THE ROLE OF SOIL REGOLITH PROPERTIES, RIVER SUSPENDED SEDIMENT AND NUTRIENT CONCENTRATIONS DURING STORM EVENTS IN THE MORUYA AND TUROSS CATCHMENTS, NSW.

John J. Drewry[1,2], Richard S.B. Greene[2], Lachlan T.H. Newham[3,4] & Barry F.W. Croke[1,5]

[1]CRC LEME, Integrated Catchment Assessment and Management Centre, Australian National University, Canberra, ACT 0200
[2]CRC LEME, School of Resources, Environment and Society, The Australian National University, Canberra, ACT 0200
[3]Integrated Catchment Assessment and Management Centre, Australian National University, Canberra, ACT 0200
[4]School of Resources, Environment and Society, The Australian National University, Canberra, ACT 0200
[5]Department of Mathematics, The Australian National University, Canberra, ACT 0200

INTRODUCTION

The combination of soil regolith properties and transport factors determines overall soil and nutrient losses to waterways. Soil and hydrological factors affecting soil erosion include overland flow and subsurface pathways, connectivity to waterways, the extent of gully and stream bank erosion and soil regolith physical and chemical factors (Greene & Hairsine 2004, McDowell *et al.* 2004). For example, factors affecting soil nutrient loss include soil texture, particularly if the soil is sandy, phosphorus (P) retention/adsorption or buffer capacity, hydrology, soil erosion risk, land use and management, and soil nutrient levels, particularly in the upper soil profile (McDowell *et al.* 2004). Nitrogen (N) and P are important soil nutrients, the loss of which to waterways may result in eutrophication with subsequent algal blooms. Recent studies have shown the importance of how soil nutrients and land use such as grazing affect water quality (Cornish *et al.* 2002, Cox *et al.* 2002).

In catchments, single storm events are responsible for high percentages of soil-derived salts such as NaCl, $CaSO_4$, sediment and N and P loads in surface water. However, current routine water quality monitoring programs in Australia often involve only monthly sampling and seldom include monitoring under actual rainfall event conditions (Newham *et al.* 2001). Australia exhibits a highly variable hydrological response (Croke & Jakeman 2001), therefore it is important to use storm event-based sampling data and groundwater-induced baseflow in load estimates. To investigate water quality impacts and loads, catchment-scale models are commonly used. Models can assist managers evaluate the likely impacts of land use and management on the long-term nutrient export status of catchments. Integrated catchment models have been developed such as the hydrological-based model CatchMODS (Newham *et al.* 2004). The CatchMODS model estimates total sediment loads from overland flow soil regolith erosion processes, and sediment from gully and stream bank erosion. This model uses event-based data to help determine long-term loads.

This research program is designed within the context of a catchment modelling framework, to assess relative contributions from diffuse sources of soil regolith nutrient and sediment export loads. This paper presents an overview of this research program including soil regolith sampling to assess soil quality, and storm event-based water quality monitoring in the lower Moruya and Tuross catchments, Australia. Also discussed are some initial results for recent flood events during July 2005.

CATCHMENT CARACTERISTICS

The Moruya and Tuross River catchments are located adjacent to one another approximately 300 km south of Sydney, and are almost wholly located in the Eurobodalla Shire of NSW. The areas of the Moruya and Tuross catchments are approximately 1600 and 1850 km^2, respectively. Both catchments have similar features with approximately 10% flat coastal plain, the remainder undulating or rugged terrain. The catchments are predominantly native forest or national park in rugged terrain, while the cleared coastal land surrounding the rivers and estuaries is used for beef cattle grazing. Dairy production in the Tuross catchment is predominant on moderately sloping land and floodplains.

SOIL REGOLITH MONITORING

The potential for nutrient loss in overland and subsurface flow increases with soil nutrient concentration, but is dependent on many factors (McDowell *et al.* 2004). In this paper we present some initial results for a soil regolith sampling program linked to a nutrient budget assessment of soil nutrient losses and cycling for selected farmland management in the Tuross-Eurobodalla region. Because CatchMODS does not quantify the losses from intensive agriculture particularly at farm-scale, we have used a nutrient budget approach to assess soil regolith nutrient losses under various dairy farm irrigated and effluent management systems (Drewry *et al.* 2005). Some initial results from that study indicated that long-term nitrogen losses from dairy farms in the region were low and were also found to be lower than other published studies.

