Sediment and nutrient generation rates for Queensland rural catchments – an event monitoring program to improve water quality modelling

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Abstract

Improving water quality model parameterisation and validation is dependent on having locally relevant sediment and nutrient data. Appropriate parameterisation is becoming increasingly important as Natural Resource Management (NRM) Groups use such models to quantify any change in water quality as a result of on-ground works. Water quality data sets for model parameterisation and validation are limited in rural catchments across Queensland. A sampling program was undertaken over four years, across four catchments in Queensland to collect sediment and nutrient storm runoff event data to improve model parameterisation and validation. Event mean concentrations (EMC) for sediment and phosphorus were higher than those reported in the literature. Total suspended solids (TSS) event concentrations ranged from 141 - 2,720 with a median TSS EMC of 785 mg/l. Total phosphorus (TP) and total nitrogen (TN) concentrations ranged from 0.07 – 2.4 mg/l and 1.0 – 5.7 mg/l respectively. The data suggest that sediment and phosphorus values for rural catchments in Queensland may be higher than typical values reported in literature. This work provides new EMC values for a range of Queensland's rural catchments. The data will improve water quality model parameterisation, calibration and validation. NRM groups using the data will have greater confidence in model outputs when quantifying the benefits of investment or prioritising funding for on-ground works.

Keywords

Event runoff, water quality models, sediment load, sampling program

Introduction

Improving estimates of sediment and nutrient loads is becoming increasingly important for Regional Natural Resource Management (NRM) planning. Firstly, Regional NRM groups are looking to demonstrate to funding providers and the community that their funding of on-ground works is making a difference to catchment water quality. Secondly for reef catchments in Queensland, under the Reef Water Quality Protection Plan (The State of Queensland and Commonwealth of Australia, 2003) pollutant load targets are to be set for all catchments draining into the marine environment. Catchment modelling coupled with measurement, offers an alternative means of predicting loads and demonstrating to stakeholders how land management changes may impact on water quality.

Popular water quality models currently being used across Australia for this purpose are EMSS (Cuddy *et al.,* 2004) and E2 (Perraud *et al*., 2005). The approach used by these models for calculating sediment and nutrient loads is to combine the base flow load (flow x *Dry Weather Concentration (DWC))* and event load (flow x *event mean concentration (EMC*)) to produce a total daily load. This paper only deals with data collection for EMC calculation as the streams in question are ephemeral and therefore generally have no dry weather or baseflow component. There are a number of definitions and methods used to determine EMC values. The approach used to derive EMC values in this work was to calculate the total load of sediment or nutrients for an event divided by the total runoff.

A lack of high quality data will almost certainly be the greatest constraint for sediment and nutrient generation models (CRCCH, 2005). To quantify loads by field measurement may take decades, is extremely costly and may not ultimately provide a clear result and is therefore often not undertaken by NRM groups. Often existing local existing data sets are used to derive event concentration data for model input. In Queensland, the most comprehensive water quality data sets reside with the State Government, Natural Resources and Water (NRW). However, the majority of this water quality data, spanning 30 years, was collected during low or no flow conditions (Waters 2006). Using low flow sediment and nutrient concentration data to calculate EMC values for annual load estimation can lead to gross underestimate of annual load as demonstrated by Waters (2006). Therefore, collection of storm runoff event data for EMC derivation will enhance load estimates and improve model inputs and output results.

In the absence of locally relevant data, regional or national values are often used. Some typical grazing and cropping EMC values reported in the literature for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) concentrations are listed in Table 1.

Table 1. Typical median, upper and lower rural EMC values for TSS, TP and TN reported in literature.

