Sedimentologically Significant Tributaries: Characterizing Sediment Connectivity in the Lockyer Valley, SEQ

Peyton Lisenby[1], Kirstie Fryirs[1]

[1] *Department of Environmental Sciences, Macquarie University, North Ryde, NSW, 2109. Email: peyton.lisenby@students.mq.edu.au*

Key Points

- Sediment connectivity influences the propagation of geomorphic responses to disturbance events
- Understanding sediment flux and (dis)connectivity helps reveal catchment-scale sediment dynamics
- Tributary shape and valley position strongly influence the degree of sediment buffering in a catchment
- Sediment barriers such as weirs alter the sediment flux regimes of tributary and trunk streams

Abstract

Understanding the potential for bedload sediment (dis)connectivity within and between trunk and tributary drainages is critical to characterizing the catchment-scale, geomorphic behavior of a basin. The ease with which sediment can flux between drainage system compartments is a key determining factor of geomorphic responses to disturbance events and the sedimentological significance of tributaries. We characterize the significance of tributary systems as bedload sediment sources to the trunk stream within the Lockyer Valley, SEQ. We used desktop analyses of tributary morphometry and sedimentary buffers and barriers to compare the (dis)connectivity dynamics of 20 tributaries of Lockyer Creek. The distribution of sediment buffers (floodplains, alluvial fans, terraces, and trapped tributary fills) and barriers (reservoirs and weirs) is a key control on the significance of each tributary in contributing new sediment to the trunk stream. The development of these buffers is strongly controlled by the morphometry of each tributary and its location within the catchment. Desktop analyses of the distribution of sediment buffers and barriers provides quick and reliable insights into where sediment is stored, sourced, and transported in basins. This provides the basis for stream managers to prioritize, target, and treat important tributaries and inter-tributary locations as part of sediment management plans.

Keywords

Sediment connectivity, confluence, sedimentary buffer and barrier, tributary basin, significant tributaries

Introduction

The relative importance (significance) of particular tributaries, in terms of their potential sediment contribution, is essential knowledge for managing entire catchments (Benda et al., 2004b; Kondolf et al., 2006; Rinaldi et al., 2009). However, before tributary-to-trunk sediment connectivity relationships can be established, the nature and variability of sediment connectivity within individual tributary catchments must be understood (Fryirs et al., 2007b). Sediment connectivity involves the transfer of sediment from its source to a sink (storage location) via geomorphic mechanisms of particle detachment (entrainment) and transport (Bracken et al., 2015). These specific mechanisms are determined by the sediment source, transport and storage processes operating within and between landscape compartments (geomorphic zones: hillslope and channel environments) (Bracken et al., 2015; Fryirs, 2013). Importantly, the exchange of water and sediment between landscape compartments is unbalanced because different geomorphic factors control water flow and sediment transport (Croke et al., 2013; Thompson et al., 2016). The relationships between landscape compartments and geomorphic processes, feedback between mechanisms of entrainment and transport, along with the variability of operational time scales for geomorphic process and mechanisms creates a complex cocktail of possible narratives that detail how sediment might be contributed to a trunk stream (Bracken et al., 2015; Brierley et al., 2006; Fryirs, 2013).

