



KIRSTIE A. FRYIRS and **GARY J. BRIERLEY**

Geomorphic Analysis of River Systems

An Approach to Reading the Landscape

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This book has a companion website:
www.wiley.com/go/fryirs/riversystems
with Figures and Tables from the book

Geomorphic Analysis of River Systems: An Approach to Reading the Landscape

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 **WILEY-BLACKWELL**
A John Wiley & Sons, Ltd., Publication

This edition first published 2013 © 2013 by Kirstie A. Fryirs
and Gary J. Brierley.

Blackwell Publishing was acquired by John Wiley & Sons in
February 2007. Blackwell's publishing program has been
merged with Wiley's global Scientific, Technical and Medical
business to form Wiley-Blackwell.

Registered office: John Wiley & Sons, Ltd, The Atrium,
Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ,
UK

The Atrium, Southern Gate, Chichester, West Sussex, PO19
8SQ, UK

111 River Street, Hoboken, NJ 07030-5774, USA

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Library of Congress Cataloging-in-Publication Data

Fryirs, Kirstie A.

Geomorphic analysis of river systems : an approach to reading the landscape / Kirstie A. Fryirs, Gary J. Brierley.

p. cm.

Includes bibliographical references and index.

ISBN 978-1-4051-9275-0 (cloth) - ISBN 978-1-4051-9274-3 (pbk.) 1. Watersheds. 2. Fluvial geomorphology. I. Brierley, Gary J. II. Title.

GB561.F79 2013

551.48'3011-dc23

2012016112

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Front cover:

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Back cover:

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Cover design by:

Design Deluxe

To those who have guided and supported us on our river
wanderings

Preface

Purpose and aims of this book

Geomorphology is the science concerned with understanding the form of the Earth's land surface and the processes by which it is shaped, both at the present day as well as in the past.

British Society for Geomorphology; sourced at:

<http://www.geomorphology.org.uk/pages/geomorphology/>

The most engaging and interesting intellectual work on geomorphic forms such as river channels has not come from computer specialists and theoretical models but from field measurements and observations.

Luna B. Leopold (2004: 10)

The scientific study of geomorphology has very divergent origins and approaches in different parts of the world. Perhaps inevitably, our perspectives and thinking are deeply rooted in our training, culture and the landscapes in which we live and work. In other words, scientific understandings have a genealogy, wherein cultural and experiential underpinnings fashion our way of thinking.

The approach to *reading the landscape* that is outlined in this book provides a way to interpret rivers across the range of environmental and climatic settings. It builds upon a solid understanding of the science of fluvial geomorphology. Field-based understandings are tied to theoretical and conceptual principles to generate catchment-specific analyses of river character, behaviour and evolution. This approach to landscape analysis views geomorphology as an

interpretative and analytical science rather than a descriptive one.

Reading the landscape entails identification of river landforms and appraisal of their relationships to adjacent features. Primary controls upon contemporary dynamics are interpreted, framing analyses in relation to their landscape and catchment context, and the imprint from the past.

This book has been constructed as an introductory text on river landscapes, providing a bridge to more advanced principles outlined in Brierley and Fryirs (2005). Chapters 1-9 present foundational understandings that underpin the approach to reading the landscape that is documented in Chapters 10-14. The target audience is second- and third-year undergraduate students, as well as river practitioners who use geomorphic understandings in scientific and/or management applications.

Inevitably, no book can cover all geomorphic principles and practices, and much material has been 'left out' of the foundation chapters. For example, those interested in the details of bedload transport modelling, of hydraulic analyses of bank erosion processes and channel geometry models or of Quaternary science are encouraged to develop more advanced understanding from other geomorphology, engineering or earth science textbooks.

This book does not provide a fully grounded and comprehensive background to geomorphic analysis. Emphasis is placed upon documentation of the approach to reading the landscape. Selected readings outlined at the end of the book provide additional background information on material covered in the various chapters. The book does not deal with specific case-studies in the body of the text. Rather, many of the figures use case-studies or real examples drawn from the literature and our own sources to complement the use of principles and forms of analysis. These are accompanied by comprehensive captions that

stand alone from the body of the text. These visual guides reflect the age-old saying: 'a picture is worth a thousand words'. We encourage the reader to 'ponder' each figure and consider what is embedded within it to gain a more complete understanding of the approach to river analysis. Similarly, there is minimal referencing in the text. This is an attempt to keep it clean and easy to read on one hand, and to not over-emphasise some literature at the expense of other literature. Instead, an extensive reading list is provided at the back of the book.