Soil samples were collected from three dairy farms from paddocks (subject to irrigation, non irrigated dry-block and effluent-application areas) to assess soil quality. Within each paddock 10–15 samples were obtained from a transect line at the standard sampling depth of 0–10 cm by standard methods. Deeper samples were also taken at 10–30 cm depth. Samples were bulked from each paddock into 1 composite sample for chemical analysis, as is standard practice. Soil chemical analyses were conducted by the Incitec-Pivot Nutrient Advantage laboratory at Werribee, Victoria. The phosphorus buffer index method (PBI) is reported in Burkitt *et al.* (2002). Other analyses are reported in Rayment & Higginson (1992). Soil quality data were analysed by analysis of variance using GenStat. Some soil quality indicators are shown in Table 1.

Table 1: Management main effects for soil regolith quality indicators (averaged over 0–10 cm and 10–30 cm)

Management	Olsen P	Colwell P	Total P	P buffer index	Organic carbon	Total N	Electrical conductivity	Exchangeable K
	(mg/kg)	(mg/kg)	(%)		(%)	(%)	(dS/m)	(meq/100g)
Dry-land	33	114	0.069	180	4.52	0.44	0.255	1.42
Effluent	56	162	0.069	201	4.25	0.40	0.247	2.42
Irrigated	20	60	0.057	115	2.87	0.28	0.092	0.27
s.e.d.	7	19	0.011	19	0.42	0.06	0.053	0.20
P	**	**	ns	**	*	*	*	***

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; s.e.d is standard error of the difference.

Many of the indicators in Table 1 showed significantly lower values under the irrigated management. The levels of bio-available P (Olsen or Colwell) showed significant differences between the treatments and demonstrate the benefit of such measurements over the total P value, which failed to show treatment differences (Table 1). Soil Olsen P levels at 0–10 cm for the irrigated treatment averaged 28 mg/kg, which was considered acceptable. In contrast, Olsen P at 0–10 cm for the effluent treatment was 68 mg/kg. The PBI of the soils under the managements listed in Table 1 is considered moderate (DPI 2005), which will help to reduce overland flow and leaching losses. Soil P levels in relation to agronomic guidelines and potential risk to waterways is discussed in more detail in the discussion section.

EVENT-BASED WATER QUALITY MONITORING

This section outlines an event-based water quality monitoring program that will be used to enable nutrient and sediment load estimation, calibration and testing of the CatchMODS model. Water monitoring sites were selected from existing Department of Planning, Infrastructure and Resources (DIPNR) stream gauges, namely gauge 217002 (Deua River at Wamban) and gauge 218008 (Tuross River at Eurobodalla). These sites are located near or adjacent to Shire Council intakes for town drinking water. Historic and real-time stream flow data are available. Due to the nature of the rapid rise of river levels, water samples were collected during the rising limb of the river hydrograph with a series of siphon samplers. Due to lack of suitable structures at a low level at Eurobodalla and the risk of having equipment washed away, the lowest samplers were therefore attached to the nearby up-stream bridge at Eurobodalla. Further samples were collected manually during the hydrograph falling limb and during low flow conditions in 2005.

The simple siphon samplers were constructed from a modified design of Newham *et al.* (2001). The samplers comprised a 1 litre HDPE plastic bottle connected to 8 mm internal diameter vinyl tubing for a siphon system via a rubber stopper, all contained within 110 mm outside diameter PVC pipe. In the field, a subsample was filtered through a 0.45 µm filter and pre-filter when turbid for dissolved nutrient determination. All water samples were analysed by the Ecowise Environmental laboratory in Canberra. For results presented in this paper, methodology (APHA 1998) was: total P and N (persulphate digestion); nitrate (APHA 4500); and, suspended solids (gravimetric). Regression relationships between concentration data were analysed using Genstat.

STORM EVENTS DURING 2005 AND CATCHMENT HYDROLOGY

Water samples were collected during 2 events in 2005. Event 1 occurred between 1-3 July and event 2 between 10-13 July. Event 1 was the largest storm event for approximately 3.5 years, peaking at 12,360

ML/d in the Tuross catchment at the Eurobodalla gauge. Similarly, in the Moruya catchment event 1 was the largest storm event for approximately 3.5 years, peaking at 10,680 ML/d at the Wamban gauge. Some of the relationships between nutrient and sediment concentrations for the storm events in July 2005 and monitoring period (January to August 2005) are presented in this section. Figure 1a shows total P (TP) and suspended sediment concentrations, and Figure 1b shows nitrate-N and total N (TN) concentrations of Tuross River water samples at gauge 218008 (Eurobodalla). Figure 2a and 2b show similar relationships for the lower Deua River at Wamban. The relationships for both catchments indicate that TP is associated with sediment, with TP concentration of the suspended sediment being approximately 0.13–0.15%. Of note is that this percentage of TP in suspended sediment is greater than the downstream dairy farm soil TP concentrations reported in Table 1, reflecting the affinity of fine sediment to adsorb P.