Sediment contributions from tributary catchments can affect many different forms of geomorphological and ecological impacts or adjustments (Czuba & Foufoula-Georgiou, 2015; Rice et al., 2001). In large catchments with numerous potentially significant tributaries, management and research efforts aimed at predicting, preventing, curtailing or even enhancing these impacts to trigger river recovery must first narrow their focus to those tributary systems that are the most sedimentologically connected to the trunk stream. One way of accomplishing this objective is to identify geomorphic or anthropogenic features in each tributary catchment that disconnect (barriers) or impede (buffers) the transport of bedload sediment between landscape compartments (Fryirs et al., 2007a; Jain & Tandon, 2010). This aids in determining what remaining proportion of each tributary has the potential to transfer sediment unobstructed (effective catchment area) (Fryirs, 2013; Fryirs et al., 2007b; Harvey, 2001; Harvey, 2002). This has important implications for assessing how effective geomorphic or anthropogenic disturbance events will be (Fryirs et al., 2007b), as sediment connectivity can exert a strong control over the propagation of responses to disturbance events. For the Lockyer Valley, SEQ, we have identified buffers and barriers that can interrupt bedload sediment connectivity in several tributary catchments of Lockyer Creek. We utilize this data to determine the proportion of buffers and barriers in each tributary related and relate this to their drainage areas. Additionally, we implement a GIS approach to determine the effective catchment area of each system and use this to indicate the relative significance of each tributary in terms of sediment delivery to the trunk stream. Characterizing bedload sediment connectivity can provide insights into where and why geomorphic channel adjustments occur by associating them with tributary sediment contributions. This information can be used to prioritize catchment management actions in the Lockyer Valley to focus on channel locations that may experience more significant or impactful forms of adjustment.

Study Site and Methods

Field Site

The Lockyer Valley is a ~ 3000 km^2 catchment located in subtropical southeastern Queensland (SEQ) about 80 km west of Brisbane (Figure 1a). This region receives seasonally variable rainfall ranging from 900 to 1800 mm associated with the El Niño Southern Oscillation, and mean monthly temperatures range between 21 and 29° C (Croke et al., 2013). Agricultural development in this region began in the early-mid 1800s with widespread farmland irrigation and weir construction developing through the early and mid-1900s (Lockyer Catchment Centre, 2000; Tew, 1979). Portions of the tributary systems within the Lockyer Valley have experienced numerous geomorphic adjustments since the late 1800s (Lisenby & Fryirs, 2016); however, the geomorphic resilience of the trunk stream has resulted in moderate gross geomorphological changes to Lockyer Creek since European settlement (Fryirs et al., 2015).

Assessment of Sedimentary Buffers & Barriers

The principal drainage of the Lockyer Valley is Lockyer Creek, which is defined here to begin at the confluence of two 3rd-order (Strahler classification) streams – Paradise and 15 Mile Creeks – in the NW part of the catchment (Figure 1a). The trunk/tributary stream networks and catchment areas (Figure 1b) were delineated using the ArcHydro toolbox (Maidment, 2002) in ArcGIS with a 1 m resolution digital elevation model (DEM), which was generated from LiDAR flown in 2013 and sourced from the Lockyer Valley Regional Council (RPS Job# 13-4019). We identified 50 tributaries of Lockyer Creek with catchment areas greater than 1 km^2. We discounted any tributary whose trunk stream was not well defined (i.e. plowed under in farm paddocks) or whose catchment area was less than 10 km^2 or less than 1 % of the trunk stream area (Benda et al., 2004a; Benda et al., 2004b) (Figure 1c), measured at the confluence location (tributary junction). The types and extent of buffers and barriers in the Lockyer Valley were determined from 1:50000 soils maps and shapefiles sourced from the Queensland State Government, Department of Natural Resources and Mines (DNRM). We used the grouped classifications of soil units in the map explanations to identify four types of sedimentary buffers – floodplains, terraces, alluvial fans, and trapped tributary fills (cf. Fryirs et al., 2007a). Buffers are landforms that prevent sediment from moving from hillslopes into channels. Barriers are features that prevent sediment conveyance along the channel network. Here they include reservoirs and weirs. Using the soils and reservoir shapefiles and previously determined catchment areas, we calculated the surface area (and proportion) of each tributary catchment that is made up of buffers or barrier (Figure 1d). Though numerous, reservoirs account for only a very small surface area in each tributary catchment (< ~ 4 %), so that their surface areas are presented collectively with the surface areas of sediment buffers in Figure 1.

