Recent trends in turbidity and suspended sediment loads in the Murrumbidgee River, NSW, Australia

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Abstract Turbidity and flow data from the Murrumbidgee River, NSW Australia were used to assess if changes in land management have altered suspended sediment loads. The data indicate that over the last 20 years the turbidity and sediment load per unit volume of flow has decreased significantly. The decrease in the sediment load is related to a number of factors, including: (a) a decrease in flow from the tributary catchments; (b) an increase in the proportion of water derived from upstream water storages; (c) a decrease in the total volume of flow in the main channel; (d) stabilization of >50% of the gully network; (e) an increase in the extent of in-stream wetlands; and (f) a massive increase in the number of farm dams. The work illustrates the difficulty in relating changes in sediment loads in large rivers to causal factors.

Key words Australia; channel erosion; land management; Murrumbidgee River; sediment loads

INTRODUCTION

European settlement 180 years ago brought massive changes in land use across the southeast of Australia (e.g. Scott, 2001). The clearing of woodlands, the introduction of grazing stock and rabbits, the drainage of valley bottoms, and the clearing of riparian vegetation caused a large increase in erosion (Prosser *el al.*, 2001; Olley & Wasson, 2003). In < 100 years nearly every valley in southeastern Australia was affected. Massive volumes of sediment were delivered to the rivers, and the form of the rivers and the surrounding landscape were changed dramatically (Olley & Scott, 2002; Olley & Wasson, 2003). Vegetated valley floors were incised; clear flowing waters became turbid; deep pools were filled with sand; and rivers, which abounded with fish and other life, became dominated by algal growth.

Over the last 50 years there have been significant improvements in the way the land is managed. The formation of the Soil Conservation Services, beginning in 1938, started a programme of educating land managers in ways of minimizing soil erosion. The introduction of myxomatosis in the 1950s greatly reduced rabbit numbers, improving the vegetation cover. Many of the gullies are now vegetated and have stabilized. In many tributary catchments in-stream wetlands have formed. The construction of water storage reservoirs and farm dams has also decreased the supply of sediment.

In this paper we used turbidity and flow data to assess temporal changes in the sediment load in the main channel of the Murrumbidgee River, NSW, Australia. An attempt is made to relate variations in the sediment load to changes in the catchment.

BASIN DESCRIPTION AND PREVIOUS WORK

The Murrumbidgee River is one of Australia's largest rivers, draining approximately 84 000 km^2 of the Murray-Darling Basin (Fig. 1). Its catchment can be divided into three distinct

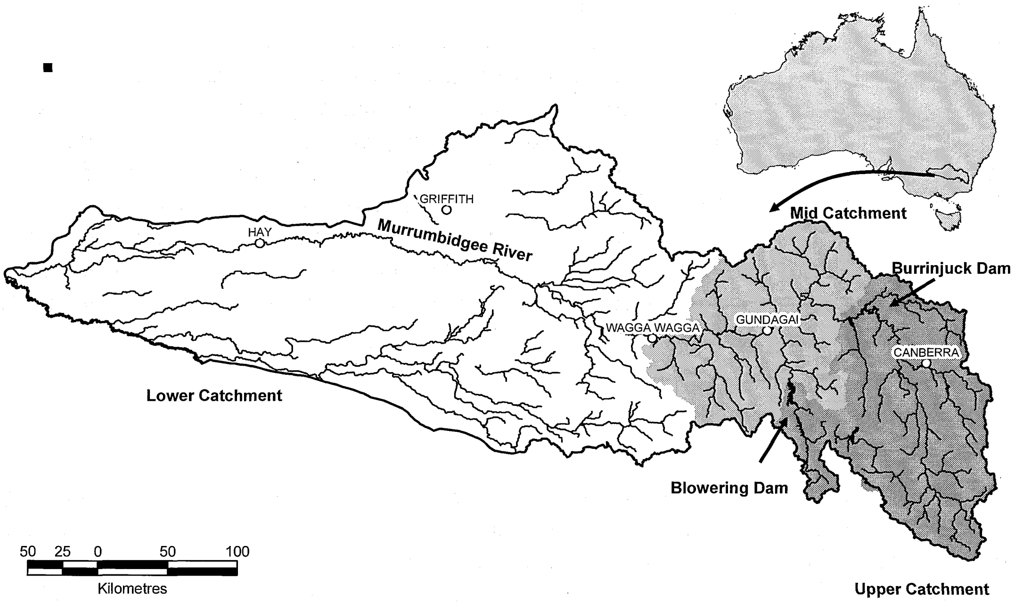

Fig. 1 Map of the basin showing key locations.

