River Variability and Complexity

Rivers differ among themselves and through time. An individual river can vary significantly downstream, changing its dimensions and pattern dramatically over a short distance. If hydrology and hydraulics were the primary controls on the morphology and behavior of large rivers, we would expect long reaches of rivers to maintain characteristic and relatively uniform morphologies. In fact, this is not the case – the variability of large rivers indicates that other important factors are involved.

River Variability and Complexity presents a new approach to the understanding of river variability. It provides examples of river variability and explains the reasons for them, including fluvial response to human activities. Understanding the mechanisms of variability is important for geomorphologists, geologists, river engineers and sedimentologists as they attempt to interpret ancient fluvial deposits or anticipate river behavior at different locations and through time. This book provides an excellent background for graduates, researchers and professionals.

Stanley A. Schumm is an internationally recognized geomorphologist, whose primary experience has been the investigation and analysis of fluvial systems. During his career Dr Schumm has worked as a geologist with the United States Geological Survey and taught at Colorado State University for thirty years. He has served on numerous professional, technical and government advisory committees in the US and around the world. He is the recipient of many prizes and awards for his scientific contributions and papers, including the Kirk Bryan Award of the Geological Society of America for his book *The Fluvial System* and in 1997 the GSA's Distinguished Career Award. He has published two other books with Cambridge. These are, *To Interpret the Earth: Ten Ways to Be Wrong* (1991) and *Active Tectonics and Alluvial Rivers* (2000, co-authored with J. F. Dumont and J. M. Holbrook).

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To my grandchildren
Katie and William Richardson
Emily and Jackson Stewart

May they enjoy their work as much as I have mine.

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Preface

The origin of this book was a project involving the geomorphic character of the lower Mississippi River and water-rights litigation between the Forest Service and the State of Colorado. The Mississippi River project revealed to me that large alluvial rivers can vary greatly in morphology downstream, although hydrologic conditions are not greatly different. This suggests that river-control works and activities such as dredging will influence a river differently depending upon channel variability and the diverse character of reaches. The water rights litigation confirmed that generalizations about rivers, such as hydraulic-geometry relations have limits depending upon scale.

It must be recognized that rivers differ among themselves, and through time, and one river can vary significantly in a downstream direction. If the morphology and behavior of large alluvial rivers are determined primarily by hydrology and hydraulics, long reaches of alluvial rivers should maintain a characteristic and relatively uniform morphology. In fact, this is not the case, and the variability of large alluvial rivers is an indication that hydraulics and hydrology are not always the dominant controls. Therefore, the purpose of this book is to present to the fluvial community examples of river variability and the reasons for them. The recognition that marked changes from one type of river or river pattern to another can occur is important for geomorphologists, river engineers, and stratigraphers.

The normal variability of a large river is not the topic here. Mark Twain beautifully describes this in one of his books *The Gilded Age* (Twain 1873, pp. 41–43) as:

> Sometimes the boat fought the mid-stream current, with a verdant world on either hand, and remote from both; sometimes she closed in under a point, where the dead water and the helping eddies were, and shaved the bank so closely that the decks were swept by the jungle of over-hanging willows and littered with a spoil of leaves; departing from these "points" she regularly crossed the river every five miles, avoiding the "bight" of the great bends and thus escaping the strong current; sometimes she went out and skirted a high "bluff" sand-bar in the middle of the stream, and occasionally followed it up a little too far and touched upon the shoal water at its head – and then the intelligent craft refused to run herself aground, but "smelt" the bar, and straightway the foamy streak that streamed away from her bows vanished, a great foamless wave rolled forward and passed her under way, and in this instant she leaned far over on her side, shied from the bar and fled square away from the danger like a frightened thing – and the pilot was lucky if he managed to "straighten her up" before she drove her nose into the opposite bank; sometimes she approached a solid wall of tall trees as if she meant to break through it, but all of a sudden a little crack would open just enough to admit her, and away she would go plowing through the "chute" with just barely room

> enough between the island on one side and the main land on the other; in this sluggish water she seemed to go like a racehorse, sometimes she found shoal water, going out at the head of those "chutes" or crossing the river, and then a deck-hand stood on the bow and hove the lead, while the boat slowed down and moved cautiously.

This description of the Mississippi River reveals considerable variability, but it is the normal variability of a great alluvial river. This discussion of rivers deals with and explains the anomalies of river form and behavior.

A good example of what is intended is provided by Simpson and Smith (2001) in their description of the variability of the Milk River in Alberta, Canada and Montana, USA. The meandering Milk River in Canada suddenly becomes braided in Montana. The difference is attributed to bank material variability and channel widening in the braided reach, which is accompanied by reduced stream power.

There is probably little that is entirely new in this book, but the organization of controls on river morphology may be useful (Figure 1.2). Often all that the modern researcher can do is to quantify the observations of earlier workers. For example, while working on the Great Plains, I recognized that bed and bank sediments appeared to control the width–depth ratio and sinuosity of these rivers. Imagine my chagrin to discover that an English engineer, W. Jessop had stated this in 1782: "Where rivers run through a country where the soil is pure clay, loam or any thing of light and homogenous quality, they are always very deep, and in general narrow; on the contrary, where they run through a soil that has in its composition a considerable mixture of sand, gravel, or other hard matter, they always become wide or shallow . . ." (Petts, 1995, p. 8). There appears to be little that is new. Nevertheless, the objective here is to provide geomorphologists, engineers, sedimentologists, and stratigraphers with descriptions and explanations of the downstream variability of rivers.

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Finally, an apology to all of my colleagues whose work I have not cited. A book could be written for each topic listed in Figure 1.2, which is beyond me.