Modelling the Environmental Processes

in large saline wetlands in Western Australia

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Abstract

Western Australian wetlands are dominated by large saline playas that are more often dry, only filling through episodic rainfall events. The relatively freshwater wetlands are typically only found along the coastal fringe. The larger saline wetlands typically have a high proportion of endemic species that are not found elsewhere. These plants and animals have adapted to a suite of hydrological and chemical characteristics that are increasingly been changed due to the mobilisation of salt and water in the catchments. The changes have been brought about by climate changes, farming practices and active ground water pumping by the resource industry.

The awareness of the diversity and importance of these wetland systems is increasing with time, but it is also recognised that irreversible changes in wetland function and loss of species will occur in the short term.

This paper will outline a short-term management option for assessing whether a proposed change will have a significant impact on the wetland's primary processes. These processes have been identified as hydro period, salt concentration, salt load, ionic composition, and nutrification, within the context of the perceived conservation value of the wetland.

Introduction

Throughout the wheat belt and goldfields there are a large number of wetlands. Some of these wetlands cover an immense area over many thousands of hectares. A number of the larger wetlands are in the northeastern goldfields, exceeding 50,000 hectares in area, and dominate the landscape. Whereas most lakes seem to be superficially similar there are significant differences between them. Most of these differences arise from the processes that form and maintain the lakes in the landscape. The most obvious processes being groundwater and surface flows, meteorology, soil types and land use in the catchment. Less obvious is the historical perspective such as the sequence of flooding and aridity over the eons.

It has been found that playa features display equilibrium with contemporary fluvioaeolian processes (Killigrew and Gilkes, 1974). In other words, flooding frequencies shaped and orientated playas. In Western Australia, most playas have characteristic lunette fields and strand lines of lakes, indicating that current lakes are perhaps only 50% the size they were at the onset of the last dune building phase (< 20,000 BP), for example Lake Toolibin and Taarblin (George and Dogramaci, 2000).

Like most wetlands in Western Australia, the goldfield wetlands don't fall into the European concept of a lake. Unlike wetlands in the wetter regions, there is no surface discharge to the sea. As a generalisation nearly all wetlands are 'terminal' in that they do not flow over land to another lake. An exception may be Lake Raeside, which at times acts as a number of distinct lakes but at other times as a 'river' but even this long chain of lakes does not discharge into the sea. Most uniquely the lakes are most often 'dry' with small areas of the main playa wet by incidental rainstorms.

Importance of saline wetlands

The lakes in the goldfields are important if only because they form a significant part of the landscape. They are an important feature of the hydrological landscape, with the catchments being relatively small. They act as important reservoirs during episodic flood events for both salt and water flowing out of the catchment and onto the playas. Present calculations suggest that the playas act as a sink for salt with the bulk of the water evaporating to the atmosphere. There is little evidence of water and salt flowing out of the lakes over land. During drier periods, evaporation is the dominant mechanism, reducing the local groundwater levels and causing a steep ground water and salinity gradient in the local area of the lake. The lunettes provide both well-drained and saturated areas that may have a high or relatively low salinity.

The episodic wetting and drying nature of the wetlands allows for a high degree of biological diversity. For instance, the groundwater gradient and presence of ancient lake sediments allows for a proliferation of small wetlands on the edge of the larger lakes. These wetlands are more likely to have a lower salinity than the main playa during wet periods as the salt tends to be flushed into the adjacent playa. As a result the small adjacent lakes support a different suite of animals and plants than the main playa. Most lakes have distinct vegetation zones around the fringes of the lake, which is thought to reflect the local drainage pattern dominated by the wetting and drying of the lakes.

The large range of niches allow for a high biological diversity in a small area. During the extended dry periods, the lake playa is the habitat for many terrestrial species such as spiders that use the playas as large collectors. Dunnarts, birds and lizards in turn predate the spiders and other insects. During wet periods the lakes support large numbers of algae, invertebrates and crustacea that in turn support significant bird populations. The many islands form relatively safe nesting sites for birds visiting during wet periods. The smaller lunette lakes around the larger playas often have a low enough salinity to support tadpoles and other species that would not normally be found in saline lakes.

