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Discussion

Comment on Lewin and Brewer (2001): "Predicting channel patterns", Geomorphology 40, 329–339 ☆

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With the aim of assessing basic alluvial channel planforms as a function of the main determining parameters, a number of stability diagrams have been published during the past several decades, starting with the well-known plots of channel slope versus bankfull discharge of Leopold and Wolman (1957) and Lane (1957). In more recent versions of these stability diagrams, a parameter representing flow energy is plotted against some geometric or grainsize parameter. In one way or another, the diagrams indicate that straight, meandering and braided patterns represent a trend of increasing flow energy (sensu Ferguson, 1987, and Knighton and Nanson, 1993). However, the discriminators could not be used in a truly predictive way, as the value of one or both of the "independent" variables was predicated upon a priori knowledge of one or more geometric properties of the pattern that was to be predicted, such as the bankfull width, depth or slope of the channel (Parker, 1976; Fredsøe, 1978; Struiksma and Klaassen, 1988). Therefore, a diagram was proposed by the first author using the parameters *potential* stream power (based on valley gradient as opposed to channel gradient) and median grainsize, variables that can be considered almost independent of channel pattern (Van den Berg, 1995). Potential specific stream power, ω, was defined as:

$$\omega = \gamma / a S_v Q^{0.5}$$

in which γ = specific weight of water (= 9810 N m^{-3}), S_v = valley gradient and Q = bankfull discharge or mean annual flood, and a regression coefficient, a, estimated from regime equations of the form

$$W = aQ^b$$

that varies between sand-bed and gravel-bed rivers. Bledsoe and Watson (2001) replaced the single discriminator in adapted diagrams by assessing the probability of the occurrence of the two patterns. In their analysis of the method proposed by Van den Berg (1995), the potential specific stream power is replaced by $S_v Q^{0.5}$, with S_v = valley slope, which is derived from ω by eschewing different values of a for sand-bed and gravel-bed rivers and thereby eliminating the γ/a coefficient. Using a logistic regression approach, Bledsoe and Watson (2001) created diagrams and models that include explicit levels of risk to more clearly depict the "fuzziness" of the transition from meandering and braiding.

In their recent paper, Lewin and Brewer (2001) seem not to appreciate the merits of the diagrams that

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have been demonstrated to correctly discriminate the classic channel patterns with minimal data requirements, and often low misclassification. They level their criticism especially at the parameters used as boundary conditions in the diagram of Van den Berg (1995), which they judge as being invalid, for the following reasons:

1. The pattern-discriminating results are achieved by applying "an unjustifiable regime-based relation" between bankfull discharge and bankfull channel width; and
2. The simplicity of the parameters used in the existing stability diagrams "obscures the complexity of processes which underlie the patterning of channel planforms", and "disguises rather than exposes the patterning processes which underpin the channel continuum".

As Bledsoe and Watson (2001) used basically the same parameters in their analysis, most of this criticism also implicate their diagrams. Although much of the criticisms levelled by Lewin and Brewer (2001) is valid, it is, in our opinion, beside the mark. More disconcerting is the possibility that their remarks might discourage the cautious use of channel planform diagrams, as they assert that the approach is unlikely to achieve meandering/braiding discrimination. Because we maintain that predictive diagrams of channel planform stability can be valuable tools in river studies, we wish to address these misjudgements regarding the parameters used and the applicability of the diagrams.

We fully agree with Lewin and Brewer (2001) that an analysis of bankfull (or annual flood) stream power and grainsize alone is far from adequate to describe the many complex processes that underlie the patterning of rivers. However, it must be stressed that this is not, nor should be, the objective of diagrams of this kind. Perhaps some improvement in the diagrams might still be possible by including measures of sediment load, resistance to lateral adjustment, i.e., vegetation and bank sediments, and by expanding the diagrams to also include the potential for vertical responses to excess stream power. Nonetheless, the diagrams we proposed approach the endpoint of a line of investigation, as suggested by Thorne (1997), rather than being a starting point for investigations that may further increase our understanding of complex controls on channel patterns. Stability diagrams of channel patterns are aimed at providing a rough indication of the channel pattern that will develop when conditions change, either by extrinsic or intrinsic drivers. One could think, for example, of the effect on channel pattern due to major shifts in boundary conditions as a result of large climatic changes, such as the transitions after the last glacial period (Brown, 1991; Starkel, 1995; Vandenberghe, 2001). Stability diagrams can also be applied in river rehabilitation projects, in order to judge whether for a set of given conditions a single- or multithread channel pattern may be expected to develop. The latter application is well illustrated by the Rhine distributaries in the Netherlands. The southernmost distributary, the Waal, is the main navigation channel. At present, studies are ongoing of the proposal to concentrate all the traffic in the Waal, and to naturalize as much as possible the other branches, including the local removal of groins. Historical data of the natural channel pattern before river straightening and deepening started cannot be used as a reference here, as these changes also included a major shift in the discharge distribution over the river branches. When plotted in the stability diagram, it becomes immediately clear that in case of removal of groins the channel pattern in all the branches will most probably remain meandering, as all points plot far below the discriminator (Fig. 1).

