

Know your catchment!

The importance of understanding controls on river styles and their distribution in catchment management

Rob J. Ferguson¹

SUMMARY: The most effective strategies for river conservation and rehabilitation work with the natural range of river behaviour in each environmental setting. River styles (see Brierley, this volume) are a generic approach to characterising the geomorphic behaviour of rivers, framed within a catchment context. It is useful for managers and decision makers who are not trained in the analysis of river behaviour to appreciate the varied factors that control the character and attributes of river styles and their patterns within differing catchments. This paper investigates the relationship between these controlling factors and river styles in the adjacent Orara and Nymboida catchments on the north coast of New South Wales.

A limited range of factors control river styles in the Nymboida catchment. In contrast, the Orara is characterised by a broader range of controls, leading to a more diverse range of river styles that require a broader range of appreciation for effective catchment wide management to occur.

MAIN POINTS OF THIS PAPER:

- Types and patterns of river styles can vary enormously in adjacent catchments; therefore insight into management gained in one catchment may not be applicable in the neighbouring catchment.
- The width and shape of a river's valley, channel slope and stream power are fundamental, direct controls on river style. Geology often controls the catchment wide distribution of styles.
- Understanding the broad controls on how rivers work within a catchment is an essential basis for managing that system.

1. INTRODUCTION

Efficient management of rivers requires a catchment based understanding of river character and behaviour. As Brierley and co-workers (this volume; Brierley et al., 1996; Brierley and Fryirs, 1997; Cohen et al., 1998, and Fryirs and Brierley, 1998 a and b) have outlined, the use of River Styles is an efficient and systematic way of getting a catchment overview, or getting to know one's catchment. Such a broad viewpoint can greatly assist rational prioritisations of resources, money and personnel.

A fundamental tenet of the river styles approach to river management is working with nature instead of struggling against it. In practice this means a thorough understanding of how the river and its various components work and link together is essential. Sediment supply, transport and deposition, for example, are controlled by a wide range of factors throughout a catchment. Sedimentation problems can therefore be effectively managed when all the controlling factors and their integration are understood catchment-wide. A broad understanding brings with it predictive abilities into the systems behaviour in the future, and what the responses to catchment modification or disturbance may be. Particularly sensitive or robust reaches will

become apparent, leading to proactive management strategies.

The purpose of this paper is to provide insight into the fundamental controls on character and behaviour of river

styles in two adjacent, but very different, catchments on the NSW north coast. It is hoped these examples will emphasise the enormous variability that can be found in adjacent rivers, thus stressing to managers the importance of gaining thorough insight into the workings of rivers in each individual catchment. It can never be taken for granted that an understanding of one river system will be applicable to its neighbours.