geomorphic regions: the upper, mid, and lower Murrumbidgee (Page, 1994). The upper region is mountainous and hilly, and is separated from the mid-region by two large storage reservoirs, Burrinjuck and Blowering (Fig. 1). These dams trap most of the sediment delivered from the upper basin (Wasson *et al.*, 1987). The mid-basin area is characterized by undulating terrain dissected by numerous stream and gully networks, which have been shown to be the primary source of sediment delivered to the lower Murrumbidgee River (Olive *et al.*, 1996; Wallbrink *et al.*, 1998). Most of the major tributaries of the mid to lower Murrumbidgee join the river in this region; their average catchment size is ~1000 km^2. Over the last 20 years a large number of farm dams have been build in these tributary catchments and between 10–20% of the tributary area is now separated from the main channel by farm dams. Many of the gullies have now stabilized with more than 50% of the gully networks in the Wagga Wagga region now well vegetated (Caitcheon, personal communication). In many tributary catchments in-stream wetlands have formed and now trap significant amounts of sediment derived from upstream (Zierholz *et al.*, 2001).

Grazing is the main land use in the upper basin. The region around Wagga Wagga (mid-basin) is a major grain producing area. There is extensive grazing on the riverine and hay plains that make up the lower basin, and intensive cropping and horticulture in the irrigation areas. A strong rainfall gradient exists across the basin; average annual totals vary from 1600 mm in the Snowy Mountains to 300 mm at Balranald. Prior to regulation the river experienced extreme variations in annual flow, with most of the flow concentrated in winter and spring (Ebsary, 1994). The river is now a major source of irrigation water and flow is heavily regulated, both by the two major dams located in the upper catchment, and by a series of weirs below Wagga Wagga (Fig. 1). The combination of regulation and extraction for irrigation has resulted in flow now being spring and summer dominated when water demand by irrigators is highest.

Using the fallout tracers ^{137}Cs and $^{210}Pb_{ex}$, Wallbrink *et al.*, (1998) demonstrated that the dominant source (~90%) of the suspended sediment in the Murrumbidgee River is channel banks and gully walls. Fallout ^{210}Pb data were also used to show that the mean residence times of fine grain sediments within the mid-Murrumbidgee system is unlikely to be more than a few years. Additional evidence from: (a) changes in the mean ^{137}Cs concentrations measured in sediments from flood and low flow waters; and (b) the presence of the short-lived surface-soil tracer ^{7}Be in flood water sediments, showed that the actual transport time of fines in this river is probably weeks to months, rather than years to decades. The low ^{137}Cs concentrations from the tributaries also indicate that most of the subsoil originates from the middle reach tributaries, and not from channel bank erosion along the Murrumbidgee River channel.

THE DATA

Daily turbidity measurements have been made at the Wagga Wagga water treatment plant since 1949. Measurements are made by visual comparison with a set of standards. While the same technique has been used for measurement of turbidity for the entire period the authors recognize that there is no guarantee that the measurements are consistent through time. However, analysis of the record indicates that the range of values has remained relatively constant with no apparent drift in trends. Turbidity has been measured at Gundagai since 1990 using a Hach turbidity meter.

The discharge record used in this study comes from the NSW Department of Water Resources (DWR) continuous gauging stations at the dams, at Wagga Wagga and at Gundagai. These stations are part of a network of gauging stations maintained by DWR throughout NSW. The rainfall data discussed comes from the Australian Bureau of Meteorology.