The approach to reading the landscape that is outlined here is complementary to a plethora of other approaches available to the geomorphologist. Scientific enquiry is multifaceted. The material in this book complements, and can be used in parallel with, modelling applications, geographic information science and remote-sensing applications, quantitative process measurements, Quaternary research and sedimentology and case-study applications. Many of these fields incorporate significant technological advances. This book is based on the premise that applications of these techniques must be appropriately contextualised through field-based, landscape-scale analyses and interpretations. Such 'geographic' knowledge is integral to geomorphic applications. Technological applications cannot replace our ability to interpret a landscape. Generic information must be framed in its place-specific context. Hopefully, emphasis upon foundation principles in fluvial geomorphology provides an appropriate platform with which to ask the right questions and make interpretations of landscape forms, processes and evolution.

The approach to reading the landscape outlined in Chapter 1 has been carefully structured to scaffold the presentation of the book. However, this is not a 'how to' book, framed around prescriptive step-by-step instructions on how to interpret fluvial forms and processes. Given space

limitations, we do not provide guidance on the specific tools and techniques that can be used to support such investigations (e.g. remote sensing, process-based field measurements, modelling applications, sedimentology). Instead, the book is about interpreting forms and processes and piecing them together at the landscape scale.

We hope that the contribution provided by this book is appraised in relation to these aspirations.

