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The natural and human structuring of rivers and other geomorphological systems: A tribute to William L. Graf

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ABSTRACT

This special issue honors the contributions of William L. Graf to geomorphology and river science. A hallmark of Will's work over the course of his career has been a focus on the natural and human structuring of river systems. More broadly, Will has been an innovator and leader who has shaped the way in which geomorphologists conduct research. Through his work, he has made fundamental contributions to basic fluvial theory, to the understanding of human impacts on river systems, and to policy-relevant science. He has demonstrated by example how to pursue policy-relevant science and to participate in science-based policy formulation. His contributions to river science can be classified into several themes: (1) the hydrology and geomorphology of suburban drainage systems, (2) riparian vegetation and river systems, (3) the spatial structure and dynamics of incised channels, (4) the dynamics of dryland river systems, (5) heavy metals in river systems, (6) dams and dam removal, and (7) water and public policy. The papers in this special issue reflect many aspects of these themes and address topics related to (1) the understanding of rivers and other geomorphic systems in the midst of dynamic physical change, (2) human influences on geomorphic processes, (3) the intersection of geomorphology and public policy, and (4) the fusion of geomorphic analysis and GIScience.

1. Introduction

During the middle part of the twentieth century the field of geomorphology underwent a transformation as the tradition of landform studies initiated by William Morris Davis, based on the cycle of erosion, began to wane and the alternative tradition initiated by Grove Karl Gilbert, which focused on process-form relationships, increased in prominence. Out of this transformation emerged seminal studies that examined quantitative aspects of landform development, emphasized process-form interactions, and focused on time and space scales relevant to societal concerns. In the United States, much early work in this emerging approach was pioneered by geomorphologists in geology who held positions either in academic institutions or in federal agencies. Although geographers outside the United States were becoming actively engaged in this transformation of geomorphology, few American geographers interested in geomorphology were championing the new approach to inquiry, especially in relation to the study of rivers. All of that changed in the mid-1970s when William L. Graf developed an interest in the geomorphology of river systems. Over the past 40 years Will has pioneered innovative scientific approaches to the study of these systems, advanced fundamental theoretical understanding of fluvial processes and forms, highlighted the important role of human agency in fluvial dynamics, and integrated science with management concerns to inform public policy. His scholarly contributions in all of these areas have been truly transformative; his influence within geography is enormous, but his work has played a role in shaping the entire domain of contemporary river science. Moreover, Will's influence extends beyond the academy. He has served as a consultant and expert witness in numerous legal cases related to environmental management, has been a policy advisor on 40 committees for federal, state, and local agencies and organizations, and has chaired National Research Council committees focusing on America's watersheds, the Platte River, the Klamath River, the U.S. Geological Survey's research priorities, and the Florida Everglades. In recognition of his contributions, he has received awards from the Association of American Geographers, the Geological Society of America, the British Geomorphological Research Group; a Guggenheim Fellowship; a Fulbright Scholarship; the Founders Medal from the Royal Geographical Society; the John Wesley Powell Award from the U.S. Geological Survey; and the Outstanding Civilian Service Medal from the U.S. Army Corps of Engineers. He is also a Fellow of the American Association for the Advancement of Science and a National Associate of the National Academy of Sciences.

In further recognition of Will's contributions and impact, a special session honoring him was organized at the Association of American Geographers annual meeting in Tampa, FL, in 2014. This all-day session included 24 papers presented by former students, students of students, and colleagues who have been influenced by Will or who have admired his work. This special issue emerged out of that session and includes a sampling of papers presented in his honor. To be inclusive, the session focused not just on rivers but on all geomorphological systems. After

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all, Will, himself, prior to his incarnation as a fluvial expert, examined processes and forms in glacial systems (Graf, 1970, 1971, 1976a, 1977a). In the interest of inclusivity, the contribution by Psuty et al. (2016–in this issue) focuses on a coastal, rather than a fluvial system, employing a sediment-budget methodology to analyze coastal morphological evolution in a public park, thereby generating science to inform coastal management — a style of investigation consistent with Will's approach to the study of river systems. The remaining papers in the volume focus on fluvial systems.

The legacy of Will's work is broad and difficult to assign to categories. Here several themes are identified to highlight important aspects of his work. The intent is to illustrate the scope of his research contributions, not to comprehensively review his body of work. The focus is restricted to Will's research related to fluvial systems.

2. The hydrology and geomorphology of suburban drainage systems

Early in his career, Will Graf became interested in research questions related to human modification of stream structure and processes in the context of suburbanization of watersheds. An important contribution of this work is that it illustrates how suburbanization, by changing fluxes of water and sediment, influences the characteristics of hillslopes, floodplains, and channels over space (Graf, 1975, 1976b) and through time (Graf, 1977b). It also connects changes in stream network structure to changes in hydrological response, thereby calling attention to the hydrological importance of transformations of the channel system in the suburbanization process, rather than just the addition of impervious surfaces. This early work initiated Will's sustained interest in the geomorphic effects of human agency, or what he referred to as anthropic processes (Graf, 1976b). The contribution by Rhoads et al. (2016–in this issue) builds on this theme by examining how human agency has altered the structure of drainage networks and the planform characteristics of stream channels in low-relief, agricultural landscapes of the midwestern United States.

