# Impact of Rainfall on Turbidity and Suspended Sediment Load at Five Sites on the Murray River Between Albury and Swan Hill and Possible Relationships to Catchment Attributes

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**Abstract** Eutrophication of the Murray River system is a major environmental problem. Much of this problem is due to excessive amounts of phosphorus in the river water and can lead to outbreaks of algal blooms. Suspended solids in the river, represented by turbidity, affect eutrophication in two ways. Firstly, they reduce the amount of light penetrating the water and thus act to limit the growth of algal blooms. However, suspended solids carry with them high concentrations of phosphorus, which in the Murray River system is the limiting factor controlling blue-green algal blooms. Daily turbidity, rainfall and streamflow data have been examined for five sites on the Murray and Edward Rivers between Albury and Swan Hill. The impact of erosion due to rainfall on turbidity levels and therefore suspended solids in the Murray River has been assessed. This was done by isolating those rainfall events which had an observable impact on turbidity levels in the river, and converting these changes in turbidity into changes in suspended solids load in the river. Daily rainfalls of around 20 mm can be seen to add approximately 50 tonnes of suspended solids to the river at each of the five daily sampling sites.

## 1. INTRODUCTION

The health of the Murray-Darling system has recently been recognised as a major environmental issue [Mackay and Landsberg, 1992]. The high levels of phosphate in the Murray River are regarded as an important component of this environmental problem, not least because of their influence on the occurrence of blue-green algal blooms [Kuhn, 1993]. Turbidity levels are an important aspect of this problem since suspended sediment carries nutrients with it as well as reducing light availability [Shafron, 1993]. For example, in the Latrobe River catchment in Victoria, strong positive correlations have been found between total suspended solids and phosphorus load [Grayson *et al.*, 1993] as well as between the turbidity of the water and total phosphorus load [Grayson *et al.*, 1994]. Consequently, understanding the sources and sinks of suspended sediment is important in coming to an understanding of phosphorus loads.

In addition, suspended sediment itself is an important environmental problem since the Murray River is used for a variety of purposes, not all of which are compatible with high levels of turbidity. For example, removing high levels of suspended sediment from water represents a considerable investment for water supply managers and industrial users of water [Murray *et al.*, 1993]. Additionally, highly turbid water can affect recreational users of the Murray and interfere with the growth of aquatic plants and fish.

This study will examine five sites on the Murray and Edward Rivers between Hume Dam and Swan Hill. Daily turbidity readings will be examined for these five sites in an attempt to relate increases in turbidity to local rainfall events. Daily, weekly or monthly turbidity readings from sites further up river will allow us to account for the influence of transported sediment.

## 2. DATA AVAILABILITY

The four sites examined on the Murray River were at water treatment plants (WTPs) for townships, and were located at :

Albury, between the Hume Dam and Kiewa River inflow;
Cobram, upstream of the town of Cobram;
Tocumwal, upstream of the town of Tocumwal; and
Echuca, upstream of the junction with the Campaspe River.

The fifth site was located on the Edward River, upstream of Deniliquin.

Figure 1 shows the location of these sampling sites and the major tributaries of the Murray River in the study area.

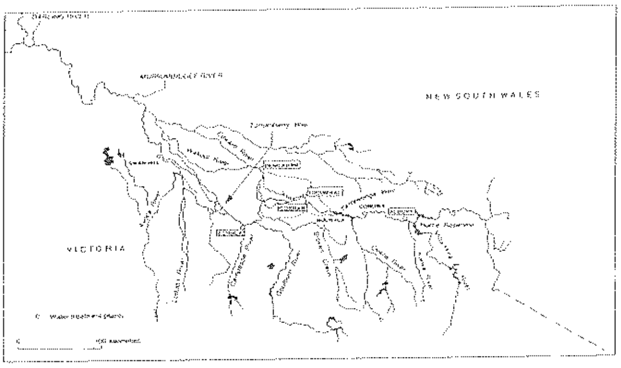

**Figure 1**
**Location of sampling sites**

Table 1 shows the period of record for which data were collected at each of the five sites.

