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Suspended-sediment transport rates at the 1.5-year recurrence interval for ecoregions of the United States: transport conditions at the bankfull and effective discharge?

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Abstract

Historical flow and suspended-sediment transport data from more than 2900 sites across the United States have been analyzed in the context of estimating flow and suspended-sediment transport conditions at the 1.5-year recurrence interval flow ($Q_{1.5}$). This is particularly relevant with the renewed focus on stream restoration activities and the urgency in developing water-quality criteria for sediment. Data were sorted into the 84 Level III ecoregions to identify spatial trends in suspended-sediment concentrations and yields to meaningfully describe suspended-sediment transport rates across the United States. Arguments are developed that in lieu of form-based estimates of say the bankfull level, a flow of a given recurrence interval ($Q_{1.5}$) is more appropriate to integrate suspended-sediment transport ratings for the purpose of defining long-term transport conditions at a site (the "effective discharge"). The use of the $Q_{1.5}$ as a measure of the effective discharge for suspended-sediment transport is justified on the basis of literature reports and analytic results from hundreds of sites in 17 ecoregions that span a diverse range of hydrologic and topographic conditions (i.e., Coast Range, Arizona/New Mexico Plateau, Mississippi Valley Loess Plains, Middle Atlantic Coastal Plain). There is sufficient data to also develop regional curves for the $Q_{1.5}$ in all but eight of the ecoregions. At the $Q_{1.5}$ the highest median suspended-sediment concentrations occur in semiarid environments (Southwest Tablelands, Arizona/New Mexico Plateau and the Mojave Basin and Range); the highest yields occur in humid regions with erodible soils and steep slopes or channel gradients (Mississippi Valley Loess Plains [MVLP] and the Coast Range). Suspended-sediment yields for stable streams are used to determine "background" or "reference" sediment transport conditions in eight ecoregions where there is sufficient field data. The median value for stable sites within a given ecoregion are generally an order of magnitude lower than for nonstable sites.
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Keywords: Suspended sediment; Effective discharge; Reference conditions; Ecoregions

1. Introduction

Sediment is listed as one of the principle pollutants of surface waters in the United States, both in terms of sediment quantity (clean sediment) and sediment quality due to adsorbed constituents and contaminants. We can view sediment transport rates and amounts as (1)

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"natural," "reference" or background, resulting from generally stable channel systems, (2) "impacted", with greater transport rates and amounts, reflecting a disturbance of some magnitude and more pervasive erosion, and (3) "impaired", where erosion and sediment transport rates and amounts are so great that biologic communities and other designated stream uses are adversely effected. Impairment of designated stream uses by clean sediment (neglecting adsorbed constituents) may occur through processes that occur on the channel bed or by processes that take place in the water column. Fully mobile streambeds and deposition of fines amidst interstitial streambed gravels can pose hazards to fish and communities of benthic macro-invertebrates by disrupting habitats, degrading spawning habitat and reducing the flow of oxygen through gravel beds. Although lethal or sublethal levels are unknown at this time, high concentrations of suspended sediment, perhaps over certain durations, can adversely affect those aquatic species that filter and ingest water. It is critical, therefore, to clearly identify the potential functional relation between an impact due to sediment and the sediment process so that appropriate parameters are analyzed.

Hundreds of thousands of kilometers of stream channels have been designated as being impaired due to sediment. States, Territories and Tribes are required to determine the maximum allowable loadings to, or in a stream that does not impair the "designated use" of that particular water body. This measure has been termed "total maximum daily load" (TMDL). However, this by no means indicates that a TMDL for sediment transport should be expressed in terms of a total load, or a daily maximum load. In fact, neither of these metrics is probably appropriate for sediment and other means of describing reference, impacted and impaired sediment transport conditions at a site are more meaningful and scientifically defensible. Associated with concerns over the effects of sediment quantity on water quality is the renewed interest in rehabilitation and restoration of stream channels and the associated focus on bankfull conditions for channel design (Rosgen, 1996). Because the bankfull flow has been ascribed by some over the years as having geomorphic significance as the "channel-forming flow" representing long-term sediment transport conditions, it deserves further attention here as a potential metric for sediment transport conditions. However, in lieu of form-based estimates of the bankfull level, a flow of a given frequency and recurrence interval is perhaps more appropriate to integrate suspended-sediment transport rates for the purpose of defining long-term transport conditions at sites from diverse regions.

1.1. Bankfull and effective discharge

The bankfull discharge has been ascribed various meanings and levels of importance over the past 50 years since Leopold and Maddock (1953) published their research on hydraulic geometry. This work established an empirical framework for observed differences in the size and shape of alluvial channels as a function of bankfull discharge. Based on the annual maximum flow series, the recurrence interval of the bankfull discharge often approximates the 1.5-year flow event (Dury et al., 1963; Leopold et al., 1964; Hickin, 1968; Dunne and Leopold, 1978; Williams, 1978; Harman et al., 1999; Odem et al., 1999; Castro and Jackson, 2001) although substantial variations around this average value have been noted (Williams, 1978).

The debate over the meaning and value of "bankfull" discharge and "bankfull" channel dimensions has intensified in recent years with the renewed focus on stream restoration and channel design. The Rosgen (1996) scheme of stream restoration utilizes average hydraulic–geometry relations for channel sizing and, therefore, relies heavily on the characteristics of bankfull stage and discharge. Associated with these stream restoration efforts is a widespread interest in developing "regional curves" for estimating bankfull discharge from drainage area or other basin parameters. Sediment water-quality issues have also been linked to conditions at bankfull discharge as a potential means of identifying impacted stream systems based on "departure" from "background" or "reference" sediment transport conditions (Simon et al., 2001). So as to avoid confusion, the *bankfull discharge* is the maximum discharge that can be contained within the channel without overtopping the banks (Leopold et al., 1964) and generally accepted to represent the flow that occurs, on average, every 1.5 years ($Q_{1.5}$).

Dunne and Leopold (1978) described the discharge at the bankfull stage as the most effective at forming and maintaining average channel dimensions. This has led to the term "bankfull discharge" being often used interchangeably with the terms “effective discharge,” “channel-forming discharge” and “dominant discharge.” The simple definition of “bankfull” by Leopold et al. (1964), as the “flow that just spills out onto the floodplain” has been used and abused over the years (Williams, 1978). One of the primary reasons for this confusion is that as originally defined bankfull discharge and the dimensions represented by hydraulic geometry relations refer to stable channels. A bankfull level in unstable streams can be exceedingly difficult to identify particularly in erosional channels because of a lack of depositional features and because channel dimensions, including water-surface elevations (of specific discharges), are changing with time. Searching for a meaningful discharge or range of discharges to compare sediment transport rates and alleviating the need for the form-based “bankfull” criteria is to use a consistent flow-frequency value that can be linked to geomorphic processes, alluvial channel form and, hence, sediment transport rates.

The *effective discharge* is the discharge or range of discharges that transports the largest proportion of the annual suspended-sediment load over the long term (Wolman and Miller, 1960). In subsequent years, various authors (Andrews, 1980; Andrews and Nankervis, 1995; Whiting et al., 1999; Emmett and Wolman, 2001; and others) have altered the original definition of effective discharge from suspended-sediment load to include bed load, bed-material load or total load to accommodate their particular sampling or analytic program. This is justified on the basis that “bed-load . . . is the most relevant from the standpoint of channel form adjustment . . .” (Knighton, 1998, p. 164). This, however, is a surprising assertion in that in most cases, the suspended load represents the bulk of the annual sediment load. These authors have found that the effective discharge for bed load may be represented by the $Q_{1.5}$ and, in stable, nonincised stream systems may be represented by the bankfull stage (Dunne and Leopold, 1978). For the purposes of this paper, we will use the definition of effective discharge as originally defined by Wolman and Miller (1960) to represent suspended-sediment transport.

The ratio between effective and bankfull discharges does, however, tend to diverge from unity with the magnitude of large, infrequent events (Wolman and Miller, 1960; Pickup and Warner, 1976; Nolan et al., 1987; Whiting et al., 1999). Pickup and Warner (1976) found the return period of the effective discharge to range between 1.15 and 1.4 years (using the annual maximum series) using bed load transport equations to estimate sediment transport. Using data from 55 streams, Nash (1994) questioned the validity of the effective discharge occurring on about 1-year intervals based on concerns of transport variability and the difficulty of describing the relation between suspended-sediment concentration and water discharge with a power function.

Whether or not the $Q_{1.5}$ or some other flow frequency can be used to represent either the bankfull or effective discharge for suspended sediment does not alter one of the major themes of this paper. That is, defining a discharge or range of discharges, expressed in terms of flow frequency or recurrence interval that can be used across a range of spatial scales in diverse environments to compare suspended-sediment transport rates.

Although clean sediment can adversely affect habitat and other designated uses in a variety of ways, this paper will be limited to discussions and analysis of methods and techniques for analyzing impacts due to suspended sediment. The purpose of the research reported here was to test the hypothesis that suspended-sediment concentrations and yields could be regionalized for the conterminous United States. The impetus and funding for this effort comes from the US Environmental Protection Agency as part of their effort to support research using scientifically defensible methodologies for developing water-quality targets for sediment.

