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Channel Recovery Mechanisms in a Forested catchment, Jones Creek, East Gippsland; lessons for river management in southeastern Australia.

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Summary :
Jones Creek, a forested sub-catchment of the Genoa River in Victoria, has undergone channel metamorphosis triggered by a series of floods between 1971 and 1978. Channel widening of the trunk stream by up to 200 % at the confluence resulted in a lagged tributary response resulting in significant changes in channel form. Channel incision and bed steepening are seen as the dominant control on subsequent changes in channel morphology within Jones Creek. Initial incision resulted in increased stream power, while sinuosity was maintained. This has subsequently been followed by phases of channel widening with a reduction in sinuosity. Estimated stream power remains high as the channel continues to go through a phase of lateral adjustment. While Jones Creek has become destabilised, it displays evidence of natural recovery mechanisms which counteract the destabilising effects of bedlevel lowering and channel widening. The effect of vegetation and coarse woody debris is to increase the ability and rate of the channel to recover by increasing channel roughness and inducing sediment retention. In many situations in south-eastern Australia, overwidened channels are colonised by within-channel vegetation. It is proposed that the occurrence of this in-channel vegetation will increase the roughness of these channels, increase sedimentation, and in the long term reduce channel capacity. In order to achieve effective river rehabilitation river management policies should aim to retain within-channel vegetation and woody debris.

THE MAIN POINTS OF THIS PAPER

- Jones Creek is a destablised alluvial system in a forested catchment
- 'Natural' channel recovery mechanisms that can be identified in this system, include :
  1. Sediment storage in the channel network
  2. Large volumes of coarse woody debris result in increased channel roughness and hence decrease velocity and associated stream power.
  3. Colonisation of within-channel vegetation increases channel roughness and increases sediment retention
- Within channel vegetation in many coastal rivers of south-eastern Australia can be viewed as an important recovery mechanism that can increase the roughness of the channel, increase sediment deposition and ultimately reduce the channel capacity of many systems which have overwidened.

1. INTRODUCTION

In order to successfully rehabilitate rivers in Australia it is essential to understand how fluvial systems behaved prior to European settlement. An understanding of how 'natural' rivers respond to large disturbances, be they flood or fire, can provide river researchers and managers an insight into how these systems recover following disturbance.

While numerous studies have highlighted that many Australian fluvial landscapes have been fundamentally altered since European settlement (Erskine, 1986, 1994, 1997; Brooks and Brierley, 1997, in press; Brierley and Fryirs, 1998) there has been much debate as to the exact causes of the changes in channel morphology in the last 200 years (Erskine and Warner 1988, 1998, Kirkup et al., 1998). The scope of this paper is not to investigate exact causes of channel change in south-eastern Australia but to draw on a case study in a forested catchment in order to document the character of channel instability and recovery mechanisms in an alluvial creek. The paper then assesses some common attributes of coastal river systems in south-eastern Australia and determines whether they are presently exhibiting recovery mechanisms.

Much of the literature that examines channel instability (bedlevel lowering and channel widening) stems from the northern hemisphere and is based on experimental, theoretical, and case studies (Schumm and Lichty, 1963; Schumm et al., 1984; Osterkamp and Costa, 1987; Simon, 1989, 1992; .Schumm, 1993). Very few of the above studies have been able to demonstrate the mechanisms of channel recovery in a destabilised fluvial system. Channel incision is a common characteristic of coastal river systems in south-eastern Australia. This process has often been followed by channel straightening, widening and bed aggradation.

This study focuses on Jones Creek, a small forested alluvial tributary of the Genoa River that has undergone bedlevel lowering, straightening and widening. It provides an opportunity to assess 'natural' recovery mechanisms in an unstable (incised) fluvial system.