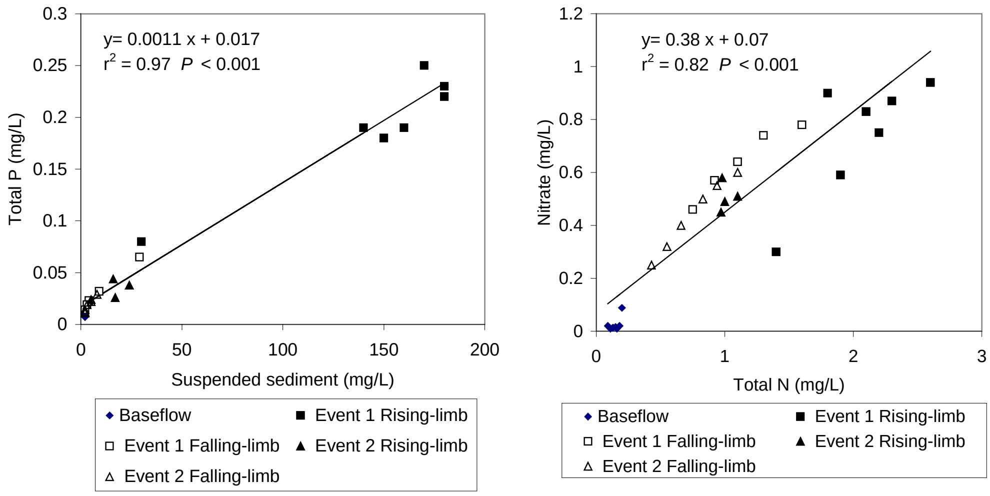

Figure 1a (left): Total P and suspended sediment concentrations. **Figure 1b (right):** Nitrate-N and total N concentrations of Tuross River water samples at gauge 218008 (Eurobodalla) monitored during baseflow (2005) and rising and falling hydrograph limbs in 2 storm events (July 2005).

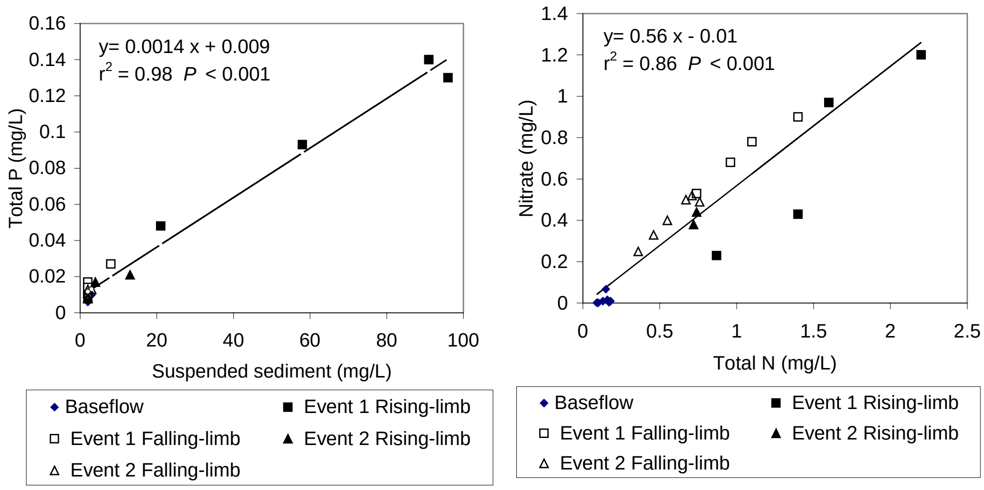

Figure 2a (left): Total P and suspended sediment concentrations. **Figure 2b (left):** Nitrate-N and total N concentrations of Deua River water samples at gauge 217002 (Wamban) monitored during baseflow (2005) and rising and falling hydrograph limbs in 2 storm events (July 2005).