**Table 1 :** Period of record for each of the five sampling sites

| Location (WTP) | Period of Daily Turbidity Record |
|---|---|
| Albury | 15 May 1992 - 31 Dec 1994 |
| Cobram | 1 June 1986 - 31 Mar 1995 |
| Tocumwal | 1 Jan 1991 - 31 Dec 1993 |
| Echuca | 1 Jan 1971 - 31 May 1993 |
| Deniliquin | 6 March 1986 - 14 May 1995 |

Daily rainfall records were acquired for the townships serviced by each of the five water treatment plants. Daily streamflow records were also acquired for Albury, Tocumwal and Deniliquin. At Cobram, daily streamflow is not recorded. Because of the proximity of Cobram to Tocumwal and the lack of tributaries entering the Murray River between these two towns, streamflow data from Tocumwal were used for Cobram. Streamflow is also not recorded at Echuca. Streamflow at Echuca was calculated by subtracting streamflow in the Campaspe River from streamflow over Torrumbarry Weir.

## 3. METHODOLOGY

For each of the five sampling sites, the daily rainfall, turbidity and streamflow were plotted through time, along with the turbidity readings from upstream stations which could have an influence on the turbidity at the station under examination. From these plots, those rainfall events which were observed to have an impact on turbidity were isolated for further examination.

In order to be sure that rainfall was dominating in producing these increases in turbidity, all those events which showed a peak in streamflow corresponding with the peak in turbidity were eliminated since they were probably transporting increased amounts of sediment from upstream, making it difficult to estimate the local contribution. In addition, all of the events which followed an upstream increase in turbidity were also eliminated from further examination since, once again, these peaks in turbidity were being caused in part by sediment being transported from upstream.

This elimination of events was necessary since it proved to be very unreliable to attempt to divide turbidity events into that portion coming from upstream and that portion due to local influences. By eliminating those events which were caused in part by increased transport of turbidity from upstream, we were left with a number of turbidity events which were not accompanied by significant increases in flow and which did not follow significantly elevated turbidity readings upstream. We concluded therefore that these events were being caused by local rainfall.

One factor which may have a large impact on the amount of sediment added to the river by a rainfall event is the rainfall intensity. As we only have daily rainfall data for the region, this is for the most part beyond analysis here. However, we can make the not unreasonable assumption that the greater the daily rainfall, the greater the rainfall intensity. This will not always be true and thus represents a source of error in our results.

At first we attempted to relate the change in turbidity in the river directly to the rainfall. However we found that, in addition to rainfall, streamflow was also having an impact on the change in turbidity in the river. That is, the higher the streamflow, the less the impact of a rainfall event. This is to be expected since the turbidity of the river is a measure of the *concentration* of sediment not the total sediment *load*. Thus streamflow must be incorporated into any equation relating rainfall to change in turbidity. It was decided to incorporate streamflow implicitly by calculating the change in total sediment load in the river from the change in daily turbidity and streamflow. These models were then compared between the five sites, in order to examine differences between the sites in terms of their sediment producing potential.

## 4. CALCULATING SUSPENDED SEDIMENT LOAD FROM TURBIDITY

Nephelometric turbidity is measured by shining a light through a sample of water with a detector aligned at an angle to the beam of light in order to observe how much of that light is scattered [Gippel, 1995]. Generally, the major influence on the scattering of light and therefore turbidity of the water is the concentration of suspended sediment. However, factors other than the concentration of suspended sediment in the water can affect the amount of light scattering. For example, other suspended solids such as vegetable matter, algae or the colour of the water can all influence the turbidity reading of a water sample. [Oliver, 1990]. Perhaps more importantly, the size distribution of the suspended sediments can influence the turbidity reading of the water. Thus, a change in turbidity between two sites may not represent an actual change in the concentration of sediment in the river. Generally however, there is usually a well defined relationship between the turbidity of the water and the concentration of suspended sediment [Gippel, 1995].

