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Patterns of sediment and organic-matter transport in Oregon Coast Range Streams

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Abstract. The concentrations of suspended sediment during periods of storm runoff in Oregon's coastal streams are related to streamflow, rate of streamflow rise and fall, and the sequence of storm events. Bedload transport of particles > 0.2 mm increases with streamflow, but rates of transport fluctuate greatly during the recession phase of a storm hydrograph. Coarse particulate organic matter (> 0.2 mm) may comprise 10 to 50 percent of the material transport along the stream bottom.

Le transport de sédiment et de matières organiques dans les ruisseaus de la chaîne côtière de l'Orégon

Résumé. Les concentrations du sédiment en suspension pendant les périodes d'écoulement après orage dans les rivières côtières de l'Orégon sont liées à l'écoulement, à la décroissance de l'écoulement et à la suite des événements d'orage. Le charriage des particules > 0.2 mm augmente avec l'écoulement, mais les quantités transportées fluctuent énormément pendant le phase de la récession de l'hydrographe d'écoulement. La matière organique de grosse taille (> 0.2 mm) peut comprende de 10 jusqu'à 50 pourcent du matériel transporté le long du fond de la rivière.

INTRODUCTION

Throughout much of the western United States, accelerated sediment production from land use is a major nonpoint pollution problem. Undisturbed basins in western Oregon may have annual suspended sediment yields of 0.5 to 1 t ha^{-1}. Land-use activities such as forest

harvesting, road construction, and controlled burning can significantly increase these yields, particularly in steep terrain. Many 2nd-, 3rd-, and 4th-order streams draining forested basins of western Oregon have high-value fisheries, thus accelerated sediment and organic-matter transport may be detrimental to instream biota (Iwamoto et al., 1978). An improved understanding of the processes by which suspended sediment, bedload sediment, and coarse particulate organic matter (CPOM) are mobilized and exported in forested basins is needed in order to assess the potential impact from increased sedimentation. This paper summarizes 1977-1979 results of sediment transport studies being conducted at Flynn Creek, a 3rd-order stream draining an undisturbed forested basin in the Oregon Coast Range.

STUDY AREA AND SAMPLING METHODS

The Flynn Creek basin comprises 202 ha of moderately steep (25-40 percent) terrain on which the principal forest species are Douglas-fir (Pseudotsuga menziesii) and red alder (Alnus rubra). Elevations range from 183 to 457 m. Mass soil erosion (soil creep, slumps, debris avalanches) are the dominant mechanisms providing soil and parent material, derived from uplifted marine sedimentry rocks, to the stream system. Instream sediment transport occurs during winter freshets when frontal storms deposit over 80 percent of the 230 cm average annual precipitation. The channel near the mouth of the basin is from 3 to 5 m wide and has an average gradient of less than 3 percent. Large organic debris deflects flows and creates log steps along the channel. The streambed consists primarily of a mixture of sand to coarse gravel, and most sections of the bed are armored with fine to coarse gravel.

An automatic pumping sampler obtained suspended sediment samples at 1- to 2-hour intervals during storm events. Bedload and coarse

particulate organic matter (CPOM) were obtained with a hand-held pressure-difference bedload sampler (Helley and Smith, 1971). The surface area of the 0.2-mm-mesh catch bag was increased from the standard 2,000 cm^2 to 6,000 cm^2 to help prevent plugging of the mesh by organic matter and sand-sized particles.

RESULTS AND DISCUSSION

During winter (November-March) 1977-1978, streamflow was 3 percent greater than the long-term average of 1.2 $\ell\ s^{-1}\ ha^{-1}$ (Fig. 1). Flows during winter 1978-1979 were 43 percent below the long-term average. However, both winters had instantaneous peak discharges of approximately 7.6 $\ell\ s^{-1}\ ha^{-1}$. A Log-Pearson Type III frequency analysis of annual peaks indicates that flows of this magnitude have return periods of approximately 2 years (Edwards, 1980). These flows also peak at, or slightly above, bankfull stage.