In the case that conditions are near the discriminating line between meandering and braided patterns, or better, near the line of 50% probability of existence of either of the two patterns, local intrinsic changes, such as a meander cut-off, may result in a local and temporary change of channel pattern. Brewer and Lewin (1998) present a good example of this. In such a case, the diagram of Bledsoe and Watson (2001) can be used in a risk analysis of potential instability of the channel pattern.

The simplicity of the parameters used in the stability diagrams *does* obscure the complexity of processes, which underlie the patterning of channel planforms (Bridge, 1993). Nonetheless, the diagrams are one very useful assessment tool in our repertoire, simply because of their good performance in discriminating the classic channel patterns (see Table 1 in Bledsoe and Watson (2001) for specific misclassification rates). Clearly, because of the simplicity of the

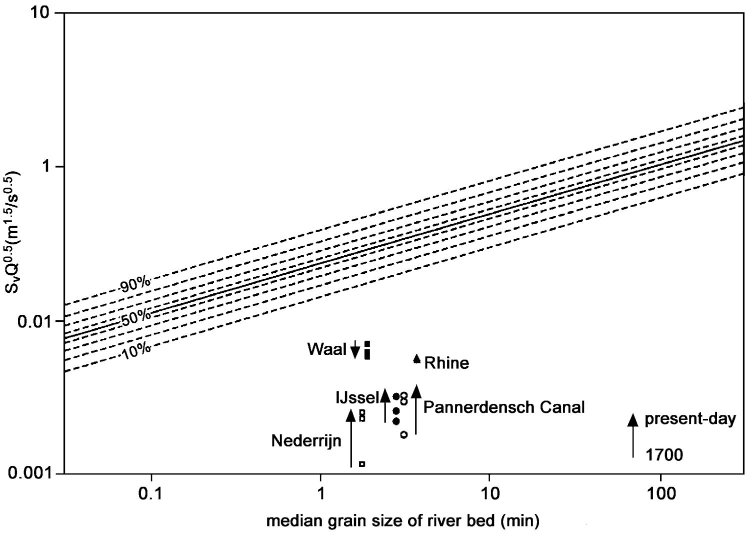

Fig. 1. Channel pattern characterisation of the Rhine distributaries, The Netherlands, over time, as represented in the Bledsoe and Watson (2001) diagram, after Hesselink (2002). The potential specific stream power parameter, or mobility index, $S_vQ^{0.5}$, refers to mean annual flood.

parameters used, a number of important factors are neglected. Sparse vegetation or a low clay–silt percentage may enhance bank erodibility and result in relatively wide channels, with a greater likelihood of becoming braided (Ferguson, 1987; Simpson and Smith, 2001). The diagrams refer to conditions of no net degradation or aggradation, which is often not realistic, and cannot be ignored. According to Holbrook and Schumm (1999), tectonic tilting, notwithstanding its slow progress, may influence the channel pattern. Therefore, one might argue that additional parameters that better represent the many processes that govern the complex patterning processes should be used to predict the channel pattern. However, such parameters almost inevitably will incorporate pattern-dependent geometric or hydraulic properties, and thus cannot be used as independent boundary conditions in a real prediction of the channel pattern.

