CHANNEL FORM AND STREAM ECOSYSTEM MODELS

Peter P. Brussock, Arthur V. Brown, and John C. Dixon

INTRODUCTION

Modeling of streams in the longitudinal profile has led to a meaningful synthesis of stream ecosystem parameters (e.g., Clibbens and Botosaneanu, 1963; Cummins, 1977; Patten, 1979; Vannote et al., 1980; Ward and Likens, 1983). The River Continuum Concept (RCC) (Vannote et al., 1980) proposed that biota of each stream reach are selected to conform to the mean state of the physical factors in that reach. Physical parameters commonly measured along the longitudinal gradient include width, depth, velocity, turbulence, temperature, substrate characteristics, and sediment load. These factors, separately or together, have been related to the biota, thought to be the major parameters controlling the physical and chemical character of the system. Nonetheless, these parameters of stream geomorphology are all related to stream form, which is a more fundamental variable and may better predict the community structure. Channel structure intensely studied feature in stream geomorphology, yet received little attention in stream modeling research. We suggest that channel form is an important contributing factor, locally, longitudinally and regionally, to the physical and community structure of the system.

Ecological models of longitudinal profiles usually divide streams into three regions: a headwater region (spring and spring-run) with turbulent flow, cobble substrate, and cold stable temperatures; a mid-reach characterized by less turbulent flow, a gravel substrate, and moderately fluctuating temperatures; and a large river section characterized by less turbulent flow, higher and more stable temperatures, and a sand to mud bed. Gradients occur between each region, and models are not always applicable without modification for different geographic regions. In some streams, community structure and physical habitat usually associated with a particular reach appear to be shifted upstream or downstream (Clibbens and Botosaneanu, 1963; Hynes, 1970; Minshall et al., 1983). Recently, Minshall et al. (1983) attributed much of the regional variability in the RCC model to climate, geologic structure, riparian condition, lithology and geomorphology.

The geomorphology of river channels changes systematically in the downstream direction. Streams in headwater reaches are characterized by V-shaped valleys with little floodplain development (Schumm, 1977), while the lower reaches are more characteristically U-shaped with broad alluvial floodplains (Schumm, 1977). Stream geomorphologists recognize a downstreamgradation of decreasing particle size and slope, but little direct attention has been paid to downstream channel form succession. A review of the fluvial geomorphic literature (e.g., Leopold et al., 1964; Morisawa, 1968; Richards, 1982) reveals a common pattern of channel form succession. Bedrock channels are usually depicted in headwater regions and progressively grade into alluvial channels (gravel and sandbed). Variations of this transition in different physiographic settings are predictable when effects of lithology, gradient and climate are considered. Hence, stream channel form changes predictably downstream, producing characteristic patterns of flow, depth, and substrate form.
A watershed classification scheme has been proposed by Lotspeich and Platts (1982) to integrate terrestrial and riverine environments into a basic ecological system. Geology and climate were selected as state factors because any change in these shifts the biological portion of the landscape. However, their hierarchical system does not include downstream changes of channel form. Other works dealing more specifically with stream characterization (Platts, et al., 1983) discuss channel form but do not expand upon downstream changes and the effect on the biota. Culp and Davies (1982) have suggested that "by coupling longitudinal zonation studies with Lotspeich's hierarchical system and the river continuum framework, the biological comparison of streams in different geographical regions could be enhanced, and the understanding of biological processes significantly aided." We suggest that by adding the channel form relationships presented in this paper to the Culp and Davies proposal geographical watershed models will be strengthened.

This paper examines the relationship between channel geomorphology and successive stream reaches and how this structure varies among geographic regions of North America in response to interactions of lithology, gradient and climate. In particular, we address how shifts in channel form along the stream continuum are predictable regionally and necessitate longitudinal shifts in holistic stream ecosystem models like the RCC. A regional perspective of streams in the conterminous United States as grouped by the most probable state of their longitudinal channel form is also presented, which results in considerable refinement of applicability of the RCC and other holistic ecosystem models by realizing the non-randomness of the effects of geology, slope and climate. The principles of this paper can be applied to all stream systems but discussion and analysis is limited to the United States because of its familiarity to the authors.