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2. REGIONAL SETTING

Jones Creek drains a 31 km^2 subcatchment of the Genoa River in far East Gippsland, Victoria (**Figure 1**). Approximately 90% of Jones Creek catchment falls within Coopracambra National Park. The study reach, which is in the lower 3.5 km of Jones Creek, has an alluvial channel with a sinuosity of 1.53, mean bankfull width of approximately 33 m, and mean depth of 2 m. There are however, no systematic changes in channel width, mean depth, cross sectional area, sinuosity or bed material size along the 3.5 km study reach. The forested floodplain increases in width downstream from 50 m to 500 m towards the Genoa River confluence. The average floodplain slope in the lower section of the catchment is 0.009 m/m while overall channel slope within the study area is 0.0045 m/m. Jones Creek is characterised by widespread bank erosion, with numerous examples of bank collapse and tree fall. There are large amounts of coarse woody debris (CWD), and log jams evident within the channel. Various palaeochannels are evident proximal to the channel and on the distal floodplain. Jones Creek is a mixed load system, transporting silt, sand and gravel (gravel component averages 40 — 85 mm).

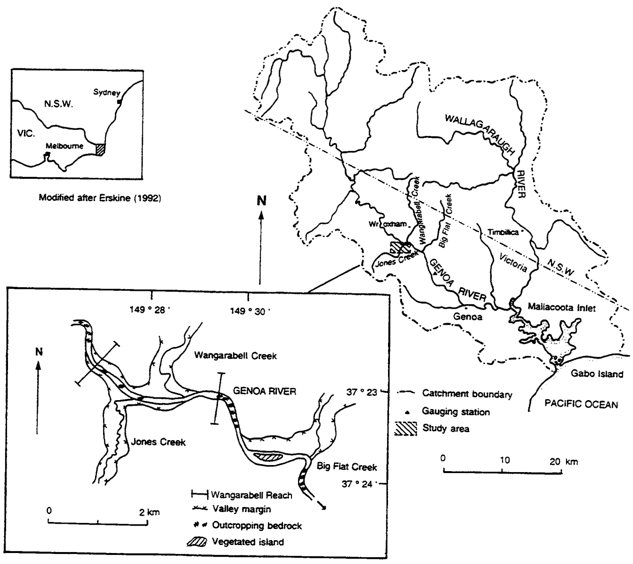

Figure1: Genoa catchment and Jones Creek study area.

This study uses rainfall records from Wroxham (10 km NE of Jones Creek) and Timbillica (25 km NE of Jones Creek). These records indicate a mean annual rainfall of 900 mm. Based on monthly and maximum 48 hour rainfall at Wroxham since 1971, periods of above average rainfall were 1971-1978, 1983-1988 and 1991-1995. These periods of high rainfall have been related to anecdotal and historical evidence of localised flooding to establish a flood record. While it is not possible to determine the magnitude of floods in Jones Creek, it is possible to highlight the above periods as times of flood activity in the catchment.

3.CHANNEL METAMORPHOSIS IN JONES CREEK 1967 - 1998

Since 1972, Jones Creek has undergone channel metamorphosis, resulting in a channel which has widened by two fold and has increased it's depth by up to 1.5 m. It has also decreased its sinuosity from 2.1-1.7 in 1972 to 1.53 in 1998, associated with a series of meander cutoffs. These changes in channel form have been initiated by changes to the tributary-trunk stream relationship (sensu Fryirs and Brierley, in press). Floods in 1971 and 1978 widened the Genoa River by up to three fold, dramatically altering the character of the confluence with Jones Creek. Channel widening of the Genoa River removed the tributary confluence bars and shortened the lower section of Jones Creek by 75 - 100 m. Floods between 1972 — 1978, including the highest 48 hour rainfall in the 25 year record, resulted in the destabilisation of tributaries of the Genoa River such as Wangarabell Creek and Jones Creek (Cohen and Brierley, subm).

Three phases of channel change have been identified along Jones Creek since 1972 (**Figure 2**). Phase 1, between 1972 and 1983, was characterised by bed incision as channel depth increased by up to 1.5 m. Associated with this adjustment, bedslope increased from 0.0033-0.0037 m/m to 0.0046 m/m. These changes in channel morphology and slope resulted in an inferred increase in bankfull specific stream power from 30-35 W/m^2 in 1972 to 185 W/m^2 in 1983 (Cohen and Brierley, subm). While there was some localised channel expansion in this period, Jones Creek maintained a high sinuosity throughout this phase.

