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Large Woody Debris and the Geomorphology of a Perennial River in Southeast Australia

Andrew Brooks[1]

SUMMARY

Large woody debris (LWD or snags) was probably one of the dominant geomorphic controls in many Australian rivers prior to European settlement. Likewise, the widespread removal of LWD from channels in desnagging operations was a dominant factor leading to the extensively altered channels common throughout the continent today. Pre- and post-disturbance channel conditions in the Cann River, East Gippsland, were modelled to demonstrate some of the geomorphic effects of LWD under both circumstances. The analysis shows that full desnagging of the pre-disturbance channel results in a 10 fold increase in bedload transport, and reorienting logs to 30 degrees from the bank is equivalent to removing 50% of the LWD. To create the same hydraulic resistance associated with LWD in the current channel as in the former channel requires the reintroduction of between 3.5 and 7 times the original in-channel LWD volume - depending on angle of orientation. Given that this is likely to be an unrealistic short or medium term management objective, LWD reintroduction must be viewed as one of a range of river management strategies. Nevertheless, the potential geomorphic benefits of LWD must be considered in all river management strategies. The most realistic way of reintroducing the necessary volumes of LWD into channels in the long term will be from natural recruitment. Therefore, there is a pressing need to re-establish well-vegetated riparian buffer strips, comprising an appropriate mix of suitable species as sources of LWD. Bank revegetation and stabilisation strategies must precede any LWD reintroduction programs.

Key Points

- LWD (snags) was potentially one of the dominant controls on channel morphology and dynamics in many pre-disturbance rivers, particularly perennial alluvial rivers.
- The hydraulic resistance associated with high LWD loadings can alone reduce bedload transport by an order of magnitude.
- Due to numerous threshold changes (see Brooks, this volume), LWD dynamics will be fundamentally different in post-disturbance rivers. LWD reintroduction programs must take account of such changes.
- The practice of LWD removal or reorienting existing LWD in rivers should be discontinued.
- The best way to reintroduce LWD into rivers in the long term is to re-establish a natural source in a healthy, vegetated riparian buffer zone

1. INTRODUCTION

A recent Land and Water Resources Research and Development Corporation (LWRRDC) publication in the Riparian Management series on Snag Management (LWRRDC, 1998) highlighted the beneficial effects of large woody debris (LWD) from an ecological perspective. Australian river managers have, until recently (and some recent National Heritage Trust applications suggest this view is “alive and well”), pursued a concerted campaign to remove snags from rivers, both to improve their navigability, and for flood mitigation based on the perception that LWD is an impediment to flood water conveyance (Gippel et al., 1992). The argument for retaining LWD within rivers is built primarily on the known importance of LWD for fish and macro-invertebrate habitat (eg. Koehn & O’Connor, 1990), and justified on the basis that the presence of snags within rivers has a relatively minor influence on flood levels (Gippel et al., 1992). However, there is still a perception that the positive ecological benefits of LWD need to be weighed against the perceived negative impact that LWD is thought to have as an agent increasing channel instability (eg. bank erosion), as well as the supposed impact on flood stage. The work of Gippel and others (see Gippel et al., 1992; Gippel, 1995; Shields & Gippel, 1995; Gippel et al., 1996 a, b) has allayed the flow afflux concerns and the snag management guidelines (LWRRDC, 1998) are primarily aimed at addressing this issue.

The snag management guidelines, however, do not consider the potential beneficial role of LWD in maintaining channel stability or the potential for using LWD as one of a range of options for stabilising disturbed rivers. This is not a criticism of the report’s authors, as the research into this issue in Australia is limited. Nevertheless, river managers need to recognise that there is another angle to the LWD issue that must be considered when devising river management strategies. Unfortunately, introducing the geomorphic role of LWD into the snag management “mix” presents us with a dilemma, as the means for addressing the hydraulic and geomorphic goals are apparently contradictory.

