Sediment sources in the Lake Burragorang catchment and their management

Paul Rustomji and Scott Wilkinson

CSIRO Land and Water, GPO Box 1666, Canberra, ACT, 2601. E-mail: paul.rustomji@csiro.au

Abstract

Recent CSIRO modelling of suspended sediment sources in the Lake Burragorang catchment has predicted that hillslope erosion, mainly from non-agricultural areas may be the dominant source of suspended sediment delivered to the reservoir. Gully and riverbank erosion in the agricultural areas are predicted to be comparatively minor sources of sediment delivered to the reservoir under current conditions. Both of these predictions are consistent with suspended sediment fluxes measured at a network of eleven gauging stations in the Lake Burragorang catchment and also with geochemical tracer data from the catchment. The management of diffuse hillslope erosion as a sediment source in steep forested catchments is likely to be difficult. However, management actions implemented in agricultural areas of the catchment will be of benefit, particularly for local aquatic ecosystems and to reduce delivery of contaminants attached to sediment.

Keywords

Lake Burragorang, sediment budget, erosion

Introduction

There is an increasingly well recognised need for agencies responsible for supplying water to urban populations to take a “catchment to consumer's tap” approach to managing their water resources (Hamilton *et al.,* 2006). For many water utilities, this has involved a shift in emphasis from simply managing water treatment regime extraction (from a reservoir for example) to a broader emphasis on managing the complete path water takes from the catchment, through storage and treatment infrastructure and ultimately to the consumer.

The philosophy of having multiple, independent barriers that combine to produce safe drinking water is also becoming widespread (Hrudey *et al.,* 2006). For example, the Australian Drinking Water Guidelines note that “Prevention of contamination provides greater surety than removal of contaminants by treatment, so the most effective barrier is protection of source waters to the maximum degree practical” (National Health and Medical Research Council, 2004). Catchments generating high quality runoff can thus comprise one component of a multi-barrier system and increasingly emphasis is being placed by water utilities on monitoring and managing their catchments (e.g. Foran *et al.,* 2000) to better understand the sources of important pollutants and their movement through the drainage network. Pollutants of concern may include biologically active constituents such as pathogens and virus's that pose a direct risk to human health (see review by Brookes *et al.* 2004), but may also include abiotic pollutants that degrade the physical or chemical properties of the water and/or impose costs for treating the water to an acceptable standard (Holmes, 1988). This latter group includes sediments and nutrients (Gianessi & Peskin, 1981, Pettersson, 1998). Indeed the distinction between biotic and abiotic components is in some cases artificial with some microscopic pathogens and viruses sorbed to and transported with larger particles including mineral sediment (Brookes *et al.,* 2004). Understanding the location of important pollutant sources provides a rational basis for targeting catchment management action (e.g. Lu *et al.,* 2004), which, in the Australian context as elsewhere, is particularly important given the large catchment areas typically required to ensure adequate water supply security given the relatively low and variable precipitation regime (Peel *et al.,* 2001).

CSIRO has recently completed a series of studies investigating the sources of sediments and nutrients delivered to the reservoir (Lake Burragorang) that provides most of metropolitan Sydney’s drinking water. This research was undertaken to assist the Sydney Catchment Authority (SCA) improve the catchment’s water quality. This CSIRO research has included:

1. A study of historic floodplain deposition patterns (Rustomji & Pietsch, *in press,* Rustomji *et al.*, 2006).
2. An erosion process and sediment source study using geochemical and radionuclide sediment "fingerprinting" methods (Caitcheon *et al.*, 2006).
3. An analysis of suspended sediment fluxes at eleven stream gauging stations within the catchment (unpublished data).
4. Modelling of the sediment and nutrient sources within the catchment using the SedNet model (Read *et al*., 2003; Rustomji, 2006).

This paper presents some key findings of this research, identifies the major components of the catchment's sediment budget and discusses some of the management options available to improve water quality generated by the catchment and delivered to the reservoir. Being an overview of a multi-component research project, the references cited above should be consulted for more detail on each of the project sub-components.

The Lake Burragorang catchment is 9000 km^2 in size and extends from the Blue Mountains west of Sydney southwards to the Southern Tablelands. Approximately half the catchment lies in the Sydney Basin and half in the Lachlan Fold belt geologic provinces. The catchment (apart from the Southern Tablelands) like much of the country east of the Great Dividing Range in New South Wales is strongly dissected, with local relief exceeding 500 m in many areas. The steeper parts of the catchment are predominantly forested and have higher rainfall than the Southern Tablelands. Whilst the catchment is much steeper than much of Australia in general, many aspects of it, such as the mountainous, forested landscape near the reservoir are comparable to other Australian water supply catchment environments.

