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# Channel bifurcation and adjustment on the upper Yadkin River, North Carolina (USA)

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ABSTRACT

The bifurcation of river flow around large stable islands, also known as anabranching, represents a distinctive form of river adjustment that is uncommon in the Appalachian Piedmont province of the eastern U.S. Within this province, highly localized river branching similar to classical anabranching forms exists in one area near the foot of the Blue Ridge Escarpment. This paper examines channel form and processes along a reach of the upper Yadkin River in North Carolina (USA) before and after a flood-induced division of its flow into two subparallel branches, both of which remain active 35 years later. The research draws on aerial photograph analyses, channel surveying, and observations of inset channel benches, flood frequency analysis, and discharge monitoring and modeling to analyze planform history and to track and explain changes in newly excised and losing channels along the bifurcated reach. The characterization of this branched reach resembles some descriptions of gravel-dominated laterally active anabranching, although the match is imperfect. Reductions in valley slope and confinement and the presence of local valley constrictions near the base of the escarpment steeplands have been conducive to long-term sedimentation and a greater likelihood of branching. A period of relatively rapid cross section adjustment occurred on both branches soon after bifurcation, and this may have permitted the losing branch to remain open. Well-stratified benches currently observed along the losing branch are interpreted to be largely the late product of a waning early major adjustment phase and moderate, recent, and perhaps ongoing variations in flow division and appear to be not fully adjusted to prevailing discharges. Coarse benches along the newly excised branch are better-adjusted inset floodplain fragments created primarily by lateral migration and point accretion. Patterns of benchfull flow frequency variation are interpreted to indicate that the flow bifurcation ratio has been neither static nor monotonically changing in recent decades. Further exploration of branching in this environment, otherwise dominated by single-thread meandering patterns, is of importance for a variety of management and ecological concerns.



## 1. Introduction

Changes in environmental and internal system variables prompt river form adjustments that are of consequence for land use and conservation, river corridor ecosystems, and environmental management (Dunne and Leopold, 1978; Schumm, 1985; Marston et al., 1995; Newson, 1995; Downs and Gregory, 2004; Brierley and Fryirs, 2005). The bifurcation of river flow around large stable islands, also known as anabranching, represents a distinctive form of river adjustment found in some geomorphic settings (Knighton and Nanson, 1993; Nanson and Knighton, 1996; Tooth and McCarthy, 2004; Carling et al., 2013). Although they have been observed in a range of environments, rivers characterized by anabranching over large distances are globally uncommon relative to single-thread types (Knighton, 1998; Burge, 2006; Huang and Nanson, 2007; Charlton, 2008). This is particularly true of the Appalachian Piedmont province of the southeastern U.S., an area in which historical agriculture has played a large role in fluvial sediment budgets (Trimble, 2008), and single-thread meandering streams currently predominate (Wohl, 2002). Although the frequency of branching has not yet been precisely quantified in the Piedmont, river observations from maps and Google Earth imagery (Google Inc., 2013) reveal that branching channels make up a minute proportion of total river distance relative to single-thread channels in this province. Yet some locations exist where branching over short distances is relatively common, and bifurcated flow has persisted over at least the last several decades. The persistence of branched flow at some locations and the adjustment dynamics of individual branches are of potential importance for river management concerns in such areas, including issues of infrastructure, flood hazard, and riverine ecology (Richards et al., 2002; Downs and Gregory, 2004)

One of the few locations in this region where examples of branching may be observed is along the base of the southeast-facing Blue Ridge Escarpment in North Carolina (USA) (Fig. 1), where confined steepland valleys open into gentler partially confined valleys of the western Piedmont. Here, four rivers, the Catawba, Wilson Creek, Linville River,

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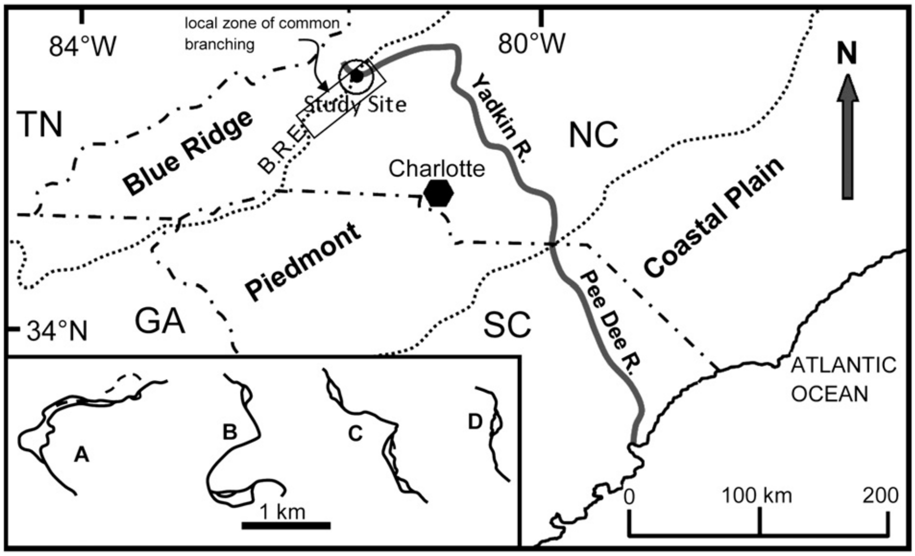