Suspended-sediment concentration

The suspended sediment concentrations measured for the six major storms occurring during the two winters (Fig. 2) illustrate several characteristic response patterns and factors affecting these patterns. First, increased streamflow almost always increases sediment concentrations. The important influence of flow on sediment concentrations has led to extensive use of sediment-rating curves to evaluate and predict concentrations in stream systems. These curves typically take the form $S = aQ^b$, where S = suspended sediment concentrations, Q = streamflow, and a and b are regression coefficients. However, the sediment concentration associated with a given flow will commonly vary by an order of magnitude or more in most streams. Thus we assume flow characteristics other than instantaneous discharge are profoundly influencing instream concentrations.

A second factor, hydrograph slope (dQ/dt, where Q = streamflow and t = time), also has an important effect on measured suspended sediment concentrations. For example, Brown and Krygier (1971), analyzing data for suspended sediment from Flynn Creek and several adjacent basins, found that concentrations were typically higher during the rising limb of the hydrograph ($dQ/dt > 0$) than during the receding limb ($dQ/dt < 0$). This reponse pattern (Fig. 2) results in hysteresis when sediment concentrations for an individual storm are plotted as a function of streamflow (Paustian and Beschta, 1979).

Hydrograph slope can be further correlated with sediment concentrations, as shown by storm 1, the first major runoff in winter 1977-1978 and storm 4, the first major runoff of winter 1978-1979 (Fig. 2). The availability of sediment within the channel systems from weathering and erosional processes during previous months is assumed to be similar. However, the sediment-rating curve for storm 4 (Fig. 3) indicates much higher concentrations at a given flow than the curve for storm 1. Because the source area for streamflow increases during a storm, making more sediment available, concentrations are highest when streamflow increase (dQ/dt) is greatest. This occurs because the transport of suspended sediment is usually not limited by stream power. The rate of increasing flow (dQ/dt) for storm 4 is approximately twice that of storm 1. Although concentrations at a given discharge radically differ for these two storms, the total sediment discharge (as flow increased from 3 to 6 $\ell\ s^{-1}\ ha^{-1}$) is essentially the same.

A third factor, storm sequence (which relates to the "memory" of a stream system), also causes sediment-rating curves to vary. Sediment concentration decreases with each successive storm (see storms 1, 2, 3, Fig. 2). Apparently, su
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3, Fig. 2). Apparently, suspendable sediment removed from the basin by early storms decreases the amount available for subsequent storms as long as peak flows do not exceed those of the previous ones. As a result, sediment-rating curves for rising flows during storms 1, 2, and 3 (Fig. 3) show that suspended sediment concentrations decrease with each successive storm. This seasonal change in curves for Coast Range streams has also been demonstrated with data for monthly flow and concentrations (Beschta, 1979). Thus, stream discharge, rate of streamflow rise and fall, and the sequence of storm events are interrelated factors influencing sediment concentrations in undisturbed mountain streams.

CPOM and bedload

Oregon's Coast Range streams transport relatively large amounts of coarse particulate organic matter (CPOM) during storms. Although short-term fluctuations in CPOM transport are apparent (Fig. 4), generally the rates increase with increased streamflow and gradually decrease after the hydrograph peak. The estimates shown are conservative in that they represent only material in transport within 7.6 cm of the streambed.

Bedload transport, consisting of particles > 0.2 mm, typically increases with increasing flow (Fig. 4), but, in contrast to suspended sediment and CPOM transport, it continues to increase erratically after the hydrograph peak. Although data for only one storm are shown in Fig. 4, similar patterns have been found during other storms at Flynn Creek. Field observations indicate that the bedload in transport is not distributed uniformly across the channel but rather in "streamers" which migrate laterally back and forth, which can cause relatively large sampling errors. However, additional measurements at Flynn

Creek with a vortex bedload sampler, similar to one described by Hayward and Sutherland (1974), show similar fluctuations in bedload discharge. The relatively large fluctuations or pulses in transport rates during the recession limb may represent periodic scour and fill of upstream channel sections that release sand-sized sediments. Median particle size (d_{50}) of material transported as bedload remained less than 1 mm during the entire storm. The large temporal fluctuations in bedload transport further indicate that bedload equations developed for steady state are not applicable to the transient flows of mountain streams. Because suspended sediment and CPOM levels of transport are relatively low during receding flows, periods of active bedload transport may improve gravel quality and spawning habitat for resident and anadromous fish.