2. Availability of data and regionalization

Analysis of suspended-sediment transport at the national scale requires a large database of suspended-sediment concentrations with associated instantaneous water discharge. Data of this type permit analysis of sediment transport characteristics and the development of rating relations (Porterfield, 1972; Glysson, 1987). Collection of suspended-sediment data is time consuming and expensive in that it must take place over a broad range of flows to accurately evaluate the long-term sediment transport regime at a site. However, the US Geological Survey (USGS) has identified more than 6000 sites nationwide where at least one matching sample of suspended-sediment and instantaneous flow discharge has been collected (Turcios and Gray, 2001). At many of these sites, data on the particle-size distribution of suspended- and bed-material sediment are also available. Kuhnle and Simon (2000) identified additional sites containing data collected by the USGS and other agencies such as the ARS at their experimental watersheds. At more than 2900 of the sites, there is sufficient data (minimum of 30 matching samples) to develop relations between flow and suspended-sediment concentration and load. USGS and ARS suspended-sediment sampling strategies are usually designed to obtain samples over a broad range of flows, particularly during storms when a large proportion of the annual load may be transported. In addition, peak-flow files maintained by the USGS were available for most of the sites. This massive historical database serves as the foundation for analyzing sediment transport characteristics over the entire range of physiographic conditions that exist in the United States, including Hawaii and Puerto Rico. Finally, it should be stressed that the sediment transport rates reported here represent two phases of sediment movement; wash load (generally silts and clays) and suspended bed-material load (generally sands) but excludes bed load. Stream systems dominated by bed load, therefore, may not be well represented here.

To be potentially useful for practitioners in stream restoration and water quality studies, sediment transport relations derived from this existing database must be placed within a conceptual and analytical framework such that they can be used to address sediment-related problems at sites where no such data exist. Sediment transport characteristics and relations need to be regionalized according to attributes of channels and drainage basins that are directly related to sediment production and transport. In a general way, attributes such as physiography, climate, geology and ecology are differentiated within the ecoregion concept (Omernik, 1995). These divisions have been used successfully as a means of regionalizing hydraulic–geometry relations in the Pacific Northwest (Castro and Jackson, 2001). Fig. 1 shows the 84 ecoregions in the continental United States along with the locations of existing historical suspended-sediment data. No effort was made to further subdivide within ecoregions on the basis of dominant bed-material size class. However, in

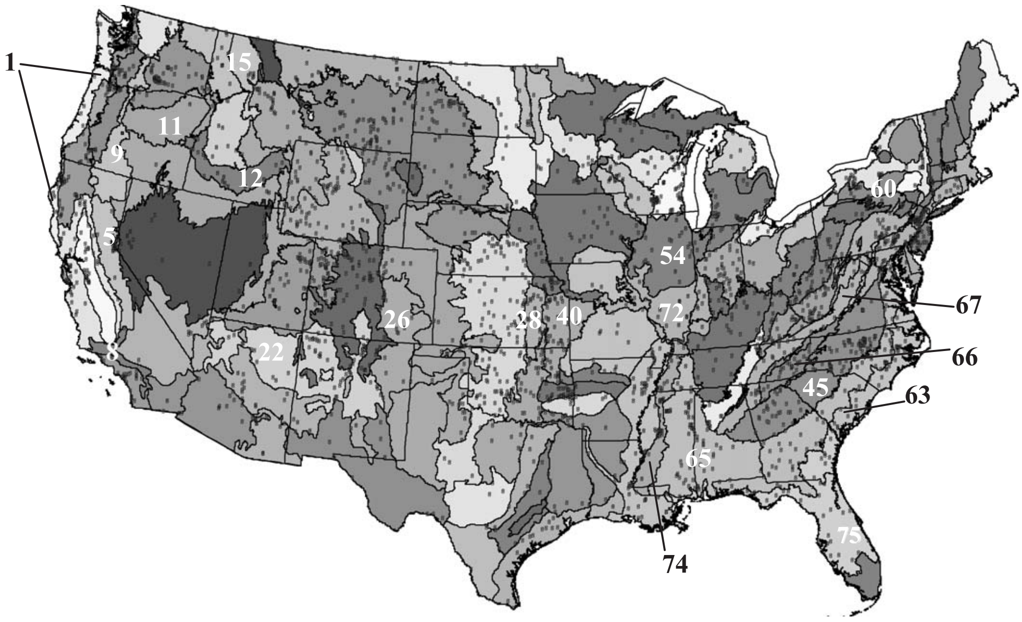

Fig. 1. Level III ecoregions of the continental United States showing locations of sites with at least 30 samples of suspended-sediment and associated flow discharge. Numbers indicate ecoregions referred to in the text.

the following eight ecoregions, a sufficient number of sites were visited to determine relative channel stability, thereby providing a basis to compare differences in suspended-sediment transport between stable and unstable sites:

1. Coast Range (no. 1)
2. Northern Rockies (no. 15)
3. Arizona/New Mexico Plateau (no. 22)
4. Flint Hills (no. 28)
5. Central Irregular Plains (no. 40)
6. Middle Atlantic Coastal Plain (no. 63)
7. Southeastern Plains (no. 65)
8. Mississippi Valley Loess Plains (MVLP; no. 74)

A stable channel is one that over a period of years does not experience net changes in width, depth, gradient or planform and can essentially transport all sediment delivered from upstream without net erosion or deposition.

3. Analysis of suspended-sediment discharge

Analysis of suspended-sediment transport data involves establishing a relation between flow and sediment concentration or load. Instantaneous concentration data combined with either an instantaneous flow value or flow data representing the value obtained from the stage-discharge relation at 15-min intervals are best. Mean daily values of both flow and sediment loads, which are readily available from the USGS, tend to be biased towards lower flows, particularly in flashy basins. Simon (1989a) showed how the slope of sediment transport relations varies over time and the course of fluvial adjustment. Kuhnle and Simon (2000) indicated that the coefficient of the rating relation may also be useful as a generalized measure of sediment transport rates, particularly at low flows. It seems, however, that the suspended-sediment transport rate at the “effective discharge” may hold the greatest potential as a measure of sediment transport when comparing a large number of sites in a specific region. Although the effective discharge represents only one point along the transport relation, it can be viewed as an integration of the entire relation if we accept the time-based concepts implicit in its definition.

3.1. Effective discharge calculations

To provide a check on the validity of the $Q_{1.5}$ as an estimate of the effective discharge for suspended sediment a three-step process is required: (i) construct a flow-frequency distribution; (ii) construct a sediment transport rating relation; and (iii) integrate the two relations by multiplying the sediment transport rate for a specific discharge class by that discharge. The discharge class with the maximum product is defined as the effective discharge (Andrews, 1980).

The flow data used for this analysis should be of the greatest available frequency, such as those corresponding to 15-min stage data. These data are more difficult to obtain, as they are not readily available from USGS sources. We were, however, able to obtain these data from the USGS for 10 sites located in two ecoregions in Mississippi. In lieu of the 15-min flow data, mean daily flow data were also obtained for about 500 sites representing 17 different ecoregions. Flow data are ranked and then subdivided into 33 discharge classes (Yevjevich, 1972). Subdividing classes using an arithmetic distribution often results in the majority of flows falling into the lowest discharge class. To overcome this problem and supported by the general log–normal distribution of flows, a logarithmic distribution is used. This procedure was used for the 10 sites in Mississippi and the other 500 sites across the United States to test the recurrence interval of the effective discharge.

3.2. Suspended-sediment transport rating relations

A first approximation, suspended-sediment transport rating (Porterfield, 1972; Glysson, 1987; Simon, 1989a) of discharge versus concentration is plotted in log–log space and regressed with a power function (Fig. 2). Trends of these data (in log–log space) often increase linearly and then break off and increase more slowly at high discharges. Preliminary analyses of the studied streams show that although sand concentrations continue to increase with discharge, the silt–clay fraction attenuates, causing the transport relation to flatten. A simple transport rating developed with a single power function and with this kind of data trend commonly over-estimates concentrations at high flow rates, leading to significant errors in calculating annual loads and the effective discharge. To alleviate this