The biological diversity has not been well documented but it is anticipated that any taxonomic study of a goldfield's lake will turn up undescribed species or species well outside of previously known ranges. For instance, a recent study by CALM on wheat belt lakes included spider species as part of the collection. Information at the start of the study started with a hundred odd species likely to be found in wetlands but ended with a collection of over 500 hundred species, many of which were previously undescribed. This is true for Lake Minigwal that at times seem to have a covering of spider webs. The biodiversity of the goldfields is not well known and any attempt to describe the wetlands using biological functions is thwarted by the lack of knowledge.

The wetlands in the goldfields serve an important function in maintaining the hydrological balance of the catchment and support a significant biology that is composed of species that are largely unknown.

Why are the playa lakes there?

George and Coleman (2001) sums up the general accepted geological processes that are common to most large playas. Playas occur in arid environments where the groundwater is shallow. They appear to be initiated at a point of impounded surface flow (such as could due to differential compacting of sediments and or geological barriers). They experience deflation following denudation (due to phases of aridity and salinisation), there remains a supply of sediment, regular inundation (prevents vegetation colonising the areas) and there is sufficient erosive capacity for its continued removal (particularly wind).

The major lakes in the goldfields generally follow the major palaeochannels but often the main playa is displaced to one side of the channel. This has led many people, including the author, to suppose that the palaeochannels are important to the origin and maintenance of the large lakes. Whereas this is still possible, it is also likely that the playas and palaeochannels co-occur as features of the lower part of an ancient catchment, and in our time frame has little impact on each other. Whatever the relationship, the playas have accumulated large amounts of sediment and salts washed from the catchment over a long period of time. There is little opportunity for these solids and dissolved solids to migrated further than the large playas.

What are the key processes needing protection?

Coleman and Meney (2000a) considered the following key processes as critical to the maintenance of wetland biological communities:

1. wetlands operate within, and depend on, their natural fluctuating salinity range. That is, many biota require the lower end of the salinity range to germinate and breed. A change in the distribution of high and low salinity levels is likely to be reflected in a shift in species composition. Therefore, both the upper critical thresholds, and the lower critical thresholds, need to be understood on a temporal basis.
2. wetlands operate within, and depend on, their natural fluctuating hydroperiod range.
3. the natural diversity values of secondary saline wetlands is likely to vary from wetland to wetland, depending on other variables such as hydroperiod change, surrounding habitat and original salinity status. In many cases, the loss of fauna will reflect degradation of vegetation assemblages, both within and surrounding the wetland.

The key physical parameters in the <u>processes</u>, <u>characteristics</u> and/or <u>functions</u> of a natural wetland are:

Water
Salt
Ionic Composition
Nutrients

The argument is made that maintaining the status quo of the above wetland parameters best protects the biological diversity. Any change to these wetland parameters will change the physical characteristic of the wetland and that changes to the wetland function will have an unknown effect of the biological diversity. This led Coleman and Meney (2000a) to argue that the most cost and time effective method of evaluating any proposed change to a wetland is to estimate the proposed change from the wetland's baseline status.

One aspect of the saline wetlands that has not been well documented or discussed in the literature is that the biological communities in the playa lakes rely on the surface environment. So that although the groundwater movements are critical to the salt and water balance in the lake as are all of the other parameters, the important interface is the surface of the lake or what may be called the biological skin of the wetland. This terminology is more appropriate for the wetlands of the goldfields as they do not have a significant water body for most of the time and the dimension of the biological activity is mostly in a thin surface layer. The surface conditions are determined by a number of parameters that include

- Evaporation
- Rainfall
- Surface runoff
- Groundwater levels
- Soil types within the catchment, and
- Landuse.