Effective Catchment Area

Effective catchment area is defined here as the tributary catchment area that contributes unobstructed sediment to the trunk stream (cf. Fryirs et al., 2007b). To determine this area, we first assumed that bedload-sized sediment will not move over slopes of 2° on hillslopes (cf. Fryirs et al., 2007b), alluvial surfaces, or in the channel. Therefore, areas with a slope of < 2° will disconnect sediment from that portion of the catchment (Fryirs et al., 2007b). This 2° slope threshold was then applied to the DEM, where cells with a slope of < 2° were deleted. We tested this approach over four tributary catchments (Table 1) to assess how realistic our effective catchment areas would be at cell sizes of 1 m, 5 m, and 25 m. We found that a 25 m cell size to be the most comparable to field based observations of buffer extent. We then determined the location of every drainage point in each tributary catchment and summed the drainage areas for all points that fell within 25 m of each tributary's trunk stream (longest tributary drainage line). The effective catchment areas derived are indicative rather than absolute measures of sediment-contributing tributary areas, however their power lies in the ability to make across-catchment comparisons of (dis)connectivity between tributary catchments and sediment source areas.

Table 1. Effective catchment area* testing for DEMs of different cell sizes.

Cell Size (m)	Tributary Effective Catchment Areas (km^2)			
	Murphys	Alice	Tenthill	Laidley
1	0.7	2.9	2.7	0.9
5	4.1	13.4	19.4	9.8
25	14.0	24.5	50.1	23.3

* Effective catchment area test used a 2° slope threshold

Results and Discussion

Influence of Basin Buffering, Shape, and Valley Position

Of the 50 tributaries identified, 20 had total catchment areas > 10 km^2 or > 1 % of the entire Lockyer Creek catchment (Figures 1b, c). Generally, the proportion of each tributary containing a buffer or barrier increased downstream along Lockyer Creek (Figure 1a, d). Consequently, the tributary's position in the entire Lockyer Creek catchment is a key control on how 'buffered' the tributary can be, where the basin shape chiefly dictates the size of the tributary catchment (cf. Benda et al., 2004b; Thompson et al., 2015). Of particular note are the differences in buffering between the Tenthill and Laidley catchments. These are the two largest tributaries of Lockyer Creek and they share a catchment divide; however, the Laidley confluence is positioned well downstream of the Tenthill junction. The shapes of these basins are almost inverse of one another, where Tenthill is narrowest in its lower portion while Laidley is the widest. Correspondingly, the Laidley catchment is twice as buffered as the Tenthill catchment, 30 vs. 15 %, respectively. The influence of tributary catchment shape is most clearly seen in the Blind Gully catchment. It is the 6th largest tributary but the most buffered at 55 %, 20% higher than the next most buffered tributary, Plain Creek. Benda et al. (2004a) found that tributary basins which increase in size downstream are more likely to produce geomorphic impacts and adjustments along the trunk stream because the channel networks will tend to coalesce downstream producing larger tributary channels capable of transporting more water and sediment. Our results indicate that the degree of buffering must also be accounted for as wider basins can accommodate larger buffered areas (cf. Fryirs & Gore, 2014). Lisenby and Fryirs (2016) found that the Laidley Creek trunk stream significantly decreases in size as it approaches its junction with Lockyer Creek.

Effective catchment area data (Figure 1e) highlight the significance of the upstream tributaries. Despite having much smaller catchment areas, these tributaries have effective catchment areas comparable to the larger, downstream tributaries. The Tenthill catchment has the largest effective catchment area which is likely related to its catchment size, ideal position and basin shape. Notably, the Flagstone and MaMa tributaries, which are the 4th and 5th largest tributary catchments (Figure 1b), have the 2nd and 3rd largest effective catchment areas (Figure 1e). These tributaries, though smaller, have a similar shape and positon to the Tenthill catchment (Figure 1a). Their shapes allow for more, steeper catchment areas to be contained within the catchment which equivocates to larger effective catchment areas given our 2° slope threshold. This trend is less apparent in the Rocky catchment. Despite being shaped similar to the Flagstone, MaMa, and Tenthill tributaries, being positioned upstream, and having the 8th largest catchment area, it has only the 13th largest effective catchment area. This is undoubtedly related to it being proportionally more buffered than these other three tributaries (Figure 1d). Our results, combined with those of Benda et al. (2004a) and (Benda et al., 2004b), indicate that tributary basin shape can influence the proportion of buffering and effective tributary area. This, in turn, can influence the potential for geomorphic adjustment at the tributary-trunk stream confluence.