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[1] Macquarie University School of Earth Sciences, NSW, 2109. Ph (02) 9850 9448 email: abrooks @ laurel.ocs.mq.edu.au

The snag management guidelines outline an approach aimed at maintaining as much LWD volume as possible for ecological reasons, while minimising its hydraulic resistance and hence flow afflux. From a geomorphic perspective though, the more LWD the better, and the higher the hydraulic resistance the better. Hydraulic resistance is maximised by greater numbers of logs, which are oriented perpendicular to the flow. Here lies the dilemma. Evidence is presented here which suggests that rather than causing instability problems in rivers, LWD is an essential element in maximising channel stability.

2. OTHER RESEARCH INTO THE ROLE OF LWD IN RIVERS

Research, primarily from overseas, demonstrates the important role LWD plays in river geomorphology from a range of perspectives. We know that LWD can impart significant hydraulic resistance within river channels (Shields & Gippel, 1995; Gippel, 1995), and this factor alone can reduce mean stream power, reducing bank shear stresses and, on a reach averaged basis, reduce bank erosion rates. Bed shear stresses, and hence bedload transport rates, are also reduced (Mosley, 1981). A considerable amount of potential energy dissipation is associated with log steps in steep streams with extensive LWD (Keller et al, 1995). When the hydraulic resistance associated with LWD is combined with the physical trapping ability of LWD in channel beds, and bed reinforcement tendencies, bedload transport rates in rivers can be dramatically reduced (eg. Keller & Tally, 1979; Mosley, 1981; Shields & Smith, 1992; Keller et al, 1995). The effects of removing naturally occurring LWD have been studied overseas (eg. Beschta, 1979; Shields & Smith, 1992), and similar detrimental effects have been implicated in Australia (Erskine & White, 1996; Erskine & ID&A, 1997). The beneficial effects of LWD reintroduction on channel morphology are also beginning to be appreciated (Wallace et al, 1995), as is the role of LWD in channel recovery following major channel instability (Cohen, 1997). It also likely that floodplains could not have evolved as they did without the influence of LWD on in-stream processes (Brooks, in prep). The combined influence of the hydraulic resistance factors and bed stabilisation means that in some streams the effect of LWD on overall channel morphology may be more significant than that of living riparian vegetation.

2.1 LWD and Catchment Scale

As with live riparian vegetation, the extent to which LWD affects flow resistance and bed stability in general diminishes with increasing channel size (Abernethy & Rutherfurd, 1998), and river channel size tends to increase, downstream. There are two reasons why this is the case. First, as with vegetation, a greater proportion of channel cross sectional area will be occupied by LWD in low order (small) channels (Keller & Tally, 1979; Bilby & Ward, 1989; Nakamura & Swanson, 1993; Keller et al, 1995; Abernethy & Rutherfurd, 1998), and very often the trees falling into low order streams are close to perpendicular to the flow, causing maximum blockage to the flow (blockage ratio). LWD in low order channels also tends to have a fairly random longitudinal distribution and it is under these circumstances that hydraulic resistance and bed stabilisation are maximised.. It is also in true that in many first and second order streams, LWD will be suspended above the channel, and will, therefore, not have a direct influence on channel geomorphology (Bilby & Ward, 1989; Fetherston et al, 1995). Thus, in many channels there is threshold of channel scale, below which the influence of LWD on channel morphology diminishes.

To some extent the relationship between LWD and channel scale assumes that there is consistent LWD recruitment throughout the system, which is rarely the case. In virtually all published studies that have looked at this relationship, human impact on LWD becomes more prevalent in higher order, lowland rivers (Triska, 1984; Wallace & Benke, 1984; Gippel et al, 1992). Hence, nearly all LWD studies will be biased due to both removal of LWD in higher order channels, and reduced or negligible recruitment due to vegetation clearance. Nevertheless, the scalar relationship does still hold true for most rivers. In addition, many middle order east coast Australian rivers display a tendency for downstream decreasing channel capacity (Nanson & Young, 1981; Woodfull et al., 1996), so local LWD trends must be placed in this context.