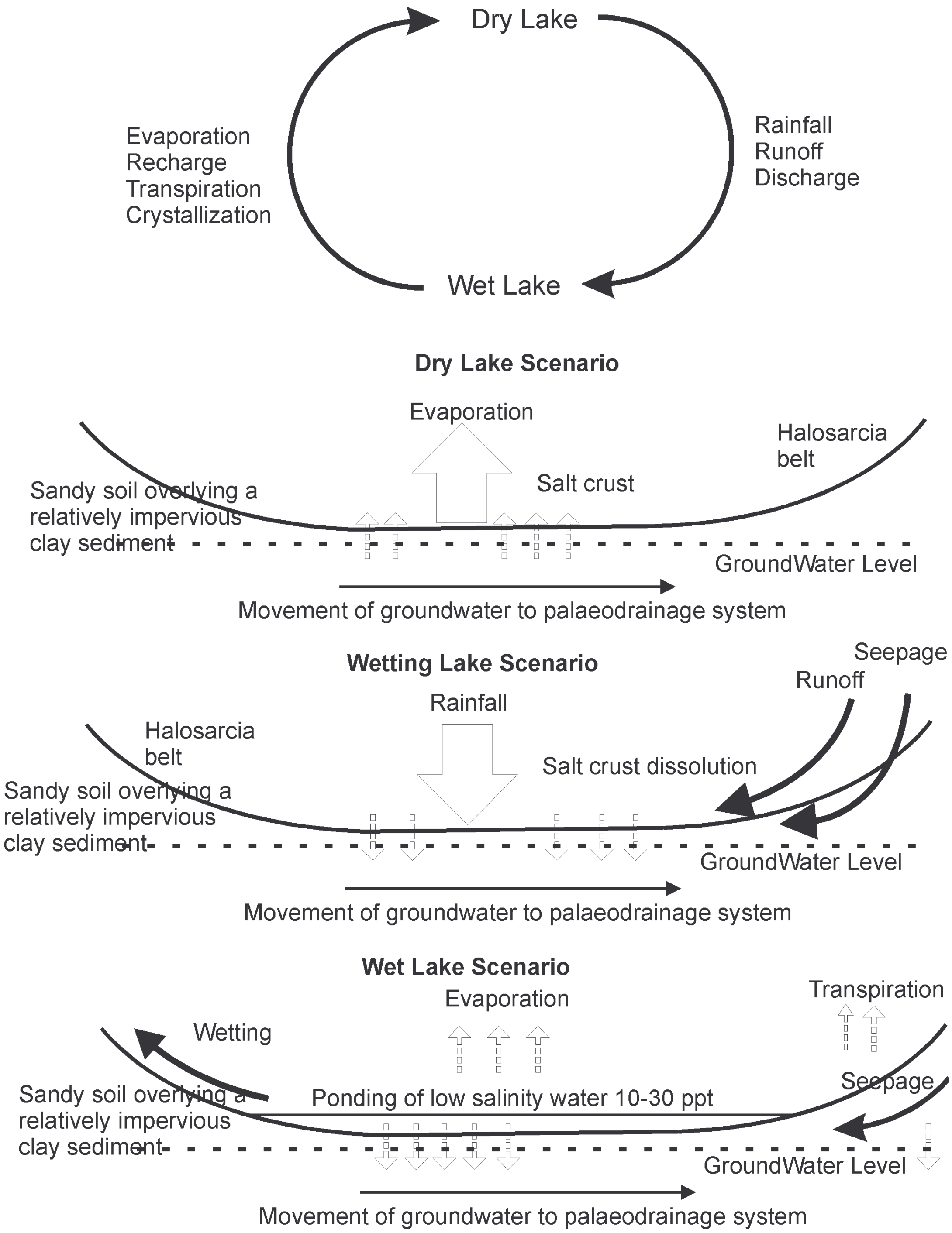
Most of these can be influenced directly or indirectly by a number of human activities such as mining discharge, infrastructure, bore draw down, grazing, roads and causeways.

