Protecting high-value assets from salinity in the Avon Richardson catchment, Australia

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Introduction

It is recognised that salinity in Australia is much harder to tackle than was widely appreciated a decade ago. There is also acknowledgement that tighter targeting is needed and a shift from a threat-based to an asset-based approach (Adamson 2007, McAlinden *et al.,* 2003, Sparks *et al.,* 2006). The Salinity Investment Framework (SIF3) was developed to help regions make more cost-effective and defensible decisions. SIF3 has been trialled in the North Central Catchment Management Authority (NCCMA) region in Victoria (Ridley and Pannell, *this conference* and www.sif3.org). Part of SIF3 involves identifying high-value assets, assessing the threat of salinity, and the feasibility and cost-effectiveness of protection. To support SIF3, robust biophysical information is required.

Work by Ridley and Pannell (*this conference)* identified the highest value assets in the North Central CMA region which can be used as a short-list for detailed work to assess whether protection is feasible, through planting of deep-rooted perennials (native vegetation or lucerne) or engineering. The work reported assesses the technical requirements and financial costs of protecting assets in the Avon Richardson catchment (371,000 ha, 350-600 mm/yr rainfall, over 85% under annual species), one of four river basins in the NCCMA region, using a linked biophysical surface and groundwater model.

The aims of the work reported in this paper are to assess the:

1) groundwater extraction volumes required to protect assets

2) response times of protecting assets using engineering or planting - native vegetation or lucerne

3) indicative costs of asset protection using engineering or planting options

Methods

Identification of high-value assets. The highest value localised assets were identified as follows:

(a) Compiling a list of assets based on their official government recognitions in international (e.g. Ramsar listing), national, state and bioregional classifications;

(b) Conducting workshops with key stakeholders and community members to identify assets of highest value to the local community;

(c) Consulting local experts;

(d) Verifying draft asset lists with CMA staff and other stakeholders of the regional bodies.

Modelling approach. The modelling approach used to assess the on-site and off-site impacts of intervention strategies to protect assets uses a combination of a suite of farming system models linked into a catchment framework with connection to a distributed, multi-layered groundwater model. The model known as the Catchment Analysis Tool (CAT) explicitly links farming system models to account for land use, topography, soil type and climate with a fully distributed multi-layer groundwater model, in this case MODFLOW (McDonald and Harbaugh, 1988). The CAT framework (Beverly *et al*., 2005; DSE, 2007) estimates impacts of interventions using paddock/farm scale biophysical models and a lateral flow model, integrated within a catchment framework.

Groundwater conceptualisation and model attribution. A three-layer MODFLOW groundwater model was developed based on available stratigraphical delineation. The uppermost unconfined layer represented the amalgamation of the Pliocene Sand Aquifer (Parilla Sand) and Quaternary Alluvium (Shepparton, Coonambigdal, etc.) aquifers. Underlying this system was the confined/unconfined deep lead (river gravel aquifer) layer representing the Calivil Formation and extends from the upper parts of the catchment to beyond the north of the catchment. The third layer represented the Palaeozoic basement geology and was considered to exist across the entire model domain. This aquifer represents the basement aquifer of the region. The groundwater model adopted a uniform grid of 100 m resolution and weekly time-steps. Surface hydrology and drainage features were also incorporated into the model. Figure 1 shows the unconfined extent of each aquifer.

Model calibration. The groundwater model calibration criteria were based on matching representative groundwater bore hydrograph levels, mapped discharge extent, depth-to-watertable estimates and regional baseflow volumes. Representative bores totalling 135 in number were selected based on duration and frequency of monitoring, screen depth and location within the catchment.

Extraction volume required to protect high-value assets. The calibrated groundwater model was used to estimate the daily extraction volume required to maintain the watertable beneath each asset to a depth of 2 metres under equilibrium conditions. This was chosen based on the assumption that a depth of less than this results in land salinisation. This estimate was derived by representing the extent of each asset as a surface drain with a base depth that was set at surface elevation less 2 metres. The inflow volume to each drain represents the extraction volume under current land use.