The form of the turbidity-suspended sediment relationship was examined by Post *et al.* [1995]. It was concluded that the relationship between turbidity and suspended solids derived by Oliver [1990] for a number of sites on the Murray River between Hume Weir and Lake Mulwala is an appropriate one to use. This relationship is given by :

$$c=1.41t+1.917 \qquad (1)$$

where : $c$ = sediment concentration (mg/L)
$t$ = turbidity of the water (NTU)

The sediment concentration in mg/L can then be converted into a sediment load in tonnes/day thus :

$$s=\frac{cf}{11.57} \qquad (2)$$

where : $s$ = sediment load (tonnes/day)
$f$ = streamflow (cumecs)

While this technique may lead to some inaccuracies in the calculation of actual loads at each of the sites, by using the same equation for all five sites, the relative sediment loads between the sites will be reasonably accurate.

## 5. RESULTS

### 5.1 Albury WTP

During the period of record, there were 14 days on which rain fell and was observed to have an impact on local turbidity levels. These increases were not accompanied by large increases in flow or elevated turbidity levels at upstream sites (Hume Dam and Heywoods). It was therefore concluded that these 14 events were being caused by sediment being washed into the river downstream of Hume Dam. That is, local rainfall events were responsible for these elevated levels of turbidity.

The smallest daily rainfall observed to have an impact on turbidity was 11.6 mm. This indicates that daily rainfalls less than this do not appear to have any impact on turbidity in the river. This could be due to the fact that any rainfall less than this does not mobilise significant volumes of sediment, or it could be that the sediment that it does carry does not have an observable impact on the turbidity in the river, even at low flows.

There will be errors in the rainfall records which may influence whether or not certain events show a turbidity response. For instance, some of the rainfall events may have a wide areal distribution, leading to greater volumes of runoff and therefore turbidity, while some may be quite localised. For the purposes of this study, we are forced to assume that the rainfall readings are representative of the local area and therefore comparable since we have no information to the contrary. This is of course an issue for all of the stations and one that we have little control over. It is possibly one of the major sources of error in this technique.

The SPPS statistical package was used to derive a linear regression model, relating the change in sediment load in the river to the rainfall. Non-linear transformation of the input and output variable were considered, but because of the small size of the data set, the fact that the relationship appears to be linear (see Figure 2), and that we do not have any information about the type of non-linearity that could be present, it was decided to use a linear relationship between rainfall and sediment production.

The derived equation was :

$$\tau=3.72r-54.95 \qquad (3)$$

where : $\tau$ = sediment added to the river (tonnes/day)
$r$ = daily rainfall (mm)

The coefficient of determination ($R^2$) for (3) is 0.75. $R^2$ here is defined as the square of the correlation coefficient between the observed and predicted values of change in sediment load [Norusis, 1993, p. 318]. Figure 2 shows the observed data used to calibrate (3).

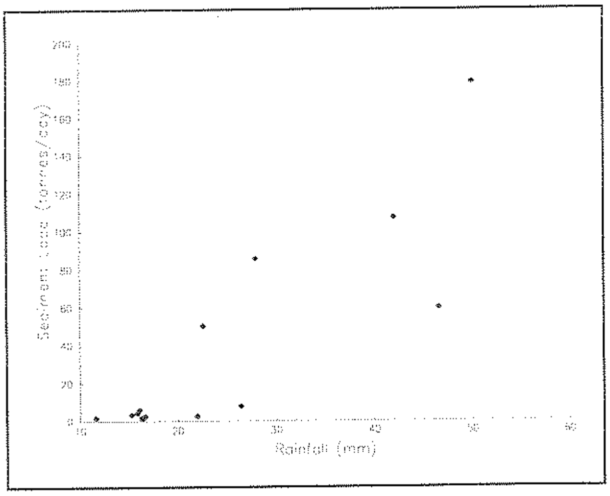

**Figure 2**
**Sediment added to the river**
**from rainfall events at Albury**

This relationship was derived for 14 daily rainfalls between 11.6 mm and 50.0 mm and thus it is only strictly applicable over that range of rainfalls. In particular, for rainfalls less than 11.6 mm, no effects on turbidity could be observed, while for events greater than 50.0 mm, it is likely that some non-linear relationship between rainfall and sediment added to the river may apply.