Modelling some of the key processes

It is not possible to model all of the key parameters mentioned by Coleman and Meney (2000a). For instance nutrient concentration can only be determined by measuring the background levels and comparing them with that is being proposed in the discharge. Ionic composition is another key parameter that is difficult to model. This parameter is best dealt with by comparing the discharge water and the background concentrations of major ions with standard concentrated seawater at the same salinity. Salinity, salt load and hydroperiod are parameters that can be modelled, and given the complexity of the environment it is often best to model them to gain a better understanding of the changes being considered.

The salinity of the biological ‘skin’ of the playa lakes has all the attributes of a chaotic or fractal phenomenon (Gleick,1998). These attributes include an underlying change with a feed back mechanism (discharge, recharge, and evaporation) and a temporal pattern. A conceptual model was constructed of the processes that would impact or influence the surface of the lakes. An obvious feed back pattern is changing evaporation rates with salinity and presence of salt crust, and the presence or absence of a water body. In the terminology of chaos theory the small basins on the lake playa serve as ‘attractors’. The value of recognising the chaotic nature of the surface salinity is to identify the variability of salinity on the surface as an intrinsic function of the lakes and their biological systems. The fact that the system is chaotic in nature makes it very difficult to model, although it has been found that linear models are still useful.

Figure 1 Conceptual Model of Lake Processes



A mathematical model was developed by *actis* Environmental Services to gain some insight to the changes that might be expected when a discharge is made to the surface of a large playa lake.

1.1 Model Description

In order to understand the implications of groundwater pumped from mine sites to lakes, a mathematical model of the lake's surface hydrology was developed to assess temporal changes to the hydrological and salt balance. Model inputs comprise evaporation, surface runoff, rainfall, seepage and the expected mine discharge characteristics.

Discharge onto the lake playa will spread out and form a very shallow water body of quite considerable size that will change with the vagaries of the wind. Predictions of the inundated area based on the calculated volume of the water body can only be considered highly approximate. This in turn influences the accuracy and stability of gross evaporation and seepage calculations within the model.

It should also be emphasised that the model is based on a number of important assumptions as described below:

- Seepage characteristics are assumed to be consistent and uniform over the entire area of the lake playa. Measured permeability has actually ranged from 4mm/day to 0.036mm/day (D. Blandford pers. comm.).

- The interaction between surface and ground water is modelled in one direction only (recharge from surface water to groundwater). This is likely to be valid under most circumstances, as the mine discharge would create a head of water that drives groundwater recharge. However it is known that some areas of the playa receive natural groundwater discharges from surrounding areas. In fact it is believed that the shoreline vegetation depends on this phenomenon.

- The assumption also is that the groundwater aquifer has the capacity to accept additional recharge of salt and some water without changing any groundwater flow characteristics. For lower rates of mine discharge this is probably a valid assumption, and any lateral movement / changes in the groundwater beyond the limits of the surface ponding would be minor. For a large discharge that will have an impact on a significant area of the lake this assumption becomes suspect and changes in groundwater level and salinity beyond the surface water body may be environmentally significant both at the time of the discharge and at a later date.

- The rain falls equally over the entire catchment and that the fall is reflected by a single point source in some cases where that information is available, and annual averages for a regional centre where it is not.

- The salt load into the catchment is equal to that estimated by Hingston and Gailitis (1976) and that the equivalent of one year's salt fall washes into the lake every year.

- The catchment runoff is based on an algorithm tested on more temperate catchments in the wheat belt that uses historical rainfall (Coleman and Meney 2000c) and has been calibrated against major rainfall events that were known to fill major lakes in the goldfields.

These issues and assumptions are acceptable if they are known and it is understood that the model is only meant to provide comparisons of key environmental attributes of the lake playa under different conditions, and not provide detailed hydraulic predictions.

1.2 Limitations of modelling

Topography of Lake surface (Bathometry)
The surface topography has a major impact on the area of water exposed to evaporation. Most lake playas have a subtle but distinctive surface shape. If the lakes surface is assumed to dead flat which it isn't, then the water on the surface would immediately expand in a thin layer and evaporate. For the purpose of modelling, and it believed to be realistic, the surface of the playa is assumed to be a number of ellipsoid indentations that when one fills it over flows to the next. It is probable that the playas have a gradient from one end to another but this rarely has any impact except in major flood events where there is enough water to fill all of the minor basins that make up the playa.