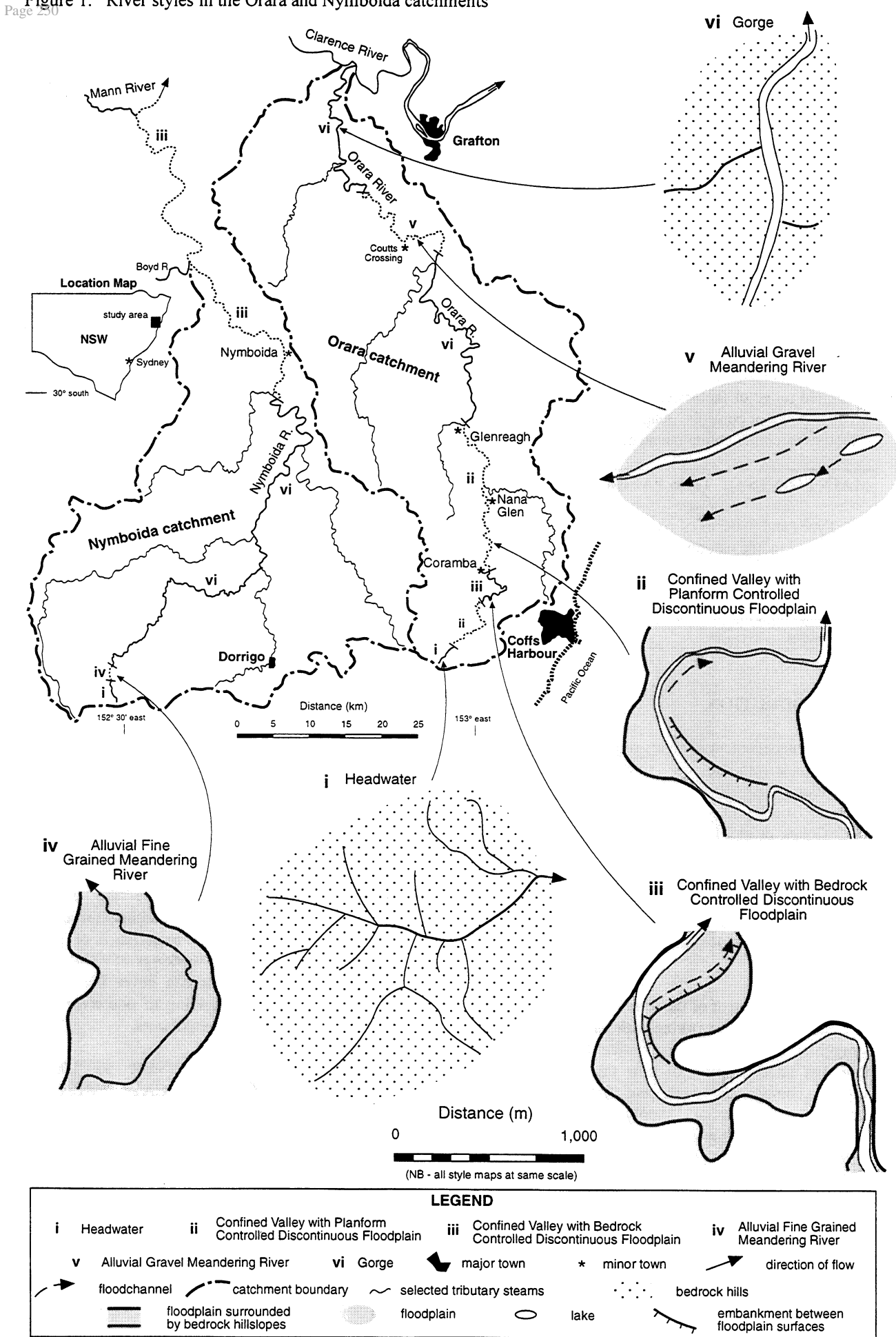
2. THE RANGE OF RIVER STYLES IN ORARA AND NYMBOIDA CATCHMENTS.

2.1 Regional Setting and Landscape Units

The Orara and Nymboida Rivers are both part of the Clarence catchment (22,000 km²), located on the NSW North Coast, inland from Coffs Harbour (see Figure 1). Both sub-catchments are major systems in their own right, with catchment areas of around 2,000 km².

¹ Physical Geography, Macquarie University, North Ryde, NSW 2109
Ph 02 9850 9448 Fax 02 9850 8428 Email rferguso@laurel.ocs.mq.edu.au

Figure 1: River styles in the Orara and Nymboida catchments



There are widely differing **landscape units** in the two catchments. The Orara has headwaters in **rugged hill country**, but most of the catchment lies in or **undulating low-** or **rolling hill country**, or **dissected sandstone plateau**. Differing types of landscape unit can have dramatic impacts on river style, especially through changes in resistance to erosion through differing rock types. The long profile of the trunk Orara River (see Figure 2) drops steeply from around 500 m above sea level to around 200 m elevation, then very gently descends at around a metre per kilometre (0.001 m/m) or less to its confluence with the Clarence River. A number of generally south-north flowing tributaries (see Figure 1, but note that not all are depicted), with catchment areas of up to 200 km² join the trunk.

