streams; and
- evaluate the impacts of drainage discharge on the surface soil surface chemistry of downstream natural creeks and streams.

Material and methods

To evaluate the downstream impacts of drainage discharge four drainage systems were selected, being Narembeen, Dumbleyung, Tammin and Pithara. The largest among these was Narembeen deep drainage of around 100 km length completed during 1998 and 1999. The drainage discharge from this system is highly acidic and saline, especially during summer, and carries heavy metals at significant concentration levels (Ali *et al*, 2004c). At Dumbleyung, the drainage system of around 3.5 km total length was installed during 2001. The drainage discharge quality is similar to that from Narembeen. The deep drainage at Pithara, of around 18 km length, was completed during 2004. The drainage discharge from this system is less acidic and saline than Narembeen. At Tammin, a trial of groundwater pumping to lower the watertable is discharging into a local creek. The installation was completed during 2005 and the discharge from this site is also acidic and saline. At each of the drainage systems, the drainage or pumped water is discharged into natural streams, although all have been impacted by secondary salinity.

Two sites were selected for each drainage system, one on the creek immediately downstream the drainage outlet into the creek hereafter called the "treated" site and one in the nearby untreated creek hereafter called the "untreated" site. All together eight sites (four treated and four untreated) were selected across the wheatbelt. At each of the treated and untreated sites two locations ("upper" and "lower") were selected. The treated streams are defined as those that receive drainage or pump discharge from an upstream drainage system and are named as "treated" sites in the remainder of this report. The streams selected in the nearby untreated catchments are named "untreated" sites in the remainder of this report.

The instrumentation at these sites included in-stream probes measuring electrical conductivity (EC), pH, depth and temperature, and automatic water samplers for continuous monitoring of water quality, and weather stations and rain gauges to monitor weather patterns and rainfall. To assess whether releasing drainage discharge into streams has any impact on the water quality and stream bed chemistry, bi-annual water and stream bed sampling was carried out at all four locations at each of the four sites, for chemical analysis, during February, September 2005 and December 2006. At each location and sampling occasion soil samples were collected from two depth intervals, being 0–100 and 100-200 mm depth. The samples were analysed for aluminium (Al), silicon (Si), Iron (Fe), Arsenic (As), Lead (Pb) and Nickel (Ni).

Results and discussion

This study clearly showed the adverse impacts of drainage discharge on the water quality of the receiving streams. The electrical conductivity (EC) of the treated streams was almost always higher than that of the untreated systems. The higher EC at treated systems was due to the release of highly saline drainage water into these streams. Similarly the pH of the treated systems was lower than that of the untreated systems except at Pithara where it was similar at treated and untreated sites. Figure (1) shows higher pH at treated sites than untreated sites at Narembeen. Significant rainfall events produced runoff and dilution of the drainage water reduced EC and raised the pH of the mixed surface and drainage waters during and immediately following these events. Extended dry periods on the other hand caused the EC to further increase and pH to further decline due to strong evaporation and the small fraction of surface water in the drainage water.

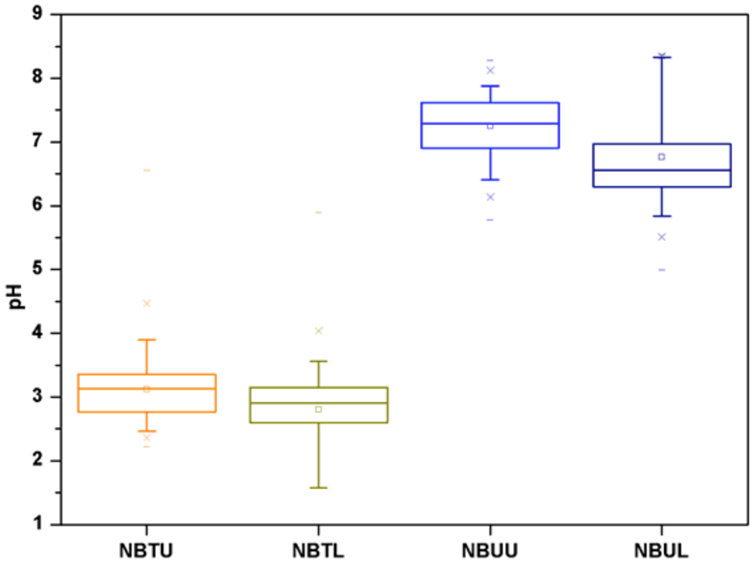

Figure 1 The box plots of pH at the treated and untreated sites at Narembeen. (Note: NB: NaremBeen; T or U (third): Treated or Untreated; and L or U (last): Upper or Lower location)