CHARACTERIZATION OF LOCAL CHANNEL FORM

Channel form can be considered in three different sedimentological settings: a cobble and boulder bed channel, a gravel bed channel, or a sand bed channel. In this paper gravels refer to substrate material made up mostly of granules, pebbles, and cobbles. Granules range in size from 2 to 4 mm, pebbles from 4 to 64 mm, cobbles from 64 to 256 mm and boulders > 256 mm (Wentworth, 1922; Richards, 1982). In the cobble and boulder bed channel, pools develop behind large boulders (Figure 1A), or large accumulations of inorganic and organic debris that block flow (Miller, 1958; Leopold, et al., 1964; Richards, 1982). Ripples are poorly defined due to the paucity of gravel size substrate. The pool and ripple spacing is variable and not clearly related to any function of width (Leopold, et al., 1964). Localized deposition occurs in pools during low flow while above average flows result in one continuous erosional area. Generally, the valley is V-shaped, streams flow across bedrock and display no floodplain development (Figure 1B) (Schumm, 1977).

In gravel bed streams, pools and riffles are more distinct (Figure 1C) and development is related to sinuosity, what turn is produced when there is excess energy beyond what is needed to transport supplied load and overcome friction. Stream response is to change flow direction by selective erosion and channel migration (Richards, 1982). Stream flow through alluvium and floodplain development is modest to extensive (Figure 1D) (Schumm, 1977). Riffles are topographic high points in an undulating bed profile where the upstream pool depth is controlled by the elevation of the downstream riffle, but is independent of channel width or roughness (Richards, 1982). Riffles are regularly spaced and composed of coarser sediment (Leopold, et al., 1964). A reversal of bed and shear stresses occurs between riffles and pools over a range of discharges (Richards, 1982), so that pools are depositional areas at low flow and erosional at high flow. Scour at high flow may expose cobbles or bedrock, which may be covered again during periods of low flow (Hack, 1957; Laske, 1979). A net loss of material downstream occurs even though distinct depositional areas (riffles) are formed at high flow.

Sand bed channels (Figure 1E) have active beds at discharges less than bankfull and are characterized by the development of ripples, dunes, flat beds, standing waves and antidunes depending on flow velocity. The abundance of fine material and low relief dampens ripple formation. Flow is less turbulent and moves through extensive floodplains (Figure 1F) (Schumm, 1977). Slope is controlled by the gravel component and the stream channel is easily modified by a single flood event, due to the relatively small size of the bed material.

Most river systems display a variety of channel forms along their profile, which reflects changes in a continuum of various energy conditions (Richards, 1982). The ideal river depicted in stream models is patterned after one that originates in mountains and flows onto an alluvial valley; cobbles are successively replaced downstream by gravel, sands and silts (Illies and Botosaneanu, 1963; Vannote, et al., 1980; Cays, 1981). Accordingly, headwaters have boulder and cobble type channel structure which merges with a gravel-type structure in the mid-reaches and a sand bed-type in the larger river section (Figure 1A, 1C, 1E), which is the usual case in streams originating in mountainous regions. It is important to note that large rivers rarely have visible pools and ripples since abundance of fine material and large volumes of water tend to drown out any structure that might be present. In contrast to the mountainous streams, streams of the Great Plain and Coastal Plain (Hunt, 1974) have no high relief areas. Accordingly, there is a lack of irregularly spaced pools and riffles resulting from high debris inputs seen in mountain