Table 1. Landscape Units in the Orara/Nymboida Catchments

Landscape Unit	Typical Peak Elevation (m)	Typical Valley Floor Elevation (m)	Typical Hillslope Angle (°)
Orara Catchment			
Steep Rugged Hill Country	560	160	20-30
Rolling Hill Country	260	180	10-25
Dissected Sandstone Plateau	490	60	5-20
Low Undulating Hill Country	290	20	<15
Nymboida Catchment			
Rugged Uplands	850	560	20-30
Rolling Upland Hill Country			
-western Dorriggo Plateau	1360	1200	10-20
-eastern Dorriggo Plateau	830	740	10-20
Rugged Hill Country	430	180	20-30

Much of the Nymboida's headwaters are on basaltic **rolling uplands** of the Dorriggo Plateau, at elevations of up to 1350 m (see Table 1). The rest of the catchment (examined as far as the confluence with the Boyd River, see Figure 1) consists of **rugged uplands** on Paleozoic metasedimentary rocks. The headwaters of the Nymboida lie at elevations of 700-1400 m. The long profile (see Figure 2) is characterised by a relatively low gradient section on the uplands, followed by a steep drop (up to 0.1), before gradients flatten out at around 0.001. There are numerous tributary streams,

especially west of Dorriggo (see Figure 1), that have similar long profiles to that of the trunk Nymboida. West of Dorriggo they flow from the south to the northeast, and east of Dorriggo from the south to the north.

2.2 Characterisation of river styles in the Orara and Nymboida catchments

In this study, reference is only made to the trunk streams in both the Orara and Nymboida catchments. Heading down the trunk Orara channel, the river styles encountered are as follows:

Headwater streams have small catchment areas (see Figure 1 and Table 2), generally in steep hill country. The valley is very narrow, allowing no room for floodplain development. Waterfalls and rapids are common in upper reaches, and pools and riffles become more common in downstream sections. Bed material is dominated by boulders up to a metre diameter.

Where valley widths increase, floodplains form. The first style on the trunk Orara is **confined valley with planform controlled discontinuous floodplain** (Figure 1). The valley has a relatively consistent width of up to 1000 m, within which the channel is free to migrate from one side of the valley to the other. Valley width is the dominant control on the shape of floodplains in map view, reflecting the ability of the river to set its own course. In contrast, **confined valleys with bedrock controlled discontinuous floodplains** (Figure 1) have an irregular valley shape with open pockets of floodplain interspaced with very narrow reaches where the valley narrows. The channel is pinned for substantial distances against the valley margin, which gives floodplains a different shape in map view from those seen in the confined, planform controlled valley setting. Consequently, floodplain processes, especially erosion by flood flows, tend to be of a different nature.

In **gorges** (Figure 1) along the Orara, the channel occupies the entire valley width, which is usually less than 120 m, allowing no room for floodplain development. Bedload material is sand and boulders up to 15 cm. Bed character is dominated by riffles and pools up to 3 km long.

Alluvial gravel-bed meandering rivers (Figure 1) have the widest valleys (see Table 2) and expanses of floodplain seen on the Orara. There are frequent long pools in the channel, in which the bedload material is sand and gravel up to 15 cm. The floodplains are characterised by numerous floodchannels which carry overbank flows. Mud vertically accumulates at a slow rate on these floodplains.

On the trunk Nymboida River, the downstream pattern of river styles is as follows:

Headwaters (Figure 1) occur in basaltic rolling hill country of the Dorrigo Plateau. They generally have lower slopes than those in the Orara headwaters. However, substantial waterfalls (i.e. Dangar Falls near Dorrigo) are common. Boulders are rare, as is sand, but mud is commonly deposited both in the channel and on floodplains. When valleys widen to allow floodplain development, the river style is **alluvial fine grained meandering river** (Figure 1). The river is narrow and sinuous but stable. This style usually only persists for a few kilometres along any given stream course.