The ratios of effective area to total tributary area again emphasize the significance of the most upstream tributary catchments – Paradise, 15-mile, Murphys, and Alice (Figure 1f). Despite being the 11th largest catchment, the Alice tributary has the 4th largest effective catchment area and the highest ratio of effective area to total tributary area (Figures 1e, f). The upper-most tributaries also have the highest ratio of total tributary area to trunk stream area (Figure 1c) which indicates that they have high potential to influence the sediment regime of the upper reaches of Lockyer Creek (cf. Rice, 1998). Ratios of buffering between the tributary and trunk stream catchments compare buffering in each tributary to buffering in the trunk stream, measured upstream from the tributary junction (Figure 1g). Those tributary catchments that are less buffered than trunk stream catchment upstream (ratios < 1) may have greater potential to influence the sediment regimes at and downstream of their respective confluences. The confluence of Paradise and 15-Mile Creeks will set the initial sediment regime for Lockyer Creek, and then each downstream tributary has the potential to alter that regime. We identify four tributaries with a ratio of < 1 – Alice, MaMa, Redbank, and Buaraba. Notably, the Murphys tributary has a ratio of over 3 because it is twice as buffered as the other three upstream-most tributary catchments. Additional research is underway along Lockyer Creek to determine the accuracy of the modeled output against field-based data, to ascertain how significant these tributaries are in terms of disrupting the sediment conveyor belt of this system (Rice, 1998).