FACTORS THAT INFLUENCE STREAM CHANNEL DISTRIBUTION

In gravel bed streams, pools and riffles are more distinct (Figure 1C) and development is related to sinuosity, what turn is produced when there is excess energy beyond what is needed to transport supplied load and overcome friction. Stream response is to change flow direction by selective erosion and channel migration (Richards, 1982). Stream flow through alluvium and floodplain development is modest to extensive (Figure 1D) (Schumm, 1977). Riffles are topographic high points in an undulating bed profile where the upstream pool depth is controlled by the elevation of the downstream riffle, but is independent of channel width or roughness (Richards, 1982). Riffles are regularly spaced and composed of coarser sediment (Leopold, et al., 1964). A reversal of bed and shear stresses occurs between riffles and pools over a range of discharges (Richards, 1982), so that pools are depositional areas at low flow and erosional at high flow. Scour at high flow may expose cobbles or bedrock, which may be covered again during periods of low flow (Hack, 1957; Laske, 1979). A net loss of material downstream occurs even though distinct depositional areas (riffles) are formed at high flow.

Sand bed channels (Figure 1E) have active beds at discharges less than bankfull and are characterized by the development of ripples, dunes, flat beds, standing waves and antidunes depending on flow velocity. The abundance of fine material and low relief dampens ripple formation. Flow is less turbulent and moves through extensive floodplains (Figure 1F) (Schumm, 1977). Slope is controlled by the gravel component and the stream channel is easily modified by a single flood event, due to the relatively small size of the bed material.

Most river systems display a variety of channel forms along their profile, which reflects changes in a continuum of various energy conditions (Richards, 1982). The ideal river depicted in stream models is patterned after one that originates in mountains and flows onto an alluvial valley; cobbles are successively replaced downstream by gravel, sands and silts (Illies and Botosaneanu, 1963; Vannote, et al., 1980; Cays, 1981). Accordingly, headwaters have boulder and cobble type channel structure which merges with a gravel-type structure in the mid-reaches and a sand bed-type in the larger river section (Figure 1A, 1C, 1E), which is the usual case in streams originating in mountainous regions. It is important to note that large rivers rarely have visible pools and ripples since abundance of fine material and large volumes of water tend to drown out any structure that might be present. In contrast to the mountainous streams, streams of the Great Plain and Coastal Plain (Hunt, 1974) have no high relief areas. Accordingly, there is a lack of irregularly spaced pools and riffles resulting from high debris inputs seen in mountain
Channel Form and Stream Ecosystem Models

Figure 1. Three Fundamental Channel Forms Found in Streams: A, B - Bedrock Cobble and Boulder Bed (debris regulated); C, D - Alluvial Gravel Bed; E, F - Alluvial Sand Bed.

FACTORS INFLUENCING CHANNEL FORM

Channel structure in a particular stream is dependent on many factors, but particle size, bed load, and competence are most important. However, these factors are dependent on relief, lithology, and climate as reflected by runoff. The effects of continental glaciation are reflected in some areas. Using map overlays, these parameters were integrated and seven distinct stream regions emerged, representing a particular succession of channel forms downstream from the headwaters (Figure 2). A brief discussion of each parameter and its relation to channel form follows.

High relief produces watersheds with steep valley walls, high gradients, and coarser sediments (Strahler, 1950; Richards, 1962). Low relief areas tend to produce large basins with longer streams and gentler gradients (Morisawa, 1968). As noted earlier, steep gradients produce high debris inputs resulting in irregular riffle structure. A topographic map was used to determine relief in this analysis.

Amount of runoff produced in an area is an accurate measure of stream flow and prevailing climate. Runoff is the total amount of water flowing in a stream that is derived from baseflow and overland flow. An average annual runoff map of the United States (Langbein, et al., 1949) was used to determine runoff patterns. It gives a general regional view of stream flow as well as an indication of areas dominated by intermittent and ephemeral streams.