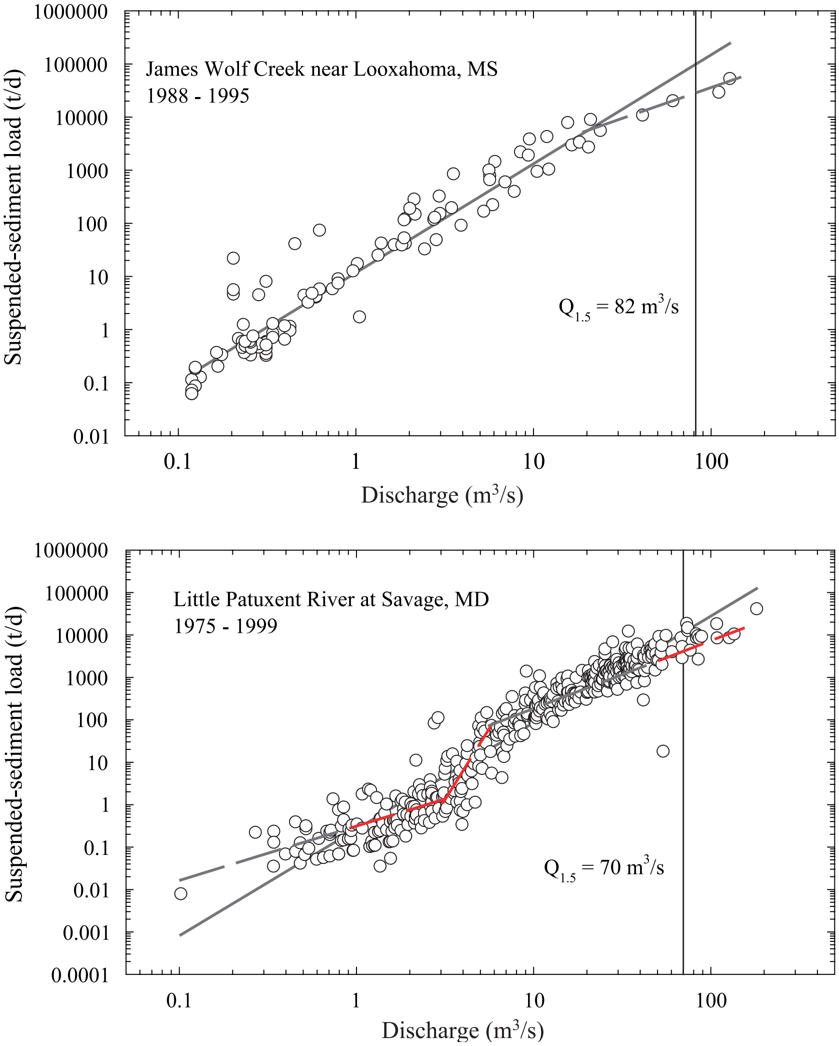

Fig. 2. Examples of first approximation suspended-sediment transport ratings (solid line) and modified ratings (dashed line) used for analysis. Values of the $Q_{1.5}$ are shown for each site.

problem, a second (or even third) linear segment (in log–log space) is often fit with the upper end of the data set (Simon, 1989a; Fig. 2). The break in slope is determined visually. This adjustment to the upper end of the rating directly addresses one of Nash's (1994) concerns regarding the use of a single power function to describe the relation between flow and suspended-sediment discharge over the entire range of flows. The concentration at the midpoint of each discharge class is then calculated from the rating relation and multiplied by the discharge and its percent occurrence. The discharge class containing the highest value is, by definition, the effective discharge.

3.3. Recurrence interval of the effective discharge for suspended sediment

The effective discharge (Q_{eff}) was calculated using the above procedure for the 10 sites in Mississippi using 15-min flow data (Table 1) and the other 500 sites using mean daily flow data (Table 2). Results show, that for a given ecoregion, the median recurrence interval of the effective discharge for suspended sediment ranges from 1.1 to 1.7 years. The $Q_{1.5}$ was obtained for all sites from log-Pearson III analysis of the annual maximum series (Fig. 3A) and compared to the effective discharge calculated by the above procedure (Tables 1 and 2). For the 10 Mississippi streams analyzed, the $Q_{1.5}$ proved to be a good approximation being, on average, about 10% greater than the calculated effective discharge (Simon et al., 2001). Results from the other ecoregions show, as expected, a greater range given the diversity of geomorphic conditions, with the median ratio of Q_{eff} to $Q_{1.5}$ between 0.6 and 1.3 (Table 2). Still, results showing the remarkably consistent recurrence interval value for the effective discharge indicate that using the $Q_{1.5}$ as a measure of estimating the effective discharge at the remaining study sites is reasonable. We may then be able to extend this argument to the bankfull discharge given the numerous authors that have found that the bankfull and $Q_{1.5}$ discharges are similar for regions as diverse as the arid American Southwest (Odem et al., 1999) and the Pacific Northwest (Castro and Jackson, 2001).

The consistent results supporting the use of the $Q_{1.5}$ as a measure of the effective discharge are not meant to be definitive for all streams in every ecoregion of the United States but as a mechanism to define and compare suspended-sediment transport rates from historical data sets from the different ecoregions spanning the country. Further, the selection of a single flow frequency, in this case, the $Q_{1.5}$, provides a degree of internal consistency by which to compare suspended-sediment transport rates from diverse regions of the United States.

Table 1
Comparison of $Q_{1.5}$ and effective discharge (Q_{eff}) for 10 sites in Mississippi using 15-min flow data

Site	Q_{eff} (m^3/s)	$Q_{1.5}$ (m^3/s)	$Q_{\mathrm{eff}}/Q_{1.5}$
Abiaca Creek (Creuger)	45.1	72.0	0.63
Abiaca Creek (Seven Pines)	67.1	114.0	0.59
Batupan Bogue	332.0	272.0	1.22
Fannegusha Creek	235.0	171.0	1.37
Harland Creek	146.0	156.0	0.94
Hickahala Creek	228.0	235.0	0.97
Hotophia Creek	264.0	97.0	2.72
Long Creek	250.0	333.0	0.75
Otoucalofa Creek	85.7	152.0	0.56
Senatobia Creek	196.0	284.0	0.69
Average			1.04
Median			0.84

Table 2
Summary of results of effective discharge (Q_{eff}) calculations for suspended sediment using mean daily flow data

Ecoregion number	Ecoregion name	Median recurrence interval of effective discharge (years)	Median $Q_{\mathrm{eff}}/Q_{1.5}$	Number of sites
1	Coast Range	1.2	0.71	31
5	Sierra Nevada	1.5	0.99	32
8	Southern California Mountains	1.7	1.20	1
9	Eastern Cascades	1.1	0.56	1
11	Blue Mountains	1.7	0.92	2
12	Snake River Basin	1.3	0.95	20
15	Northern Rockies	1.2	0.82	13
22	Arizona/New Mexico Plateau	1.4	0.96	40
26	Southwest Tablelands	2.3	1.71	17
28	Flint Hills	1.7	1.30	21
40	Central Irregular Plains	1.4	0.94	41
54	Central Corn Belt Plains	1.1	0.60	24
63	Middle Atlantic Coastal Plain	1.1	0.50	22
65	Southeastern Plains	1.2	0.60	121
67	Ridge and Valley	1.1	0.92	44
72	Interior River Lowland	1.2	0.70	12
74	Mississippi Valley Loess Plains	1.1	0.58	33

4. Regional flow relations at the $Q_{1.5}$

The annual maximum peak-flow series for each of the sites with available data was used to calculate the effective discharge ($Q_{1.5}$) from the log-Pearson Type III distribution (Fig. 3A). The resulting $Q_{1.5}$ data were sorted by Level III ecoregion and regressed with drainage area to develop regression relations of the form

$$Q_{1.5} = xA^{y} \tag{1}$$

where $Q_{1.5}$ is water discharge in m^3/s; A is drainage area in km^2; and x and y are regression coefficient and

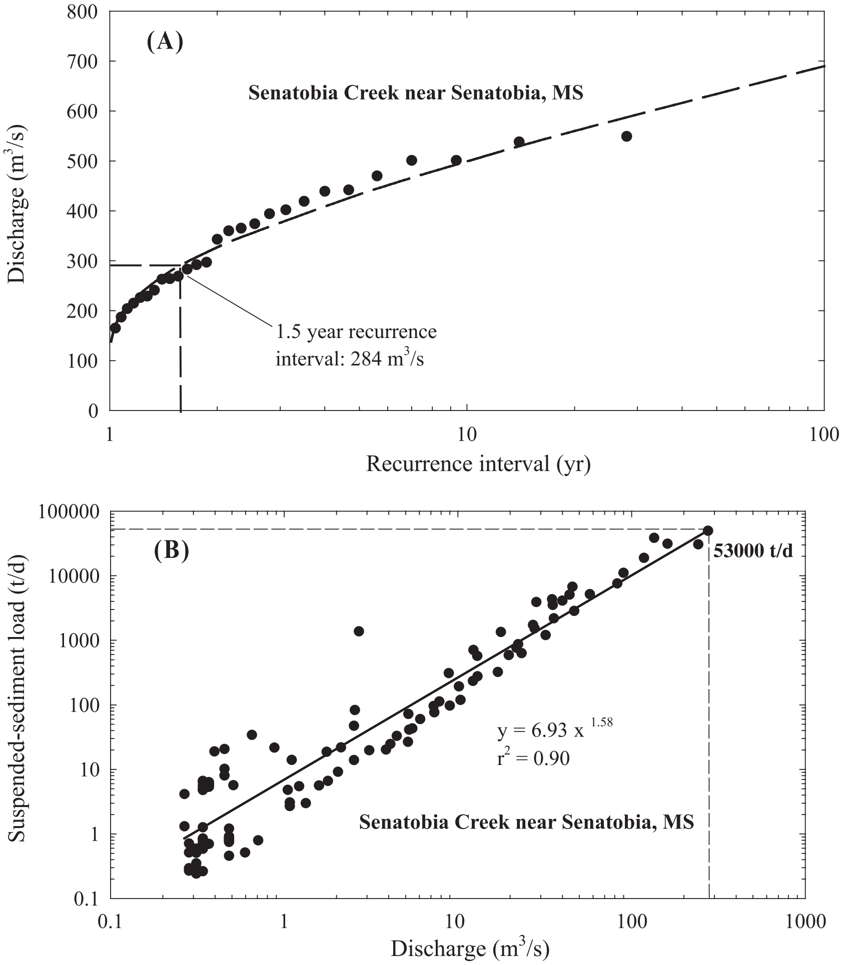

Fig. 3. Examples of (A) log-Pearson III distribution of annual peak flows used to determine the $Q_{1.5}$ and (B) suspended-sediment load at the $Q_{1.5}$.

exponent, respectively. In eight of the ecoregions, there were an insufficient number of sites to develop regression relations. Of the remaining 76 ecoregions, 75% of the derived relations included at least 17 sites and had r^2 values of at least 0.60; 50% of the relations included at least 27 sites and had r^2 values of 0.80. For this report, no effort was made to test additional variables in a multiple-regression framework that might have improved the significance and applicability of the relations. Still, the ensuing results provide estimates of the $Q_{1.5}$ for most of the Level III ecoregions of the United States (Table 3). Caution should be exercised in the use of the relations in Table 1 where there are few observations and/or where r^2 values are low.

