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Hydrogeomorphology
- An Introduction -

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Hydrogeomorphology is fundamentally a branch of geomorphology concerned with the hydrologic basis of some landform evolution. It recognizes that over a large part of Earth's surface, the transport and redistribution of rock waste that are responsible for the evolution of both erosional and depositional landforms are driven by hydrologic processes.

The presence of water in Earth materials weakens them and renders them susceptible to collapse or erosion (Yatsu, 1988; Selby, 1993), and the pore-pressure fields within them at critical times affect their collapse and their mobility (Iverson and Major, 1986, 1987). The formation of channel networks that must incise Earth's crust in order to drive landform evolution (Okunishi, 1974; Dunne, 1980, 1990) is also driven by a set of runoff generation processes with flow magnitudes and stress-inducing characteristics that require hydrologic study. Erosion by surface water is yet another process of landform evolution that has required geomorphologists to spend considerable effort in defining aspects of hillslope surface runoff (Dunne and Dietrich, 1980; Abrahams and Parsons, 1992; Dunne *et al.*, 1991). In alluvial geomorphology, the need to connect river flows, and therefore basin hydrologic conditions, to sediment fluxes (Koltermann and Gorelick, 1992) or to the scales of channel features (Leopold *et al.*, 1964) is well documented.

Thus, a quantitative theory of landform evolution in geologic and climatic context requires that the storage and flux rates of water, its flow paths and pressure fields be quantitatively related to their controls: climate, rock properties, and topographic and stratigraphic boundary conditions. Without such a theory, or a connected set of theories, it is difficult to analyze the simultaneous effects of many controlling variables with nonlinear interactions, or to extrapolate beyond the empirical record of geomorphic events (be they landscape-deranging landslides or the gradual evolution of erosion surfaces punctuated by tectonic deformation or climatic change).

In the absence of a coherent body of quantitative theory, some geomorphologists have developed useful concepts that summarize many geomorphic interactions qualitatively in a form that

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allows much progress to be made in the interpretation of field relations. Examples include the "complex response" concept (Schumm, 1977), and "geomorphic thresholds" (Bull, 1991). These concepts provide a type of "short-hand" level of explanation that allows parts of a geomorphic field problem to be isolated or analyzed in an ordered sequence of steps, but in many cases they also highlight the need for a more quantitative definition of the force and resistance aspects of geomorphic processes that are frequently controlled by hydrology.

Acceptance of the need to incorporate more hydrologic analysis into geomorphological interpretation has certain stimulating effects on geomorphological studies, not all of which have been fully taken advantage of. For example, in hydrology there is clear acknowledgment of the need for precise field measurements of the status of water and of the Earth-material properties that influence it, and of the need to interpret such measurements in fluid mechanical terms. Equally sophisticated field measurements and interpretation penetrate geomorphology rather slowly, and much remains to be done in making geomorphologically significant measurements of critical material properties, fluid stresses, and sediment fluxes at levels of precision that are adequate for testing theories about process mechanics (Dietrich and Gallinatti, 1991). Hydrologists have made considerable progress in quantifying and analyzing the nature and hydrological role of spatial heterogeneity in Earth materials (Delhomme, 1979; Freeze, 1980), and geomorphologists need to confront the same problem, not only in hydrologic properties but in those geological characteristics that determine resistance to mobilization (Yatsu, 1966; 1988). Hydrology also provides geomorphologists with some suggestions for transcending the problem of temporal scale in extrapolating from short-term measurements to the longer time scale of landform evolution through probability analysis and stochastic modeling to provide the "long-term sediment transport equations" that are implied in the sediment flux term in Okunishi's (1994) equation (1). However, as Okunishi (1994) discusses, this problem of extension of geomorphic process understanding to the time scale required for significant redistribution of mass in landform evolution remains a difficult one, and it will require taking advantage of the rapidly expanding array of techniques in geochronology for dating geomorphic surfaces and materials over age ranges of millions of years.

Quantifying relationships between landform evolution and hydrologic processes in the manner illustrated by hydrogeomorphological studies has a reciprocal benefit for hydrology. It provides understanding and information useful to hydrologists trying to predict various aspects of surface hydrology. The interests of some geomorphologists in runoff generating mechanisms and flow paths were reflected in the volume edited by Kirkby (1978) and contributed to the development of process hydrology, some of which is reflected in the current volume. The requirement of hydrogeomorphologists for a method of predicting hillslope pore pressures that acknowledged the role of hillslope topography in localizing landslides led to another geomorphological contribution to hydrology (Iida, 1984; Dietrich et al., 1986). Geomorphic insights (Kirkby and Chorley, 1967) led to the development of TOPMODEL (Beven and Kirkby, 1979), which is now widely used by hydrologists for catchment-scale predictions of runoff and soil-moisture distribution (e.g. Wood *et al.*, 1991). The influence of channel network structure on the shapes of hydrographs (Surkan, 1969; Kirkby, 1976; Rodriguez-Iturbe and Valdes, 1979; Gupta *et al.*, 1980; Beven and kirkby, 1993) is yet another aspect of the increasingly widespread recognition that topography is a major hydrologic factor. Interestingly, the role of floodplains of various types and scales in modulating flood waves, sedimentation patterns, and therefore floodplain formation itself, seems ripe for coordinated hydrogeomorphological investigations, but they remain to be done.

Thus it seems inevitable that some hydrologists and some geomorphologists will continue to need to learn more about each other's science, and will make contributions across the traditional disciplinary boundary, particularly as hydrology expands its focus to include more general Earth-science issues as well as engineering (National Research Council, 1991). This natural evolution can be fostered through the definition and refinement of common interests and goals under the title of Hydrogeomorphology, and the Workshop in which the following papers were offered represented one part of such an effort, which continues to be an vigorous activity within the Japanese Geomorphological Union.

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