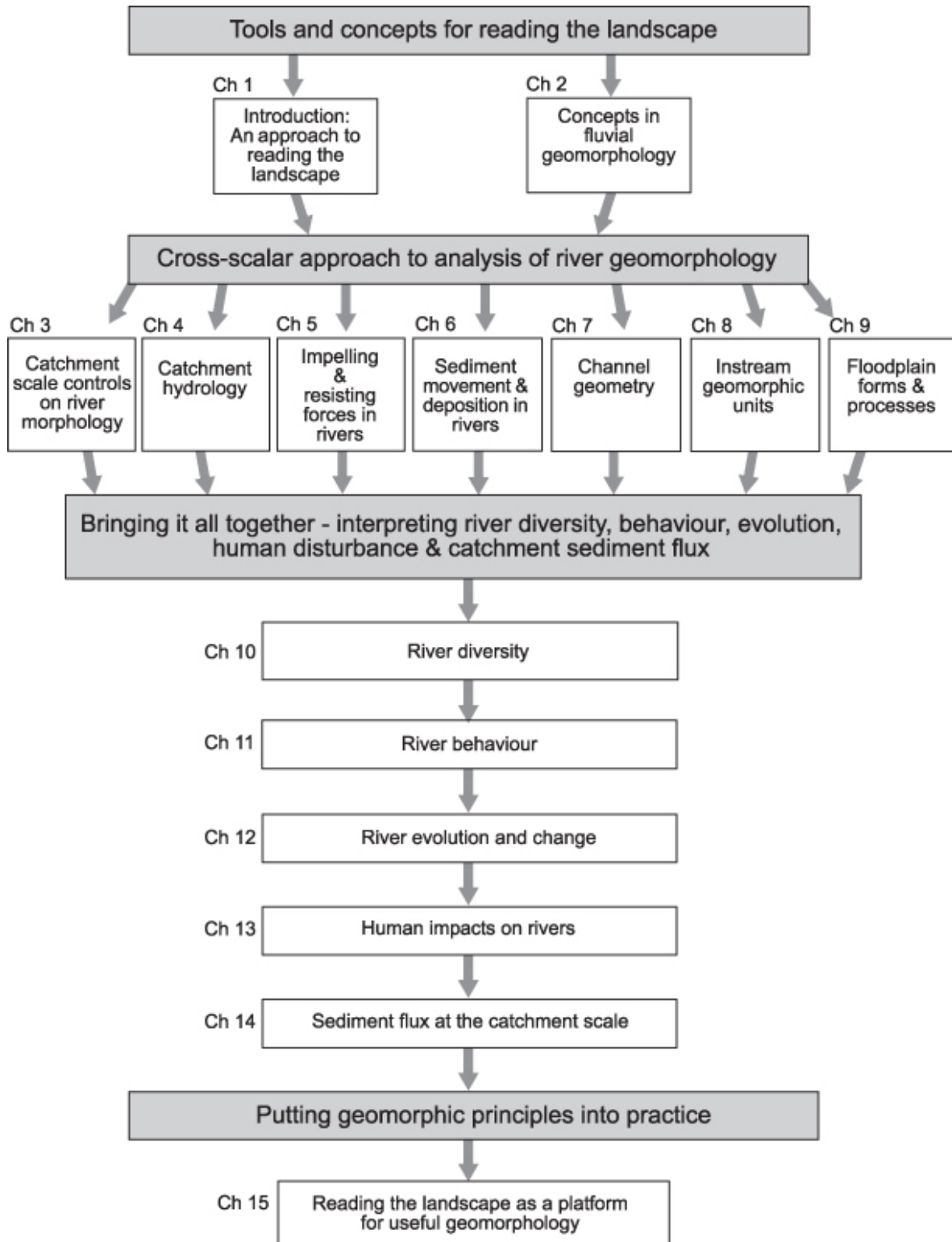
Kirstie A. Fryirs and Gary J. Brierley

Structure of the book

The structure of the book is shown in [Figure 1](#). Chapters 2–9 scaffold information to provide the relevant foundations for reading the landscape. Chapter 1 sets the context for why fluvial geomorphology is important and useful in science and management. Chapter 2 documents key spatial and temporal concepts that underpin enquiry in fluvial geomorphology. Chapter 3 overviews catchment-scale relationships in river systems, describing downstream relationships along longitudinal profiles and catchment morphometrics. Chapter 4 focuses on hydrologic relationships in river systems. Chapter 5 documents impelling and resisting forces that drive river adjustment. Chapter 6 explores sediment transport in rivers in relation to entrainment, transport and deposition processes. Chapter 7 describes the range of bed and bank erosion and deposition processes that determine channel shape and size. Chapter 8 analyses process–form associations of instream geomorphic units, documenting the spectrum of features from sculpted bedrock forms to mid-channel and bank-attached bars and finally fine-grained sculpted features. Chapter 9 analyses process–form associations of floodplain geomorphic units,

outlining the role of formative and reworking processes. The influence of valley confinement as a control upon floodplain forms is outlined.

Figure 1 Structure of this book.



The approach to reading the landscape is documented in Chapters 10-14. Tips for reading the landscape are presented at the ends of these chapters. Chapter 10

combines analyses of channels, sediment transport and geomorphic units with channel planform to assess the spectrum of river diversity from bedrock-confined, to partly-confined to alluvial river forms. This is framed around a constructivist approach to analysis of river form. Chapter 11 interprets river behaviour, outlining forms of adjustment for different types of river and the range of river behaviour at different flow stages. Chapter 12 examines river evolution and river change. The imprint of geologic and climatic controls on contemporary forms and processes is discussed. Chapter 13 explores direct and indirect human impacts on rivers. Chapter 14 brings together analyses of sediment budgets and connectivity to present a framework for examining catchment-scale sediment flux and how this can be used to predict likely future river adjustments. The final chapter draws together these threads, summarising the approach to reading the landscape under three banners: Respect diversity, Understand system dynamics and evolution, and Know your catchment.

Acknowledgements

Writing a book is always challenging. At the outset, we thought our earlier efforts in writing our 2005 book would prepare us well to meet this challenge. Perhaps inevitably, this proved to be a little naive. With this book, our intent was to provide a background resource book that would 'fill a gap' in setting up the River Styles framework. Our return to first principles of geomorphic enquiry led us to question everything. In this light, it is amazing that this book is now complete (though such matters are never finished).

Teaching undergraduate and postgraduate courses over many years has helped us in our efforts to communicate complex ideas and develop interpretative skills in fluvial geomorphology. The test of these understandings comes through applications in different field situations. We thank those challenging and supportive undergraduate and postgraduate students who have assisted us in our respective teaching environments.

Field experiences and professional short courses have greatly enriched our careers, fashioning the way we see, analyse and interpret landscapes. We are indebted to our teachers, mentors and fellow practitioners who have helped to frame our way of thinking and communicating.