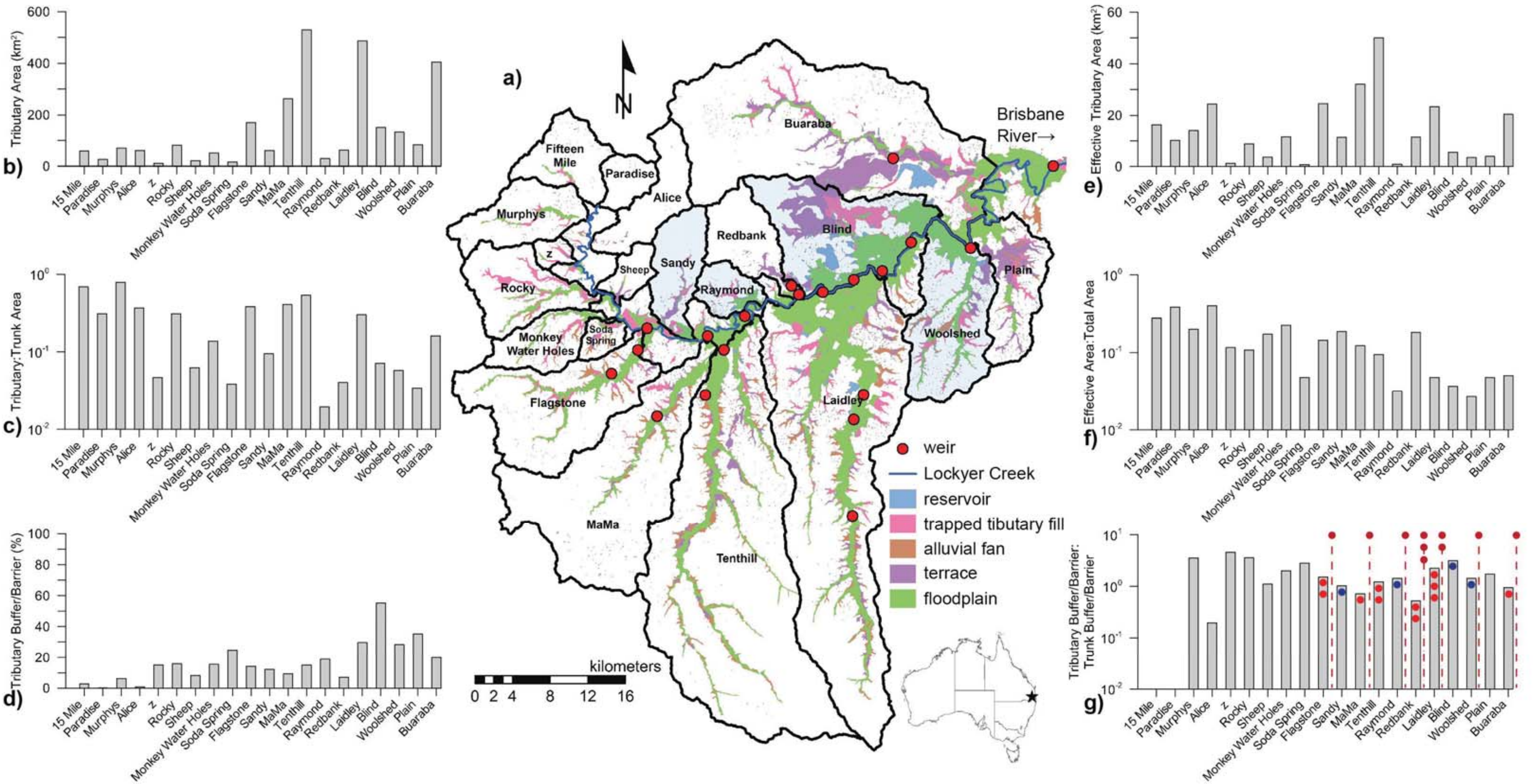

Figure 1. a) Location, tributaries, and buffers/barriers of the Lockyer Valley, SEQ. b) Tributary areas. c) Ratio between tributary area and trunk stream (Lockyer Creek) area upstream of confluence. d) Buffer/barrier area of each tributary catchment. e) Effective catchment areas for each tributary. f) Ratio between tributary effective area and total tributary area. g) Ratio between the percentage of buffer/barrier of each tributary catchment and the percentage of buffer/barrier for the trunk stream (Lockyer Creek) upstream of confluence. Note that the red dashed lines indicate weir locations along Lockyer Creek, red dots indicate weir locations within a tributary catchment, and blue dots indicate impoundments along a tributary's trunk stream.

Influence of Instream Weirs as Barriers

There are 10 weirs located along the Lockyer Creek trunk stream (Figures 1a, g), which will impede the downstream propagation of bedload sediment. Thoms and Walker (1993) found that instream weirs could trap up to 13 % of the total sediment load; however, additional bed load sediment is often mobilized immediately downstream of weirs due to reduced sediment loads in the water spilling over weir tops (Kondolf, 1997; Rinaldi, 2003; Thoms & Walker, 1993). The position of these weirs along Lockyer Creek may influence the significance of any downstream tributaries. If the weirs trap enough sediment, the downstream tributaries become the dominant sediment source to the trunk stream. Additionally, some of the tributary's trunk streams are impounded or contain weirs in their lower reaches (Figure 1g). This will further reduce the bedload sediment supply to Lockyer Creek. Of the six tributaries with the largest effective catchment areas, five have weirs along their lower channel reaches. Thoms and Walker (1993) found that the coarse sediment trapped in tributary weirs will alter the particle size distribution of sediment loads in the trunk stream. The abundance of downstream weirs along Lockyer Creek and within the larger, downstream tributaries re-emphasizes the importance of the mid-upstream tributary catchments (upstream of Flagstone Creek). Notably, the Alice Creek tributary has the largest effective catchment area without the downstream impedance of a weir.