In addition to giving a prediction of the sediment added to the river due to a certain sized rainfall event, (3) can be used to predict the change in turbidity in the river for a certain streamflow simply by working backwards through (1) and (2).

### 5.2 Cobram WTP

During the period of record at Cobram WTP, there were 20 days on which rain fell at Cobram and was observed to have an impact on local turbidity levels. The smallest daily rainfall which was observed to have an impact on turbidity levels was 13.6 mm and the largest daily rainfall chosen for analysis was 51.8 mm.

Similarly to Albury, the change in turbidity was converted to a total sediment load and a statistical model was built relating this change in sediment load in the river to rainfall.

The derived equation was :

$$\tau = 2.16r - 11.23 \qquad (4)$$

The coefficient of determination for (4) is 0.72. Figure 3 shows a plot of rainfall versus change in sediment load for Cobram.

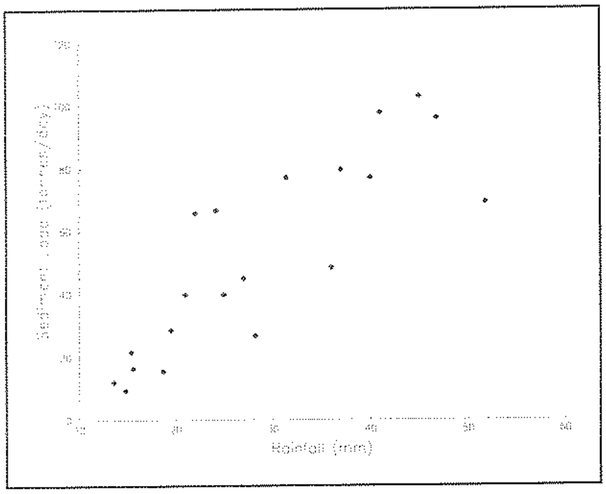

**Figure 3**
**Sediment added to the river**
**from rainfall events at Cobram**

The relationship between daily rainfall and sediment added to the river appears to be linear over this range of rainfalls and is reasonably well defined.

### 5.3 Tocumwal WTP

During the period of record at Tocumwal WTP, 13 rain days were identified which had a significant impact on turbidity in the river. The smallest daily rainfall identified was 14.8 mm and the largest was 50.8 mm.

As for Albury, the increase in turbidity for each rainfall event was converted into a change in sediment load in tonnes/day, and this sediment load related to the rainfall. The derived equation relating change in sediment load in the river to rainfall was :

$$\tau = 1.47r + 28.77 \qquad (5)$$

The coefficient of determination for this relationship is quite poor at only 0.13. The reason for this low value can be seen in Figure 4 which shows the observed data points on which (5) was based.

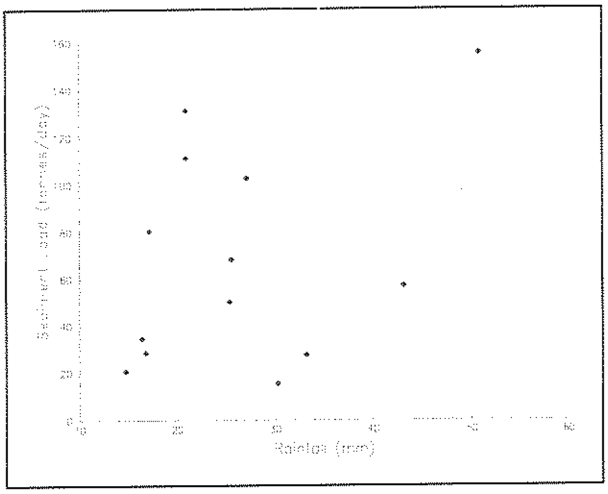

**Figure 4**
**Sediment added to the river**
**from rainfall events at Tocumwal**

For Tocumwal, the relationship between rainfall and sediment load is quite poor compared to any of the other sites. The reason for this is not known. It may be due to errors in the rainfall, turbidity readings, or perhaps some of the events chosen for analysis had increases in turbidity due to factors other than rainfall. Despite the generally poor fits at Tocumwal, the average size of the increase in sediment in the river due to rainfall can be seen in Figure 4, and thus Tocumwal can be compared to the other stations in terms of its sediment producing potential.