The episodic nature of climate data or the problem of averages.
If a limited view of the rainfall averages in the northeastern goldfields were to be believed it would be possible to think that a consistent rainfall of about 20 mm occurs every month to give the annual average of 240 mm. It is true that the averages show that about 20 mm of rainfalls every month. The reality is that an area is more likely to receive the entire annual average in one month and nothing falls for the remainder of the year. The rain is also geographically patchy in that one area is likely to get rain when another does not. This can be seen in Table 1 where the average rainfall is significantly higher than the median. It can also be seen that ten percent of the years have twice the average rainfall and ten percent have less than half of the average rainfall. This makes it very difficult to predict runoff that relies on historical rainfall as well as current rainfall to be accurate (Adrian Peck 2000 pers. comm.). If the average rainfall for Laverton or Leonora were used to predict runoff it just would not occur. Using averages in a model tends to understate the variability of the changes on the lake's surface. The model tends to predict a stable equilibrium on the playa that does not occur.

Table 1 Climate Statistics from Laverton (BOM)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Mean (mm)	14.6	36.5	19.9	22.2	23.3	19.4	16.2	14.2	10.1	11.5	13.6	20.9	222.
Decile 5 (mm)	6.6	19	5.6	8.5	21.8	13.2	10.4	8.6	5	5.8	9.8	11.7	197.1
Decile 9 (mm)		68.8	57.8	56.4	55.8	41.2	42.4	25	35.2	34.1	47.8	65.4	470.7
Decile 1 (mm)	0.2	0.2	0.6	0	0	0.4	0	0	0	0	1.5	1.2	119.9

The issue of averaging values for modelling purposes mainly concerns rainfall and related hydrological functions; evaporation for instance is very consistent. Gross evaporation (that with precipitation removed from the measured pan evaporation) only varies with the season. Evaporation will be influenced by cloud cover, wind speed and humidity but the main factor is solar energy.

Table 2 Gross evaporation in Laverton (BOM)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Mean Daily Evaporation (mm)	14.4	12.2	10.0	7.2	4.4	3.2	3.2	4.4	6.8	9.3	11.5	13.0	8.1

