Nutrient retention capacity of a constructed wetland in the Cox Creek sub-catchment of the Mt. Bold Reservoir, South Australia

by

Nor Azman Kasan

(*B.Sc. (Hons.) in Industrial Biology, M.Eng. in Environment*)

School of Earth and Environmental Sciences,
The University of Adelaide

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List of abbreviations

Aluminium	Al
Analysis of variance	ANOVA
Calcium	Ca
Carbon dioxide	CO_2
Dissolved inorganic phosphorus	DIP
Dissolved organic phosphorus	DOP
Dry weight	DW
Equilibrium phosphorus concentration	EPC
Filterable reactive phosphorus	FRP
Hydraulic loading rate	HLR
Iron	Fe
Organic matter	OM
Particulate inorganic phosphorus	PIP
Particulate organic phosphorus	POP
Phosphorus accumulation rate	P_{accum}
Phosphorus	P
Sediment accumulation rates	SR_{accum}
Sedimentation rate	SR
Subsurface flow	SSF
Surface flow	SF
Suspended solids	SS
Total nitrogen	TN
Total phosphorus	TP
Water residence time	WRT

Declaration

I declare that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference has been made in the text.

I consent to this copy of my thesis, when deposited in the University Library, being made available for loan or photocopying.

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Nor Azman Kasan

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Abstract

The Cox Creek sub-catchment is located in the Piccadilly Valley, South Australia. It exports disproportionately high loads of nutrients and sediment to the downstream Mount Bold reservoir. The excessive application of inorganic fertilisers to agricultural land in the Cox Creek sub-catchment has enhanced nutrient exports downstream. This has led to eutrophication and algal blooms in Mount Bold Reservoir, an important water supply for the city of Adelaide, which has a population of approximately 1.3 million people. The Cox Creek constructed wetland includes a sedimentation basin and a series of constructed wetland ponds, which were implemented to reduce nutrient loads passing downstream. The objective of this research was to evaluate the capacity of the constructed wetlands to retain nutrients and better understand key processes for nutrient retention such as macrophyte uptake, sediment sorption and sedimentation in the Cox Creek wetland system. How different flow regimes influence these processes was also investigated.

Based on historical inflow and outflow data from 2004 to 2009 for the Cox Creek wetland system, six different flow rate classes were classified and the nutrient loads delivered by each of these flow rate classes were calculated. It was hypothesized that the higher the flow class the shorter the water residence time and so reduced opportunity for nutrient retention through processes such as sedimentation. The very dry flow class (0 to 1 ML day^{-1}) had the longest water residence time (14.8 days) and contributed the lowest total phosphorus (TP) and total nitrogen (TN) loads (TP: 10.2 kg yr^{-1} and TN: 81.0 kg yr^{-1}). In comparison, the high flow class (46 to 300 ML day^{-1}) had the shortest water residence time (0.1 days) and contributed the highest nutrient loads (TP: 433.4 kg yr^{-1} and TN: 1726.2 kg yr^{-1}). The percentage of TP and TN retention (TP: 60 to 69% and TN: 18 to 76%) showed that nutrient loads at the inflow were greater than that of the outflow after the construction of the wetland in 2006. Therefore there was a net retention of nutrients in the Cox Creek wetland system during the study period, suggesting it is effective at reducing nutrient loads passing downstream.

In order to investigate the ability of macrophytes to store nutrients, the seasonal TP and TN storage by *Schoenoplectus validus* and *Phragmites australis* were compared between

Reed Bed and Pond 1 of Cox Creek wetland system. The TP and TN storage were significantly higher in Reed Bed (TP: 22.0 gP m^{-2} and TN: 118.5 gP m^{-2}) than in Pond 1 (TP: 1.0 gP m^{-2} and TN: 10.3 gP m^{-2}). TP storage peaked in spring 2008 for *S. validus* and *P. australis* in Pond 1. This was also the case for *S. validus* in Reed Bed, but TP storage peaked in summer 2009 for *P. australis* in Reed Bed. TN storage peaked in spring 2008 by both species in Reed Bed. This was also the case for *S. validus* in Pond 1, but TN storage peaked in summer 2009 for *P. australis* in Pond 1. Based on the results, it appears that the presence of macrophytes can reduce nutrient loads passing downstream, with the amount of nutrients stored highest during spring and summer. Therefore, the best timing for harvesting for removal of wetland nutrients is after spring, when nutrient storages are expected to be highest, preferably in mid summer season.

The sediment redox potential was higher in Reed Bed than in Pond 1, suggesting macrophytes may have the ability to release oxygen from roots and increase phosphorus (P) adsorption in Reed Bed. Using P adsorption-desorption experiments, the equilibrium P concentration (EPC) was calculated as a measure the P adsorption capacity of sediments in Reed Bed and Pond 1. EPC is used to identify sediment as a source or sink of P. When P concentration of porewater is greater than the EPC, then the sediment will adsorb P and vice versa. The EPC values were lower in Reed Bed than in Pond 1, indicating greater P adsorption capacity of Reed Bed sediment than Pond 1 sediment. Phosphorus fractionation of the sediments showed that of the inorganic forms of P (loosely sorbed-P, Ca/Mg-P and Fe/Al-P) and the Fe-P was consistently higher in Reed Bed than in Pond 1. Under oxidised conditions, the ferric ion complexes adsorb P, reducing the amount of P available for diffusion to the overlying water. Therefore, it appears oxygen release by macrophytes in Reed Bed may promote P storage in sediments, with greater P-binding capacity in Reed Bed than Pond 1.

Sedimentation was determined as the main process that determines the nutrient retention capacity of the Cox Creek wetland system. Based on measured sedimentation rates at the inlet and outlet of Reed Bed and Pond 1 in three different flow events, the average of sedimentation rate across the study was 2.2 kg m^{-2} yr^{-1}. Even though the presence of vegetation has been shown to enhance sedimentation elsewhere, P accumulation rates were greater in Pond 1 (0.4 to 4.6 kg m^{-2} day^{-1}) than in Reed Bed (0.3 to 2.0 kg m^{-2} day^{-1}). This is likely a result of greater inflowing loads of sediment and nutrients in Pond 1 than in Reed Bed. Pond 1 receives water from both sedimentation pond and Reed Bed whereas Reed Bed only receives overflow from the sedimentation basin.

In order to quantify the performance of the Cox Creek wetland system for reducing P exports, a P mass balance was calculated. This study found that 281.6 kg yr^{-1} of P is retained in the wetland. Although there is an unaccounted amount of P in the mass balance (112 kg yr^{-1}), the relative contributions of uptake by macrophytes (36 kg yr^{-1}), sediment P adsorption (43.5 kg yr^{-1}) and sedimentation (90.1 kg yr^{-1}) are believed to be the most important mechanisms in P removal. Consequently, wetland design and operation should aim to promote these processes to maximise P removal. This should include increasing macrophyte diversity, using nutrient-poor sediments as substrate and increasing residence time of water to create favourable conditions for sedimentation in the wetland.