RESULTS AND DISCUSSION

Turbidity at both Gundagai and Wagga Wagga is linearly correlated with sediment concentration (Olive *et al.*, 1996). However, conversion of the turbidity data to sediment concentration introduces another variable into the analysis of trends in the records. Consequently we have used monthly-flow-weighted-turbidity. This is equivalent to the average turbidity observed per unit volume of water in the month, and equates to the mean monthly sediment concentration. The two records have been cross-calibrated and are shown together in Fig. 2(a). The turbidity data shows an overall decline in sediment supply over the last 50 years, particularly in the last 20 years (indicated by the 2.5 years running average). The 2.5-year running average monthly flow weighted turbidity and Wagga Wagga rainfall data (Fig. 2(b)) tend to co-vary with increases and falls in the turbidity associated with increases and falls in the local rainfall.

The decline in monthly flow weighted turbidity over the last 20 years is correlated with a decrease in flows at Wagga Wagga and an increase in the proportion of water derived from the upstream water storages (Fig. 3(c)). The high turbidities occur at the same time as flow events in the tributary catchments (compare Fig. 3(a) and (b)) supporting the hypothesis

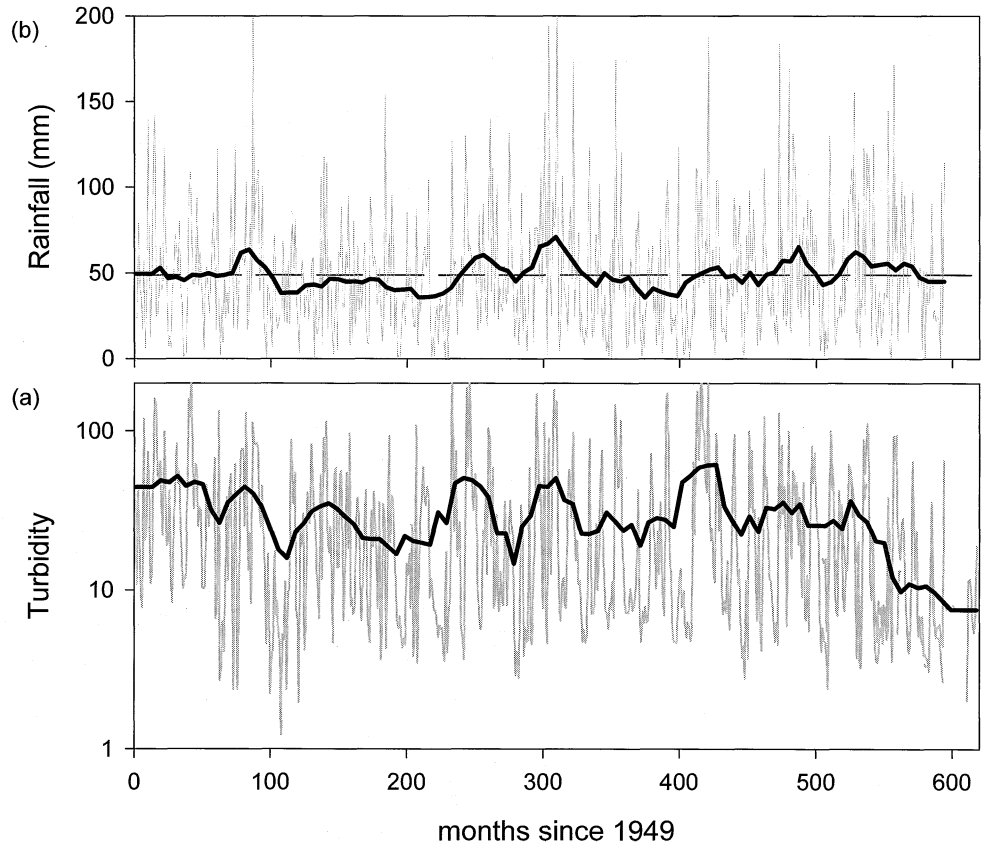

Fig. 2 (a) Monthly flow weighted turbidity for Wagga Wagga (grey line). The thick black line shows the 2.5-year running average on the combined turbidity data. (b) Total monthly rainfall at Wagga Wagga for the period since December 1948 (grey line). The mean monthly rainfall for this period is shown as the horizontal dashed line. The thick black line represents a 2.5-year running average.

proposed by Olive *et al.* (1996) that the tributaries are the primary source of sediment causing the higher turbidity. The decrease in flows from the tributary catchments over the last 20 years may be related to a decrease in regional rainfall. Or it may be a result of the construction of more than 20 000 farm dams in the catchment.