Phase 2, between 1983 and 1992, was characterised by large increases in width and an associated reduction in sinuosity, as the planform of Jones Creek straightened. Bed aggradation and alternate bar development also occurred throughout this phase. In contrast to conventional cutoff models where entire bends are preserved, straightening and widening in Jones Creek occurred as the channel adjusted its planform laterally. This has resulted in the formation of a series of geomorphic units close to the contemporary channel representing the 1983 channel position. These have been termed realignment features. An assessment of the dimensions of these realignment features along with available cutoffs has provided data on the changes to the hydraulic geometry of the system throughout the various phases of instability. By 1992, the channel of Jones Creek was 32.3m wide, compared to 16 m in 1983. This second phase of channel activity was also characterised by the 1983 Ash Wednesday wildfire which burnt out the entire study area. While it is now known that channel instability in Jones Creek preceeded the 1983 fires, this event may well have had secondary impacts as a result of changed catchment conditions (ie change in floodplain vegetation composition, reduction in woody debris and changed hydrological conditions).

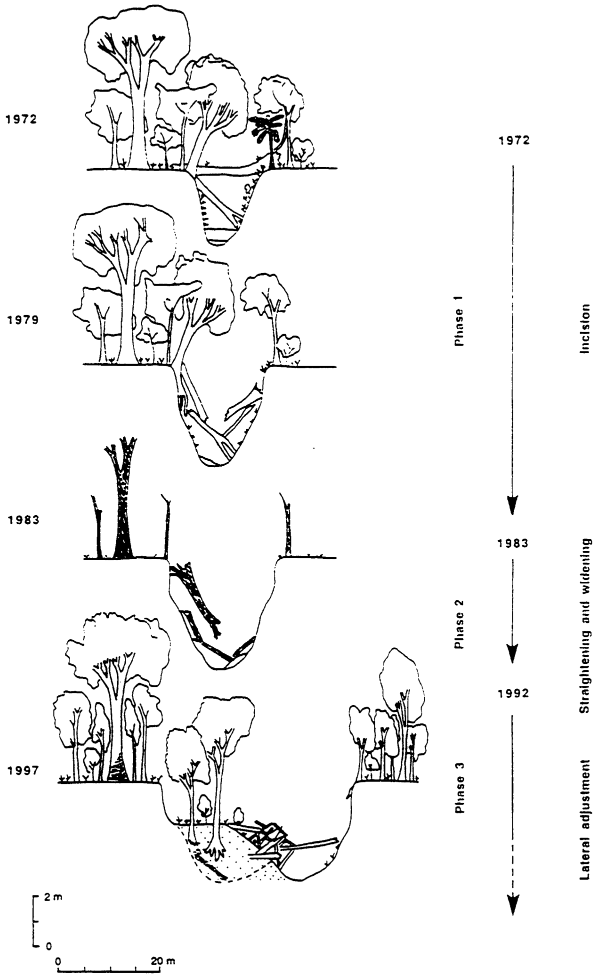

Figure 2 Schematic channel changes in Jones Creek highlighting the three phases of channel metamorphosis.

Phase 3 (1992 to the present) has been a period of further localised channel expansion and lateral adjustment. In contrast to Phase 2, this time interval has seen only minor changes in sinuosity. Further straightening has occurred in the recent 1998 flood along with continued aggradation of realignment features. Bed aggradation has also occurred throughout the study reach in Phase 3, with some localised bed degradation occurring in areas that have recently straightened. This highlights that the responses to bed incision are not spatially or temporally uniform. Given the large channel dimensions, high stream power values have been maintained through this period.

In the 26 year period between 1972 and 1998 Jones Creek has undergone rapid changes in channel form represented by channel realignment and changes in the hydraulic geometry of the system. For more detail on methods or data presentation see Cohen (1997) or Cohen and Brierley (subm).

4.CHANNEL RECOVERY OF AN INCISED SYSTEM

To date there has been remarkably little research on the mechanisms and timing of natural recovery processes in a fluvial system subjected to channel destabilisation. This study highlights certain processes which aid in the overall recovery of an incised system.