Lithology of a particular area is a reflection of the dominant rock-type present, information which is readily derived from the geologic map of the United States published by the United States Geological Survey (1974). Generally, streams flowing across consolidated material will have steeper gradients than those flowing on unconsolidated materials. In alluvial channels, lithology, structure, and weathering regime control the nature of the alluvium (Hack, 1957) and influences the extent of pool and riffle development. Streams flowing on flat-lying sedimentary strata form steeper gradients on less resistant rock, such as sandstone. Nevertheless, steeper gradients are produced from resistant rock when streams flow...
across or through folded rock (Morisawa, 1968). Igneous and metamorphic rocks are generally more resistant to stream erosion than sedimentary rocks and have steep associated stream gradients (Schumm, 1977). Unconsolidated material, such as alluvium with a significant amount of sand, produces a low gradient stream with slope controlled by the gravel component (Richards, 1982). Gradient generally decreases downstream regardless of rock type because relief is less downstream. Also, gradient in many regions is relatively independent of lithology because the amount of relief predetermined the range of potential gradients. Hence, lithology only modifies the gradient of streams and is most important in upstream reaches.

Continental glaciation affected channel structure in two ways. In some areas, glaciers removed nearly all sand and gravel size particles and left only boulders and cobbles. Riffles and pools in such areas are dependent upon the location of this large material. In other areas, large amounts of fine material were deposited resulting in sand bed channels.

Figure 2. Stream Regions in the Contiguous United States Based on Variations of Longitudinal Patterns of Channel Form Succession. Abbreviations following stream region title correspond to headwater, mid-reach, and large river sections, respectively: DR = Debris Regulated, G = Gravel Bed, S = Sand Bed. 1. Glaciated Igneous Region (DR, G-DR, S-G); 2. Eastern Mountain Region (DR, G-DR, S-G); 3. Glaciated Interior Region (S-G, G, S); 4. Mid-continent Region (G-S, G, S-G); 5. Eastern Coastal Region (S, S, S); 6. Ephemeral Region (G-S, G, S-G); 7. Western Mountain Region (DR, G-DR, S-G).

DESCRIPTION OF UNITED STATES STREAM REGIONS

The seven stream regions depicted in Figure 2 represent broad regional variations in channel form in the United States. Field observations by the authors in each of these regions have confirmed at least the general applicability of this map. However, because of the generalizations necessary to produce it, the boundary lines between regions represent transition areas. A region characterized by one type of succession in all likelihood contains some channel patterns more characteristic of other regions, especially those found around its perimeter. Patches of prairie in a deciduous forest biome are an analogous situation. Measurement and characterization of individual study streams can be used to overcome this problem. Expected downstream changes in channel form in each of the seven regions are given in Figure 2.

Glaciated Igneous Region

This region includes the Adirondack Mountains, New England Province, and the Canadian Shield which extends into

Figure 2: Stream Regions in the Contiguous United States Based on Variations of Longitudinal Patterns of Channel Form Succession. Abbreviations following stream region title correspond to headwater, mid-reach, and large river sections, respectively: DR = Debris Regulated, G = Gravel Bed, S = Sand Bed. 1. Glaciated Igneous Region (DR, G-DR, S-G); 2. Eastern Mountain Region (DR, G-DR, S-G); 3. Glaciated Interior Region (S-G, G, S); 4. Mid-continent Region (G-S, G, S-G); 5. Eastern Coastal Region (S, S, S); 6. Ephemeral Region (G-S, G, S-G); 7. Western Mountain Region (DR, G-DR, S-G).
from Minnesota, Wisconsin, and some of Michigan. These streams are dominated by igneous and metamorphic rock with a thin cover of glacial drift. The relatively low abundance of gravel size particles, along with an increased amount of large debris, results in the development of debris regulated pool and riffle areas. Headwaters have pool and riffle development due to debris accumulations. Moderate alluvial pool and riffle development occurs in the mid-reaches with poor bedrock outcrop. Their long profile resembles that of the ideal stream of longitudinal models, but differs fundamentally in the relative abundance of coarse and fine material. To headwater pools and riffles characteristic of the mid-reaches of mountain streams are well-developed from headwaters to large river sections. These streams are characterized by the alluvial pool and riffle development described in previous stream models. Structure described as characteristic of a downstream reach is shifted upstream.