### 5.4 Echuca WTP

During the 22 years of record at Echuca, 36 rain days were identified which had a clear impact on turbidity levels. The smallest daily rainfall identified was 20.0 mm, and the largest was 74.7 mm.

As for the other stations, the change in turbidity was converted to a change in sediment load using (1) and (2). This change in sediment load was then compared to the rainfall on each of the 36 days chosen for analysis. The following equation was derived which relates the change in sediment load in the river to the daily rainfall :

$$\tau = 7.17r - 139.45 \qquad (6)$$

The coefficient of determination for (6) is 0.40. The data from which (6) was derived are shown plotted in Figure 5.

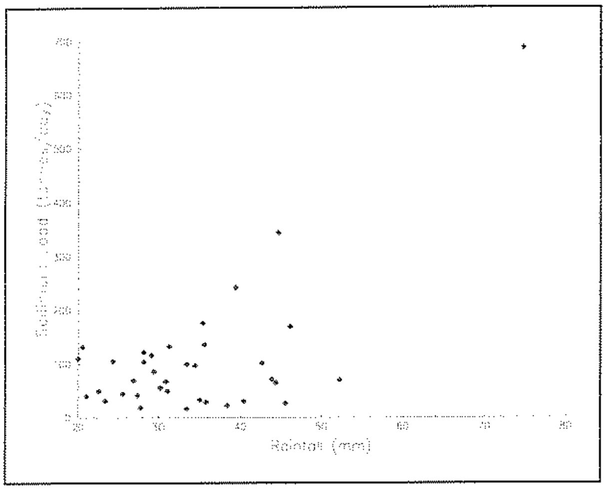

Figure 5
Sediment added to the river
from rainfall events at Echuca

The data point relating to the 74.7 mm rainfall is an influential point and does certainly draw the relationship out. However, even with this point removed, the derived equation is similar. Thus this point was retained for the purposes of analysis.

### 5.5 Deniliquin WTP

Note that streamflows are not often measured at Deniliquin and thus when streamflows were not available, downstream flows over Stevens Weir on the Edward River had to be added to streamflows from the Wakool, Yallakool and Colligen Rivers, as well as the Wakool Canal in order to calculate the total streamflow at Deniliquin.

It proved to be more difficult to isolate increases in turbidity at Deniliquin due solely to rainfall events. Thus for the period of record, only 9 rain days could be identified which were observed to have an impact on turbidity which were free from upstream influences. The reason for this difficulty is probably because rainfall appears to have less impact on turbidity levels at Deniliquin than at any of the other sites. The smallest daily rainfall identified was 21.2 mm and the largest was 51.0 mm.

Once again, (1) and (2) were used to convert increases in turbidity to a change in sediment load. A relationship was then derived between rainfall and change in sediment load in the river. The derived equation was :

$$\tau = 2.16r - 36.03 \qquad (7)$$

The coefficient of determination for (7) is 0.92, which is very high, but it is only based on 9 points and thus is somewhat unreliable. Figure 6 shows the 9 data points used to derive (7).

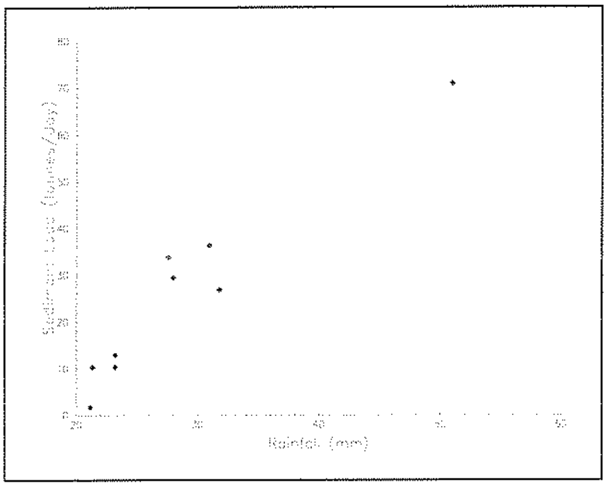

Figure 6
Sediment added to the river
from rainfall events at Deniliquin

Once again, the relationship between rainfall and sediment added to the river appears to be linear over this range of rainfalls.