Source	Land-use		EMC (mg/l)		
			TSS*	TP#	TN@
Chiew & Scanlon 2002 (South East Qld)	Grazing	Lower	25	0.08	0.6
		Median	140	0.34	2.7
		Upper	350	0.7	4.2
Searle 2005 (South East Qld)	Grazing	Lower	40	0.12	0.9
		Median	140	0.28	1.6
		Upper	380	0.72	4.6
Fletcher *et al.* 2004 (Australia & International review)	Agriculture /cropping/ Grazing	Lower	60	0.20	1.7
		Median	200	0.50	4.0
		Upper	500	1.80	9.0
Lin 2004 (review of United States literature)	Variable forest & Agriculture	Median	55-113	0.01 -0.17	0.5 - 6.1

*Total suspended solids, # Total phosphorus, @ Total nitrogen

Chiew and Scanlon (2002) and Searle (2005) data were derived for South East Queensland only, whilst Fletcher *et al*. (2004) (predominantly urban with some rural) and Lin (2004) (urban and rural) undertook extensive reviews of literature both nationally and internationally. The median EMC values for TSS in Table 1 ranged from 55-200 mg/l with a maximum of 500 mg/l. Median TP EMC values ranged from 0.01 – 0.5 mg/l with median TN values ranging from 0.5- 6.1 mg/l. Unpublished storm runoff event data sets across Queensland suggests that EMC values may be higher than values reported in the literature.

In 2003, the National Action Plan (NAP) Water Quality team identified that there was a clear lack of event data available across Queensland. To address the issue, the NAP team undertook a water quality sampling program over four years, in four catchments across Queensland. The aim of the work was to collect sediment and nutrient data during storm runoff events to quantify the typical EMC values for ephemeral catchments across Queensland and assess their spatial variability. This paper summarises event data collected from 2002-2006 across four Queensland catchments.

Methods

Storm runoff event monitoring occurred across four of the six NAP catchments in Figure 1. Data reported in this paper are a collation of 25 event data sets across the four catchments. The 25 events were sampled as follows: three events sampled in the Burdekin (130,000 km^2), two events in the Condamine Alliance (25,000km^2), eleven events in the Fitzroy (136,000km^2) and nine in the Murray Darling (280,000km ^{2}).

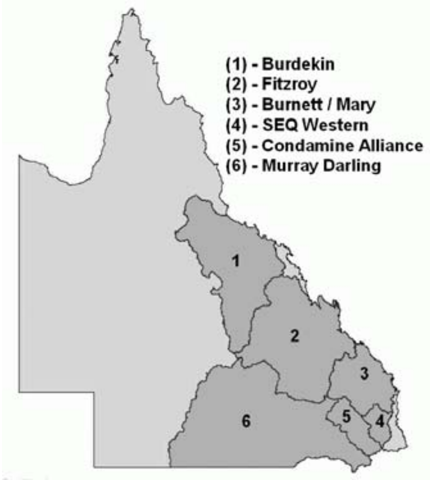

Figure 1. Storm runoff event monitoring was undertaken in catchments numbered 1, 2, 5 and 6.

Site selection
A number of factors were considered in site selection: (a**)** *Upstream contributing area and land use* – Where possible single landuse subcatchments were monitored at a range of scales, with the minimum catchment area being 344 km^2 (b**)** *Availability of hydrological data* –Monitoring sites were chosen on the availability of discharge data. (c**)** *Distance downstream of a storage* – Where a monitoring site was below a storage, the storage volume and its contribution to event load was taken into account in load calculation

Sample collection and processing
All sediment and nutrients were collected as grab samples collected 0.2m below the surface, from the middle of the channel cross section where possible or from representative section of the flowing stream. Nutrient samples were chilled in the field and frozen upon arrival in the laboratory. The NRW sampling protocols were followed (NRM, 2000). Sampling frequency was highly variable for each site, however the aim was to capture a range of sediment and nutrient samples over the runoff hydrograph. For all data reported in this paper, a minimum of three samples was collected across the hydrograph, with at least one sample on the rising limb, one near the peak and one on the falling limb. The average number of samples per event was eight. All samples were sent to Queensland Health Scientific Services Laboratory for analysis. Samples were analysed for TSS, TP and TN.

EMC calculation
To derive sediment or nutrient loads for each event, a flow-weighted mean concentration approach was used (NAPWQSIP-a, 2006). The flow-weighted concentration method involves multiplying the average concentration for a given period of time by the mean flow for that period to obtain a succession of estimated loads, that when summed equal the event load. EMC values were then calculated by dividing the total event load by the event flow volume.