The second scalar change in the role of LWD relates to the relative size of the debris compared to the size of the channel. In low order channels the height of trees falling into channels will generally be greater than channel width (Keller & Tally, 1979; Bilby & Ward, 1989; Thorne 1990; Nakamura & Swanson, 1993; Keller et al, 1995). In these circumstances the logs are often tied into both banks and will remain as they fell. Such LWD can remain *in situ* for considerable periods of time - up to several thousands of years under some circumstances (Nanson et al, 1995). As channel width increases (ie. with increasing catchment scale) the height of the recruitable riparian vegetation tends to be less than channel width. LWD, in these circumstances tends to be realigned, often almost parallel to the flow (Kochel et al, 1987; Fetherston et al, 1995; Abbe & Montgomery, 1996). Under these circumstances the blockage ratio is minimised, but the role of LWD in scroll, and point bar accretion and bank toe protection is increased (Nanson, 1980; Abbe & Montgomery, 1996). In wider channels, there is also a greater potential for LWD to be transported beyond the fall point, and to become incorporated into log jams (Fetherston et al 1995; Abbe & Montgomery, 1996). Thus, as channel size increases a greater proportion of the LWD at a given site is likely to have been transported from upstream.

2.2 LWD and bank erosion

The presence of extensive LWD within a channel does not necessarily mean that localised bank erosion will not occur. Indeed, in heavily vegetated small and moderate sized rivers, a high proportion of lateral channel migration may be associated with either single large trees, or LWD jams (Keller & Swanson, 1979; Gregory & Gurnell, 1988; Gregory et al., 1993). This is not necessarily a "bad river" that needs to be "fixed", nor does it mean that the river banks will be eroded more overall than if there were no LWD in the channel. The total effect of LWD in a channel must be viewed on a reach average basis, and overall rates of change must be considered. Discrete log jams will also play an entirely different role to uniformly distributed LWD. Log jams tend to have profound influences on channel morphology at specific sites, but depending on their downstream frequency, may or may not have a significant influence on total flow resistance. Log jams can cause local bank erosion, and may even trigger channel avulsion or cutoffs (Triska, 1984; Gregory & Gurnell, 1988; Nakamura & Swanson, 1993; Abbe & Montgomery, 1996). The situation where log jams will have the greatest effect on total channel morphology is where the backwater effects of successive jams are superimposed on upstream jams. Depending on the stability of the jams, flow resistance and bed level control will be maximised under these circumstances.

2.3 Pre-Disturbance LWD loadings in Australian Rivers

As outlined in the companion paper to this (Brooks, this vol.) the widespread nature of desnagging and major channel changes to Australian rivers makes it difficult to estimate pre-disturbance LWD loadings or distribution. The evidence from the Thurra River study (Brooks, this vol.) provides some direct evidence for pre-disturbance LWD characteristics, but in the broader context we have to rely on indirect evidence. Historical records of the desnagging operations gives us the best indication that LWD loadings in most pre-disturbance rivers were generally very high when compared to the post-disturbance state of most rivers (Gippel et al. 1992). We can also get a good indication of the likely geomorphic role of LWD exerted in rivers from some direct observations of channel adjustment following desnagging. Strom (1962 p.43) described how :

> *"in one part of the Latrobe River in eastern Victoria, the original removal of snags was followed by a deepening of the bed which uncovered a second layer of snags, and the removal of these revealed a third layer, the total deepening being in places about 6 feet."*

Such observations provide clues, not only about the immediate geomorphic control of LWD on channel morphology, but also the significance of LWD in long term channel and floodplain evolution. It also provides an interesting insight into the disregard by river managers for the geomorphic consequences of their narrow management objectives.