What are the main sources of sediment delivered to the reservoir?

Analysis of water quality data collected within the Lake Burragorang catchment has indicated that forested catchments developed upon Sydney Basin sandstones near the reservoir have area specific suspended sediment yields of approximately 40 $t/km^2/yr$ (unpublished data). Such a yield is equal to or in many cases greater than the area specific suspended sediment yields generated from agricultural areas in the flatter and drier parts of the catchment, such as the Mulwaree River and upper Wollondilly River sub-catchments. The lack of gully erosion in the forests, the predominance of bedrock dominated channels and generally intact riparian vegetation suggests that these relatively forest high sediment yields are due to high rates of hillslope erosion during infrequent, large magnitude rainfall events.

A sediment budget for the Lake Burragorang catchment (Rustomji, 2006) was constructed using the SedNet model (Prosser *et al.*, 2001). This modelling study incorporated the 40 $t/km^2/yr$ sediment yield for forested areas of the catchment (but not to the upper Wollondilly River and Mulwaree River sub-catchments that are not developed on the Sydney Basin sandstones). The model predicted that the suspended sediment yield from hillslope erosion is the dominant source of sediment delivered to the river network, generating approximately seven and thirty times the mass of sediment generated by gully erosion and river bank erosion respectively. Furthermore, the close proximity to the reservoir of heavily forested sub-catchments (with limited downstream floodplain area available for deposition) means that they represent an important, if not the dominant source of sediment ultimately delivered to the reservoir. Whilst this conclusion is based on modelling of the catchment's sediment budget, it does concur with geochemical tracer data that indicate 68% of the fine sediment deposited in the Wollondilly arm of the reservoir is sourced from surface soil (Caitcheon *et al.*, 2006).

This conclusion differs from that reached in previous studies in south eastern Australia (e.g. Wallbrink *et al.*, 1996, Wasson *et al.*, 1998 and Olley & Wasson, 2003) that have identified gully erosion as the dominant sediment source in many catchments. This conclusion has been seen to apply particularly strongly to the Southern Tablelands region of New South Wales, where an extensive gully network developed in the period following European settlement (Eyles, 1977; Prosser, 1999). Whilst this conclusion of a gully-dominance may be accurate when considering Southern Tablelands sediment budgets integrated over the last 200 years for example, it may not necessarily hold when considering a sediment budget characteristic of the last 20 years. This is because gully networks develop over time and the rate of sediment supply from gully erosion is related to the rate of network extension, which also varies in time. Network extension is most rapid during the early, formative phases of a gully network (typically the first 50 years) and subsequently declines as potential new incision sites become scarcer (e.g. Prosser & Abernethy, 1996). Many of the gullies in the Lake Burragorang catchment were initiated shortly after European settlement of the catchment in the mid-1800s. Olley and Wasson (2003) have demonstrated that sediment yields from gullied catchments of the region peaked in the late 1800s to early 1900s and have subsequently declined, due to inferred low rates of gully network extension. This pattern is reflected in reduced floodplain aggradation rates observed in agricultural catchments over the last 20 to 100 years (Rustomji *et al.,* 2006). Some gullies may also be re-aggrading, as described by Zierholz *et al.,* (2001) and Rustomji *et al*., (2006), which further serves to decrease sediment yields from gullied landscapes. Thus the question of what is the main sediment source in a given catchment is highly dependent upon the timeframe being considered, particularly where gully erosion has occurred within the catchment.

These temporal changes in sediment supply from gully erosion have been represented by assuming that the catchment's gullies are yielding 20% of their estimated long term average sediment yield (calculated according to Prosser *et al.,* 2001). Whilst this percentage is an estimate, it is a plausible assumption and variations in the exact percentage do not alter the broad conclusion that gully erosion currently represents a secondary sediment source within the Lake Burragorang catchment.

Finally, river bank erosion is predicted to be a minor source of sediment input to the river network. Whilst river bank erosion rates are difficult to predict accurately due to the strong temporal and spatial variability in their occurrence, modelling predictions for the catchment indicate that it comprises a minor component of the Lake Burragorang catchment's sediment budget. This is likely to be a robust conclusion unless bank erosion rates are being under-predicted by an order of magnitude or more. Field evidence suggests that such an under-estimation is unlikely with some channels in the agricultural parts of the catchment having contracted in the post-European settlement period due to increased sediment storage (Rustomji *et al*., 2006), suggesting that bank erosion is not widespread.

