River Discharge to the Coastal Ocean
A Global Synthesis

Rivers provide the primary link between land and sea, historically discharging annually about 36 000 km^3 of freshwater and more than 20 billion tons of solid and dissolved sediments to the global ocean. Together with tides, winds, waves, currents, and geology, rivers play a major role in determining the estuarine and coastal environment. The movement of freshwater and the distribution of river-derived sediments to the ocean have fundamental impacts on a wide variety of coastal environments, ranging from the Mississippi and Nile deltas, to coastal Siberia, to the Indonesian archipelago.

Utilizing the world's largest database – 1534 rivers that drain more than 85% of the landmass discharging into the global ocean – this book presents a detailed analysis and synthesis of the processes affecting the fluvial discharge of water, sediment, and dissolved solids. The ways in which climatic variation, episodic events, and anthropogenic activities – past, present, and future – affect the quantity and quality of river discharge are discussed in the final two chapters. The book contains more than 165 figures – many in full color – including global and regional maps. An extensive appendix presents the 1534-river database as a series of 44 tables that provide quantitative data regarding the discharge of water, sediment and dissolved solids. The appendix's 140 maps portray the morphologic, geologic, and climatic character of the watersheds. The complete database is also presented within a GIS-based package available online at www.cambridge.org/milliman.

River Discharge to the Coastal Ocean: A Global Synthesis provides an invaluable resource for researchers, professionals, and graduate students in hydrology, oceanography, geology, geomorphology, and environmental policy.

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Foreword

We began this book primarily to collate into a single database relevant environmental data for rivers that discharge directly into the global ocean. As the book evolved, however, it began to take on a life of its own, and now contains, following a brief introductory chapter, three rather long chapters that attempt to give an overview to the environmental controls on fluvial discharge, short-term and longer-term temporal variations, and the impact of human activities on global rivers and their watersheds.

As geological oceanographers, we tend to view rivers differently than most hydrologists, geochemists or geomorphologists. While our data, analyses and interpretations of these data touch upon fundamental processes that govern fluvial runoff, physical, and chemical weathering, transport, dispersal and sedimentation, we do not explain in detail how fluvial systems work. We do, however, include a rather extensive bibliography that can help direct the interested reader to relevant literature.

In presenting such a large database – more than 1500 rivers – some of the data almost invariably will prove to be erroneous. We may have transposed numbers, and almost surely we have missed some key data sources. Where errors or omissions occur, we request the reader notify us – kindly, if possible – so that we can correct our mistakes and set the record straight.

There are many people whose help made this book possible. Because of the long time – more than three decades for JDM – over which we acquired and analyzed these data, we almost certainly have inadvertently omitted several (we hope not many) people, to whom we apologize. The Global River Data Centre (GRDC) and the US Geological Survey National Water Information System (NWIS) provided a large number of data used throughout the book. Charlie Vörösmarty's RIVDIS and Arctic RIMS databases were also very helpful, particularly in creating their various user-friendly internet databases. We also made liberal use of Michel Meybeck's global river database (Meybeck and Ragu, 1996), without which our discussion of chemical weathering in Chapter 2 would have been impossible.

Maria Michailova deserves special mention for the way in which she substantially clarified the extensive database for Russian rivers, many of which we either did not know or got wrong in our earlier attempt at a collation of global data (Milliman *et al*., 1995). We also thank Yoshi Saito for help with data from Japan and China; Steve Smith for data from Mexico and southeast Asia; Yang Zuosheng, Wang Ying, Wang Houjie, S. L. Yang and Kevin Xu (China); Jim Wilson (Ireland); Kristinn Einarsson (Iceland); Lea Kauppi and Pirkko Kauppila (Finland); Des Walling (England); Wolfgang Ludwig, Maria Snoussi and Albert Kettner (Mediterranean and Black Sea rivers); Guadalupe de la Lanza Espino (Mexico); Bastiaan Knoppers (Brazil); Pedro Depetris (Argentina); Juan Restrepo (Colombia); John Largier (South Africa); Pham Van Ninh (Vietnam); Murray Hicks and Berry Lyons (New Zealand); Kao Shuh-ji (Taiwan); Harish Gupta (India); Peter Harris (Australia); and Professor da Silva (Sri Lanka). Jeff Mount and Jon Warrick opened our eyes regarding California rivers.

There are many other colleagues and friends without whom parts of this book would have been difficult, if not impossible, to write. Phil Jones (Climate Research Unit, University of East Anglia) provided us with a 100-year precipitation database from which Kehui (Kevin) Xu was able to synthesize several maps used in Chapter 2. Kevin also provided us with a number of other maps that we used throughout Chapters 3 and 4. Jon Warrick, James Syvitski, Kao Shuh-ji, Noel Trustrum and Bob Gammish were extremely helpful in supplying us with photographs used in Chapters 3 and 4, as was Juan Restrepo in sharing with us his land-use maps of the Magdalena watershed. Mike Page's and Noel Trustrum's photo of a dammed lake (Fig. 3.55) is also gratefully acknowledged. The time spent with Leal Mertes on the Santa Clara provided much insight and many memories, and she would have almost certainly provided us with a startling cover for this book; we mourn her passing.

Additional conversations with and insights from James Syvitski, Des Walling, Michel Meybeck, and Jean-Luc Probst over the past 15 years also were extremely helpful. We thank them all for their continued friendship.

Bob Meade has been an admirable mentor and longtime steadfast friend. Our many conversations and insights over the years have proved particularly useful in helping us understand better the whys and wherefores of, as Bob would term it, potamology. Bob's critical reading of the first draft of this book proved invaluable; any omissions or errors in this book almost certainly occurred after his careful editing.

A particular heart-felt thanks goes to Marilyn Lewis, at the SMS/VIMS library, who, through the wonders of Interlibrary Loan, obtained for us many of the books and reprints that facilitated our access to the river literature.

Harold Burrell's graphic skills, coupled with his patience as we continually reconsidered and re-thought figures for the book, are gratefully acknowledged.

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Finally, JDM thanks Ann Milliman for enduring those many evenings when thoughts of rivers and this book took precedence over some of the more domestic and romantic aspects of our life. KLF thanks her family and friends for their patience and encouragement throughout the process.