4.1 Sediment retention in vegetated realignment features

System recovery in Jones Creek is dependent on within-channel aggradation and subsequent stabilisation of depositional surfaces. The deposition and colonisation of channel marginal features or incipient floodplains is part of this process. Long term channel recovery is dependent on the reduction of stream power, the increase in sinuosity (within a wider channel), the decrease in channel width, and subsequent reconnection of the channel to its floodplain, so that floodplain inundation results (Schumm et al., 1984).

The literature on incised channels rarely identifies mechanisms of system recovery. Based on volumetric analysis undertaken in this study, 171,000 m^3 of material was eroded from the study area during the expansion phase. Of this total, 99,200 m^3 was sand sized material. It was estimated that 33 % of this sand sized material is presently stored within the channel in realignment features, cutoffs, point bars and bed storage. Other studies in south-eastern Australia (Brierley and Murn, 1997; Brierley and Fryirs, 1998; Fryirs, 1995) have found similar storage components in incised valley fills. The storage of this material is part of the recovery process. Further analysis of this sand sized material shows that 65 % of this stored material is 'locked up' in vegetated realignment features (**Figure 3**). Unlike the studies mentioned above, where virtually all stored sediment is available to be reworked due to the lack of vegetation stabilising sediment in the channel, Jones Creek has only a small proportion of stored sediment available to be reworked as a result of rapid rates of colonisation.

Rates of colonisation of depositional surfaces are extremely high in Jones Creek with Black wattle (*Acacia mearnsii*) being the dominant early successional species. This process is common throughout Jones Creek and is seen by other authors as part of the overall recovery process of an incised channel (Erskine et al., 1990). The rapid rate of colonisation of depositional surfaces increases the volume of sediment locked up and will ultimately reduce long term sediment supply to the incised channel, thus promoting further channel recovery. It also enhances channel recovery by reducing channel cross-sectional area, and inhibits downstream changes in channel geometry associated with the passage of sediment slugs.

