

# Salinity discharge and water salt balance of the Wybong Catchment in the Hunter Valley

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## Introduction

Salinisation is one of the most significant environmental problems facing Australia's land and water resources. The core cause of increasing salinity is the clearing of perennial native vegetation and its replacement with annual crops and pastures. This major change in land use has altered the natural water balance, reducing the amount of evapo-transpiration and resulting in increasing groundwater recharge (Allison and Hughes 1983). The changes in the water balance results in substantial increases in groundwater levels. This leads to the mobilization of salts within the regolith up towards the ground surface and discharge saline groundwater to the streams (Allison and Schonfeldt 1989). Salt export from cleared catchments is usually well in excess of salt input and is considered to be primarily sourced from groundwater discharge to streams (e.g. Williamson et al. 1987). The rate of salt export from a catchment is a function of rainfall, hydrogeological conditions, salt storage, catchment size and the amount of cleared native vegetation (Jolly et al. 2001). It is also considered that catchments situated in low rainfall zones typically have high stream salinity and salt storage, while those in high rainfall zones more rapidly export stored salts. Consequently, high rainfall zones have low salt storage and stream salinity (Schofield and Ruprecht 1989). Identifying a catchment's salt balance is a key tool for analyzing the salinity status and trend. In particular, the salt output/input (O/I) ratio is an important indicator for identifying salinization (Peck and Hurle 1973; Williamson 1998). The O/I ratio is approximately unity prior to clearing of native vegetation & indicates a state of salt equilibrium (Peck and Hurle 1973). Clearing mobilizes salt stored in the soil profile through increased recharge causing additional leaching of salt into the groundwater and an elevation of the hydraulic head in the aquifer, with the consequent increase in the groundwater discharge volume and its salt load.

In this study, salinity discharge and the water and salt balances of Wybong catchment are investigated. Wybong catchment is located in a region within New South Wales, Australia, where salinity is considered to be a major environmental issue. The salt discharge is investigated from the EC and flow and the water-salt balance is calculated by the salt O/I ratio.

## Methods

### *Water and salt outputs in streamflow*

Stream flow and EC were recorded at Yarraman gauging station (# 210040) in the lower Wybong catchment. The data were sourced from the Pinneena (DNR 2006) database. EC was measured in ( $\mu\text{S}/\text{cm}$ ) and stage was measured with pressure transducers. Flow record began in 1955 and EC was recorded from 1993 to 2007 at the site. Both daily streamflow and EC data have gaps in the periods of record & the IHACRES (Croke et al. 2005) rainfall runoff model was used to fill gaps in the daily flow record. Run off was predicted by using rainfall and evaporation data with a calibration mode  $R^2$  equals to 0.76. Major ion concentrations for stream waters were used to calculate a conversion factor for EC to TDS ( $\text{mg}/\text{L}$ ) where TDS is the summation of the measured ions. The conversion factor was obtained from a linear regression of EC and TDS measurements as  $R^2$  equals to 0.94. This conversion factor, 0.60, was used for calculating salt load. The daily salt load was calculated as the product of daily flow and EC as Eq. 1.

$$S(\text{Tonnes} / d) = 0.60 \times 10^{-3} EC(\mu S / cm) \times Q(\text{ML} / d) \quad (1)$$

A regression relationship of streamflow and calculated salt load were used to estimate salt load where EC data were missing. The processed data set consisted of daily values for which corresponding streamflow and EC values existed. The missing EC data were interpolated by

calculating EC from the division of salt load, and flow and the conversion factor. The annual output of water from the catchments was calculated by summing the daily flow at Wybong gauging station. Daily salt load was calculated as the product of daily flow and salt concentration. Finally, daily salt loads were summed to produce annual salt loads.

### ***Water and salt inputs from rainfall***

Inputs of water to the catchment from rainfall were estimated using a GIS-based approach which utilised available coverage of interpolated rainfall surfaces. Monthly rainfall surfaces (1993-2007) for the catchment were generated using the ANU spline program (Hutchinson 2002) from the available Bureau of Meteorology Data. The monthly rainfall surface grids were summed to provide annual rainfall, then projected and clipped to the required catchment boundary. An ARC/INFO Macro Language (AML) routine was then used to calculate the area-weighted annual rainfall for the catchment.

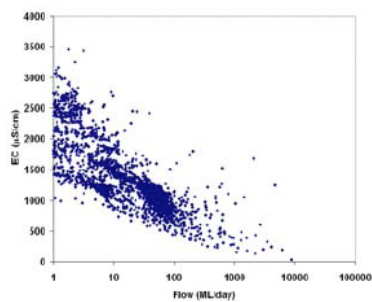
Total deposition (dust and rainfall) and rainfall samples had been collected by SPCC (1986) for each event during the period 1984-1986. Average dust salt deposition (TDS) was calculated by difference in ion concentration between the samples. Rainfall was collected from 1984 to 1990 and average TDS was calculated. All the samples were analysed for major cations and anions and the Bunnan sampling station which is located within the Wybong catchment was used to estimate rainfall and dust salt inputs. The average dust salt input into the catchment was calculated using the average TDS concentration from 1984 to 1986 and multiplied by the rainfall mass. The rainfall salt input was calculated from the 1984-1990 average.