Runoff contributing area
Due to the inherent variability in rainfall extent, the sampling location may have been a significant distance downstream of where runoff was generated. In an attempt to estimate the actual contributing area of runoff for each event, 5km daily rainfall grids (SILO, 2004) were compiled for each catchment. The daily rainfall grids were summed over the number of days that the rain fell in the catchment and the resulting grid was then clipped to the catchment boundary upstream of the measuring point (Figure 2). The runoff contributing area was defined as the area of the catchment where the sum of the daily rainfall totals exceeded 50mm. For example in Figure 2, rainfall continued for four days and the daily rainfall grids were summed over this period. The rainfall grid and land use grids were then overlayed to determine the specific landuse for the area where the rainfall event occurred.

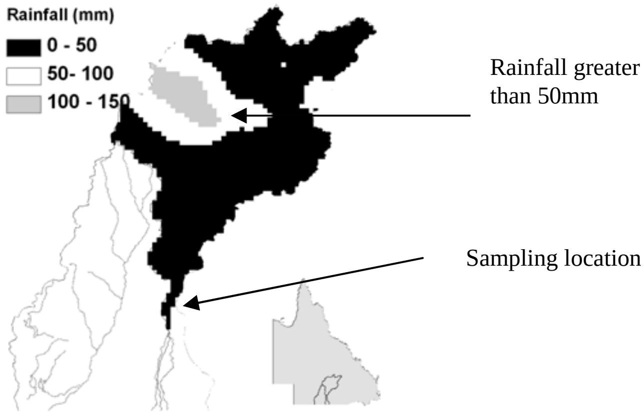

Figure 2. Example of rainfall grid clipped to catchment boundary within the Murray Darling catchment. The rainfall grid was used to estimate runoff contributing area. (Note: catchment area shaded by rainfall grid is 49,000 km^2.

Results

Table 2 summarises the TSS, TP and TN concentrations for the 25 events monitored over the four year period. TSS EMC values were wide ranging from 141-2,720 mg/l. Median TSS EMC values were much higher than those reported in Table 1 (785 mg/l vs 55-200 mg/l). TP EMC values ranged from 0.07 – 2.4 mg/l with a median of 0.5 mg/l which was comparable to the upper limit of TP EMC values in Table 1. TN EMC values were similar to those reported in Table 1 ranging from 1.00 -5.74 mg/l with a median TN EMC of 1.87 mg/l. Where the contributing catchment area was less than 40,000 km^2, EMC values showed high variability (Figure 3). Greater than 40,000km^2, EMC values were between 300 – 1,100 mg/l with low variability.

Table 2. Summary of TSS, TP and TN EMC values for 25 storm runoff events across four Qld catchments

	Catchment Area (km^2)	EMC (mg/l)		
		TSS	TP	TN
Lower	344	141	0.07	1.00
Median	14,175	785	0.50	1.87
Mean	29,750	1,022	0.65	2.21
Upper	135,757	2,720	2.40	5.74
Standard Deviation		720	0.53	1.09

Table 3. Average recurrence intervals for the 25 events sampled.

Average Recurrence Interval (years)	Number of Events
<5	**20**
5-10	**3**
10-15	**2**