2.4 LWD in a Post-Disturbance Environment

As argued in Brooks (this vol) there is extensive evidence that many alluvial river channels are considerably larger now than they were prior to European disturbance. In many respects this increase in channel capacity is similar to the downstream increase in channel capacity discussed above. So a pre-disturbance 4th order channel, which might have had high unit loadings of LWD with the majority of logs traversing the channel, may now simulate a former 6th or 7th order channel, where LWD comprises a much smaller proportion of the channel cross section, and where most logs may now be transported by floods and easily reoriented away from the perpendicular. When these relative changes in the relationship between channel dimensions and LWD are combined with the widespread reduction in absolute LWD loadings, the contrast between pre- and post-disturbance LWD/channel interactions is that much more pronounced. LWD reintroduction strategies must consider such changes.

3. LWD AND RIVER GEOMORPHOLOGY - AN AUSTRALIAN CASE STUDY

3.1 The Study

Brooks (this vol) outlined a comparative study between a disturbed and an undisturbed river in East Gippsland highlighting the pre- and post-disturbance character of two alluvial lowland rivers. A key controlling variable in the pre-disturbance Thurra River was the high LWD loadings in that channel. These were extrapolated to the palaeo-channel condition of the Cann River. The modelling approach adopted in this study provides an opportunity to estimate some of the effects that LWD had on the pre-disturbance Cann River and to compare this with the post-disturbance channel condition. It also provides a means of modelling the effects of altering snag loadings and orientation on channel geomorphology, and highlights some important issues associated with LWD reintroduction.

Independent Variables								*Dependent Variables*							
%LWD removed	*W* *(m)*	*A* *(m^2)*	*S* *(m/m)*	*P*	f_{grain}	f_{bends}	f_{lwd}	f_{form}	f_{tot}	U_{bf} *(m/s)*	Q_{bf} *(m^3/s)*	*ks* *(m)*	ω (W/m^2)	***% incr.*** *ω*	***Gb*** ***(kg/s)***
0	17.9	33.8	0.0007	2.6	0.012	0.051	0.185	0.217	0.465	0.43	14.52	3.77	4.80		**0.36**
20	17.9	33.8	0.0007	2.6	0.012	0.051	0.148	0.174	0.385	0.47	15.97	3.19	5.28	**10**	**0.52**
40	17.9	33.8	0.0007	2.6	0.012	0.051	0.111	0.139	0.313	0.52	17.70	2.62	5.85	**22**	**0.76**
60	17.9	33.8	0.0007	2.6	0.012	0.051	0.074	0.111	0.248	0.59	19.88	2.04	6.57	**37**	**1.17**
80	17.9	33.8	0.0007	2.6	0.012	0.051	0.037	0.089	0.189	0.67	22.79	1.46	7.53	**57**	**1.90**
100	17.9	33.8	0.0007	2.6	0.012	0.051	0.000	0.071	0.134	0.80	27.05	0.90	8.94	**86**	**3.43**

Table 1 **Model simulation of removing LWD from Cann palaeo-channel (CRPC)** see Brooks (this vol) for site description. Each step represents the removal of 20% of the original LWD volume. Model output shows the increase in stream power and bedload transport rate associated with each 20% reduction in LWD load. *W* =mean channel width; *A* = mean channel cross sectional area; *S* = bed slope, *P* = sinuosity; f_{grain}, f_{lwd}, f_{form} & f_{bends} = grain, LWD, form and bend friction factors respectively; f_{tot} = sum of the four *f* factor components; U_{bf} = mean velocity at bankfull; Q_{bf} = bankfull discharge; *ks* = equivalent roughness height; *ω* = unit stream power; *Gb* = bedload transport rate. See text for discussion of independent and dependent variables in this simulation.