In contrast, **gorges** (Figure 1) on the Nymboida are extensive in the middle parts of the catchment. Typically highly confined, they can be incised up to 200 m below the immediately surrounding rugged hills. Rapids are common (the Nymboida is one of the State's most popular white water rafting rivers), as are boulder bars and pools. The lower sections of the Nymboida, above the Mann River, are classified as **confined valley with bedrock controlled discontinuous floodplain** (Figure 1). Floodplain pockets are 1-2 km long but generally less than 500 m wide. The channel is characterised by long pools interspaced with boulder riffles, with occasional point bars. Multiple surfaces are common on the floodplains.

3. CONTROLS ON RIVER STYLES

River styles represent the natural character and behaviour of river system. They are not a direct measure of river condition. To assess river condition requires not only a thorough appreciation of river evolution but also an assessment of their recovery potential (Fryirs, this volume). There are two scales of controls on river styles. Firstly there is the direct local impact of say, gradient, which controls a discrete river style. Then there are the factors which control the overall distribution of styles within an entire catchment, or between adjacent catchments.

3.1 Controls on individual river styles

The controls on individual river styles differ between the two catchments. In the Orara, gradient and narrow valley width are the primary controls on the **headwater** style (see Table 2). The steep slopes and associated high stream power allow the large boulders to be transported, and when it decreases, the largest boulders will not be transported. Once the valley width increases to greater than around twice the channel width, floodplains start to form and fine sediments accumulate.

In the Nymboida, the headwater setting is very different from the Orara due to the underlying basalt, which erodes to give rolling hills and thick, rich soils. The slopes of this region are much lower than along the Orara (see Figure 2). Large boulders are generally absent from this style, but otherwise the fundamental controls are the same, with floodplains occurring where valley width permits. Stream power values are lower than the Orara headwaters (see Table 2).

The primary control on the two types of **confined valley** is the shape of the valley, and low gradients. Work on the Manning and Bellinger catchments (Reinfelds, pers. comm., 1998) indicates that floodplains only form when the gradient is below a certain critical threshold (around 0.01). In the bedrock controlled setting, stream power is highly variable over distances of less than 1-2 km, as the valley width varies greatly over such distances (see Figure 1). Narrow sections have much higher stream power values than wider sections as flood flows are forced through a narrow valley cross section. This gives a different assemblage of within-channel and floodplain geomorphic units, as well as having implications for sediment transport, bank erosion, water quality and flora/fauna (especially in the channel).

In the **planform controlled discontinuous floodplain** river style (Figure 1), the valley width is generally more constant, and the pattern and morphology of floodplains more consistent. Stream power values are far less variable, therefore giving less reach to reach variability and leading to a more homogeneous unit in terms of management.

The **gorge** river style is controlled primarily by valley width. It is noteworthy that gorges on the lowermost Orara (see Figure 1) occur in low gently undulating hill country whereas gorges in the Nymboida occur in very rugged hill country (see Table 1). The net result is a confined river with no scope for lateral movement or floodplain development. There are, however, differences at the geomorphic unit level between the two, with the Nymboida containing much coarser bed material (large boulders) than the Orara (dominantly sand). This is primarily a consequence of the higher slope on the Nymboida (see Figure 2), which gives it a greater stream power (up to 1200 W/m² cf. <100 W/m² for the Orara gorges) and hence ability to move larger material. However, this also reflects differences in the calibre of sediment eroded from the catchment. The metasediments of the Nymboida erode to give boulders, whereas the extensive sandstones in the Orara produce sand sized sediment