### **Results and discussion**

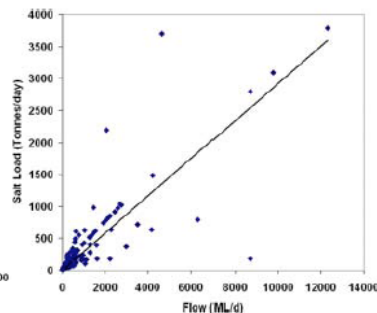
A prolonged drying trend has reduced stream flows in many parts of the Hunter Valley and contributed to the increased stream salinities. Since 2002 salinity in this catchment has increased from a mean of 1 mS/cm to 2 mS/cm and the mean daily flow has reduced from 80 ML/day to less than 20 ML/day after the year 2000. There is a complex relationship between stream EC and river flow in the Wybong catchment (**Fig.1**). This could be due to numerous salt discharge processes across the catchment such as diffuse groundwater, interflow, and point discharges from faults, the distribution of rainfall across the catchment, and due to possible data errors. **Fig. 2** shows the relationship between estimated daily stream salt load and stream flow. The greatest export of salt occurs at the largest flows. The trend over the measurement period is shown in **Fig.3**. The long term mean salt concentration 431 mg/L can be found by the relationship between cumulative stream salt load,  $\Sigma S(10^6 \text{ tonnes})$  and cumulative discharge,  $\Sigma Q(km^3)$ :

$$\Sigma S = 0.4307 \Sigma Q \quad (2)$$

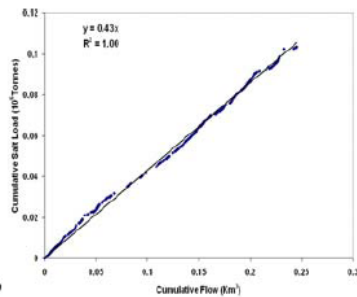
From the **Fig. 3**, it is evident that the salinity in the water decreases with discharge during rainfall events or wet periods due to dilution effects. However, Fig.3 also shows increased salinity occurring immediately after high discharge events. One of the possible reasons can be made that groundwater may be contributing to salt load for such high salinity just after the high discharge.



**Fig. 1.** Relationship between mean daily stream EC and stream flow, Q, for Wybong for the period 1993- 2005.



**Fig. 2.** Relationship between daily salt load and daily stream flow, at Wybong for the period 1993-2005.



**Fig. 3.** Relationship between cumulative flow and salt load for Wybong for the period 1993-2005.

**Table1** Estimated annual salt output/input ratios, based on TDS inputs and outputs Year

Year	Rainfall Input water (ML/year)	Rainfall Input salt (Tonnes/year)	Stream export (ML/year)	Outputsalt (Tonnes/year)	O/I	Dust salt
1993	523	1991	17671	7661	3.85	1480
1994	296	1129	2253	1718	1.52	839
1995	435	1657	2516	1453	0.88	1232
1996	501	1909	17588	9148	4.80	1419
1997	389	1480	16398	7699	5.20	1100
1998	620	2360	93430	37555	15.91	1754
1999	534	2033	34109	15239	7.50	1511
2000	567	2161	42703	19736	9.13	1606
2001	399	1518	3298	2397	1.58	1128
2002	299	1137	109	158	0.14	846
2003	410	1560	579	649	0.42	1160
2004	490	1866	367	516	0.28	1387
2005	407	1550	435	672	0.43	1152
2006	190	724	54	110	0.15	538
2007	281	1071	16965	4850	4.53	796
Mean	423	1610	16565	7304	4.54	1197

### **Catchment salt balances**

Salt O/I balance is used to summarize the catchment's salinity condition and indicates possible salt sources and supply. The results of salt load output/input ratios estimated from TDS are shown in Table 1. It is observed that the salt load output/input ratios are more than 1 throughout most of the record periods. The highest salt imbalances occurred in the wettest year of 1998, with O/I ratios of 15.19, because of more salt flux from the groundwater. In this period, the significant masses of salt are moved through the catchment and it increases the stream salinity. In many years such as 1993- 1994, 1996-2001 and 2007, salt outputs were greater than the salt input. This is because groundwater, soil landscape and regolith may contribute the additional salt to the stream. In Table, it is often observed that salt input is greater than salt output and this salt may be stored on the landscape. The driest period of 2002, the flow was comparatively less and O/I ratio 0.14 is estimated. The salt output was considerably less than the input, indicating that salt was concentrated in the catchments during this period. Table 1 also shows that the dust salt was the highest in the year of 1998 and lowest dust salt found in 2006. Since dust mobilisation from mining work as waste rock piles which increase the stream salinity. A portion of the solutes also delivered to the catchment via rainfall and dust recharge the more regional aquifers which might then discharge in other catchment. However, this result may vary because the period taken under

consideration for calculating the TDS (1984-1990) was different from the current period (1993-2007).

### **Conclusion**

This paper has investigated flow independency of salt load at certain period. The increase in cumulative salt load just after a rainfall event suggests salinity rises in the catchments due to groundwater contributions. The derived mean catchment salt O/I ratio from 1993 to 2007 is 4.54. The most significant salt imbalance in the Wybong catchment occurred during the year of 1998 and 2002. The salt O/I ratio, in most of the years, is greater than 1 which emphasises that the salt ratio is not in equilibrium in the catchments.

### **Acknowledgments**

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