Due to editorial constraints there is insufficient space here to outline all the methods and assumptions that have gone into the modelling. The approach is an adaptation of that developed by Millar and Quick (1993, 1998). However, in this case:

- bank angle is set (ie. using the observed values)
- channel slope is fixed (also using observed values)
- bedload transport is calculated using the method of Ackers and White (1973) - deemed more appropriate for sand-bed streams such as these (Brownlie, 1981).
- friction factor was sub-divided into four sub-components after Shields and Gippel (1995) - see Brooks (this vol).

Conceptually the model operation is the same as the published version of Millar & Quick (1993, 1998), where stable hydraulic geometry is assumed to correspond to an optimal channel cross section associated with maximum bedload transport. Channel geometry is calibrated to the observed condition by inputting a series of trial bed perimeter values and the depth is then adjusted to satisfy the discharge constraint (Q_{bf}). In this formulation the bank stability parameters (H/H_{crit}) are known, and hence the observed bank angle (θ) is used. Channel slope (*S*) is known and is assumed to be equivalent to the energy gradient. Reach averaged channel cross sectional area (*A*), hydraulic radius (R_h), and the bedload parameters (D_{50}, D_{35}) are all known.

By sub dividing the friction factor (f_{tot}) into its four components (f_{grain}, f_{form}, f_{lwd} & f_{bends}) the effect of varying individual components on bedload transport rates can then be modelled. In this case the effect of varying LWD loadings and orientation is tested.

3.2 Results

As was described in Brooks (this vol.) the pre-disturbance condition of Cann River was reconstructed and modelled based on dimensional evidence from palaeo-channels and the hydraulic parameters from the similar contemporary Thurra River. Form- and LWD-resistance were found to be key parameters in Thurra River (Brooks, this vol.), and the same has been assumed to apply to the Cann palaeo-channel (CRPC). The first simulation models the effect of removing LWD from CRPC in 20% increments (Table 1, Fig. 1). As discussed in Brooks (this vol) the high values for f_{form} are associated with extreme pool/riffle bed level variability, which is assumed to be largely an indirect function of the high LWD loading. Therefore, removing LWD not only reduces the hydraulic resistance directly associated with LWD, but also reduces f_{form}.

3.2.1 LWD Removal and Bedload Transport

The first simulation represented in Table 1 demonstrates a direct relationship between the hydraulic effect of LWD and channel geomorphology. Using CRPC, the effect of removing LWD on unit stream power (ω) and bedload transport capacity (*Gb*) is modelled. The demonstrated increase in bedload transport is purely a function of the altered hydraulic conditions within the channel (f_{form}, f_{lwd}). Thus, it does not include the physical trapping of bed material by LWD, or the reinforcement of the bed by LWD which will increase apparent bed cohesion and limit the depth of bed material mobilisation. It is assumed in this simulation that channel dimensions remain unchanged, which in reality is unlikely as positive feedbacks increasing the likelihood of major channel change. The simulation is modelling the instantaneous increase in bedload transport capacity with modification to either the total LWD loading or to LWD orientation. In reality channel enlargement is likely to soon follow such modifications. In effect, this modelling exercise is simulating the first step in the cascade of consequences that are likely to follow the LWD modifications.

The benefit of this approach is that we can take a highly complex natural system, within which we know there is a complex web of feedbacks and interactions over different timeframes, and isolate the response within one part of this system (in this case bedload transport), to a specific stimulus (in this case modifications to the natural LWD characteristics). In reality, all the variables presented in Tables 1 and 2 are dependent variables. Which means that if one variable is altered in some way, all the other variables will be adjusted once the full effect of all interactions is allowed to ripple through the whole system. However, in this simulation, the bedload characteristics (f_{grain}), as well as the channel parameters: W, A, S, P, f_{bends} have been assumed to be independent variables. The variable being adjusted is f_{lwd}, and the dependent variables are: f_{form}, U_{bf}, Q_{bf}, ks, ω and Gb.