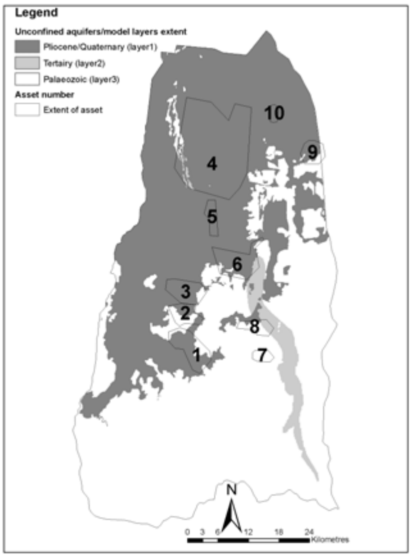

Figure 1 Location of high-value assets in relation to groundwater extent and conceptualisation

Intervention extent and response time. The process for identifying the area needed to be planted to trees or lucerne in order to reduce the watertable beneath each of the ten high-value assets was:

a) Derive catchment recharge estimates for (i) current land use, (ii) native vegetation, and (iii) lucerne;

b) Systematically replace in blocks of 100 ha the recharge estimates of (a)(i) with either (a)(ii) or (a)(iii) whilst maintaining (a)(i) recharge in the rest of the catchment. This generates approximately 3,710 recharge data sets each for (ii) and (iii);

c) Run the groundwater model for each of the 3,710 recharge data sets and identify those 100 ha blocks that affect each high-value asset. The collection of blocks that affect each asset defines the capture zone for (a)(ii) and (a)(iii);

d) Replace the recharge estimates of (a)(i) with either (a)(ii) or (a)(iii) in the capture zone (for each asset) whilst maintaining current practice recharge (a)(i) in the rest of the catchment. Rerun the groundwater model to derive the response time to establish a new equilibrium state. This requires 10 runs each for (a)(ii) and (a)(iii).

Costs of asset protection. The costs of protecting assets were based on estimated establishment costs and recurring annual costs. For revegetation, lucerne establishment was assumed as $250/ha and revegetation as $650/ha (direct seeding), with this cost applied over the whole capture zone (the actual zone of intervention is the capture zone minus the area of existing wetland and existing perennial vegetation which was not available at the time of writing). The opportunity costs of changing land use were assumed to be $50/ha/yr for lucerne production and $200/ha/yr for native vegetation. Converting opportunity costs to present value figures over 20 years (5% real discount rate) resulted in figures for opportunity costs of $623/ha for lucerne and $2492 for trees/ha for trees. For engineering, establishment costs used were installation of pumps (assumed as $10k for up to 3ML/day; $20k for 3-5; $50k for 5-15; $100k for 15-30) plus construction of a lined evaporation basin ($100k/ha for 7ML/ha/year disposal). Annual pumping costs were assumed as $5k/year/ML) plus salt disposal costs ($30/t at assumed salinity concentrations of 26,000 mg/L for Donald, Buloke, Wooroonook and Chirrup; 12,000 mg/L for York Plains, Avon Plains, Batyo Catyo; 10,000 mg/L for Cope Cope, Box and Jesse swamps). Establishment and annual costs for vegetation and engineering, plus the annual opportunity costs associated with each option were converted to present value using a 5% real discount rate over 20 years. We acknowledge the estimates are oversimplifications. The political acceptability of disposal options was not considered.

Results

Model calibration. The root mean square error between observed and simulated potentiometric head at representative observation bores in each modelled aquifer ranged between 0.94 and 0.97. The calibrated model had a scaled rms error of 3.85% and an absolute residual mean of 3.50m which was considered acceptable with respect to the scale and hydrogeological complexity of the catchment.

Extraction volume required to protect high-value assets. Ten high-value assets were identified, 5 of which were considered as very high in value (4 wetlands and the township of Donald). Three assets (Lake Batyo Catyo, Wooroonook lakes and Chirrup swamp) were high in value and two (labelled moderate value) were added after discussion with local experts (Table 1). The asset capture zone areas ranged from 515 to 23,048 ha. Extraction volumes required to maintain a watertable depth to 2 m beneath each asset are also reported. They reflect the size of the asset and the watertable depth before pumping. The highest extraction volume was 29.9 ML/day to protect Lake Buloke (largest asset and already affected by salinity) and the smallest was 1.6 ML/day for Box Swamp (small asset). Apart from Lake Buloke, the 4 most highly-valued assets had extraction volumes ranging from 3.0 ML/day for York Plains to 12.2 ML/day for the Cope Cope lakes. On a weighted area basis, the York Plains was estimated to require 8 times less extraction volume per ha of capture zone than Avon Plains lakes.

Intervention extent and response time. The extent of the capture zones (eg. recharge areas) required under different landuse change scenarios to reduce the watertable beneath each asset are also summarised in Table 1. The corresponding response times range from less than 1 year to 94 years, with longest time for Box Swamp, the only asset in direct connection with the bedrock aquifer. The variability in response time for assets in connection with the alluvial aquifer (reported as layer 1 in Table 1) is caused mainly by the relative size of intervention and aquifer transmissivity.