5. Suspended-sediment transport rates at the effective discharge by Level III ecoregion

Using the procedures for developing suspended-sediment transport relations and the $Q_{1.5}$ described above, values of concentration and yield (load divided by drainage area) were obtained for each site. This was accomplished by applying the calculated $Q_{1.5}$ to the suspended-sediment rating relation to obtain the transport rate (Fig. 3B). So as not to extrapolate relations beyond measured bounds, sites were excluded from the analysis if the $Q_{1.5}$ exceeded the maximum sampled discharge by 50% or more. The remaining data set (2430 sites) was sorted by ecor-

Table 3
Regional curve equations (of the form $Q=xA^y$) for the $Q_{1.5}$ differentiated by Level III ecoregion in the conterminous United States

Ecoregion number	Ecoregion name	x	y	r^2	p Value	Number of sites
1	Coast Range	2.270	0.754	0.885	< 0.001	31
2	Puget Lowland	0.188	1.067	0.939	< 0.001	12
3	Williamette Valley	1.452	0.714	0.986	< 0.001	9
4	Cascades	2.254	0.685	0.858	< 0.001	19
5	Sierra Nevada	0.121	0.919	0.686	< 0.001	34
6	Southern and Central CA Chaparral and Oak Woodlands	2.307	0.469	0.290	< 0.001	55
7	Central California Valley	4.198	0.447	0.573	0.002	14
8	Southern California Mountains	–	–	–	–	1
9	Eastern Cascades Slopes and Foothills	–	–	–	–	1
10	Columbia Plateau	0.027	0.987	0.752	< 0.001	24
11	Blue Mountains	–	–	–	–	2
12	Snake River Basin	0.013	0.964	0.681	< 0.001	18
13	Central Basin and Range	0.103	0.633	0.550	< 0.001	18
14	Mojave Basin and Range	0.069	0.690	0.499	0.022	10
15	Northern Rockies	0.201	0.855	0.888	< 0.001	16
16	Idaho Batholith	0.070	1.051	0.965	< 0.001	8
17	Middle Rockies	0.161	0.786	0.727	< 0.001	45
18	Wyoming Basin	0.017	0.944	0.714	< 0.001	64
19	Wasatch and Unita Mountains	0.095	0.722	0.882	< 0.001	8
20	Colorado Plateaus	0.045	0.841	0.805	< 0.001	58
21	Southern Rockies	0.098	0.817	0.701	< 0.001	60
22	Arizona/New Mexico Plateau	0.627	0.522	0.591	< 0.001	52
23	Arizona/New Mexico Mountains	0.631	0.564	0.693	< 0.001	18
24	Chihuahuan Deserts	977.000	– 0.247	0.250	0.253	7
25	Western High Plains	4.864	0.231	0.349	0.002	24
26	Southwestern Tablelands	0.615	0.524	0.330	< 0.001	39
27	Central Great Plains	2.767	0.366	0.344	< 0.001	115
28	Flint Hills	9.931	0.379	0.690	< 0.001	19
29	Central Oklahoma/Texas Plains	10.965	0.344	0.530	< 0.001	36
30	Edwards Plateau	11.995	0.353	0.940	0.157	3
31	Southern Texas Plains	–	–	–	–	2
32	Texas Blackland Prairies	9.550	0.357	0.815	0.014	6
33	East Central Texas Plains	20.370	0.265	0.214	0.433	5
34	Western Gulf Coastal Plain	15.276	0.612	0.569	0.005	12
35	South Central Plains	4.645	0.517	0.660	< 0.001	16
36	Ouachita Mountains	51.880	0.519	0.208	0.217	9
37	Arkansas Valley	7.178	0.456	0.886	< 0.001	17
38	Boston Mountains	161.000	0.061	0.074	0.824	3
39	Ozark Highlands	6.383	0.543	0.919	< 0.001	11
40	Central Irregular Plains	7.129	0.462	0.898	< 0.001	45
41	Canadian Rockies	–	–	–	–	1
42	Northwestern Glaciated Plains	0.081	0.729	0.843	< 0.001	21
43	Northwestern Great Plains	0.062	0.759	0.761	< 0.001	137
44	Nebraska Sand Hills	1.950	0.268	0.580	0.017	9
45	Piedmont	3.090	0.597	0.823	< 0.001	74
46	Northern Glaciated Plains	0.938	0.301	0.402	0.003	20
47	Western Corn Belt Plains	4.645	0.414	0.622	< 0.001	53
48	Lake Agassiz Plain	0.070	0.710	0.733	0.002	10
49	Northern Minnesota Wetlands	0.000	1.243	0.957	0.133	3
50	Northern Lakes and Forests	0.778	0.598	0.723	< 0.001	20
51	North Central Hordwood Forests	0.687	0.578	0.970	< 0.001	16

(continued on next page)

Table 3 (*continued*)

Ecoregion number	Ecoregion name	x	y	r^2	p Value	Number of sites
52	Driftless Area	0.433	0.650	0.804	< 0.001	22
53	Southeastern Wisconsin Till Plains	1.054	0.504	0.463	< 0.001	25
54	Central Corn Belt Plains	1.021	0.644	0.846	< 0.001	23
55	Eastern Corn Belt Plains	1.247	0.707	0.903	< 0.001	33
56	S. Michigan/N. Indiana Drift Plains	0.206	0.791	0.861	< 0.001	14
57	Huron/Erie Lake Plains	0.463	0.788	0.934	0.002	6
58	Northeastern Highlands	0.630	0.806	0.921	< 0.001	24
59	Northeastern Coastal Zone	1.954	0.640	0.612	< 0.001	14
60	Northern Appalachian Plateau and Uplands	0.485	0.859	0.928	< 0.001	9
61	Erie Drift Plains	–	–	–	–	2
62	North Central Appalachians	0.457	0.877	0.948	< 0.001	7
63	Middle Atlantic Coastal Plain	1.023	0.604	0.882	< 0.001	29
64	Northern Piedmont	2.065	0.661	0.769	< 0.001	55
65	Southeastern Plains	1.213	0.685	0.805	< 0.001	104
66	Blue Ridge	1.888	0.708	0.876	< 0.001	23
67	Ridge and Valley	1.507	0.702	0.929	< 0.001	51
68	Southwestern Appalachians	2.218	0.745	0.952	< 0.001	12
69	Central Appalachians	1.062	0.810	0.924	< 0.001	36
70	Western Allegheny Plateau	1.321	0.714	0.881	< 0.001	41
71	Interior Plateau	3.206	0.638	0.942	< 0.001	37
72	Interior River Lowland	3.126	0.568	0.954	< 0.001	14
73	Mississippi Alluvial Plain	4.036	0.556	0.824	< 0.001	38
74	Mississippi Valley Loess Plains	12.303	0.443	0.608	< 0.001	32
75	Southern Coastal Plain	0.618	0.680	0.821	< 0.001	31
77	North Cascades	–	–	–	–	2
78	Klamath Mountains	1.549	0.711	0.686	< 0.001	22
79	Madrean Archipelago	–	–	–	–	2
80	Northern Basin and Range	86.896	– 0.147	0.016	0.838	5
81	Sonoran Basin and Range	17.061	0.164	0.109	0.351	10
82	Laurentian Plains and Hills	0.342	0.870	0.999	< 0.001	5
83	Eastern Great Lakes and Hudson Lowlands	0.596	0.786	0.930	< 0.001	32
84	Atlantic Coastal Pine Barrens	0.502	0.823	0.601	< 0.001	21

$Q_{1.5}$ is expressed in m^3/s and A is in km^2; p = significance level.

egion to differentiate between regional trends in suspended-sediment transport. Suspended-sediment transport data at the $Q_{1.5}$ are reported in terms of concentration (mg/l) and also as a yield (tons/day/km^2) to compare streams of varying size within ecoregions. Because data for individual ecoregions were often non-normally distributed, quartile measures were used to describe data ranges and central tendencies. Table 4 shows quartile values sorted by ecoregion as well as the inter-quartile range (central 50%) of the distribution.