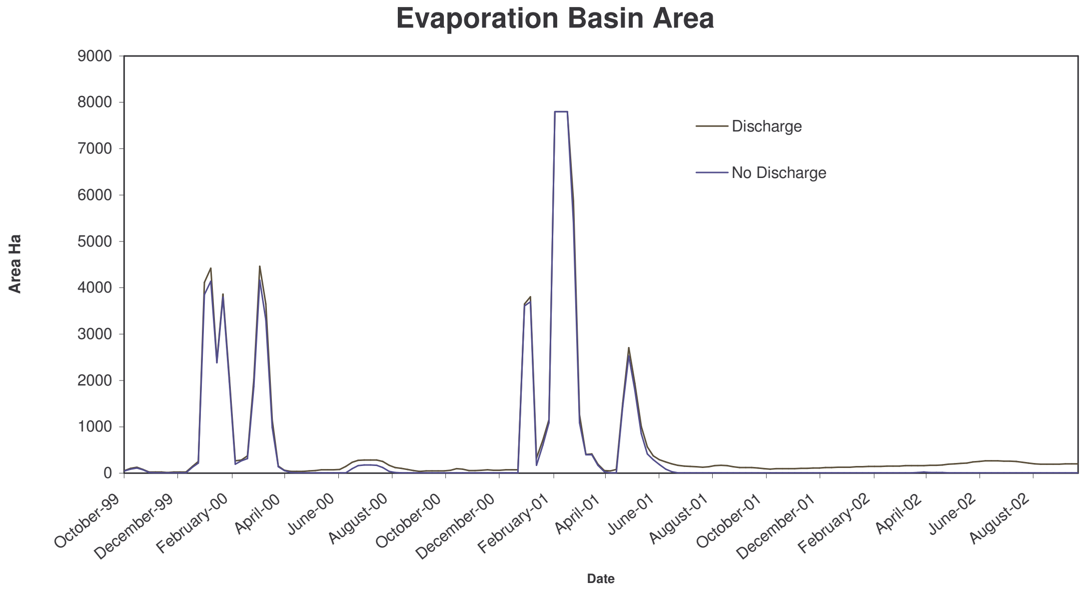
Recharge and discharge rates

The rate of discharge and recharge of ground water on the playa surface is a moot point. As the conceptual model suggests both may occur and under most environment conditions it is likely that both are occurring at any one time at different locations across the playa. From observations it is likely that the lunettes around the playa are discharging groundwater for long periods and it is likely that the centre of the playa is recharging salt and water when there is surface water available. It is obvious to anyone who has trekked or driven across the surface of playas that the surface texture and composition is not homogenous.

Conclusions from Modelling

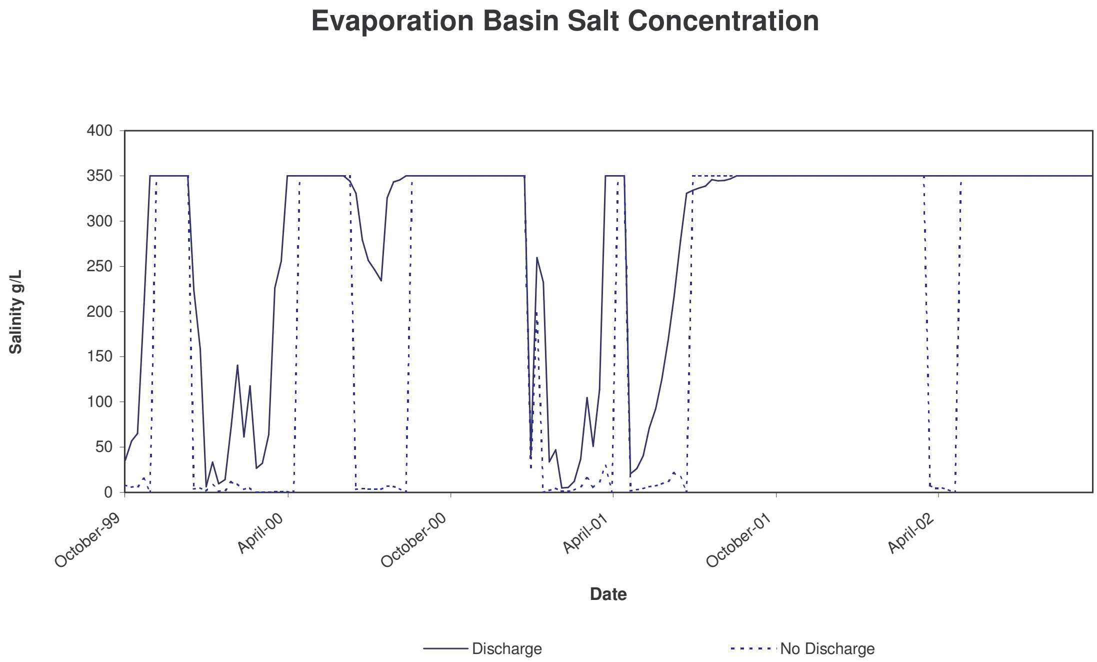
The flatness of the playa means that any input whether it is from rain or a discharge will cover large areas. A discharge of reasonable size, that is 30-40 L/sec, will cover a large area with no other imputs (~250 ha) but the area is not normally significant compared to the large areas of playa. The difficulty of using averages to calculate modelled changes on a large playa lake is demonstrated in Figure 2. Real data was used up until June 2001 and then averages were used for the future predictions. The variation in the area covered in water does not occur when using averages.