The temporal patterns of suspended sediment, CPOM, and bedload transport identified here for an undisturbed 3rd-order Oregon coastal stream during periods of storm runoff are part of an extended study. Defining important factors influencing these response patterns in undisturbed and managed basins is prerequisite to solving sedimentation problems facing wildland hydrologists.

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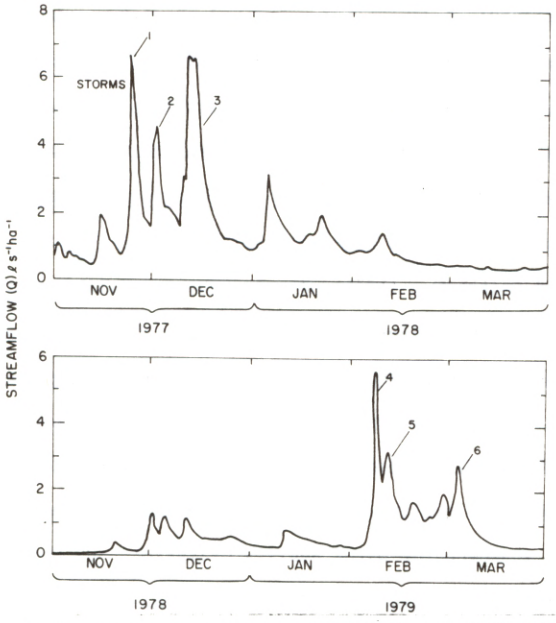

FIGURE 1. Daily streamflow for the 1977-1978 and 1978-1979 winter periods at Flynn Creek, Oregon Coast Range.

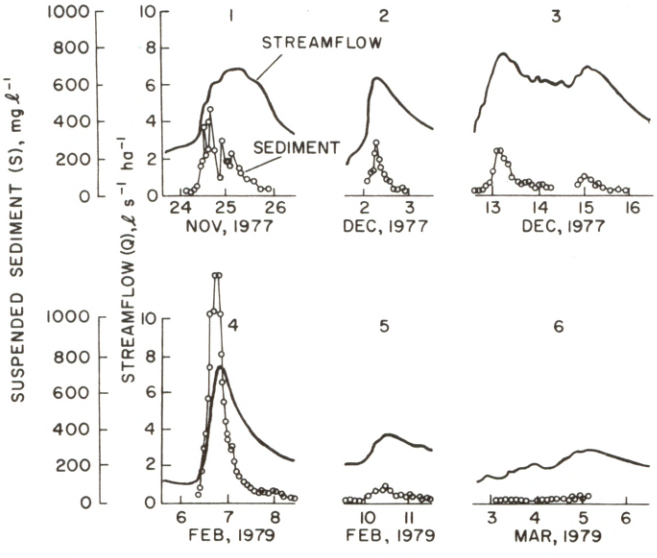

FIGURE 2. Streamflow and suspended sediment concentrations for six storms at Flynn Creek, Oregon Coast Range.