Data from the Hawaiian Islands provide a fairly concise picture of the utility of the technique (Fig. 4) to differentiate regional differences in suspended-sediment transport rates. Taken collectively, median suspended-sediment yield values at the $Q_{1.5}$ represent some of the highest in the United States (164 tons/day/km^2) and range over three orders of magnitude. Although Level III ecoregions have not been mapped for the Hawaiian Islands, we can differentiate them based on general geology and anthropogenic disturbance. The Hawaiian data was initially separated into Oahu and non-Oahu sites to discriminate the most populous island containing the city of Honolulu and the site of urban sprawl and large-scale highway construction. This distinction provides a significant comparison in suspended-sediment yields with median values between the two groups differing by two orders of magnitude (Fig. 4). Sites on Oahu displayed the heightened rates (248 tons/day/km^2) typical of

Table 4
Quartile values for suspended-sediment yields and concentrations at the $Q_{1.5}$ for Level III ecoregions in the continental United States

Ecoregion	Minimum	Yield quartiles			Maximum	log (75th % – 25th %)	Minimum	Concentration quartiles			Maximum	log (75th % – 25th %)	Number of sites
		25th %	50th %	75th %				25th %	50th %	75th %			
1	1.29	12.2	55.8	183	413	2.23	34.8	251	874	2510	6070	3.35	43
2	1.09	3.62	8.45	93.8	1130	1.96	53.1	192	517	2440	38,800	3.35	23
3	0.07	0.43	2.89	12.7	221	1.09	3.53	41.6	115	401	2400	2.56	9
4	0.19	1.00	5.24	98.4	1560	1.99	4.25	18.0	120	2690	23,600	3.43	20
5	0.02	0.08	0.29	0.66	6.29	– 0.24	6.62	16.5	35.6	106	660	1.95	42
6	0.14	1.32	15.5	50.8	271	1.69	75.7	396	1530	5400	18,500	3.70	53
7	0.02	0.05	0.30	4.94	136	0.69	19.3	73.6	122	277	4940	2.31	14
8	0.11	0.11	0.11	0.11	0.11	–	47.4	47.4	47.4	47.4	47.4	–	1
9	1.21	1.21	1.21	1.21	1.21	–	284	284	284	284	284	–	1
10	0.04	0.19	0.35	0.89	22.5	– 0.15	23.4	74.2	177	334	9180	2.41	43
11	0.60	0.73	0.85	0.98	1.11	– 0.60	104	119	134	148	163	1.48	2
12	0.002	0.02	0.03	0.11	1.28	– 1.05	4.62	32.1	59.8	73.4	607	1.62	19
13	0.001	0.03	0.03	0.14	1.00	– 0.96	27.2	70.1	143	262	434	2.28	18
14	0.0003	0.05	3.04	8.08	22.6	0.90	2.63	526	5150	12,800	26,300	4.09	10
15	0.01	0.04	0.05	0.54	1.73	– 0.30	2.53	8.30	30.1	66.9	133	1.77	17
16	0.06	0.14	0.34	0.52	0.96	– 0.42	10.10	15.1	36.0	52.7	128	1.58	8
17	0.03	0.12	0.19	0.53	3.91	– 0.39	8.28	46.4	93.4	184	448	2.14	46
18	0.01	0.28	1.22	3.70	104	0.53	14.7	238	961	3610	68,500	3.53	71
19	0.001	0.08	0.16	3.91	12.1	0.58	5.91	47.51	98.4	1170	1990	3.05	8
20	0.03	0.42	1.22	3.60	347	0.50	40.8	403	1410	4280	141,000	3.59	66
21	0.02	0.07	0.22	0.55	86.0	– 0.32	6.76	25.6	67.7	222	20,900	2.29	60
22	0.01	0.32	6.50	47.0	1190	1.67	39.6	305	4140	69,600	255,000	4.84	48
23	0.004	0.14	0.35	1.32	37.7	0.07	8.39	35.7	157	952	5110	2.96	17
24	0.01	0.16	0.32	0.70	3.41	– 0.27	169	1680	2420	3140	4720	3.16	7
25	0.02	0.06	0.29	2.84	140	0.44	361	413	1020	4810	21,200	3.64	22
26	0.13	1.53	13.3	68.3	247	1.82	266	1350	9530	23,400	58,700	4.34	37
27	0.02	1.09	6.36	14.8	532	1.14	257	1550	3770	8200	37,400	3.82	113
28	0.39	1.31	16.3	44.4	382	1.63	210	736	1270	2040	9390	3.12	21
29	0.40	2.25	13.3	27.2	268	1.40	194	725	1770	2810	15,600	3.32	35
30	0.12	0.41	0.70	0.99	1.28	– 0.24	24.3	73.3	122	171	220	1.99	2
31	0.09	0.09	0.09	0.09	0.09	–	89.0	89.0	89.0	89.0	89.0	–	1
32	0.01	0.28	1.97	4.13	8.99	0.59	16.8	161	555	681	976	2.72	7
33	0.11	0.28	0.45	1.67	3.77	0.14	69.0	173	250	1020	1180	2.93	5
34	0.02	0.60	1.14	2.11	4.54	0.18	7.71	138	363	657	3300	2.72	12
35	0.12	0.48	1.23	3.17	9.85	0.43	36.0	66.4	108	359	1630	2.47	24
36	0.60	2.80	3.30	7.70	13.5	0.69	5.18	44.1	91.7	122	196	1.89	9
37	0.74	2.23	3.92	5.60	15.3	0.53	61.6	79.1	196	547	6830	2.67	26
38	1.23	1.42	1.61	3.22	4.83	0.26	10.3	180	351	383	415	2.31	3
39	0.02	0.44	1.99	2.41	6.32	0.29	16.1	33.3	71.9	85.1	351	1.71	14
40	0.12	1.64	8.18	26.2	428	1.39	62.7	477	1020	1950	6440	3.17	53
41	–	–	–	–	–	–	–	–	–	–	–	–	1
42	0.02	0.05	0.14	0.37	3.76	– 0.49	29.5	110	170	893	2860	2.89	21
43	0.01	0.11	0.35	1.98	140	0.27	14.7	117	362	2210	70,300	3.32	135
44	0.25	0.41	0.47	1.02	1.75	– 0.21	539	866	2110	3840	6940	3.47	8
45	0.36	2.53	7.79	36.3	1440	1.53	24.9	127	257	699	5210	2.76	91
46	0.001	0.003	0.01	0.04	1.73	– 1.43	13.6	21.4	60.4	131	798	2.04	20
47	0.06	0.39	2.89	42.9	804	1.63	90.7	341	1810	5170	10,900	3.68	53
48	0.02	0.04	0.07	0.12	0.36	– 1.10	12.4	101	193	283	776	2.26	12
49	0.01	0.01	0.01	0.04	0.08	– 1.52	13.7	16.6	19.5	126	233	2.04	3
50	0.01	0.03	0.24	3.24	27.5	0.51	4.25	7.55	46.3	320	1500	2.50	39
51	0.02	0.06	0.09	0.60	5.27	– 0.27	11.5	19.1	40.0	90.3	324	1.85	24

(continued on next page)

Table 4 (*continued*)

Ecoregion	Minimum	Yield quartiles			Maximum	log (75th % – 25th %)	Minimum	Concentration quartiles			Maximum	log (75th % – 25th %)	Number of sites
		25th %	50th %	75th %				25th %	50th %	75th %			
52	0.21	0.82	3.27	34.4	154	1.53	67.8	225	1050	3300	8950	3.49	30
53	0.09	0.53	2.59	11.6	123	1.05	20.2	47.2	251	644	2520	2.78	48
54	0.19	0.49	0.78	6.54	28.3	0.78	52.5	106	166	846	1600	2.87	24
55	1.27	2.27	4.46	8.67	22.1	0.81	136	205	358	466	787	2.42	35
56	0.02	0.08	0.15	0.28	4.16	– 0.70	4.70	18.6	32.7	44.0	259	1.40	18
57	0.22	0.39	1.02	3.13	8.64	0.44	50.4	75.4	119	357	862	2.45	7
58	0.25	0.42	0.87	1.75	9.96	0.12	10.3	30.8	72.5	138	334	2.03	26
59	0.06	0.11	0.74	1.84	6.68	0.24	11.0	14.0	55.1	79.9	231	1.82	12
60	0.30	2.15	5.83	16.1	140	1.14	4.59	111	408	973	6990	2.94	17
61	0.31	3.79	7.27	10.8	14.2	0.84	62.6	390	717	1040	1370	2.82	2
62	0.12	0.52	0.98	1.85	7.20	0.12	3.87	17.4	32.5	93.4	277	1.88	16
63	0.02	0.03	0.16	0.56	38.0	– 0.28	4.02	6.35	22.1	57.8	524	1.71	30
64	0.15	5.69	23.5	128	2560	2.09	16.0	225	663	1770	8530	3.19	68
65	0.02	0.16	0.52	2.79	281	0.42	5.04	22.3	62.7	227	6440	2.31	140
66	2.22	5.18	13.1	19.2	223	1.15	130	225	343	719	3250	2.69	26
67	0.10	1.06	2.75	7.71	355	0.82	13.2	76.7	162	293	2940	2.34	68
68	1.23	4.36	14.8	42.5	79.4	1.58	40.7	74.2	322	508	1550	2.64	16
69	1.94	6.53	14.2	30.2	415	1.38	41.9	207	386	841	5760	2.80	67
70	0.75	2.30	8.64	25.3	172	1.36	52.7	169	435	853	1910	2.83	57
71	0.45	1.81	3.53	9.1	88.4	0.86	44.5	133	249	347	1150	2.33	37
72	0.07	0.19	0.59	4.80	252	0.66	76.1	143	222	578	3390	2.64	28
73	0.07	0.30	0.88	1.91	21.0	0.21	55.30	110	242	368	4280	2.41	37
74	6.00	41.1	173	318	6390	2.44	461	998	2170	3620	15,600	3.42	27
75	0.01	0.02	0.05	0.11	1.14	– 1.05	3.85	6.13	11.5	19.9	55.7	1.14	32
77	0.02	0.07	0.11	0.16	0.21	– 1.05	1.65	6.09	10.5	15.0	19.4	0.95	2
78	0.37	2.97	10.5	111	607	2.04	50.3	119	581	2820	8470	3.43	29
79	1.52	1.52	1.52	1.52	1.52	–	2030	2030	2030	2030	2030	–	1
80	0.06	0.11	0.27	0.51	0.78	– 0.40	155	180	199	317	639	2.14	4
81	0.0003	0.002	0.22	2.23	41.6	0.35	3.35	116	503	4590	35,100	3.65	10
82	0.07	0.09	0.12	0.18	0.34	– 1.05	5.60	9.81	13.7	14.9	20.8	0.70	7
83	0.05	0.56	3.21	24.5	151	1.38	7.67	37.0	195	966	5270	2.97	51
84	0.01	0.02	1.63	3.14	18.42	0.49	3.36	4.57	65.48	157.97	537	2.19	21