The approach to reading the landscape that is conveyed here reflects our way of synthesising collective understandings and experiences gained through our careers. We hope that our efforts effectively capture shared understandings in our endeavours to interpret river forms, processes and evolutionary trajectory. Ultimately, it was our shared desire for better use of geomorphology in river management practice that has encouraged us to write this book.

Most of the graphics in this book were designed by Kirstie Fryirs and drafted by Dean Oliver Graphics, Pty Ltd. We thank Dean for his commitment to this project. Alan Cheung also drafted several figures for the book. Comments by two anonymous reviewers substantially improved the book.

We also thank colleagues in the Department of Environment and Geography, Macquarie University, and the School of Environment, University of Auckland, for their support.

Kirstie acknowledges the support of a Macquarie University Outside Studies Program grant for finance towards her study leave in 2010. This allowed her to dedicate significant time to completing this book.

Gary also received significant support from the University of Auckland for study leave in 2009. During this period he worked in Beijing, western China and Singapore. Stimulating intellectual conversations accompanied his writing efforts at this time. He is indebted to Zhaoyin Wang (Tsinghua), He Qing Huang (Chinese Academy of Sciences), Xilai Li and Gang Chen (Qinghai University) and David Higgitt (National University of Singapore) for their support. The Director of the School of Environment at the University of Auckland, Glenn McGregor, also supported Gary's efforts to complete this book. Megan de Luca, Petra Chappell and Simon Aiken worked as research assistants to provide resources to assist in the writing of several chapters. Many of the ideas outlined here have benefited from stimulating conversations at the University of Auckland and elsewhere; particular thanks are given to Claire, Helen, Carola, Kes, Stephanie, Ashlee, Marc, Brendon and Cecilia ... among many others, and with apologies to those overlooked.

The front cover of the book depicts a painting by an Australian indigenous artist, Les Elvin, who was NAIDOC Artist of the Year in 2008. Les is of the Wonnaruah community of the Upper Hunter region in eastern NSW. His

painting 'Playful Platypus' depicts one of the local rivers with pools and Platypus, an indigenous species of fresh-water ecosystems in Australia. We chose this painting for several reasons. Firstly, because of its connection to place and country which is a key message in the reading the landscape approach advocated in this book. Also, the Upper Hunter is a place where we have both spent considerable time undertaking fieldwork. This landscape, amongst many others, has shaped the reading the landscape approach.

As always, our families are our strength. Again, we thank them for their unwavering support.

CHAPTER ONE

Geomorphic Analysis of River Systems: an Approach to Reading the Landscape

Introduction

Landscapes have been a source of fascination and inspiration for humans for thousands of years. Sensory responses to landscapes vary markedly from person to person. To many, spiritual associations evoke a sense of belonging, perhaps tinged with nostalgic sentiments. To others, a sense of awe may be accompanied by alienation or innate fear. Artists strive to capture the essence of landscapes through paintings, prose, poetry or other media. Our experiences in life are often fashioned by the landscapes in which we live and play. Relationships and associations vary from place to place and over time. New experiences may generate new understandings, wherein observations are compared with experiences elsewhere. These collective associations not only reflect the bewildering range of landscapes in the natural world, they also reflect the individual consciousness with which we relate to landscapes, and the influences/experience that fashion our way of thinking, whether taught or intuitive. No two landscapes are exactly the same. Each landscape is, in its own way, 'perfect'. Different sets of controls interact in different ways in different settings, bringing about unique outcomes in any particular landscape. Just as importantly,

interactions change over time, such that you cannot step in the same river twice (Heraclitus, 535–c. 475 BCE). Sometimes it seems a shame to formalise our understandings of landscapes within the jargonistic language of scientific discourse, but that is what geomorphologists do!

In simple terms, geomorphology is the scientific study of the characteristics, origin and evolution of landscapes. Geomorphic enquiry entails the description and explanation of landscape forms, processes and genesis. Implicitly, therefore, it requires both a generic understanding of the physics and mechanics of process and an appreciation of the dynamic behaviour of landscapes as they evolve through time. The key to effective use of geomorphic knowledge is the capacity to place site-specific insights and relationships in their broader landscape context, framing contemporary process–form linkages in relation to historical imprints. Theoretical and modelling advances are pivotal in the development and testing of our understanding. However, the ultimate test of geomorphological knowledge lies in field interpretation of real-world examples.