Here, the most relevant question is not whether a better prediction of channel planform is possible, but why the basic channel patterns discriminate so readily with simple parameters. When examining the existing diagrams, it appears that the channel pattern is most sensitive to the bankfull width/depth ratio. In the Parker and Anderson (1975) diagram, where the ratio of channel depth to width appears on the abscissa, it is even possible to discriminate four channel pattern classes, according to the number of braids. This good performance can be explained by considering the ratio of the adaptation lengths of water motion and sediment motion on riverbed deformation. Based on a theoretical analysis, Struiksma et al. (1985) found that the latter ratio, an interaction parameter that is governed mainly by the width/depth ratio, determines whether bars in a river will be damped, stable or increasing. Reducing the width of a river, for example, will reduce the interaction parameter, which means an increase in flow stability and a tendency to damp or reduce the number of bars (Struiksma and Crosato, 1989). Similar conclusions follow from theoretical considerations of the width/depth ratio and the dynamic instability in channel flow by Parker (1976), Blondeaux and Seminara (1985) and others (Dade, 2000). Thus, the clue for the prediction of the channel pattern seems a proper prediction of the channel width. Unfortunately, the existing width predictors are rather unreliable, as demonstrated for instance by Chew and Ashmore (2001). This may partly be due to the fact that migrating channels are wider than the non-migrating ones for which the predictors were designed, as inner bank advance cannot keep up with the outer bank erosion (Mosselman et al., 2000). Moreover, hydraulic geometry equations such as those proposed by Blench (1966), Henderson (1966), Parker

(1979) and Griffiths (1993) refer to channel slope, a channel pattern-dependent parameter. Most importantly, the vast majority of width predictors suggest that bankfull width is positively related to stream power. This is also clearly illustrated in Fig. 6 of Van den Berg (1995), in which the width/depth ratio and potential specific stream power relative to reference values are plotted (see also Cao and Knight, 1996). This makes stream power an appropriate parameter to predict channel patterns: with increasing stream power, channel width increases, and the channel pattern increasingly tends to become braided. Conversely, as illustrated in Fig. 1, with a lowering of the stream power, channels tend to become relatively narrow and single-thread. Some data presented by Makaske (1998) suggest that the pattern ultimately ends up with low energy "straight" at an $S_vQ^{0.5}$ value that is one order of magnitude below the 10% risk of braiding line in Fig. 1.

We also agree with Lewin and Brewer (2001) that the regime-based relations between bankfull discharge, Q, and bankfull channel width, W, as used by Van den Berg (1995) to define potential specific stream power are inappropriate to predict the width of braided rivers. However, the use of these regime functions was aimed at providing reference width values, not to predict actual channel widths. Most field data indicate a value of the exponent b in the regime function of about 0.5 (Hey, 1997). The uncertainty therefore concerns the proper choice of the value of a. As correctly indicated by Lewin and Brewer (2001), the channel width values obtained with the regime functions are strongly biased towards non-braided channels, and a higher value may therefore provide a better representation of the overall mean. However, the consequence of a multiplication of the values of a by some constant, aiming at the removal of the bias, would not change the diagram, except for a shift in the value marks on the ordinate. In other words, whether or not the regime equations result in pattern-biased width values is not important. Another, more relevant, point is whether sand-bed rivers and gravel-bed rivers should be analysed separately or not. Bed material in sand-bedded channels is transported mainly in the suspended mode, whereas in gravel-bed rivers the bed material is transported mainly as bed-load. Moreover, these channel types differ in bedforms, armouring potential, and vertical adjustability. Therefore, gravel/cobble-bed rivers and sand-bed rivers are fundamentally different and often require disparate approaches in analysis. Bledsoe and Watson (2001) attempted to resolve both issues by dropping the regime coefficients altogether and treating sand and gravel/cobble channels separately. Indeed, the results indicate some differences. For instance they suggest that: (1) misclassification rates are reduced if sand and gravel/cobble streams are treated separately, and (2) the transition to braiding in sand-bed rivers may be more dependent on the calibre of the bed material as compared to channels with coarser beds.

Ultimately, every predictive tool represents a trade-off between model complexity and the risk of misrepresenting the system of interest. We believe that predictors of river pattern based on planform-independent descriptors of flow energy and boundary materials are parsimonious tools that provide an advantageous balance of simplicity and predictive accuracy. These models have a variety of useful applications in geomorphic assessments, including preliminary assessments of rehabilitation plans or proposed watershed-scale modifications such as urbanization. As with any geomorphic analysis tool, simple predictors of channel pattern must be tempered with both an awareness of the controls not represented in the models and explicit statements regarding the level of uncertainty. The criticisms of Lewin and Brewer (2001) do not, however, provide the grounds for summarily dismissing this entire class of models. Because complex mechanistic models tend to consume many resources and still perform poorly, we believe models like those proposed by Van den Berg (1995) and Bledsoe and Watson (2001) can be a practical and informative *component* of predictive assessments of river and stream behaviour.

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