## 6. ANALYSIS OF RESULTS

Figure 7 shows the change in sediment load in the river predicted to occur due to daily rainfall events ranging in size from 20 mm to 80 mm for the five sites examined. Change in sediment load was used for the site comparisons rather than change in turbidity since change in turbidity represents a change in concentration and is therefore dependent on streamflow.

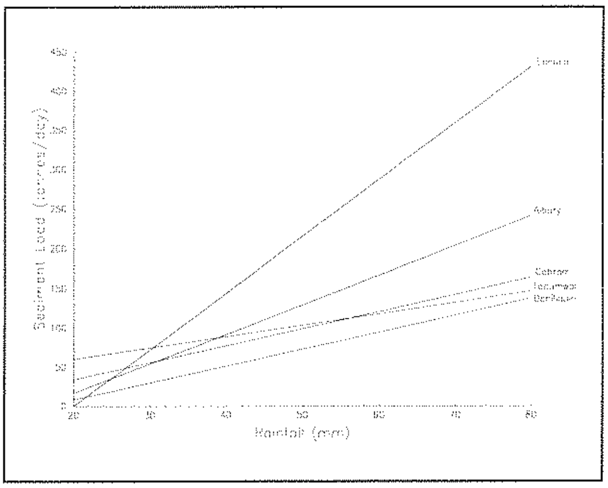

Figure 7
Comparison of sediment added to the river
from rainfall events at all five sites

Echuca has the largest sediment producing potential of the five sites, followed by Albury, and then Cobram, Tocumwal and Deniliquin. The differences between the sites are much more noticeable at higher rainfalls, while at lower rainfalls, the five lines converge somewhat. This is reasonable in that it is the larger rain events which are expected to have a major impact on erosion, since they are likely to be more intense and consequently have greater sediment producing potential.

It is believed that the differences in sediment producing potential between the five sites may be related to characteristics of the landscape close to the river. This is because of differences in the potential erosion between the sites. For example, where the riparian zone is sparsely vegetated, greater quantities of sediment could be washed into the river than where the riparian zone is well vegetated. The differences in sediment production between the sites could also be related to the way in which water runs off. For instance, erosion would be greater when water is allowed to runoff the land very quickly, for example on steep slopes and impermeable soils. This sort of runoff behaviour can be identified by a unit hydrograph approach and the parameters defining the unit hydrograph have previously been shown to be related to catchment attributes such as slope and vegetation [Post and Jakeman, 1995]. Further work is currently being carried out on this data set, in addition to data from the Murrumbidgee River, in order to attempt to identify similar relationships here.

## 7. CONCLUSIONS

Blue-green algal blooms have recently been identified as one of the major environmental problems facing Australia today [Shafron, 1993]. In the Murray-Darling River system, these blooms appear to be phosphorus limited. Supply of phosphorus in these waters is strongly linked to turbidity, since suspended sediment is known to carry with it large quantities of phosphorus [Gippel, 1995]. It is therefore essential to quantify the sources of sediment and therefore turbidity in the Murray river in order to control phosphorus supply and consequently blue-green algal outbreaks.

For the five Water Treatment Plants (WTPs) where daily turbidity data have been recorded, daily rainfalls greater than approximately 20 mm have been observed to increase the turbidity of the Murray river. Rainfalls less than 20 mm may also deposit considerable volumes of sediment into the river, but because of the volume of water in the river, the impact of this sediment is not always seen. Echuca shows the largest increase in sediment load due to rainfall events, followed by Albury, and then Cobram, Tocumwal and Deniliquin. The reasons for this may be related to the attributes of the river, riparian zone or catchment upstream of each of the WTPs. These potential influences are currently being investigated, both for the sites presented here, and also for a number of sites on the Murrumbidgee River.

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