3. Riparian vegetation and river systems

The dynamic interaction between riparian vegetation and river systems is another theme of pioneering work by Will Graf. Although the interaction between plants and river systems is a major emphasis of contemporary research, such was not the case in the 1970s. The focus of Will's research was on tamarisk, an invasive species that escaped cultivation as an ornamental plant and spread rapidly throughout the southwestern United States. In one of his most widely cited papers (Graf, 1978), Will demonstrates how the spread of tamarisk has affected geomorphic processes in the Colorado River system by promoting deposition and the preservation of islands and bars, which has led to a reduction in channel width. Subsequent papers highlight the widespread nature of tamarisk invasion as well as management aspects of this environmental problem, emphasizing controls on tamarisk growth, management approaches, and the costs of management (Graf, 1980a, 1982a). A strong connection between biota and landscape response is evident in the paper by Florsheim et al. (2016–in this issue), which examines how the effects of wildfire on vegetation influences the process of dry ravel on hillslopes.

4. The spatial structure and dynamics of incised channels

During the 1970s the focus of research in fluvial geomorphology began to shift from an emphasis on equilibrium adjustments in river systems toward recognition of disequilibrium dynamics. Work by Stanley Schumm (1973) on thresholds and complex response paved the way for these new ideas and influenced others, including Will Graf. Incised channels became an archetype of fluvial features that are not necessarily adjusted to prevailing environmental conditions and that undergo an evolutionary sequence of development in response to disturbance. In a groundbreaking paper, Will used an innovative analysis of dendrochronologic data based on an analogy to the decay of radioactive isotopes to show how the incisional response to disturbance in gully systems in Colorado migrates upstream over time and space (Graf, 1977c). The functional form of the relation between the distance over which incision has moved headward and time is exponential. In other words, the rate at which incision moves upstream progressively diminishes over time. This landmark study defines explicitly the relaxation times of fluvial systems to natural and human-induced disturbance. Subsequent work by Will built on this theme to examine the temporal and spatial dynamics of incised channels, especially in relation to controlling factors of stream power and vegetation (Graf, 1979a,b, 1982b, 1983a,b). He also introduced the conceptual framework of catastrophe theory to examine channel adjustments in disturbed fluvial systems (Graf, 1979c, 1988a). An important geographical focus of this work is on incised channels in the Henry Mountains of Utah (Graf, 1982b, 1983b), the locale where G.K. Gilbert (1877) developed seminal ideas about equilibrium adjustments in fluvial systems. Will's research builds on and counterbalances the classic work by Gilbert.

The theme of channel incision and natural versus human-induced disturbance plays a central role in the paper by Chin et al. (2016–in this issue), who examine how wildfire in a small watershed in Colorado has triggered feedbacks among fluvial responses and human actions that have promoted incision. It also is evident in the work by Wasklewicz and Scheinert (2016–in this issue) on the dynamics of an alluvial fan, where channelization and entrenchment of the trunk stream has resulted in sustained runouts of debris flows and development of a telescoping fan morphology.

5. The dynamics of dryland river systems

Research on the dynamics of dryland river systems, particularly rivers in the southwestern United States, is one of the most recognizable strands of Will Graf's exceptional body of work. Besides the studies of incised channels, Will's entrée into this line of investigation began with the exploration of the spatial distribution of rapids in canyons of the Colorado River and Green River systems and the stability of the rapids under the present hydrologic regime, which is heavily influenced by the closure of large dams on these systems (Graf, 1979d, 1980b). He subsequently turned his attention to the inherent planform instability of dryland rivers (Graf, 1981, 1983c). A useful outcome of this work is the development of a probabilistic mapping approach to changes in channel locations through time based on analysis of maps and aerial imagery within a geographic information system framework (Graf, 1984, 2000). The research also shows how channel change in dryland river systems is episodic and spatially variable — conditions that reflect an inherent lack of equilibrium adjustment in these systems. A practical implication of this research is that the complexity of adjustments between process and form in dryland rivers complicates the definition of floodplains compared to floodplain delineation for stable humid-temperate rivers (Graf, 1988b).

Will's research at the watershed scale has shown how sediment storage and removal vary over time and space in dryland fluvial systems (Graf, 1983d, 1987, 1989). This work provides a broad context for his process-based studies of channel incision, illustrating how long-term periods of aggradation that produce basin fills are punctuated by relatively short-term episodes of net erosion that produce incised channels. The results also suggest that changes in climatic conditions, rather than overgrazing, are largely responsible for changes in the sediment regimes of rivers in many areas of the southwestern United States — a finding that has important implications for public policy related to land management (Graf, 1986). Will summarized his perspective on the dynamics of dryland watershed and river systems in Fluvial Processes in Dryland Rivers (Graf, 1988c), a seminal book that illustrates the innovative mix of approaches he has employed to investigate interactions between process and form in these systems, including the use of instrumented records, field surveys, aerial photography, sedimentological analysis, dating methods, historical ground-based photography, historical documents,