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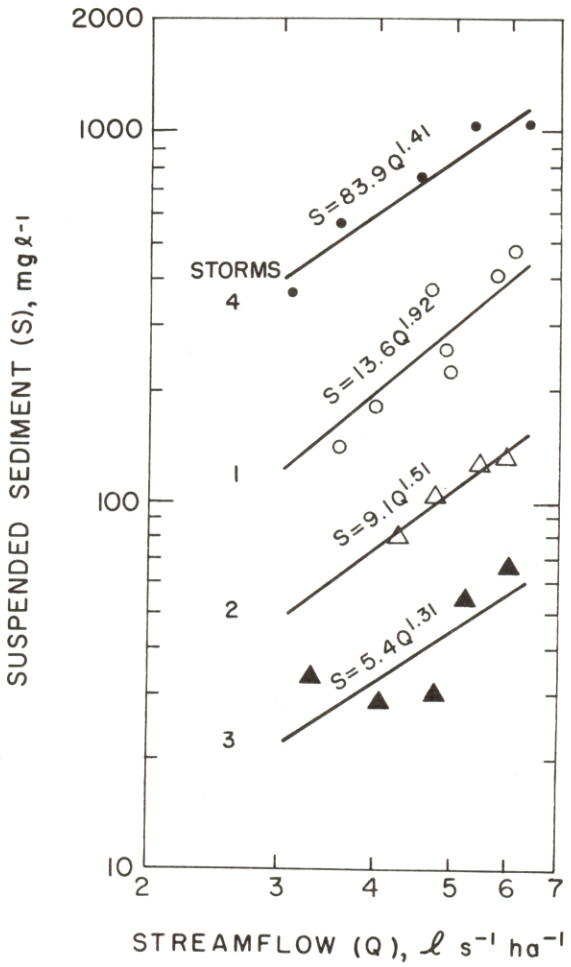
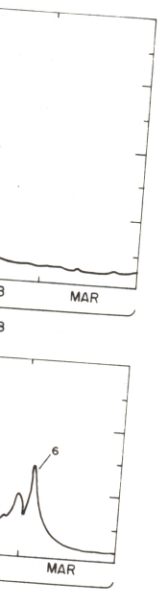


FIGURE 3. Relation of suspended sediment concentration to streamflow from 3 to 6 l s^{-1} ha^{-1} during the rising limb of storm hydrographs at Flynn Creek, Oregon Coast Range.



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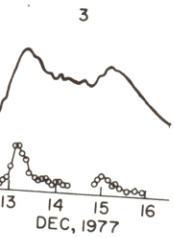

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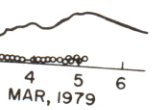

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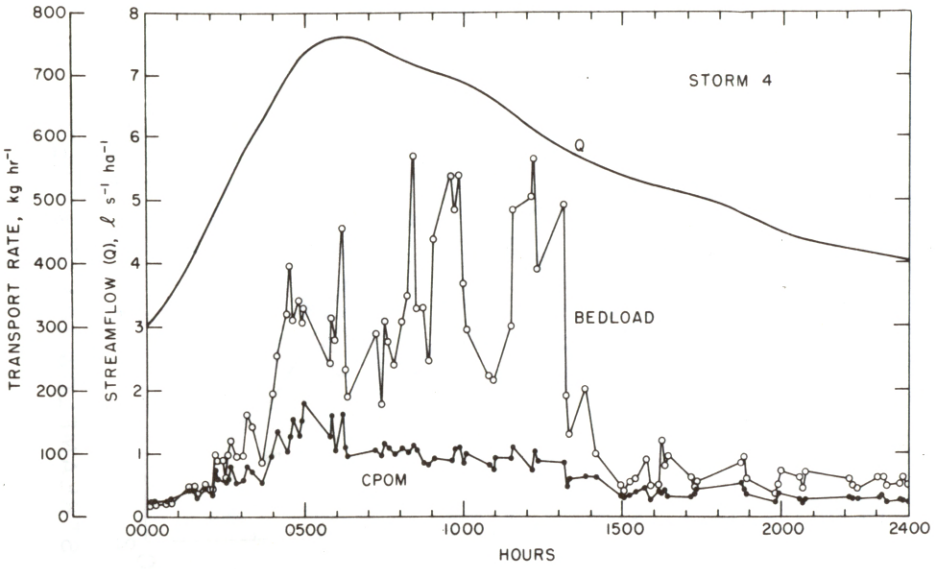

FIGURE 4. Bedload and coarse particulate organic matter (CPOM) transport for the storm of February 7 1979, at Flynn Creek, Oregon Coast Range.