Values shown of the inter-quartile range (75th percentile minus 25th percentile) are log base 10 of the actual values.

disturbed, humid-tropical environments. Further distinction to attempt to account for differences in geologic age, and indirectly sediment availability, clearly shows the very low transport rates from the youngest island, Hawaii (Big Island; Fig. 4) where fresh lava flows mark its lack of soil development. Here, the median suspended-sediment yield was 0.73 tons/day/km^2.

Examples of suspended-sediment concentrations and yields at the $Q_{1.5}$ from a geographic range of ecoregions are shown in Fig. 5. Values of suspended-sediment transport within a single ecoregion may represent a broad range of conditions including various states of channel and watershed stability, dominant bed-material size class, and anthropogenic influence. Still, about 70% of the ecoregions have inter-quartile ranges for suspended-sediment yield within a single order of magnitude. Large inter-quartile ranges (two orders of magnitude) in ecoregions such as the Mississippi Valley Loess Plains (no. 74), Coast Range (no. 1) and Northern Piedmont (no. 60) represent areas where anthropogenic disturbances combined with erodible soils and high, seasonal rainfall create conditions for large increases in suspended-sediment yields.

Measured suspended-sediment concentrations at the $Q_{1.5}$ reached more than 100,000 mg/l in some of the semiarid streams of the southwest such as in the

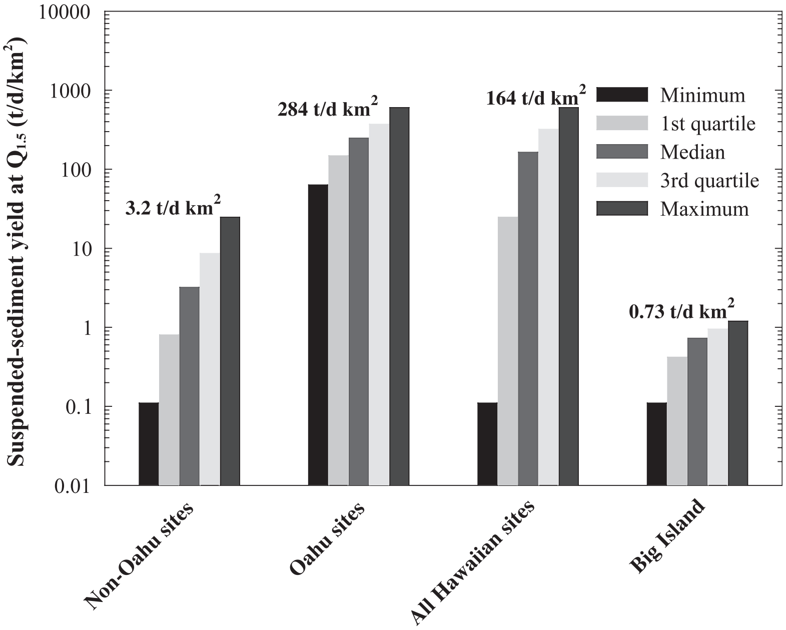

Fig. 4. Variation of suspended-sediment yields for the Hawaiian Islands showing exceptionally high values for sites on urbanized Oahu, moderate values on the nonurbanized islands and low values on the geologically young "Big Island" of Hawaii. Bold numbers refer to median value.

Arizona/New Mexico Plateau (ecoregion 22; Fig. 5). In fact, ecoregions in this part of the United States have some of the highest median concentrations in the nation owing to large quantities of available sediment in storage, limited vegetative cover and the flashy nature of runoff events (Fig. 6A). Examples of these ecoregions include the Southwest Tablelands (no. 26; 9530 mg/l), Mojave Basin and Range (no. 14; 5150 mg/l) and Arizona/New Mexico Plateau (no. 22; 4140 mg/l). Midwestern ecoregions such as the Central Great Plains (no. 27; 3770 mg/l), the Nebraska Sand Hills (no. 44; 2110 mg/l) and the MVLP (no. 74; 2170 mg/l) also showed high median values at the $Q_{1.5}$. Of these, only the MVLP can be considered a humid region and the high median concentration reflects the highly erodible nature of the loess hills and the generally unstable conditions of the stream systems. As expected, the lowest values occurred in ecoregions characterized by gently sloping gradients such as the Southern and Middle Atlantic Coastal Plains (nos. 75 and 63, respectively) and those characterized by shallow soils and resistant bedrock such as the Northern Rockies (no. 15) and the Laurentian Plains and Hills (no. 82).

A somewhat different picture of peak values emerges from the national distribution of suspended-sediment yields at the $Q_{1.5}$ (Fig. 6B). The highest median yield values occur in humid regions such as the MVLP (no. 74; 173 tons/day/km^2) and the Coast Range (no. 1; 55.8 tons/day/km^2) where plentiful flow energy is available for sediment transport and where over-steepened channel gradients in the case of the former and accelerated mass wasting in upland areas in the case of the latter produce high suspended-sediment yields. Areas of the semiarid southwest have moderate suspended-sediment yield values where flows tend to attenuate rapidly downstream through infiltration, thereby reducing transport rates with increasing drainage area. The geographic distribution of lowest median yields shows a similar pattern to the distribution of the lowest median concentrations. Differentiation based on Level III ecoregion is further supported by the expected systematic decrease in both median concentrations and yields as one moves downslope from the Blue Ridge (no. 66) through the Piedmont (no. 45), Southeastern Plains (no. 65) to the Middle Atlantic (no. 63) and Southern (no. 75) Coastal Plains (Fig. 6A,B).