This book outlines general principles with which to interpret river character, behaviour and evolution in any given system. Emphasis is placed upon the development of field-based skills with which to read the landscape. Field-based detective-style investigations appraise the relative influence of a multitude of factors that affect landscape-forming processes, resulting patterns of features and evolutionary adjustments. Interactions among these factors change over time. Inevitably, such investigations are undertaken with incomplete information. Information at hand has variable and uncertain accuracy. Some facets of insight may be contradictory. Individual strands of enquiry must be brought together to convey a coherent story. Significant inference may be required, drawing parallels with

records elsewhere. Unravelling the inherent complexities that fashion the diversity of the natural world, the assemblages of features that make up any given landscape and the set of historical events that have shaped that place is the essence of geomorphic enquiry. Just as importantly, it is great fun!

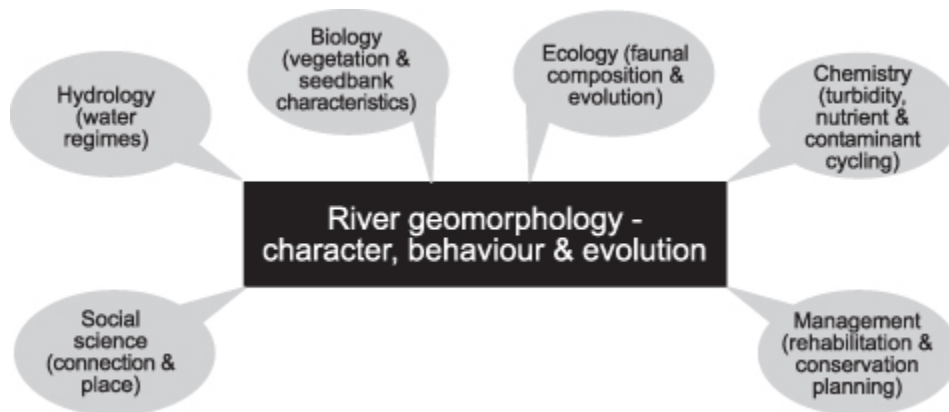
Although this book emphasises process-form relationships on valley floors, it is implicitly understood that rivers must be viewed in their landscape and catchment context. Rivers are largely products of their valleys, which, in turn, are created by a range of geologic and climatic controls. Hillslope and other processes exert a primary control upon what happens on valley floors. Sediment delivery from river systems, in turn, exerts a major influence upon coastal-zone processes. Source-to-sink relationships are a function of catchment-scale controls on sediment supply, transport and delivery. Efforts to read the landscape place site-specific observations, measurements and analyses in an appropriate spatial and temporal context. Understanding of this dynamic landscape template provides a coherent platform for a wide range of management applications.

How Is Geomorphology Useful?

Geomorphologists have a long tradition of applying their science in environmental management. Geomorphic insights provide a physical platform with which to develop cross-disciplinary practices and applications that build upon an understanding of how the natural world looks and behaves. Landscapes determine the template upon which a range of biophysical processes interacts ([Figure 1.1](#)). For example, insights from fluvial geomorphology provide an understanding of physical processes that create, maintain,

enhance or destroy riverine habitat (i.e. the physical space that flora and fauna inhabit). Habitat availability in the channel and riparian zone (and floodplain) of a river is a function of the diversity of landforms on the valley floor. Marked differences are evident; for example, along perennial and ephemeral streams or in a gorge relative to a swamp. Distinct vegetation patterns are found on differing channel and floodplain surfaces, reflecting access to water (and inundation frequency), substrate conditions and morphodynamic interactions between flow and vegetation. Vegetation may have a negligible influence upon some rivers; elsewhere, it may be a primary determinant of process-form relationships. Concerns for ecohydraulics and ecohydrology have major implications for the management of flow, sediment and nutrient fluxes. Water chemistry and turbidity are largely a function of catchment lithology, and the nature/amount of sediment that can be readily entrained by a river.

Figure 1.1 Geomorphology as a physical template atop which other interactions occur.



Alterations to the geomorphic structure of rivers have enormous implications for the operation of biophysical fluxes that affect the movement of water, sediment, nutrients, etc. Hence, a geomorphic template provides a basis for 'whole of system' thinking, aiding the development of coherent plans and strategies for environmental