Alluvial rivers occur where the valley widths are such that the channel is not regularly impinging on the valley margin. The **fine grained meandering** style characteristic of the upper Nymboida is mainly a function of valley width and sediment. The fine sediment that is the main product of eroding basalt gives a narrow, sinuous channel (also a reflection of the small upstream catchment areas - see Table 2), and even though the valley is often less than 200 m wide, this combination of factors produces extensive floodplain on either side of the channel, hence the alluvial classification. Although stream power values are relatively high due to the relatively steep gradient, this does not lead to bank erosion due to the cohesive nature of the clay rich sediment. In contrast, the Orara **alluvial gravel meandering** style requires a valley width of 1-3 km to produce extensive continuous floodplains, as its catchment area is more than an order of magnitude greater (see Table 2). Gradients are low, which combined with the extensive valley that accommodates floodwaters, gives low stream power values.

3.2 Controls on patterns of river styles within a catchment

The fundamental control on catchment wide patterns of river styles is the landscape unit. Examination of 400 coastal subcatchments were examined as part of the Stressed Rivers work completed for NSW DLWC as a component of the Water Reforms (Brierley et al., 1998) revealed an idealised downstream pattern of river styles in a catchment that starts with headwaters, sees valley expansion that allows confined valley settings (usually bedrock controlled first, followed by planform controlled), which then expands into alluvial valleys. Coastal systems may then flow across the coastal plain. Gorges are wild cards that can occur almost anywhere along a coastal NSW river, and be of highly variable length. However,

they always occur where streams flow down through an escarpment.

Landscape units are primarily a reflection of underlying geological controls. These fall into two main classes, lithological and structural. **Lithological** controls are variations in rock type, and the upper Nymboida is an excellent example, as rolling hills, with the associated alluvial fine grained meandering styles are found only on the basalt. **Structural** controls include the influence of folds and faults. There are good examples of the latter in the lower Manning River.

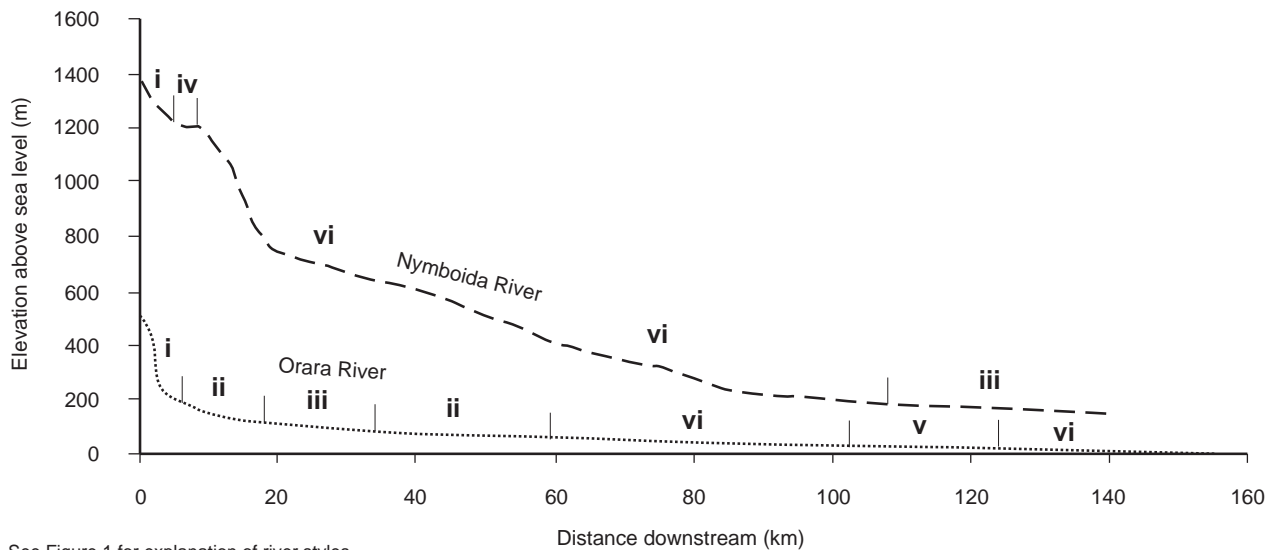
In many NSW coastal catchments (i.e. Bega on the NSW far south coast - see Brierley and Fryirs, 1997 and Fryirs and Brierley, 1998b) an escarpment clearly separates upland landscape units from lower lying hill country. The position (or absence) of an escarpment reflects the complex interaction between geologic factors (especially uplift history) and long term downcutting of rivers. Escarpments produce abrupt and very steep steps in long profiles, more pronounced than that observed on the Nymboida (see Figure 2).