**Fig. 1.** Regional location map for the Yadkin River drainage. BRE stands for the Blue Ridge Escarpment, the base of which coincides with the Blue Ridge/Piedmont boundary on the map. The small rectangle incorporating the study site encloses an area within which examples of branching are common. The inset box shows the patterns of some branched rivers: (A) Catawba River, (B) Linville River, (C) Wilson Creek, and (D) Yadkin River.

and Yadkin River, exhibit examples of active branching before becoming consistently single-thread farther downstream (Fig. 1; inset). These four rivers account for nine out of the ten total branched reaches identified from imagery along the base of the Blue Ridge Escarpment in North Carolina. The occurrence, form, and persistence of flow bifurcations along such rivers parallel some observations of anabranching rivers, in addition to observations of avulsion and cutoff processes common in a wider range of river types.

Comparisons of branching patterns and processes are complicated by the great environmental and morphological diversity actually encompassed by such forms. Several classes of anabranching have been defined, each having particular associations within a spectrum of process regimes and material characteristics. Nanson and Knighton (1996) identify six different anabranching river types on the basis of differences in specific stream power, bed material size, bank material size, lateral migration rate, vertical accretion rate, and the ratio of island length to channel width. The end members of the anabranching type sequence are anastomosing streams at the low power, fine-grained end of the group and gravel or mixed load streams with higher power and variable rates of lateral migration. Regardless of type, branching is typically initiated during overbank flooding by avulsion of the primary flow into other areas of the floodplain in which excision of a new channel is possible. This could be an older partially or completely filled paleochannel or slough or a previously excised channel that is commonly inundated but not eroded during most overbank floods (Nanson and Knighton, 1996; Slingerland and Smith, 2004; Brierley and Fryirs, 2005). Avulsion is often preconditioned by channel aggradation, low valley gradients, and availability or proximity of slope-advantaged flow pathways and locally assisted by triggering phenomena such as log jams and other flow obstructions, and the presence of weak spots in natural levees (Slingerland and Smith, 2004; Phillips, 2012).

Following a bifurcation, new and old channels will adjust to new flow regimes. Factors affecting the morphological evolution of these channels include differences in channel gradient, bifurcation angles, floodplain erodibility, vegetation stature, and flood regime characteristics (Hooke, 1995; Fuller et al., 2003; Schumm, 2005; Kleinhans et al., 2011; Thomas et al., 2011). Studies of avulsions and cutoffs have provided useful information on the trajectories and rates of new channel evolution. For example, Fuller et al. (2003) observed a chute cutoff on a wandering river (type 5 anabranching of Nanson and Knighton, 1996) in the U.K. that began with an initial period of bed erosion that later gave way to bank erosion as the dominant adjustment type, with sinuosity increasing only after major bed incision. These changes occurred over a brief (2-year) time period, and although the full relaxation time had not expired, major adjustments appear to have occurred rapidly. Hooke (1995) also observed rapid relaxation times for adjustment of meander cutoffs on single-thread, active gravel-bed streams, apparently between 6 and 12 years. These analyses — which derive from observation of short, young channel reaches — might serve as analogs for new but longer branches, at least in channel segments closest to bifurcations in branched rivers.

Most studies of avulsions and cut-offs have focused on the evolution of newly excised channels and provide little insight into the development of the older losing branches, which have been termed *abandoning* by Burge (2006). In abandoning channels, discharge will be much reduced, leaving them in an overfit state (Slingerland and Smith, 2004). Such a channel is likely to contract over time via vertical, lateral, and/or oblique accretion to match the new discharge regime (Slingerland and Smith, 2004; Stouthamer and Berendsen, 2007). Channel contraction has been studied in the context of the effects of flows diminished by human agency (Friedman et al., 1998; Changxing et al., 1999; Brandt, 2000; Graf, 2006; Baker et al., 2011), drought (Warner, 1987, 1994; Erskine and Livingstone, 1999; Royall et al., 2010), or under unaltered flow conditions following artificial channel enlargement (Simon and Hupp, 1986; Simon and Rinaldi, 2006). In many cases, small floodplain-like features inset within the higher channel banks have been observed to result from the new conditions. These features have commonly been referred to as *benches* in many studies, although several variations on the term and its genetic connotations have been identified (Vietz, 2008). Woodyer (1968) and later Erskine and Livingstone (1999) used the term *in-channel bench* for such features that lay below the elevation of the main valley flat. Other terms such as *berm* (Schumm, 2005) and channel *inset* (Bourke, 1994; Thoms and Olley, 2004) have also been used to denote the same or similar form, although genetic similarities or distinctions are not always clear, and equifinality is likely.

Kleinhans et al. (2011) used historical mapping data and modeling to understand how channel width adjustments via bank and bench accretion in branches (*bifurcates*) of the river Rhine are related to the morphodynamics, stability, and longevity of upstream bifurcations. They found that abandoning channels that could adapt their widths to loss of discharge more rapidly, stayed open longer owing to the maintenance of deeper flows with greater sediment transport capacity. Thus, upstream bifurcations persist longer when their downstream bifurcates