In addition to storm flow, catchment baseflow contributed from groundwater inflow can be an important component in river hydrology. Baseflow index estimates the proportion of total observed flow due to baseflow. Here, we present some brief results to put this in a catchment perspective. Daily flow data from the DIPNR database was checked to ensure flow records with zero flow were a true reflection. To estimate baseflow in these catchments, the "minimum filter" was used (Croke *et al.* 2002). The estimated mean annual baseflow component of total observed flow for Tuross and Moruya catchment gauges varied from 39–59%. For example, Table 2 shows the baseflow index for gauge 218008 (Eurobodalla) was 50%, but storm flow variation was high. Further evaluation of this data will be used to estimate long-term nutrient loads from baseflow, in conjunction with storm event loads.

Table 2: Estimated annual baseflow fraction, baseflow and observed flow for gauges 217002 (Wamban) and 218008 (Eurobodalla).

Gauge number	Years of data	Annual mean flow (ML/d)	Annual mean baseflow (ML/d)	Annual baseflow index	Standard deviation flow	Standard deviation base flow
217002	1959-2004	871	399	0.46	5200	1049
218008	1977-2004	793	397	0.50	4782	954

DISCUSSION

Soil regolith properties

Agronomic guidelines for grazed dairy pasture recommends soil Olsen P targets lower than some values in our study, although irrigated land appears well managed. For example, an Olsen P level of 18–25 mg/kg at 0–10 cm is considered adequate for Victorian dairy pastures, and > 25 is considered high (DPI 2005). In contrast, New Zealand agronomic guidelines recommend Olsen P (0–7.5 cm depth) to be less than 40 mg/kg. Colwell P levels were also found by Lawrie *et al*. (2004) to be similar to or greater than the levels for non-irrigated and effluent paddocks in our study. In contrast, total soil P (0–5 cm) was found to be much greater on effluent application areas in the study of Drake (2005) with total P up to 0.4%, although effluent had been applied for longer periods in that study. The PBI of the soils under the managements listed in Table 1 are considered moderate (DPI 2005), which will help to reduce losses. In contrast, effluent application has been shown to reduce P sorption capacity in some NSW soils, which may contribute to increased P leaching (Holford *et al.* 1997). However, the effluent application areas are only a very small proportion of the farm area, and are associated with much greater P inputs than irrigated or dry-land managed soil. Therefore, we consider the “whole farm” losses more important in a catchment context (Drewry *et al.* 2005). The potential for changes in soil nutrient levels and associated losses is being further evaluated.

From a catchment perspective, it is also our intention to assess the properties of soil regolith materials over a wider area of the catchment, and use various factors such as soil nutrient levels, soil depth, soil regolith map information, soil texture, land use, soil erodability factors and hydrology for a general risk assessment model, although this may be dependent on data availability and resolution. Such index models have been developed for farm or small catchment scale (McDowell *et al.* 2004). For example, factors enhancing P loss include soil texture, particularly sandy soil, low P retention or buffer capacity, and soil P levels above plant requirements (McDowell *et al.* 2004). Soil regolith monitoring at paddock scales, together with associated water monitoring at catchment scale, and process understanding developed from our work with CatchMODS, will help to assess soil regolith source risk, nutrient and sediment loads, and relative contributions of nutrients and sediment from land use and soil regolith sources in an overall catchment context.

Water quality monitoring

The relationship between the nitrate and TN at our monitoring sites suggests that nitrate is a lower proportion of TN during the rising-limb of the event, with subsequent greater proportions presumably as water infiltrates and moves through the soil regolith. Also of note is that 45% and 55% of the TN load was in the nitrate form in the Tuross and Moruya catchments, respectively. River nutrient concentrations during the 2 July events were considerably greater than baseflow conditions with consequently greater loads expected. Full evaluation of load estimates and measurements will be presented elsewhere. Both catchment water quality sampling points are intakes for Eurobodalla town drinking water. Concentrations of nitrate during the 2 July 2005 events were considerably less than 11 mg/L, the recommended maximum for drinking water. However, environmental acceptability depends on the sensitivity of the estuaries. In contrast, the concentrations of nitrate during the 2 events were greater than the ANZECC guideline for slightly disturbed lowland rivers (0.04 mg nitrate-N/L) in south-east Australia. Full evaluation of flow-weighted means will be presented elsewhere. We found the simple rising-stage samplers very successful. Our results showed, not unexpectedly, that the concentrations of nutrients and sediment transported at high flows were considerably greater than during baseflow conditions indicating that event-based monitoring is important to determine loads.