The Orara follows a conventional pattern of river styles as far downstream as Glenreagh (see Figure 1), characterised by expansion in valley width and (ultimately) a transition from bedrock to planform controlled discontinuous confined styles. The dramatic change to a gorge downstream of Glenreagh is associated with a change in landscape unit that is a direct function of a major lithological change (from folded metasediments to younger, near flatlying sediments of the Clarence-Moreton Basin). Unfortunately, it is not so clear what controls the subsequent change to an alluvial valley and then back to a gorge. The importance of this is the unpredictable nature of change in river style patterns.

Table 2: Controls on river styles in the Orara and Nymboida catchments

Catchment and Style	Channel Slope (m/m)	Valley Width (m)	Catchment Area (km ²)	Unit Stream Power (W/m ²)				
				2 yr.	5 yr.	10 yr.	50 yr..	100 yr.
Orara	>0.01	<20	<20	170	218	284	382	467
-Steep Headwater								
-Confined Valley Planform Controlled	<0.0001 - 0.007	250 - 1000	<550	28	40	52	70	75
-Confined Valley Bedrock Controlled	<0.0001 - 0.003	<500	<175	43	69	51	47	48
-Gorge	<0.0001 - 0.005	<120	<2000	21	37	13	83	96
-Alluvial Gravel Meandering River	<0.0001 - 0.003	1000 - 3000	<1530	22	7	7.5	13.5	15.5
Nymboida	>0.01	<20	<10	39	53	72	100	128
-Headwater								
-Alluvial Fine Grained Meandering River	>0.005	<300	<70	107	126	55	73	81
-Gorge	>0.001	<150	<1500	295	581	770	1070	1232
-Confined Valley Bedrock Controlled	<0.004	<500	1500 - 2000	73	49	62	83	93

Figure 2: Long stream profiles and river styles of the Orara and Nymboida rivers



See Figure 1 for explanation of river styles

While slope is often a key factor influencing (or even controlling) river style, it is not always the case. As Figure 2 shows, low gradient does control the extent of the alluvial fine grained meandering style on the upper Nymboida. However, there are a number of prominent breaks in slope on both the trunk Orara and Nymboida that do not correspond to changes in river style.

Variability in stream power is closely associated with gradient, as a relatively small increase or decrease in gradient can have a dramatic impact on stream power values. Stream power values reported here for river styles that contain floodplains (see Table 2) are all less than 100 W/m^2 for the 1 in 100 year recurrence interval. Magilligan (1992) and Miller (1990) suggests that stream powers greater than 300 W/m^2 can lead to catastrophic floodplain stripping. However, Miller (1995) notes that local geomorphic factors such as valley width, orientation of the channel to the valley, within-valley restrictions such as terraces and local obstacles, all influence stream power distribution in confined valleys, so the figures cited here must be seen as generally representative.

4. MANAGEMENT IMPLICATIONS BASED ON UNDERSTANDING OF RIVER STYLES

As described above, it is often extremely difficult to pin down the controlling factors on the distribution of river styles within a catchment. This must be taken into account when trying to rehabilitate or manage catchments. It is simply not possible to focus on only one variable. For example, as Figure 2 clearly shows, gorges in adjacent catchments may have radically different gradients, and hence stream power values (see Table 2). Therefore the two will need to be managed in different ways, especially in respect to sediment transport (large boulders on the Nymboida, sand on the Orara).