Table 1 High value asset groundwater capture area under trees and lucerne

ID	Location	Area of asset (ha)	Value of asset based on SIF3 Ranking	Aquifer and layer	Extraction volume ML/day	Area weighted extraction volume ML/day per1000ha	Capture area (ha) trees	Capture area (ha) for lucerne	Response time for vegetation options (years)
1	York Plains	3868	Very high	1	2.98	0.77	8331	8431	50
2	Avon Plains Lakes	2069	Very high	1	10.65	5.14	8682	8482	40
3	Lake Batyo Catyo	2946	High	1	5.63	1.91	8003	7903	55
4	Lake Buloke	23048	Very high	2	29.88	1.30	27189	26890	67
5	Donald	1263	Very high	2	4.27	3.38	5487	5387	< 1
6	Cope Cope Lakes	4274	Very high	2	12.17	2.85	10380	10180	40
7	Box Swamp	843	Moderate	3	1.59	1.88	8037	8042	94
8	Jesse Swamp	1456	Moderate	2	8.21	5.64	10764	11064	43
9	Wooroonook	1792	High	1	7.07	3.95	2066	1966	< 1
10	Chirrup Swamp	515	High	1	2.21	4.28	3775	3780	< 2

Costs of asset protection. Protection of assets is expensive. Present values of protecting assets using lucerne ranged from $1-23 million, using trees $6-85 million, and $10-252 million using engineering, with Lake Buloke always being the most expensive. Using York Plains as an example, lucerne, vegetation and engineering option present value figures were $7 m, $26 m and $20 million. Note that the costs for perennial vegetation costs have been over-estimated by the amount of the area occupying the lake beds plus existing vegetation. This will be corrected in the full paper we write from the work.

Discussion

Confidence in the hydrological results. The groundwater conceptualisation was based on the work of Ryan (1992) and subsequent work by Phil Dyson. There is considerable uncertainty in the location of the regional deep lead aquifer north of Cope Cope which casts doubt over the veracity of economic analysis, particularly with respect to engineering in the lower catchment (assets 4, 5, 6, 9 and 10) where assets are conceptualised as being in connection with the deep lead. Given this uncertainity the results appear realistic and consistent with existing knowledge. Simulated versus observed bore hydrograph comparisons are reasonable given the uncertainty associated with digital elevation data and existing groundwater pumps at Donald are extracting 0.6 ML/day which is in the range predicted by the model (0.58 ML/day to maintain the depth to watertable at 1 metre; note that only the 2 metre figures are reported in Table 1). Modelled response times also appear reasonable, being within the limits of expected response for the identified groundwater flow systems (0-100 years). The next steps needed are external review of the results and consideration of investment in protection of one or more assets with pre-treatment pump testing and establishment of appropriate monitoring networks. This work has collated and integrated spatial and temporal data sets as well as conceptualised and modelled the groundwater system in a more comprehensive and integrated way than previously available.

Feasibility of protecting high-value assets: Despite the uncertainties associated with the groundwater conceptualisation, it is clear that asset protection is very expensive. Based on the large costs associated with asset protection, and the limitations in the data used (only broadscale data available to estimate capture and intervention zones around localised assets), it is important for local drilling to occur to assess watertable depths and responsiveness of groundwater on any asset being considered for investment. Based on modelled estimates of response time and costs of intervention, the York Plains appears the most cost-effective asset to protect. Using the York Plains example, planting to lucerne is cheapest, but assessment as to whether soil types are suitable and farmers amenable is needed, as well as the need for monitoring and periodic re-sowing. The pumping assessments used to underpin the engineering assessments have the highest uncertainty. The social and political considerations of engineering, especially the acceptability of 143 ha of evaporation basins estimated as needed to protect York Plains to dispose of the salt may be hurdles. Native revegetation, although the most expensive, has low ongoing costs compared with lucerne (which will need sowing every 10 years or so), plus unquantified biodiversity, amenity and carbon sequestration benefits. Any decision about the cost of asset protection must consider the trade-offs between available budget, response time, on-going costs, biodiversity benefits and groundwater disposal.

Conclusion

CAT modelling has identified and differentiated the impacts of intervention options for key assets. The high costs of protection are sobering. Although the economic assessments are unlikely to be accurate, it is clear that the cost of asset protection is large. Despite the uncertainty associated with the hydrogeology of the lower catchment, the work has value in demonstrating how numerical modelling of landscapes and groundwater systems combined with economic analysis can provide a basis for informed discussion about asset protection, which has not occurred previously in Victoria.

Acknowledgments

We thank Lindsay Ezard, Geoff Park and Phil Dyson for support and comments, the North Central CMA for sustained interest and DSE, DPI and CRC Salinity/Future Farm Industries for funding and support.

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