Figure 2 Modelled Area of Playa



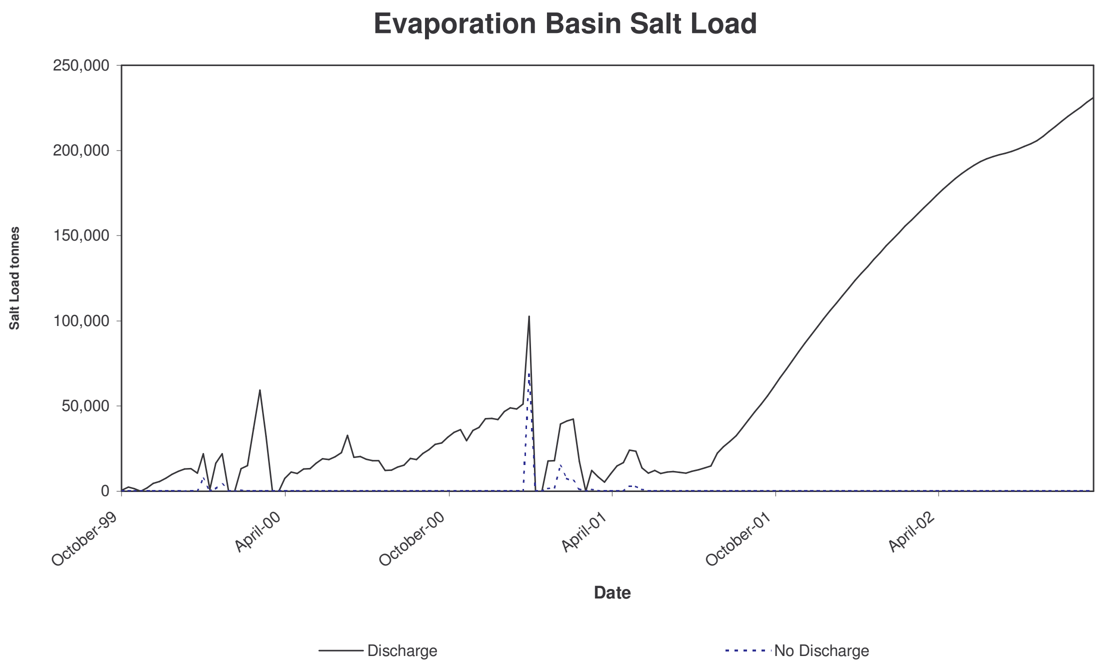
Modelling the salinity of the water on the playa shows more interesting differences between scenarios where there is a discharge and without a discharge. This is demonstrated in Figure 3 where both the discharge and no discharge scenario salinities default to 350 g/L when the playa dries out. This is probably a slight underestimation when there is a salt crust and overestimation when there is not a salt crust. The interesting point is the amount of variability in the salinity is reduced when there is a saline discharge. This is true even when there the annual averages are used.

Figure 3 Modelled Salinity of Water on Playa



The reason that there is less variation is that with a saline discharge the salt load on the surface of the playa builds up. This is shown in Figure 4. Even with a moderate discharge the salt load builds up on the lake's surface over and above the loss of salt to the sediment as recharge. The point to note from Figure 4 is that the salt load is extremely variable when real data is used and that averages tends to accumulate salt on the playa. The reason for this is that with average rainfall there is no runoff and the salt is not spread over the playa surface increasing the recharge rate. Even without a discharge the salt load can be significant on the surface of the playa but this only occurs when there is a significant runoff event and salt is moved from the catchment to the playa.

Figure 4 Salt load on the Surface of a Playa



The modelling reproduces the natural variability of the salinity and salt load on the playa of the large lakes found in the Goldfields. It shows that discharges have an affect by reducing the variability in salinity in a restricted area for most of the time but at other times the salinity of a much larger area is affected. The salt load on the surface is significantly increased, again usually over a restricted area. The hydroperiod is not impacted to a significant degree at any time.

The times that a discharge has the most significant impact is when the playa is already wet from natural events. If the natural event is very large then the impact is reduced for the period of the event, but for smaller flood events or when the volume of brine in the lake is reducing after a large event, then the discharge scenario's salt load and salinity in the lake is significantly greater than the non-discharge scenario.

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