Mid-Continent Region

This region includes the remainder of the Central Lowlands excluding the High Plains. It consists of horizontal or gently dipping sedimentary rocks with low to moderate relief. The relatively high relief of the Ouachita Mountains makes streams there similar to Appalachian streams. Also, the relatively low abundance of gravel size particles and the abundance of large debris, results in dammed strong development. Moderate alluvial pool and riffle development occurs in the mid-reaches with poor bedrock outcrop. Their long profile resembles that of the ideal stream of longitudinal models.

Eastern Coastal Region

The Coastal Plain extends from southeast Texas along the coast to New England. It includes the Mississippi Embayment, Long Island, and Cape Cod. Unconsolidated sands and gravels thicken and slope gently toward the coast. Streams originating in this region are dominated by sand bed channels along their entire longitudinal profile. Areas with alternating pools and riffles occur only in higher gradient reaches with gravel beds. The stream structure considered downstream of these areas is characterized by the Glaciated Igneous Region but contains fewer riffles. Sand bed structure, usually predominant only in larger rivers of mountainous regions, is shifted upstream to the headwater areas. Because of the close proximity of high relief areas along the Appalachian Mountains, many small streams above the Coastal Plain are debris-regulated with a cobble and boulder bed. When they traverse the Fall Line, they flow into unconsolidated sand and gravel, which results in sand bed channels. Hence, their longitudinal profile contains little alluvial pool and riffle development described as characteristic of the mid-reaches of mountain streams.
Ephemeral Region

The Basin and Range Province and the High Plains are included in this, the largest region. Average annual runoff in this region is less than one inch (Langbein, et al., 1949). Subsequently, small to mid-sized streams are dry substantial parts of the year, producing a unique environment. Streams are characterized by an abundance of sand-size debris and a lack of finer materials. Due to abundance of sand and the lack of riparian vegetation, channel adjustments are generally achieved by channel widening rather than deepening. In the usual dry state, pools and riffles are generally absent, though careful observation discloses analogous features that tend to be spaced 5-7 widths along the channel (Leopold, et al., 1964). The smallest channels that retain water throughout the year are much wider and deeper than streams in other regions. Most perennial rivers originate in the Western Mountain Region.

Owing to the biological uniqueness of this ephemeral environment, it is regarded by the authors to be dominated by a distinct stream type. It probably should be considered in most respects independent of hypothetical stream models. Nonetheless, the abundance of unconsolidated material and moderate relief seems to promote alluvial pool and riffle structure in even the smallest streams when water is present.

Western Mountain Region

Mountains and plateaus of the western United States provide areas of high relief which receive more precipitation than surrounding lowlands. This region includes the Rocky Mountains, Coast Mountains, as well as the Columbia and Colorado Plateaus. The lithology is a mixture of igneous, metamorphic, and sedimentary rock. High gradient streams typify the region. However, gradients moderate considerably across many intermountain lowlands.

Similar to the Eastern Mountain region, pools and riffles in headwater streams are debris-regulated. Fine material is usually scarce and debris piles of cobbles, boulders, and fallen trees determine the locations of riffles and pools. Mid-reaches have poor to moderate alluvial pool and riffle development, and the abundance of sediment in lowlands may result in sand bed channels. Large river reaches commonly contain rapids (Graf, 1979) and rarely have sand-bed channels because of high gradients and large bed loads. Thus, streams in this region are generally characteristic of the ideal stream, but stream bed structure of headwater reaches has been shifted downstream into the large river reaches.