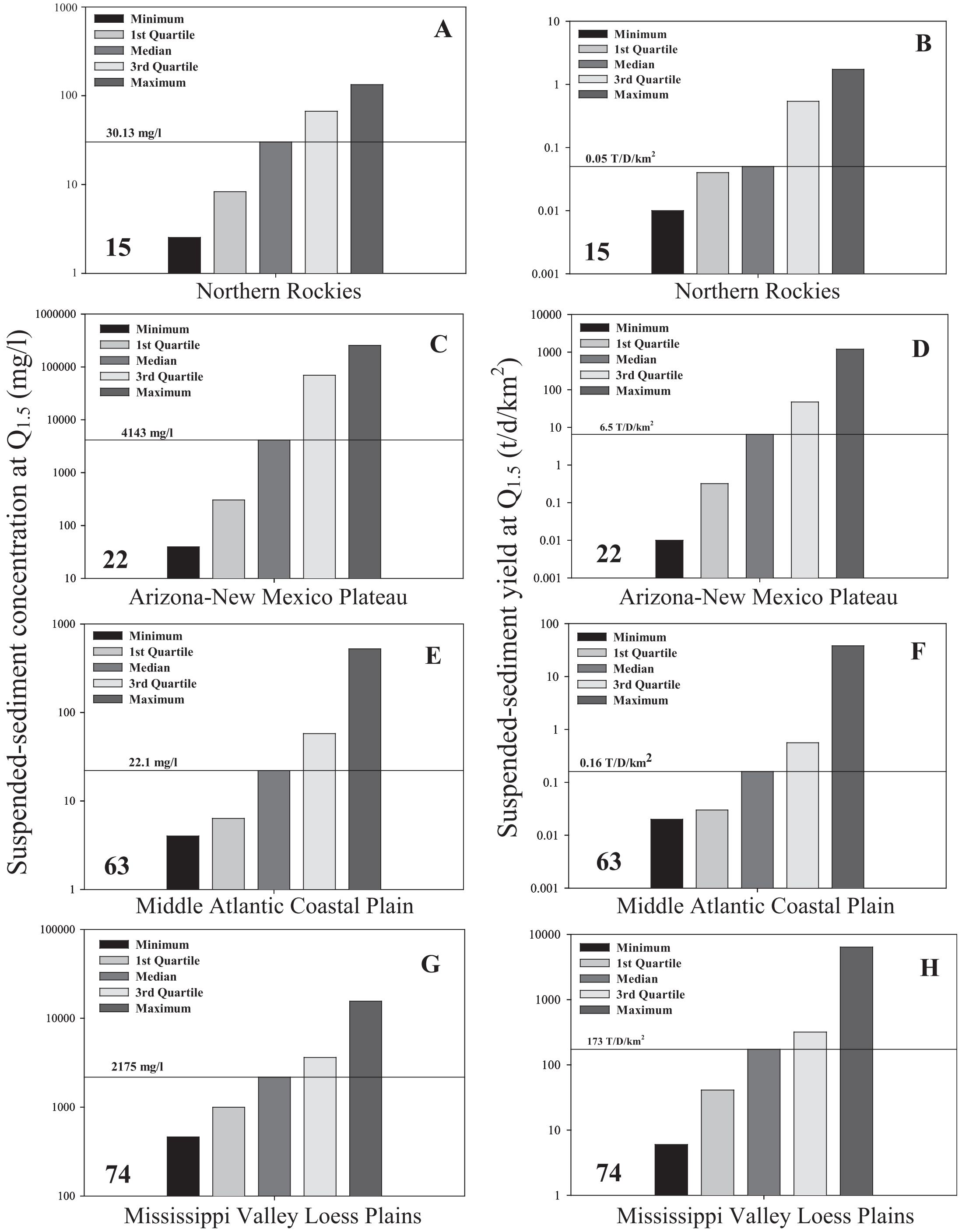

Fig. 5. Quartile measures of suspended-sediment concentrations (A, C, E and G) and yields (B, D, F and H) for a diverse range of ecoregions. Bold numbers = ecoregion numbers (Fig. 1).

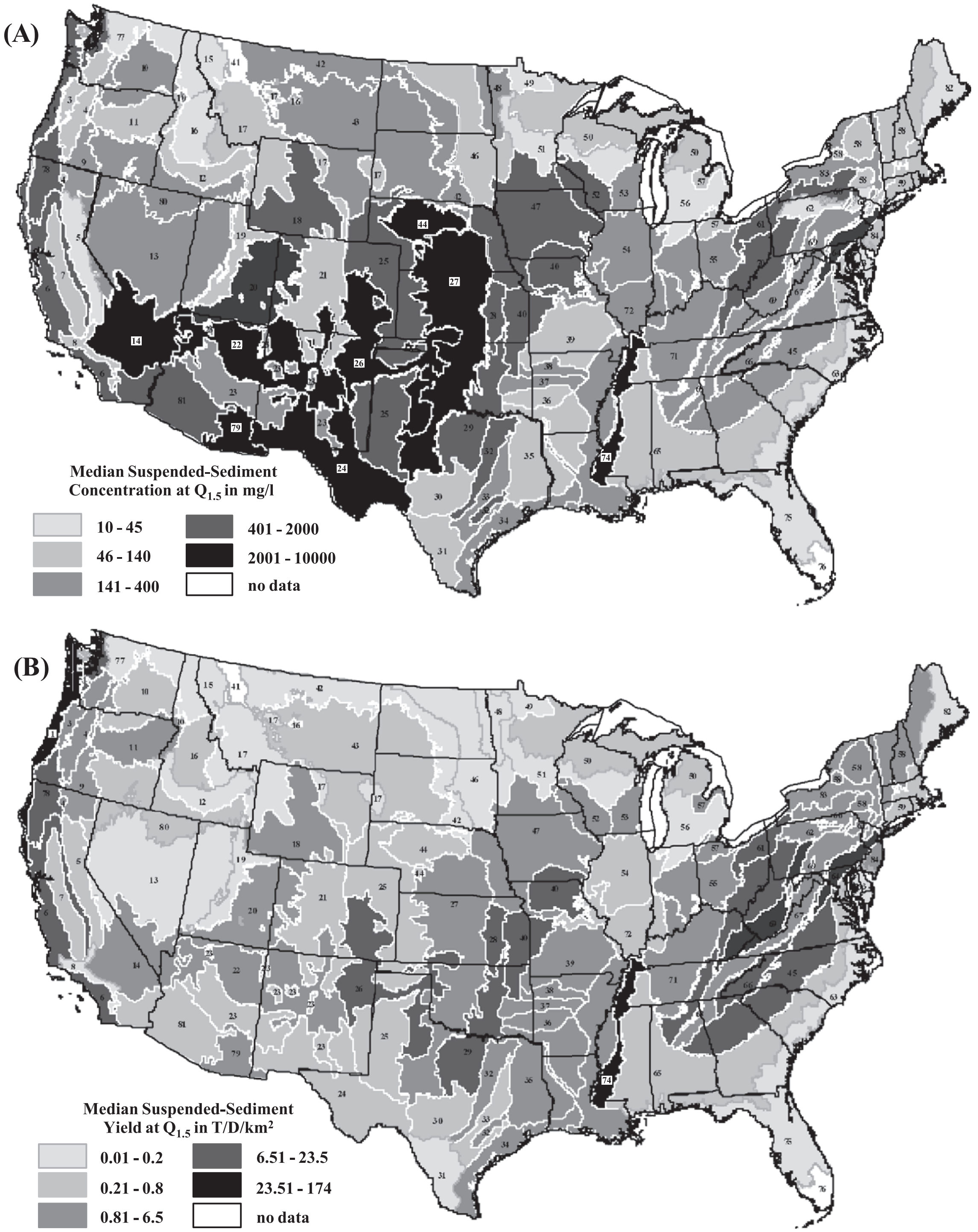

Fig. 6. Median suspended-sediment (A) concentrations and (B) yields at the $Q_{1.5}$ for Level III ecoregions of the continental United States.

These yield results differ somewhat from the classic paper by Langbein and Schumm (1958) who reported peak annual sediment yields in semiarid environments where the dominant vegetation type changed from desert shrub to grassland. Whereas our results showed some of the highest suspended-sediment concentrations in these areas, the greatest median yield values in the continental United States occurred in the humid, yet unstable systems of the MVLP and the Coast Range of the Pacific Northwest. Ample supplies of precipitation and flow energy in the disturbed streams of the MVLP provided large quantities of channel sediments, particularly streambank materials, while mass wasting of disturbed uplands areas in the Coast Range made available plentiful amounts of sediment that produced great quantities of suspended sediment per unit area. If we further consider the data from the Hawaiian Islands, a similar picture emerges, with disturbed humid-tropical areas yielding even greater amounts of suspended sediment. The combination of steep terrain and ample moisture, and the removal of relatively shallow-rooting vegetation, makes these humid tropical areas extremely sensitive to disturbance, resulting in peak suspended-sediment yields. This has also been found to be the case in the South Pacific (Lo, 1990) and in Puerto Rico (Simon and Guzman-Rios, 1990).

Areas of the lower Midwest and areas flanking the Appalachians (Fig. 6B) showed moderately high suspended-sediment yields. The relatively high values for these areas could largely be due to land disturbances and the consequent remobilization of historically stored sediment.

6. Background or “reference” suspended-sediment transport conditions

Rates and concentrations of suspended-sediment transport vary over time and space due to factors such as precipitation characteristics and discharge, geology, relief, land use and channel stability, among others. It is unreasonable to assume that “natural” or background rates of sediment transport will be consistent from one region to another. Within the context of channel design for stream restoration and developing water quality targets for sediment, there is no reason to assume then that “target” values should be consistent on a nationwide basis. Similarly, it is unreasonable to assume that channels within a given region will have consistent rates of sediment transport. For example, unstable channel systems or those draining disturbed watersheds will produce and transport more sediment than stable channel systems in the same region. This reflects differences in the magnitude and perhaps type of erosion processes that dominate a subwatershed or stream reach.

To identify those sediment transport conditions that represent impacted or impaired conditions, one must first be able to define a nondisturbed, stable or “reference” condition for the particular stream reach. In some schemes, the “reference” condition simply

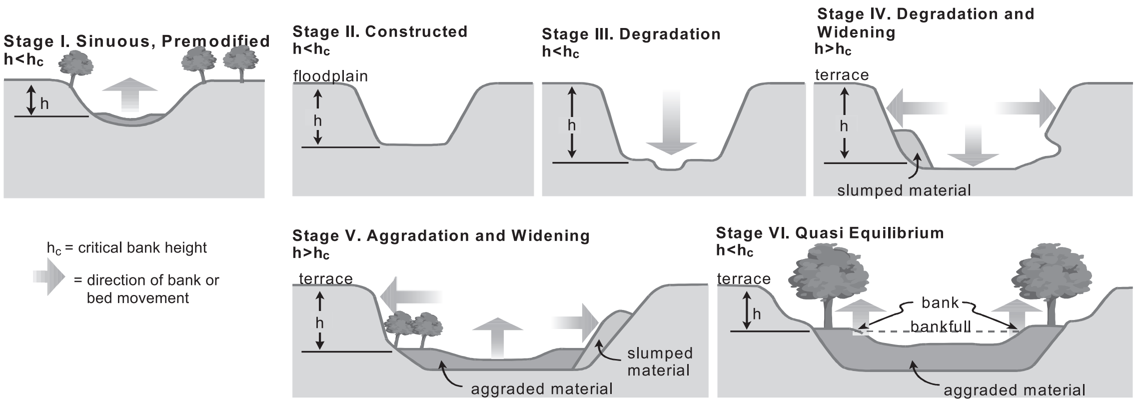

Fig. 7. Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989b) identifying Stages I and VI as “reference” conditions for Level III ecoregions.