Practical applications utilising a knowledge of the controls on river styles include the structure and design of river engineering works. For example, comparable structures in a steep Nymboida gorge would need to be much stronger to resist the high stream powers and coarse bedload transport than a similar structure in an Orara gorge. Riparian vegetation plantings would also need to take these important differences into account.

Understanding not only the distribution of river styles in or between catchments, but also the basic controls on such a distribution, gives an overview of a catchment/s. Such an overview is essential to provide a catchment overview that will enable managers to prioritise scarce resources, and prevent intensive effort being expended on isolated sites or reaches. Resource must be utilised within a framework of understanding of the functioning of the entire system. Knowledge of the distribution of conservation sites, for example, forms a key component for managing the entire catchment. These factors must be appropriately designed for the environmental setting and associated stream power. River styles therefore provide a catchment wide design tool that is also highly relevant for reach-specific planning.

5. CONCLUSIONS

Examples from two adjacent catchments show considerable variability in the presence and patterns of river style from catchment to catchment. River managers must appreciate this variability and controls on the river styles distribution in **all** catchments, as it can never be assumed that styles or patterns of styles will be similar in adjacent catchments or sub-catchments.

5. ACKNOWLEDGEMENTS

Paul Batten produced the long profile plots, and John Jansen helped in establishing stream power values. The work on the Orara and Nymboida catchments stems from consulting work carried out by the author and Gary Brierley for the north coast Department of Land and Water Conservation. Guy Lampert assisted in data collection and field work for this project. Discussions with Kirstie Fryirs and Gary Brierley have improved this manuscript.

6. REFERENCES

- Brierley, G.J. (1999). "River styles: An integrative biophysical template for river management." This volume.
- Brierley G.J., Fryirs, K. and Cohen, T. (1996). "Geomorphology and River Ecology in southeastern Australia: An approach to catchment characterisation" Graduate School of the Environment Working Paper 9603, Macquarie University. Report in three parts.
- Brierley, G.J. and Fryirs, K. (1997). "River styles in Bega catchment: Implications for management." Workshop and Field Days Guide, October 1997. School of Earth Sciences, Macquarie University. 24 pages.
- Brierley, G.J., Ferguson, R.J. and Batten, P. (1998). "Geomorphological characterisation of river styles in coastal catchments of New South Wales." Report completed for DLWC through Macquarie Research Limited as part of the Stressed Rivers Assessment. 78 pages.
- Cohen, T., Reinfelds, I. and Brierley, G.J. (1998). "River styles in Bellinger-Kalang catchment." Report completed for DLWC through Macquarie Research Limited. 119 pages.
- Fryirs, K. and Brierley, G.J. (1998a). "River styles in Dry-Murrah Catchment" Report completed for DLWC through Macquarie Research Limited. 63 pages.
- Fryirs, K. and Brierley, G.J. (1998b). "The use of river styles and their associated sediment storage in the development of a catchment-based river rehabilitation strategy for Bega/Brogo catchment, south coast, NSW" Report completed for DLWC and Bega Valley Shire through Macquarie Research Limited. 204 pages.
- Fryirs, K. (1999). "The recovery potential of river styles in the Bega catchment, NSW: A catchment based framework for the prioritisation of river rehabilitation strategies." This volume.
- Magilligan, F.J. (1992). "Thresholds and the spatial variability of flood power during extreme floods." Geomorphology 5: 373-390.
- Miller, A.J. (1990). "Flood hydrology and geomorphic effectiveness in the central Appalachians." Earth Surface Processes and Landforms 15: 119-134.
- Miller, A.J. (1995). "Valley morphology and boundary conditions influencing spatial patterns of flood flow." In: Costa, J.E., Miller, A.J., Potter, K.W. and Wilcock, P.R. (eds.) Natural and Anthropogenic Influences in Fluvial Geomorphology. American Geophysical Union, 57-81.