Of the seven stream regions described here, three of them show structural shifts upstream: Eastern Coastal, Glaciated Interior, and Mid-Continental Regions. Glaciated Igneous and Western Mountain Regions closely fit the hypothetical RCC model, Western Mountain Region shows some shifting downstream, and the Ephemeral Region appears to be relatively independent of the model. Other geomorphic successions are possible where various size streams flow into adjacent regions.

MEASUREMENT OF CHANNEL STRUCTURE

The relative lengths of each type of channel form along a longitudinal profile of a river or stream can be determined. Debris-regulated stretches characterized by boulder and cobble substrate with irregularly spaced pools and riffles (Schumnn, 1977). In contrast, riffles and rapids formed by fluvial processes tend to be regularly spaced (Keller and Melhorn, 1973). The distinctiveness of pools and riffle structure can be determined by computing ratio average depth and velocity between pools and riffles and normal flows. Measurements should be taken along the segment for consistency. Values close to one for the ratio of depth: riffle depth and riffle velocity: pool velocity indicate poorly defined pool and riffle structure. Measurement of pool and riffle structure of an entire river system would be a substantial undertaking. Preliminary measurements were probably indicate transition zones where further analysis could be concentrated as needed.

Dams and tributaries alter patterns of longitudinal successions of channel form and should be considered when measuring their structure. Release of hypolimnetic water from reservoirs causes greater than normal erosion of the channel resulting in gradient increases (Simons, 1979). The cold (viscous) water is more effective at entraining bed sediments. We suggest that the increased gradient and dominance of coarse substrate particles found below dams also resets the channel structure to a type found in the upstream reaches above the dam, and is responsible for some of the biotic shifts seen in the tailwater communities. This is in agreement with Ward and Stanford's (1983) findings that the dams are a reset mechanism for many aspects of the near continuum.

Tributaries have recently been shown to modify continuum relations according to the size of the merging stream (Bruns, et al., 1984). The confluence of two small stream seems to set community structure forward along the gradient while the merging of tributaries into larger stream reach appears to set the continuum back. This relationship conforms to that expected from a channel form perspective. Channel shape shifts slightly toward a downstream form when small tributary streams join and the discharge doubles. This increased volume is presumably responsible for the downstream shift in the biotic community. When tributaries flow into streams of higher order than themselves, the result is the addition of a significant amount of larger sediment characteristics of more upstream reaches. The channel responds to this additional debris input with an upstream type of channel form which is more capable of transporting the debris that resists flow.

EFFECTS OF CHANNEL FORM ON COMMUNITY STRUCTURE

Geomorphology of streams has pervasive influence on their biological community structure. Vannote, et al (1980), presented ship between the basis changes and to variations in three high and three low beds.

| Water Resources Bulletin | 864 |
Channel Form and Stream Ecosystem Models

INTRODUCTION

Some fundamental concepts concerning the relationship between physical structure of streams and their biota as basics for the RCC. Stream channel form predictably changes longitudinally among geographic regions in response to variations in relief, lithology, and runoff. Channel form is an important impact on stream community structure at hierarchical levels: (1) among geographic regions that have similar successions of geomorphology; (2) among reaches of streams that vary in channel form, and (3) among habitats within a reach (e.g., pools, riffles, sand beds). Difference in community structure among riffles, pools, and channels has been widely shown (Niel, 1951; Eggleston and Mackay, 1966; Hynes, 1970, and references therein; Mundie, 1971; Armitage, et al., 1974; Hynes, et al., 1974; Sullion, et al., 1982; Benke, et al., 1984). Major differences in current, substrate, depth, and secondary factors (e.g., organic matter accumulations, light, etc.), determine ability of channel types for the various functional groups (shredders, collectors, etc., sensu Cummins, 1973; Merritt and Cummins, 1984) of aquatic species. Channel geomorphology affects community structure and function by affecting trophic structure, processing efficiency, and nutrient spiralling.