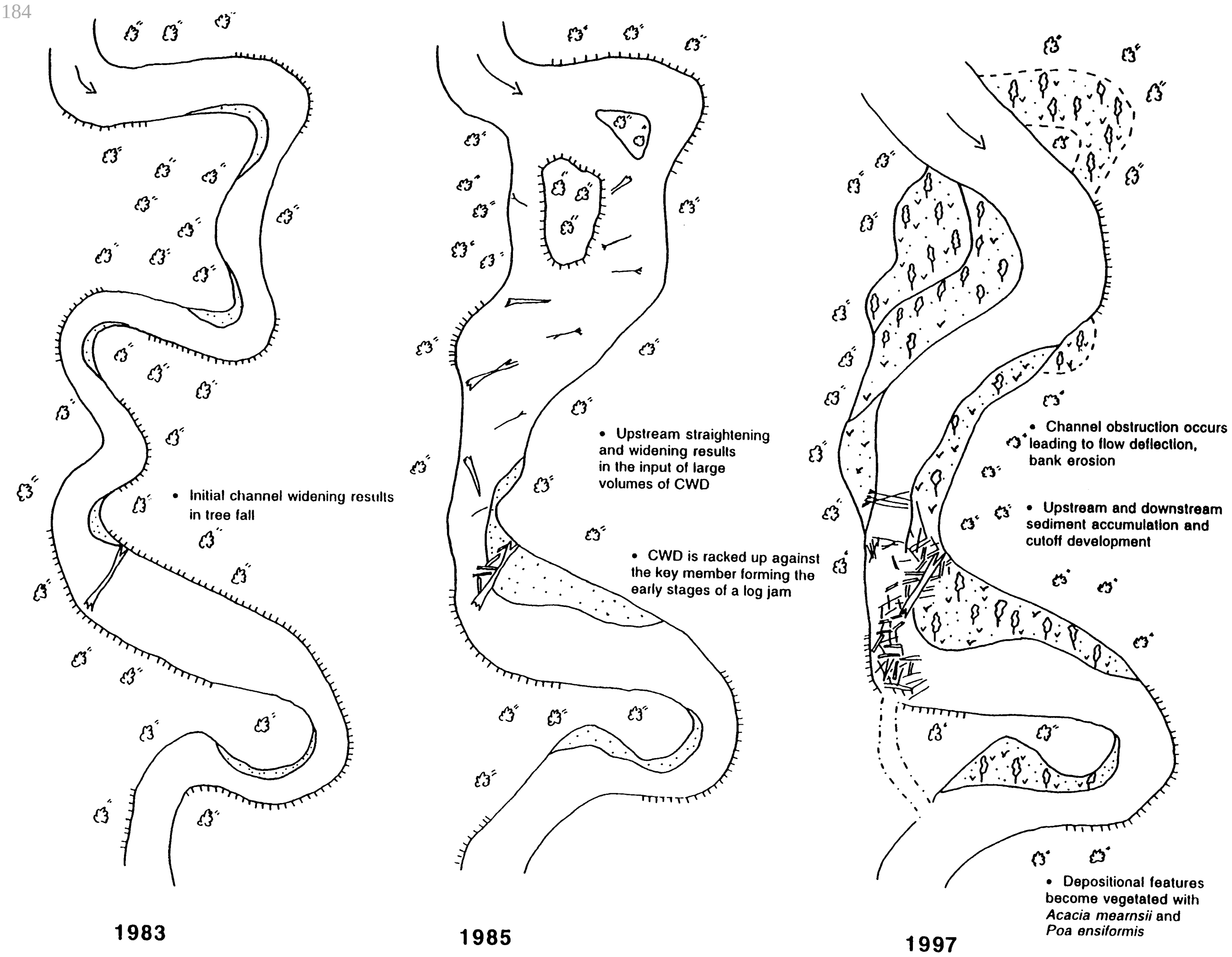

Figure 3 Schematic diagram highlighting the role of vegetation, woody debris/log jam formation and sediment retention in Jones Creek.

The rate at which colonising species grow and withstand burial is an important aspect to the stabilisation of realignment features. Black wattle (*Acacia mearnsii*) is an important successional species as it is the first species to stabilise bars and other geomorhic units. Other secondary canopy species with similar growth rates, such as River peppermint (*Eucalyptus elata*) and Manna Gum (*Eucalyptus viminalis*) provide the longer term stabilisation of these realignment features by establishing a forested surface with a range of longer lived species. Other secondary species such as Hazel pomaderris (*Pomaderris apera*), Spiny-headed mat-rush (*Lomandra longifolia*) and Sword Tussock-grass (*Poa ensiformis*) further enhance the stability of realignment features.

4.2 Within-channel vegetation

While not quantified within this study, vegetation that grows in the bed of the channel also provides an important roughness element within Jones Creek. Unlike Black wattle (*Acacia mearnsii*) which colonises bar surfaces and the low floodplain (realignment features), four rush and sedge species tend to dominate and grow in the bed, on bars and within woody debris. These include sedges and rushes such as: *Juncus usitatus*, *Cyperus eragrostis*, *Phragmites australis* and *Lomandra longifolia*.. Other successional species occur within the channel as a result of bank failure, introducing floodplain alluvium into the channel. Similar roles of within-channel vegetation have been documented by Hupp and Osterkamp (1985, 1996) and Friedman et al. (1996), highlighting the interaction between vegetation and fluvial processes in a destabilised channel.

Patterns of recovery within an incised system may depend on restabilisation on a reach by reach basis. For example, sections of the study area are experiencing bed aggradation and reduced rates of bank erosion. This has allowed for the establishment of both within-channel and channel marginal species. Recovering reaches will be susceptible to sediment transfer and storage variations, however, these variations will not result in significant changes in channel geometry or channel position. Once parts of the channel network have been stabilised, and as sediment supply is reduced, a sinuous inner channel develops allowing the channel margin to become vegetated. This process is co-dependent on sediment depletion rates from upstream and the stabilisation by vegetation of the inset channel zone.