The data presented indicates that over the last 20 years the flow weighted turbidity and hence the sediment load per unit volume of water has decreased significantly at the Wagga Wagga. This improvement in water quality in one of Australia's largest rivers is correlated with a decrease in flows derived from the tributary catchments, a related increase in the proportion of water derived from upstream water storage, and a decrease in the total volume of flow in the main channel. Over the same period there has also been a marked increase in the vegetation cover in the gully networks, an increase in the extent of in-stream wetlands and an increase in the number of farm dams. The synchronicity of these events, all of which may be expected to alter the supply of sediment, make it difficult to discern the primary cause or causes of the improvements in water quality. This is the subject of a continuing investigation.

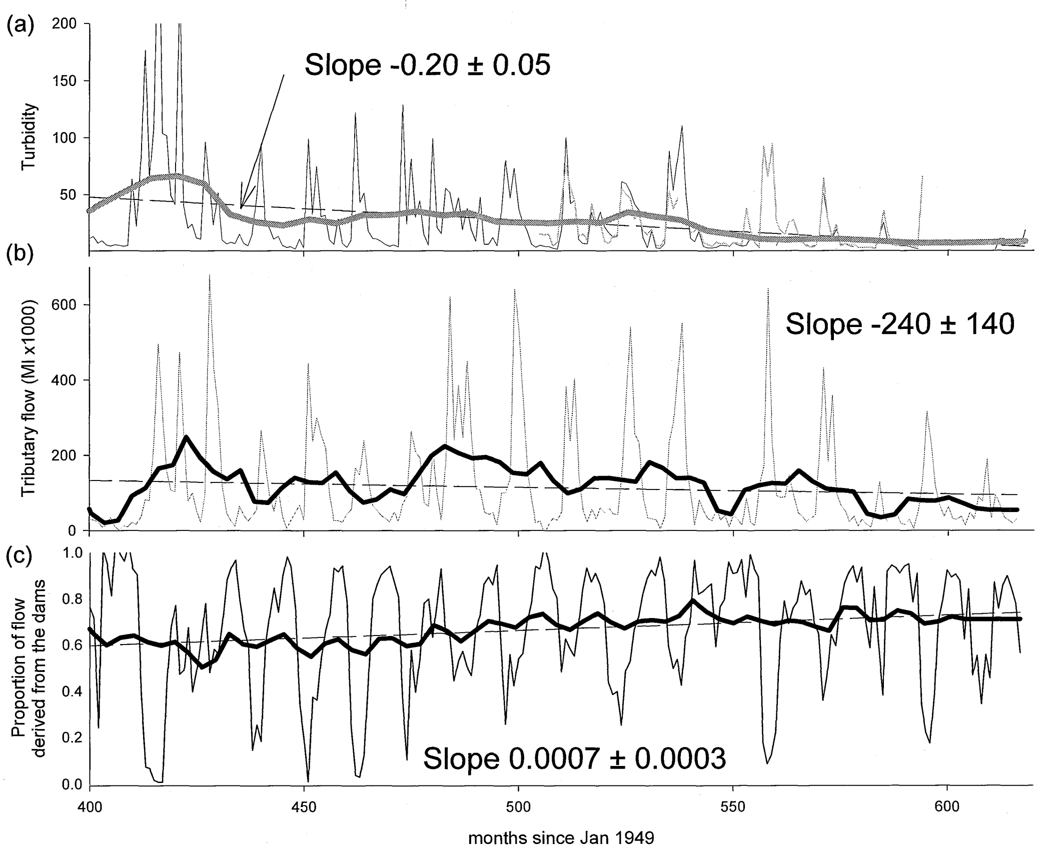

Fig. 3 (a) Monthly flow weighted turbidity for Wagga Wagga (dark grey) and Gundagai (light grey) for the period since 1981. (b) Flows derived from the tributary catchments below the dams. (c) The relative proportion of the water passing Wagga Wagga derived from the dams. In each figure the thick black line shows the 2.5-year running average on the data; the long dashed line shows the linear trends; the slope on the trend line and relative uncertainty are reported in each figure.

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