Independent Variables								***Dependent Variables***							
av.LWD angle	W (m)	A (m^2)	S (m/m)	P	f_{grain}	f_{bends}	f_{lwd}	f_{form}	f_{tot}	U_{bf} (m/s)	Q_{bf} (m^3/s)	ks (m)	ω (W/m^2)	***% incr. ω***	***Gb (kg/s)***
57.6	17.9	33.8	0.0007	2.6	0.012	0.051	0.185	0.217	0.465	0.43	14.52	3.77	4.80		**0.36**
90	17.9	33.8	0.0007	2.6	0.012	0.051	0.244	0.217	0.524	0.40	13.68	4.15	4.52	**-5.8**	**0.28**
30	17.9	33.8	0.0007	2.6	0.012	0.051	0.122	0.109	0.293	0.54	18.28	2.45	6.04	**26**	**0.86**
10	17.9	33.8	0.0007	2.6	0.012	0.051	0.042	0.037	0.142	0.78	26.25	0.98	8.68	**81**	**3.10**

Table 2 **- Model simulation for reorienting LWD in Cann River palaeo-channel (CRPC) from its average "undisturbed" orientation (57.6 deg)**. Model output shows the increase in unit stream power (ω) and bedload transport rate (*Gb*) associated with reorienting LWD. See Table1 for description of variables. See text for discussion of independent and dependent variables in this simulation.

The percentage increase in *Gb* from the undisturbed loading with each 20% reduction in LWD loading is shown in Figure 1. The key point to be made from these data is that from a hydraulic perspective alone, the removal of all the LWD present in a channel, such as Cann River in its pre-disturbance state, can lead to an order of magnitude (10-fold) increase in bedload transport rates. This will be the starting point for ascertaining the total effect of removing LWD on channel geomorphology, because the effect LWD has on physical trapping of bed material and reinforcing the bed is probably much greater than the hydraulic effect. Another important point to consider from this simulation is the apparent non-linear relationship between unit stream power and bedload transport. Mean reach unit stream power (ω) increased by a total of 86% with full LWD removal, but this equated to an 860% increase in bedload transport. Thus, the potential impact on overall channel morphology of an apparently moderate increase in stream power is greatly compounded when we consider the effect this increase has on bedload transport capacity.

3.2.2 LWD Orientation and Bedload Transport

The second simulation (Table 2) is also based on the Cann River palaeo-channel dimensions, using the pre-disturbance LWD loadings and character as determined from the Thurra River study (see Brooks, this vol.). In this case the effect of reorienting LWD on bedload transport is modelled. The base condition is derived from the Thurra rainforest reach, in which reach mean LWD loading, determined by census, equated to a blockage ratio of 5.4% (or $0.04m^3/m^2$ - ie. wood vol./unit channel surface area at bankfull stage), and in which the reach mean orientation of LWD to the banks is 57.6 degrees. Thus modelled bedload transport rates are compared with this initial state. Three alternate orientations to the observed are modelled: 1) all LWD at 90 degrees to the bank, 2) all LWD at 30 degrees to the bank, 3) all LWD at 10 degrees to the bank. The effect these conditions have on mean unit stream power (ω) and bedload transport rate (*Gb*) are then simulated, and comparisons made with the undisturbed condition (Figure 2). As with the removal simulation, it is only the hydraulic effect of the LWD reorientation that is being modelled, so these changes should be regarded as minimums for the same reasons outlined previously.

The results of this reorientation analysis show that the geomorphic effects of LWD are maximised when LWD is perpendicular to the bank. Increasing the mean observed angle of orientation from 57.6 degrees to 90 degrees results in a 21% decrease in reach mean bedload transport rates. This figure is probably an underestimate as the observed data set is biased down from 90 degrees by the more numerous but less hydraulically significant smaller LWD pieces. The 30 degree case was included primarily because this is the orientation proposed in the Snag Management guidelines (LWRRDC 1998) as being an acceptable compromise between LWD retention and complete removal. When the 30 degree simulation is compared with the removal data (Figure 1), this analysis estimates that from a bedload transport perspective, reorienting LWD to 30 degrees from the bank is similar to removing 50% of the LWD. The 10 degree simulation shows how sensitive this channel is to over zealous reorientation. In this case reorienting the LWD to a mean value of 10 degrees from the bank can lead to a 760% increase in bedload transport rates. From a bedload transport reduction perspective, this is little better than complete LWD removal.