Species diversity and production of invertebrates and fish is maximized in mid-reaches of streams (Platts, 1979; Van Etten, et al., 1980; Minshall, et al., 1983) where channel form is often alluvial pool and riffle structure. Greater variability of physical habitat in this channel form provides a greater range of microhabitats suitable for species with various requirements. Macroinvertebrate species which prefer coarse substrates and fast flow characteristic of debris-regulated streams survive in riffles, while burrowing forms and deposit feeders usually found in sand bed channels are successful in pools. Fautin produced in pools enriches quality of seston for filter feeders on riffles, enhances their production and alters their distribution (Illies, 1958; Benke and Wallace, 1980; Brown and Brown, 1984). In addition, high periphyton production in mid-reach gravel channels is reflected by increased relative abundance of grazers (Hawkins and Sedell, 1981; Minshall, et al., 1983). The lower relative abundance of grazers in cobble and boulder channels probably relates to lowered periphyton production due to the effects of steep valley slopes and canopy shading. Sand bed channels have low stability substrate with a corresponding paucity of periphyton and grazers (Benke, et al., 1984). Hence, sand or cobble bed forms usually do not support as diverse or productive communities because they do not have as much habitat diversity, seston quality and periphyton abundance as alluvial pool and riffle channels.

The balance among loading, transport, retention, storage, and utilization of inorganic and organic nutrients in different reaches of streams varies with channel form. Therefore, processing efficiency (sensu Fisher and Likens, 1973; Fisher, 1977; Bilby and Likens, 1980) and nutrient spiralling (sensu Webster, 1975; Webster and Patten, 1979; Elwood, et al., 1983), which are major theoretical constructs that address the balance among these, are also affected. It is beyond the scope of this paper to discuss effects of these in detail, but we will briefly mention how channel form is related to them. Retention of organic particles is primarily a function of substrate particle size (which determines roughness of the bed) and flow rates. Therefore, cobble-boulder beds of debris-regulated streams are generally more retentive and sand beds are least retentive. Alluvial pool and riffle channels are more retentive than debris-regulated channels during low to moderate flow when pools act as sediment traps and riffles like filters, but during high flow events they are much less retentive of organic matter. Utilization of nutrients obviously depends on the number and diversity of organisms using them as well as availability of the nutrients to the organisms. Both are maximized in mid-reaches where gravel-bed pool and riffle structure occurs.

Stream channel form is predictable longitudinally and regionally as described in this paper. The corresponding association of community structure and nutrient spiralling necessitates longitudinal shifts in holistic stream ecosystem models as channel form is shifted upstream or downstream in reference to the model or idealized stream. Similarly, the type of channel form that occurs most frequently within a region influences the types of lotic organisms which reside there. For example, Eastern Mountain Region streams have predominantly bedrock to gravel beds and support benthic communities very different from the sand bed streams of the Eastern Coastal Region.

SUMMARY

Longitudinal pattern of channel form is an aspect of river systems that has received little direct attention in modeling and classification of lotic environments. We contend that stream channel form changes predictably as described and accounts for much of the apparent deviations from holistic stream ecosystem models, both in natural and disturbed settings. Change in channel form is a good predictor of biological continuum shifts up or down stream. Consideration of this refines applicability of the RCC model and other studies of the longitudinal profile of streams.

This synthesis of geologic and community structure has produced the hypothesis that biotic diversity in streams is generally greatest in mid-reaches because mid-reaches characteristically possess distinct pool and riffle geomorphology. This channel form offers greatest physical habitat diversity (bedform, flow, temperature, substrate), intermediate nutrient retention and the highest seston quality which results in the greatest biotic production and diversity.

ACKNOWLEDGMENTS

We would like to thank W. L. Graf, K. G. Smith, D. L. Zachry, and W. L. Manger for helpful comments and criticism during preparation of the manuscript. Partial funding was provided by the National Science Foundation - Experimental Program to Stimulate Competitive Research Grant ISP 8011447 and the State of Arkansas to A. V. Brown.

WATER RESOURCES BULLETIN