Implications for managing sediment delivery to Lake Burragorang

These broad conclusions about the sediment budget for the Lake Burragorang catchment can now be used to develop management strategies for improving water quality. Improvements to water quality in the catchment will reduce treatment costs for production of drinking water and also benefit ecosystem health. Some recommended strategies are discussed below.

Hillslope erosion

The active management of diffuse hillslope erosion in steep forested areas is not easy, since there are very few treatment options available. Many of these steep forested areas are in relatively undisturbed National Park settings and the rates of sediment supply could be considered as natural rates for such environments. Indeed, very high rates of suspended sediment export (> 200 t/km^2/yr) have been noted for forested areas in the Wet Tropics of Queensland by McJannet *et al*., (2006), indicating that there is no *a priori* basis for assuming that forested areas have inherently low rates of sediment yield. The best option available might be to carefully control which of Sydney's reservoirs are used for water extraction immediately after high rainfall events, with the aim of avoiding the most turbid water. Changing reservoir extraction points may also be an option if new, sediment-laden inflows are stratified within the reservoir.

A growing body of research is also indicating that road and track networks can be a significant sediment source within forested catchments (e.g. Motha *et al*., 2003; Croke & Hairsine, 2006). Addressing sediment generation from road surfaces may represent another management option. Forest fires are an important agent of erosion. When combined with heavy post-fire rainfall, event yields of sediment and Phosphorus of 1–2 orders of magnitude higher than pre-fire event yields have been recorded (Rustomji & Hairsine, 2006, Wilkinson *et al*., 2006). Management options for preventing wildfire sediment yield impacts once fire has occurred are limited, but if the burnt area is relative small may include installing sediment curtains in the reservoir downstream of burnt sub-catchments for example.

Improving management practices on agricultural land to minimise hillslope-derived sediment delivery to the stream network would still be of value, particularly for improving water quality in local aquatic environments. Many pesticides commonly used in agricultural settings are known to be preferentially bound to sediments (Kookana *et al.* 1998), such that minimising the loss of sediments from agricultural areas, whilst not necessarily being of great importance in the catchment's sediment budget, may make an important difference in restricting movement of other sediment-adsorbed pollutants associated with agricultural practices. There appears to be only a weak association between pathogens and sediments, however viruses are known to be strongly adsorbed to fine sediment particles (Brookes *et al.*, 2004).

Some agricultural areas of the catchment (such as the Coxs River below Lyell Dam and lower Wollondilly River sub-catchments) do have efficient pathways to the reservoir due to the steep topography of their downstream catchments, which reduces the potential for sediment storage on floodplains. Water quality in the reservoir is likely to be improved by reducing hillslope erosion rates in these strongly connected areas.

Gully Erosion

Management strategies for gully erosion in the Lake Burragorang catchment should be based around the principle that many of the gully networks are relatively stable in their planform extent. This implies that emphasis should be placed on retaining sediments eroded principally from sidewall erosion within the gully system and attempting to convert established gullies from efficient conveyors of sediment (due to their channelisation) to efficient retainers of sediment.

Zierholz *et al.,* (2001) note that the re-establishment of gully floor vegetation plays an important role in inducing re-aggradation of existing gully voids. Techniques that draw upon the characteristics of existing, re-aggrading gully systems are likely to provide a good template for restoration activities. These techniques would include stock exclusion from gully networks to enhance vegetation growth which in turn should increase sediment trapping potential. Alternatively, the construction of porous flow retardation structures upon gully floors to reduce flow velocity, encourage sediment deposition (to provide a substrate for vegetation regrowth where this may be lacking) and retain moisture higher in the landscape could be possible.

Riverbank Erosion

Although riverbank erosion has been shown to be a small source of sediment relative to other sources, the riverbank erosion predictions modelled for the Lake Burragorang catchment are speculative and unconstrained. Field surveys or air photo analysis would provide a more robust perspective of bank erosion within the catchment than regional scale modelling can.

Conclusion

Recent research has suggested that hillslope erosion within the catchment of Lake Burragorang may be the dominant source of sediment delivered to the reservoir. This is because (a) yields from forested sub-catchments appear to be higher than had been previously recognised, (b) contemporary sediment yields from gully erosion are likely to be lower than in previous times because the gully network is in a comparatively stable, mature evolutionary state, and (c) river bank erosion does not appear to be widespread and hence is predicted to be a minor source of sediment delivered to the reservoir. Management guidelines that follow from these conclusions include:

1. Managing water extraction to avoid reservoirs with turbid water after high rainfall events
2. Encouragement of gully revegetation in established gully systems.
3. Management of hillslope erosion in agricultural areas for the benefit of the local aquatic environment, and
4. Local mapping of riverbank erosion to highlight eroding hotspots.

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