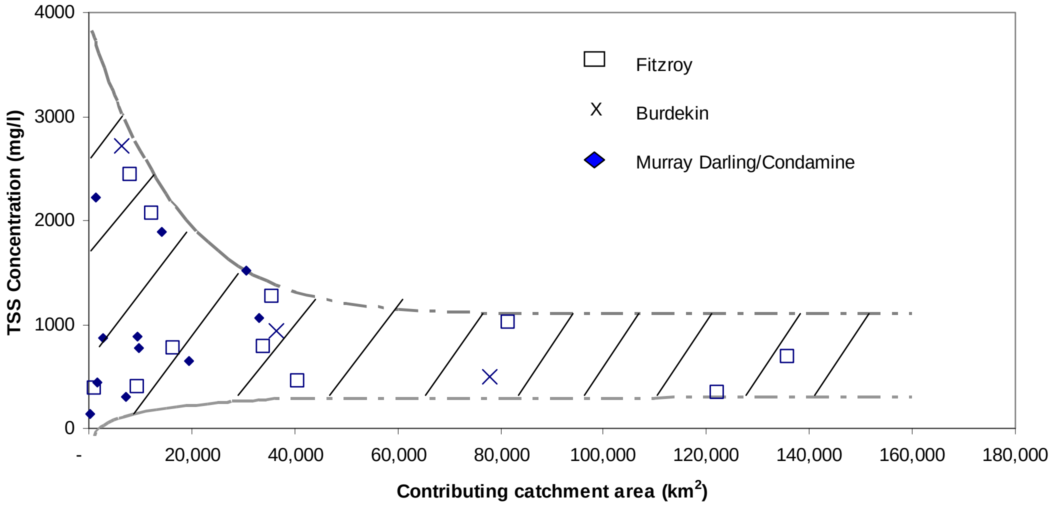

Figure 3. Total suspended sediment EMC values showed high variability below 40,000 km^2 contributing catchment area.

The cross hatched area (Figure 3) gives an indication how EMC values varied as catchment area increased. Total phosphorus and total nitrogen EMC values followed a similar pattern. Twenty of the events had less than a one in five year average recurrence interval (ARI) with the five remaining events having between 5 and 15 year ARI (Table 3).

Discussion

Median TSS EMC values were higher than those reported in the literature. Whilst the EMC values were higher than those reported, the catchments sampled generally contain high clay content soils with sediment in runoff containing in excess of 60% clay sized fractions. This particulate matter is known to stay in suspension for long periods resulting in naturally high turbidity and suspended sediment concentrations considerable distances downstream of the generation area. In addition, for many of the in-land catchments in Queensland, erosion rates are well correlated to cover. The current drought in Queensland has resulted in low cover levels being observed across much of the state. The low cover levels may have resulted in higher than normal erosion rates in some cases.

TP and TN EMC values were comparable to those reported in literature. In general the rural catchments where data collection occurred are predominantly grazed native pastures with little input of nutrients from urban landuse. Theses pastures are naturally low in fertility and generally have no fertiliser inputs, which results in low TP and TN concentrations in runoff water.

Interestingly the two highest EMC values for the Fitzroy catchment (2071 and 2440 mg/l) were generated from predominantly dryland cropping areas with low ground cover. The remainder were from predominantly grazed catchments, suggesting that the EMC values for dryland cropping may be higher than grazed catchments.

The high variability in EMC values where the catchment contributing area was below 40,000 km^2 (Figure 3) may be attributed to rainfall event characteristics and antecedent catchment conditions such as ground cover. A number of the low EMC values with corresponding low contributing areas can be explained by the observation of high ground cover in the catchment at the time of the event.

The majority of events sampled (80%) had a return period of less than 5 years. Therefore this data set does not necessarily reflect the full suite of values that may be encountered across the range of flow magnitudes. Future sampling programs will endeavour to target flows of a higher return period.

This work has provided an insight into the range of EMC values encountered for four catchments in Queensland not reported previously. The data sets reported in this paper were collected at a range of scales and highlights the variability that can occur when collecting sediment and nutrient samples for EMC calculation. Therefore, where the data is used for model parameterisation; caution is required to ensure it is applied at the appropriate scale and landuse to reflect model requirements. Where EMC data has been calculated downstream of multiple subcatchments or entire basins, the data may be more appropriate for load calculation to calibrate and validate model outputs. The use of daily rainfall grids shows potential to improve our understanding of how runoff contributing area and land use impact on sediment and nutrient generation.

Conclusion

The TSS EMC values reported in this paper for four Queensland catchments, are higher than those reported in literature. TP and TN EMC values were comparable with the literature. Dryland cropping EMC's were higher than the grazing EMC values. The data suggests that if current literature values are used for model parameterisation without an understanding of their local relevance, gross errors in load calculation could occur. The high degree of variability in EMC values measured also highlights the need for further EMC data collection across a range of landuses and event return periods. The data collected in this study, will greatly improve water quality model parameterisation and calibration for Regional NRM groups across Queensland.

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