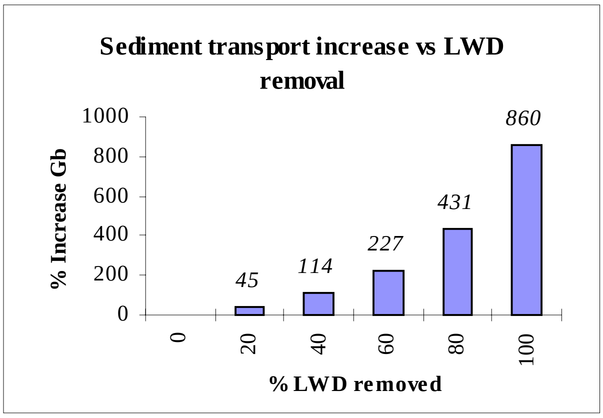

Figure 1 - % increase in sediment transport capacity (*Gb*) from the undisturbed channel condition at CRPC with associated 20% decreases in LWD loading

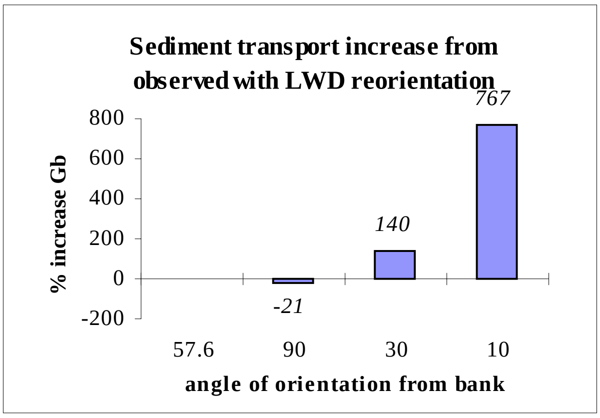

Figure 2 - % increase in sediment transport capacity (*Gb*) from the undisturbed channel condition at CRPC with altered mean LWD orientation to the bank

4 MANAGEMENT IMPLICATIONS FROM THIS WORK

While there is clearly a great deal more work to be done in understanding the long term influence LWD had on pre-disturbance river behaviour, and its potential future influence in post-disturbance rivers, there are a number of general principles that can be taken from what we now know:

- The geomorphic role of LWD must be considered in all river management strategies.
- LWD removal will increase bedload transport capacity, which in turn can lead to bed degradation and an overall increase in channel instability.
- LWD reorientation can have a similar effect.
- The bedload transport rate of rivers is minimised when LWD is oriented perpendicular to the flow.
- **The practice of realigning existing LWD is likely to cause more problems than it solves, thus LWD is best left undisturbed.**
- LWD reintroduction must be approached cautiously and strategically, given the different dimensional relationship between LWD and post-disturbance rivers channels compared with pre-disturbance channels, and the fundamentally different hydraulic characteristics of post-disturbance channels.
- To have a significant effect on flow hydraulics, extremely high loadings of LWD would be required to be reintroduced into altered channels. For example, in the contemporary Cann River channel, reintroducing the same volume of wood as was removed (ie. 51 m^3/100m of channel) would only reduce the friction factor at bankfull by 0.03. To recreate the same hydraulic resistance as in the pre-disturbance channel would require the reintroduction of between 3.5 and 7 times the original wood volume, depending on angle of orientation.
- Given these practical problems, LWD reintroduction should probably not be a first order management strategy. Rather, it should be one of a range of strategies incorporated into a long term management plan (ie. decades and more).
- The goal of any long term management strategy should be to increase LWD loadings in rivers. Given the high volumes of wood required to maximise the benefit to the river, and the low contemporary recruitment in most rivers, no further LWD should be taken from rivers. Indeed, a cultural shift is required where we consider LWD as a precious resource, that will help ensure the future geomorphic, hydraulic and ecological sustainability of rivers.