Implications for River Management

An understanding of where natural or anthropogenic sediment buffers and barriers occur and how they are distributed is a powerful tool for managing sediment dynamics in agriculturalized/urbanized catchments. A healthy bedload sediment transfer (flux) regime is necessary for morphological stability on catchment hillslopes and in channel reaches (Hassan et al., 2005). Assessing variability with catchment sediment connectivity provides insights into bedload sediment availability for geomorphic recovery after disturbance events (Fryirs & Brierley, 2001; Surian et al., 2009). Importantly, understanding sediment connectivity can aid determinations of where and how geomorphological disturbances may manifest or propagate during and after a disturbance (Harvey, 2001). Correspondingly, river managers can use sediment connectivity information to prioritize particular catchment locations, based on sediment availability, for targeted recovery or management efforts or to trace unwanted sediment back to a likely source (Koiter et al., 2013). Critically, the presence of weirs may interrupt healthy sediment transfer regimes. This may be recognized by downstream channel degradation or restricted channel recovery. Targeted efforts for maintaining or removing weirs to restore natural sediment regimes can be facilitated by sediment connectivity knowledge (Shafroth et al., 2002).

Conclusions

Understanding the nature of sediment connectivity within tributary catchments is an important step in establishing which tributary-to-trunk stream relationships are the most sedimentologically significant. This is increasingly important because catchment sediment connectivity exerts a strong control over the propagation of channel responses resulting from geomorphic disturbance events or targeted channel management actions. This paper has attempted to characterize sediment connectivity in the Lockyer Valley by mapping and measuring the extent of sediment buffers, barriers, and effective catchment areas for 20 tributary basins of Lockyer Creek. Our initial results show that a coarser spatial dataset (25 m DEM vs. 1 m DEM) can be more useful than high-resolution datasets for catchment-scale investigations of connectivity. We have found that the shape and valley position of tributary basins can have a notable influence on the degree of buffering within the catchment and that this may exert a stronger control on a tributary's sedimentological significance than catchment size. It is important to consider what lies upstream of a tributary confluence. Whether it is extensive buffering or instream weirs, the sedimentological regime upstream of a tributary junction will influence the potential sedimentological significance of the tributary. Desktop analysis of sediment buffers is an efficient way to gain basic insights into potential sediment dynamics within a catchment. In the Lockyer Valley, further work is needed to understand how the sediment regime of Lockyer Creek changes between weir locations and tributary junctions.

Acknowledgments

Funding for this project was provided by an Australian Linkage Grant (LP120200093). We would like to thank Chris Thompson and James Grove for their aid in accessing the topographic, soils, and reservoir datasets used in this study. Peyton Lisenby is supported by a Macquarie University International Postgraduate Research Scholarship and a Higher Degree Research Fund. Soils maps, reservoir, and weir data is available through the Queensland State Government Department of Natural Resources and Mines (DNRM).

References

Benda, L., Andras, K., Miller, D., & Bigelow, P. (2004a). Confluence effects in rivers: Interactions of basin scale, network geometry, and disturbance regimes. *Water Resources Research, 40*(5). doi: 10.1029/2003WR002583

Benda, L., Poff, N. L., Miller, D., Dunne, T., Reeves, G., Pess, G., & Pollock, M. (2004b). The Network Dynamics Hypothesis: How Channel Networks Structure Riverine Habitats. *BioScience, 54*(5), 413-427. doi: 10.1641/0006-3568(2004)054[0413:tndhhc]2.0.co;2

Bracken, L. J., Turnbull, L., Wainwright, J., & Bogaart, P. (2015). Sediment connectivity: a framework for understanding sediment transfer at multiple scales. *Earth Surface Processes and Landforms, 40*(2), 177-188. doi: 10.1002/esp.3635