4.3 Log jam formation and other coarse woody debris (CWD)

Schumm (1993) identified that roughness can increase in an incised system. This increase in roughness can reduce velocity and subsequent stream power. The large volume of coarse woody debris and log jams within Jones Creek are seen to reduce flow velocity and increase the roughness of the channel. This roughness element is seen as part of a negative feedback mechanism similar to that identified for channels that have undergone metamorphosis as a result of channel incision (Schumm et al., 1984).

Based on survey data there are no consistent or statistically significant trends that suggest log jams increase channel width within Jones Creek or consistently affect upstream or downstream bedslopes. However, what can be concluded is that areas of the channel that have undergone the greatest degree of channel change are now areas where CWD and log jams accumulate, often promoting sediment deposition (**Figure 3**). The lack of consistent trends is a function of the degree of lateral activity the channel has gone through and the relative young ages of log jams. The maximum age of log jams in Jones Creek is fifteen years. However, based on field observation and aerial photo interpretation, only 1 of the 109 log jams is of this age. This suggests that there is a high degree of localised reworking of log jams in incised streams (confirmed by the 1998 flood). In an incised system only large log jams, given enough time, will promote upstream sediment storage on the bed. What is apparent in Jones Creek is that smaller log jams will often induce channel marginal deposition and subsequent colonisation and stabilisation.

5.'NATURAL' RECOVERY MECHANISMS AND THEIR IMPLICATIONS FOR RIVER REHABILITATION IN SOUTH-EASTERN AUSTRALIA

One of the most commonly cited problems in coastal rivers in south-eastern Australia, especially in the north coast region is the occurrence of within-channel vegetation (Raine and Gardiner, 1995). Within-channel vegetation is often reported to divert flow into the banks causing bank erosion or onto the floodplain causing floodplain erosion. Hence, within-channel vegetation it is often removed in order to improve flood conveyance.

Based on recent work on the Nambucca catchment (Brooks et al., 1997; Doyle and Nanson, 1997) and Bellinger catchment (Cohen et al., 1998) overwidened channels that have undergone bedlevel and lateral instability are currently colonised with numerous early successional species as a result of an increase in habitat availability. While the development of within-channel vegetation can be seen as 'choking' the channel, subsequent bank and floodplain erosion will only be a serious problem where banks or inset floodplains are insufficiently vegetated.

Many of these coastal catchments exhibit channels which are up to five times the width of pre-European channels and contain floods up to the 1 in 100 year flood (sensu Doyle and Nanson, 1997). A history of European impact has destabilised many of these systems, and it is probably reasonable to expect a certain amount of continued lateral adjustment. Allowing within-channel vegetation in the form of islands or vegetated low floodplains, accompanied by strategic vegetative bank stabilisation techniques, will increase the roughness of the channel thus decreasing the velocity and promoting sediment accumulation. As shown on Jones Creek, the retention of sediment through vegetated geomorphic units is an essential part of channel recovery in geomorphic and ecological terms.

In many disturbed systems of south-eastern Australia there is no longer the supply of coarse woody debris from the floodplain or riparian vegetation, nor is there the supply of seed source to allow within channel colonisation. Many systems have therefore lost a range of natural recovery mechanisms, resulting in sediments that are continually reworked and a prolonged period of channel instability. This study has identified that in a forested catchment we are able to identify 'natural' recovery mechanisms that are often absent in fluvial systems that have been subject to a history of European disturbance.

6. CONCLUSION

This study has shown that in a destabilised alluvial river in East Gippsland, Victoria, which has undergone bed level incision, recovery mechanisms can be identified. In the period between 1972 and 1998 Jones Creek has undergone rapid changes in channel form represented by channel realignment and changes in the hydraulic geometry of the system. Channel recovery mechanisms such as sediment retention via vegetated realignment features, within-channel vegetation, coarse woody debris and log jams are all part of the channel recovery process. At present, many coastal river systems in south-eastern Australia lack a range of recovery mechanisms. However the presence of within-channel vegetation is seen as an important component to the recovery of many destabilised coastal systems. This study has shown the importance of understanding the evolution of a river system in order to make a sound assessment of current behaviour. River management policies need to encourage natural recovery mechanisms and look to retain within-channel vegetation and woody debris.

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