5. DISCUSSION AND CONCLUSION

As outlined in the snag management guidelines (LWRRDC 1998), the beneficial effects of LWD for aquatic ecology are well documented and are broadly accepted. If this were the sole management concern, then there would be no argument that LWD loadings in rivers should be greatly increased. Unfortunately, this is not the sole management concern, as river managers have been more concerned with flood mitigation. From the evidence presented here it is clear that LWD is not only beneficial for stream ecology, but it is also capable of exerting significant control on the geomorphology of alluvial rivers. Had there been greater appreciation of the geomorphic role of LWD at the time when desnagging was in full swing, some of the extensive geomorphic consequences of this management strategy may have been minimised. Nevertheless, the clock cannot be turned back - we have to live with what we now have. It is critical that we recognise that LWD should be a central component in any river rehabilitation stategy, particularly as an agent for reducing bedload transport rates. A important corollary is the recognition of changes in the nature of LWD interactions in post-disturbance rivers compared with pre-disturbance rivers.

In the case study presented here, LWD was probably the key controlling variable in the pre-disturbance channel condition. The analysis demonstrated that bedload transport rates alone could be increased by an order of magnitude above undisturbed levels be removing LWD. This can then have profound effects on a range of other aspects of channel morphology, for example, the in-filling of pools, which can then lead to increased bank erosion. Evidence also suggests that because post-disturbance channel conditions are so radically different to the pre-disturbance state, the nature of the interaction between LWD and channel dynamics in the contemporary channel condition is also fundamentally changed. Attempts to reintroduce LWD must take account of these changes, and realistic long term management goals must be developed.

It has taken 100 years or more for huge volumes of LWD to be removed from our rivers, and in all likelihood, the wood removed represented several hundred years or more of accumulation. We are not going to return this volume in the short term (or even over decades), particularly, as was demonstrated here, when in altered channels we would require more logs than were in rivers prior to European occupation, to have a significant effect on channel morphology. The volumes of wood needed to create a significant geomorphic benefit in some of our rivers are astronomical. There are real foreseeable problems with finding an ecologically sustainable source for all this wood. Therefore, the “best way forward” must be to provide for natural sources of woody debris in healthy riparian zones, probably coupled with in-channel structures designed to trap logs within the channels. In other words, woody debris management cannot proceed without comprehensive riparian zone rehabilitation. Neither should it, because a crucial precursor to any LWD reintroduction scheme must be the stabilisation of banks. LWD in channels with unstable, unvegetated banks may cause outflanking problems. Indeed, this very scenario is probably one of the primary reasons why in the past there has been such a negative perception of LWD in rivers. It is not primarily due to LWD in a channel that a completely cleared bank experiences erosion, rather it is due to the bank being unvegetated. Stabilising channels requires a combination of high LWD loadings in the channel, be it through natural recruitment or reintroduction, and well vegetated banks and riparian buffer strips. The two factors cannot be disassociated from one another.

A great deal more research needs to be conducted in Australia regarding the role of snags in rivers and river geomorphology, particularly regarding LWD reintroduction. There are also likely to be significant differences in the way LWD should be managed in low gradient inland rivers compared to the steeper, more dynamic and more altered channels of the upper reaches of western draining rivers or coastal rivers. The study presented here is one example of the latter. Nevertheless, some of the principles elucidated here will apply universally, and we know enough to take a precautionary approach and halt any further decline of LWD volumes in all rivers.

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