Brierley, G., Fryirs, K., & Jain, V. (2006). Landscape connectivity: the geographic basis of geomorphic applications. *Area, 38*(2), 165-174. doi: 10.1111/j.1475-4762.2006.00671.x

Croke, J., Fryirs, K., & Thompson, C. (2013). Channel–floodplain connectivity during an extreme flood event: implications for sediment erosion, deposition, and delivery. *Earth Surface Processes and Landforms, 38*(12), 1444-1456. doi: 10.1002/esp.3430

Czuba, J. A., & Foufoula-Georgiou, E. (2015). Dynamic connectivity in a fluvial network for identifying hotspots of geomorphic change. *Water Resources Research, 51*(3), 1401-1421. doi: 10.1002/2014WR016139

Fryirs, K. (2013). (Dis)Connectivity in catchment sediment cascades: a fresh look at the sediment delivery problem. *Earth Surface Processes and Landforms, 38*(1), 30-46. doi: 10.1002/esp.3242

Fryirs, K., & Brierley, G. J. (2001). Variability in sediment delivery and storage along river courses in Bega catchment, NSW, Australia: implications for geomorphic river recovery. *Geomorphology, 38*(3–4), 237-265. doi: http://dx.doi.org/10.1016/S0169-555X(00)00093-3

Fryirs, K., & Gore, D. B. (2014). Geochemical insights to the formation of "sedimentary buffers": Considering the role of tributary–trunk stream interactions on catchment-scale sediment flux and drainage network dynamics. *Geomorphology, 219*, 1-9. doi: http://dx.doi.org/10.1016/j.geomorph.2014.04.035

Fryirs, K., Lisenby, P. E., & Croke, J. (2015). Morphological and historical resilience to catastrophic flooding: The case of Lockyer Creek, SE Queensland, Australia. *Geomorphology, 241*, 55-71. doi: 10.1016/j.geomorph.2015.04.008

Fryirs, K. A., Brierley, G. J., Preston, N. J., & Kasai, M. (2007a). Buffers, barriers and blankets: The (dis)connectivity of catchment-scale sediment cascades. *CATENA, 70*(1), 49-67. doi: http://dx.doi.org/10.1016/j.catena.2006.07.007

Fryirs, K. A., Brierley, G. J., Preston, N. J., & Spencer, J. (2007b). Catchment-scale (dis)connectivity in sediment flux in the upper Hunter catchment, New South Wales, Australia. *Geomorphology, 84*(3–4), 297-316. doi: http://dx.doi.org/10.1016/j.geomorph.2006.01.044

Harvey, A. M. (2001). Coupling between hillslopes and channels in upland fluvial systems: implications for landscape sensitivity, illustrated from the Howgill Fells, northwest England. *CATENA, 42*(2–4), 225-250. doi: http://dx.doi.org/10.1016/S0341-8162(00)00139-9

Harvey, A. M. (2002). Effective timescales of coupling within fluvial systems. *Geomorphology, 44*(3–4), 175-201. doi: http://dx.doi.org/10.1016/S0169-555X(01)00174-X

Hassan, M. A., Church, M., Lisle, T. E., Brardinoni, F., Benda, L., & Grant, G. E. (2005). Sediment transport and channel morphology of small, forested streams. *Journal of the American Water Resources Association, 41*(4), 853-876. doi: 10.1111/j.1752-1688.2005.tb03774.x

Jain, V., & Tandon, S. K. (2010). Conceptual assessment of (dis)connectivity and its application to the Ganga River dispersal system. *Geomorphology, 118*(3–4), 349-358. doi: http://dx.doi.org/10.1016/j.geomorph.2010.02.002

Koiter, A. J., Lobb, D. A., Owens, P. N., Petticrew, E. L., Tiessen, K. H. D., & Li, S. (2013). Investigating the role of connectivity and scale in assessing the sources of sediment in an agricultural watershed in the Canadian prairies using sediment source fingerprinting. *Journal of Soils and Sediments, 13*(10), 1676-1691. doi: 10.1007/s11368-013-0762-7

Kondolf, G. M., Boulton, A. J., O'Daniel, S., Poole, G. C., Rahel, F. J., Stanley, E. H., . . . Cristoni, C. (2006). Process-based ecological river restoration: visualizing three-dimensional connectivity and dynamic vectors to recover lost linkages. *Ecology and Society, 11*(2), 5.