CONCLUSIONS

Our overall approach is being undertaken to assess nutrient and sediment loads from soil regolith and land use sources from a catchment perspective. Our results suggest concentrations of nitrate during the 2 events during July 2005 at the Eurobodalla Shire drinking water intakes were considerably less than the recommended maximum for drinking water. Further evaluation of soil regolith information and soil management, land use and subsequent implications for water quality within the catchments is being undertaken. The use of soil regolith information and management, storm event-based loads and catchment models is important to help evaluate overall catchment loads and sources.

REFERENCES

APHA 1998. *Standard methods for the examination of water and wastewater*. American Public Health Association, American Water Works Association and Water Environment Federation, Washington, D.C.

BURKITT L.L., MOODY P.W., GOURLEY C.J.P. & HANNAH M.C. 2002. A simple phosphorus buffering index for Australian soils. *Australian Journal of Soil Research* **40**, 497-513.

CORNISH P.S., HALLISSEY R. & HOLLINGER E. 2002. Is a rainfall simulator useful for estimating phosphorus runoff from pastures - a question of scale-dependency? *Australian Journal of Experimental Agriculture* **42**, 953-959.

COX J.W., CHITTLEBOROUGH D.J., BROWN J.J., PITMAN A. & VARCOE J.C.R. 2002. Seasonal changes in hydrochemistry along a toposequence of texture-contrast soils. *Australian Journal of Soil Research* **40**, 581-604.

CROKE B.F. & JAKEMAN A.J. 2001. Predictions in catchment hydrology: an Australian perspective. *Marine and Freshwater Research* **52**, 65-79.

CROKE B.F., SMITH A.B. & JAKEMAN A.J. 2002. A one-parameter groundwater discharge model linked to the IHACRES rainfall-runoff model. *In:* RIZZOLI A.E.& JAKEMAN A.J. eds. *Proceedings International Environmental Modelling and Simulation Society (iEMSs)*, 428-433.

DPI 2005. *Fertilising dairy pastures. A manual for use in the Target 10 soils and fertiliser program*. Department of Primary Industries, Melbourne, Victoria

DRAKE J. 2005. *Dairy farm effluent: effects of long term, continuous application to soils, Bega Valley, NSW*. B.Sc. Honours thesis, Australian National University.

DREWRY J.J., NEWHAM L.T.H., GREENE R.S.B., JAKEMAN A.J. & CROKE B.F.W. 2005. An approach to assess and manage nutrient loads in coastal catchments of the Eurobodalla region, NSW, Australia. (submitted). *MODSIM05. International Congress on Modelling and Simulation Proceedings.*

GREENE R.S.B. & HAIRSINE P.B. 2004. Elementary processes of soil-water interaction and thresholds in soil surface dynamics: a review. *Earth Surface Processes and Landforms* **29**, 1077-1091.

HOLFORD I.C.R., HIRD C. & LAWRIE R. 1997. Effects of animal effluents on the phosphorus sorption characteristics of soils. *Australian Journal of Soil Research* **35**, 365-373.

LAWRIE R.A., HAVILAH E.J., ELDRIDGE S.M. & DOUGHERTY W.J. 2004. Phosphorus budgeting and distribution on dairy farms in coastal New South Wales. *SuperSoil 2004: 3rd Australian and New Zealand Soils Conference*. University of Sydney. Published on CD-ROM.

MCDOWELL R.W., BIGGS B.J.F., SHARPLEY A.N. & NGUYEN L. 2004. Connecting phosphorus loss from agricultural landscapes to surface water quality. *Chemistry and Ecology* **20**, 1-40.

NEWHAM L.T.H., CROKE B.F.W. & JAKEMAN A.J. 2001. Design of water quality monitoring programs and automatic sampling techniques. *In:* RUTHERFURD I., SHELDON F., BRIERLEY G.& KENYON C. eds. *Proceedings of the third Australian stream management conference*. Cooperative Research Centre for Catchment Hydrology, 455-460.

NEWHAM L.T.H., LETCHER R.A., JAKEMAN A.J. & KOBAYASHI T. 2004. A framework for integrated hydrologic, sediment and nutrient export modelling for catchment-scale management. *Environmental Modelling & Software* **19**, 1029-1038.

RAYMENT G.E. & HIGGINSON F.R. 1992. *Australian laboratory handbook of soil and water chemical methods*. Inkata Press, Melbourne

Acknowledgments: This research was undertaken with scholarship funding from The Australian National University and the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME). Thanks to Adam Wiggins, DIPNR for supplying recent flow data.