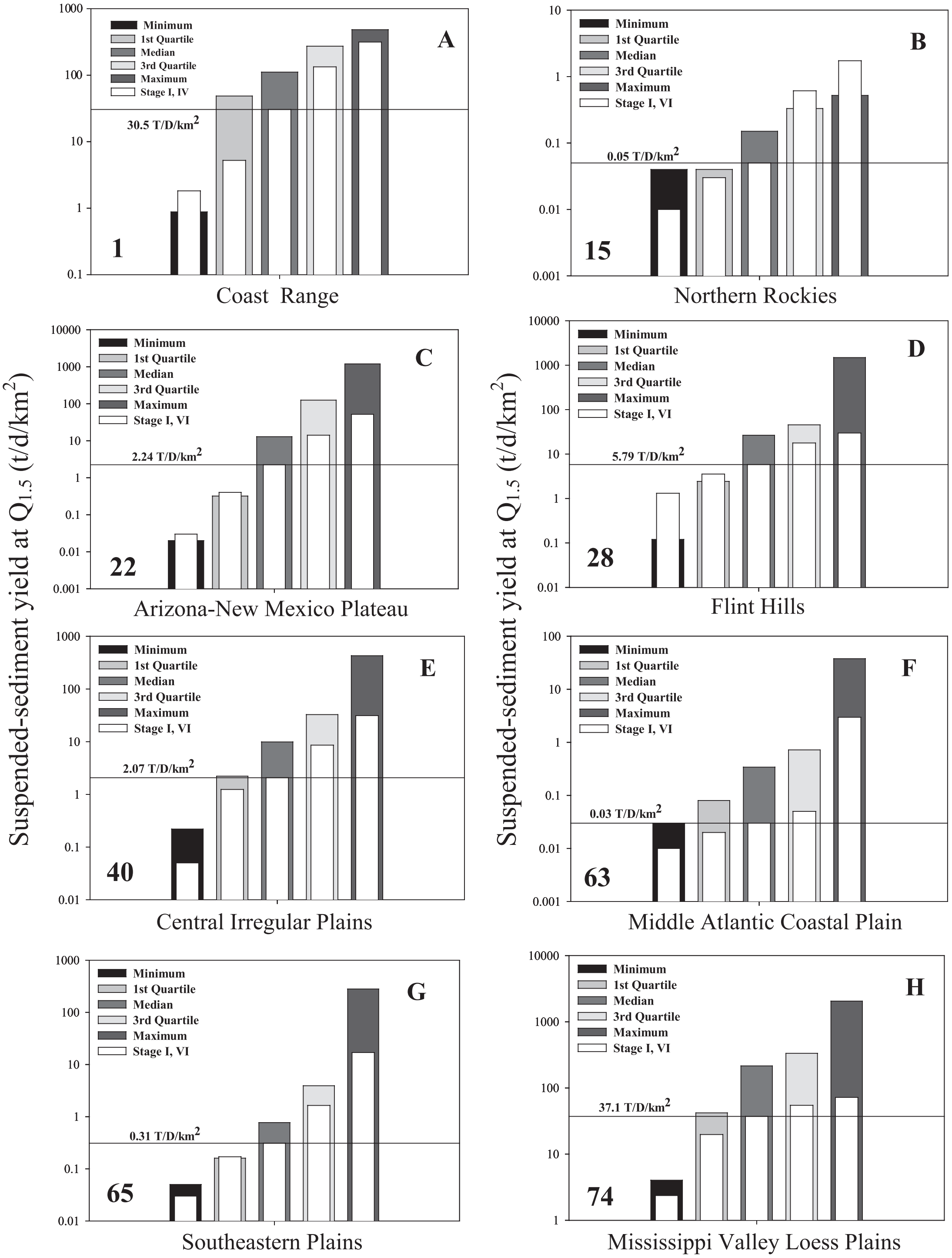

Fig. 8. Quartile measures of suspended-sediment yields at the $Q_{1.5}$ for reference/stable (Stage I and VI) sites and all other sites in eight ecoregions. Yield values shown are preliminary "reference" values. Numbers in bold are ecoregion numbers (Fig. 1).

means “representative” of a given category of classified channel forms or morphologies (Rosgen, 1985) and as such may not be analogous with a “stable,” “undisturbed” or “background” rate of sediment production and transport. Although the Rosgen (1985) stream classification system is widely used to describe channel form, stream types D, F and G are, by definition, unstable (Rosgen, 1996, pp. 4–5). These stream reaches, therefore, would be expected to produce and transport enhanced amounts of sediment and represent impacted conditions. Thus, although it may be possible to define a “representative” reach for stream types D, F and G, a “reference” condition transporting “natural” or background rates of sediment will be difficult to find.

As an alternative scheme, the channel evolution frameworks set out by Schumm et al. (1984) or Simon and Hupp (1986) and Simon (1989b) are proposed (Fig. 7). With stages of channel evolution tied to discrete channel processes and not strictly to specific channel shapes, they have been successfully used to describe systematic channel stability processes over time and space in diverse environments subject to various disturbances such as stream response to channelization in the Southeast US Coastal Plain (Simon, 1994) and midwestern US (Simon and Rinaldi, 2000); volcanic eruptions in the Cascade Mountains (Simon, 1999); and dams and forest practices in Tuscany, Italy (Rinaldi and Simon, 1998). Because the stages of channel evolution represent shifts in dominant channel processes, they are systematically related to suspended-sediment and bed-material discharge (Simon, 1989a; Kuhnle and Simon, 2000), fish-community structure (Knight et al., 1997), rates of channel widening (Simon and Hupp, 1992) and the density and distribution of woody-riparian vegetation (Hupp, 1992).

An advantage of a process-based channel evolution scheme is that Stages I and VI represent two true “reference” conditions. In some cases, such as in the midwestern US where land clearing activities near the turn of the twentieth century caused massive changes in rainfall–runoff relations and land use, channels are unlikely to recover to Stage I, pre-modified conditions. Stage VI, re-stabilized conditions are a more likely target under the present regional land use and altered hydrologic regimes (Simon and Rinaldi, 2000) and can be used as a “reference” condition. However, in pristine areas where disturbances have not occurred or where they are far less severe, Stage I conditions can be used as a reference.

The working hypothesis for determining background or “reference” values for suspended-sediment transport in this study is that stable channel conditions can be represented by channel evolution Stages I and VI. Therefore, effective discharge-sediment yields for Stages I and VI in a given ecoregion represent background or “natural” transport rates. Quartile measures for Stages I and VI conditions occurring at the study sites are shown overlaying data from all other sites in those ecoregions in Fig. 8. As expected, Stage VI sediment yield values are considerably lower for each quartile measure in each of the ecoregions. The median value for stable sites within a given ecoregion are generally an order of magnitude lower than for non-stable sites. Preliminary values are shown on the individual subplots in Fig. 8 assuming the median Stage VI value (2nd quartile) is used as an estimate of the stable, “reference” suspended-sediment yield for an ecoregion (Fig. 8). Note the four order-of-magnitude range of median “reference” values for the eight ecoregions, further supporting the premise that water quality targets for sediment need to be done at least at the Level III ecoregion scale, if not smaller. These results should be considered preliminary as more sites in each of the ecoregions are evaluated for stage of channel evolution, additional Stage VI sites are identified in other states, and the data set is further differentiated by dominant bed-material size class.

7. Summary and conclusions

Using the ecoregion concept devised by Omernik (1995), historical flow and suspended-sediment transport data from more than 2900 sites nationwide have been analyzed to develop regional flow curves and suspended-sediment transport rates for each ecoregion. Data from about 500 sites across the US were used to calculate the recurrence interval of the effective discharge for suspended-sediment transport. Median values for the 17 ecoregions tested ranged from 1.1 to 1.7 years. Thus, the $Q_{1.5}$ proved to be a reasonably good measure of the effective discharge for suspended sediment and was used in conjunction with derived suspended-sediment transport relations to calculate concentrations and yields at all sites. Peak median concentrations occurred in the semiarid areas of the southwestern US, while maximum yields occurred in the Mississippi Valley Loess Plains and the Coast Range. Background or "reference" suspended-sediment transport conditions were determined by sorting the data into stable and unstable sites using the Simon and Hupp (1986) and Simon (1989b) model of channel evolution and by taking the median value for stable sites (Stages I and VI) in a given ecoregion.

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