Buffering capacity of the natural surface water and streams helped improve the pH of the mixture as it travelled downstream at Dumbleyung and Tammin. Spot sampling of the treated system at Dumbleyung suggested that, at around 5 km downstream of the confluence, the pH of the treated system rose above 7 and was very similar to that of the untreated system. It is unknown for how long the buffering capacity of the receiving stream will hold and maintain the pH of the mixture at neutral levels. The drains at Dumbleyung and the pump at Tammin produce relatively small quantities of discharge that the receiving creek systems are currently neutralising; if these drainage systems are lengthened, or the receiving streams lose their buffering capacity, adverse impacts are likely to become more significant. The buffering capacity of the natural system was less visible at Pithara and Narembeen either due to an inherent lack or it was already diminished at those sites. The collected data clearly showed the adverse impacts of drainage discharge on water quality of the downstream surface water systems.

The concentration of heavy metals in the water was higher at treated sites than at untreated sites. The pH of the mixture of surface water and drainage water (or drainage water alone when there is no surface water) controls the concentration of heavy metals in the solution. When the pH of the mixture drops blow 5, many heavy metals become available in solution in free elemental form. When the pH rises above 5 most of these heavy metals are removed from the solution by geochemical reactions binding them with the sediment.

At Dumbleyung the concentration of heavy metals in the mixture of surface and drainage waters reduced as it travelled downstream. The buffering capacity of the natural system at this site helped raise the pH of the mixture, and geochemical reactions bound heavy metals with the solid matrix. At other sites this was less evident. Factors such as length, age and effectiveness of the drainage systems, weather conditions and buffering capacity of the natural systems might have some influence on the scale, magnitude and extent of these impacts.

Except at Tammin, no impacts of drainage discharge into natural streams on the soil chemistry were observed in our soil sampling on three different occasions. Higher concentration of heavy metals at the treated site at Tammin was most probably due to the different chemistry of the pumped groundwater from significant depth (50 m) and the minimal dilution as there was very little water otherwise in the stream. Due to the dry weather, surface runoff was not sufficient to dilute the low pH and highly saline pumped groundwater which impacted the chemistry of surface soils at the treated site. It is also likely that the stream bed soil had a low buffering capacity. These impacts were not evident at the other sites. There was some evidence to suggest that the impacts of drainage on the stream bed soil chemistry are starting to appear in the treated system at Narembeen. They are not yet statistically significant but it is suspected that these impacts will grow and become significant when the natural system loses its buffering capacity.

Conclusions

At most drainage systems evaluated the disposal of drainage discharge into the natural creeks increased the salinity level in the treated streams in comparison to nearby untreated natural creeks systems. Similarly the discharge of drainage water into natural creeks/streams also impacted on their pH by lowering it significantly. A lower pH (< 5) in turn helped bring heavy metals into the solution in free elemental form potentially harmful to both flora and fauna of natural creeks. At some treated systems (Dumbleyung and Tammin) however EC and pH of the mixture of surface and drainage water improved as it travelled downstream due to the buffering capacity of the natural system resulting in reduced concentration of heavy metals in the solution. The rainfall and extended dry periods also impacted significantly on both pH and EC of the treated systems. Factors such as size, age and effectiveness of the drainage systems, weather conditions and buffering capacity of the natural systems are likely to have influence on the scale, magnitude and extent of these impacts.

Except at Tammin, the impacts of drainage discharge on the stream bed chemistry of these systems were not evident on our three sampling dates. Higher concentration of heavy metals at the treated site at Tammin was most probably due to minimal dilution effects and different chemistry of pumped water from depth. Due to the dry season surface runoff was not sufficient to dilute the low pH and highly saline pumped groundwater and prevent impacts on the chemistry of bed soils. There is some evidence that impacts on the stream bed chemistry of the treated system in Narembeen are starting to appear. They are not yet statistically significant but it is suspected that these impacts will grow as the system loses its buffering capacity.

We conclude that the impacts of discharging drainage water into the natural creeks on the water quality of these downstream natural creeks/streams are evident. Therefore the uncontrolled and continuous discharge of drainage discharge into the natural creeks should not be allowed to avoid the downstream environmental impacts.

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