Kondolf, M. G. (1997). PROFILE: Hungry Water: Effects of Dams and Gravel Mining on River Channels. *Environmental Management, 21*(4), 533-551. doi: 10.1007/s002679900048

Lisenby, P. E., & Fryirs, K. A. (2016). Catchment- and reach-scale controls on the distribution and expectation of geomorphic channel adjustment. *Water Resources Research*, n/a-n/a. doi: 10.1002/2015WR017747

Lockyer Catchment Centre. (2000). *Living in the Lockyer : a landholders guide to land, water, wildlife and vegetation management in the Lockyer Catchment and surrounds*. Forest Hill, Qld: Lockyer Catchment Centre.

Maidment, D. R. (2002). *Arc Hydro: GIS for Water Resources*: ESRI Press.

Rice, S. (1998). Which tributaries disrupt downstream fining along gravel-bed rivers? *Geomorphology, 22*(1), 39-56. doi: http://dx.doi.org/10.1016/S0169-555X(97)00052-4

Rice, S. P., Greenwood, M. T., & Joyce, C. B. (2001). Tributaries, sediment sources, and the longitudinal organisation of macroinvertebrate fauna along river systems. *Canadian Journal of Fisheries and Aquatic Sciences, 58*(4), 824-840. doi: 10.1139/f01-022

Rinaldi, M. (2003). Recent channel adjustments in alluvial rivers of Tuscany, central Italy. *Earth Surface Processes and Landforms, 28*(6), 587-608. doi: 10.1002/esp.464

Rinaldi, M., Simoncini, C., & Piégay, H. (2009). Scientific design strategy for promoting sustainable sediment management: the case of the Magra River (Central-Northern Italy). *River Research and Applications, 25*(5), 607-625. doi: 10.1002/rra.1243

Shafroth, P. B., Friedman, J. M., Auble, G. T., Scott, M. L., & Braatne, J. H. (2002). Potential Responses of Riparian Vegetation to Dam Removal: Dam removal generally causes changes to aspects of the physical environment that influence the establishment and growth of riparian vegetation. *BioScience, 52*(8), 703-712. doi: 10.1641/0006-3568(2002)052[0703:prorvt]2.0.co;2

Surian, N., Ziliani, L., Comiti, F., Lenzi, M. A., & Mao, L. (2009). Channel adjustments and alteration of sediment fluxes in gravel-bed rivers of North-Eastern Italy: potentials and limitations for channel recovery. *River Research and Applications, 25*(5), 551-567. doi: 10.1002/rra.1231

Tew, A. M. (1979). *History of the Gatton Shire in the Lockyer Valley*. Gatton, Australia: Gatton Shire Council.

Thompson, C. J., Croke, J., Fryirs, K., & Grove, J. R. (2016). A channel evolution model for subtropical macrochannel systems. *CATENA, 139*, 199-213. doi: http://dx.doi.org/10.1016/j.catena.2015.12.012

Thompson, C. J., Fryirs, K., & Croke, J. (2015). The Disconnected Sediment Conveyor Belt: Patterns of Longitudinal and Lateral Erosion and Deposition During a Catastrophic Flood in the Lockyer Valley, South East Queensland, Australia. *River Research and Applications*, n/a-n/a. doi: 10.1002/rra.2897

Thoms, M. C., & Walker, K. F. (1993). Channel changes associated with two adjacent weirs on a regulated lowland alluvial river. *Regulated Rivers: Research & Management, 8*(3), 271-284. doi: 10.1002/rrr.3450080306