Upland Research Needs in the Southern California Inland/Coastal Sediment System[1]

Brent D. Taylor[2]

Abstract: For the past several years Caltech in cooperation with several agencies has been studying the regional sediment system in coastal southern California. The first key element in this system are the upland catchments which deliver geological debris to low-lying inland areas and the shoreline. Through the Caltech study quantitative estimates have been obtained for upland sediment yields, and four important areas for further research have been identified.

One of the important dynamic processes in the natural environmental system in southern California is sediment movement. This movement, or system of movements, involves the continual relocation of surface geological materials -- erosion from upland catchments, delivery of this material to inland depositional areas (alluvial fans, valleys, coastal plains) and to the coast, though in some cases, even under natural conditions, the coastal deliveries are deposited in marsh or lagoon areas and many never reach the shoreline. Sand-sized material delivered to the shoreline is transported up and down coast by ocean waves and currents and thereby forms and nourishes beach areas. Eventually much of this sand is lost to offshore areas via submarine canyons (Chamberlain 1954), and by other processes. Finer silt and clay particles, which constitute the major part of the sediment load delivered to the ocean, do not deposit at the shoreline but are carried offshore and deposited outside of the surf zone.

During the past five years a research group at the Environmental Quality Laboratory at the California Institute of Technology, in conjunction with the U.S. Forest Service and other agencies, has been studying the coastal sediment system in southern California. Primary objectives in this study have been to quantitatively define 1) sediment movements under natural conditions, and 2) the effects of man-made inland and coastal structures on this system.

LITTORAL CELLS

Along a coastal section natural conditions often define a reach of coastline that is essentially independent of upcoast and downcoast conditions. The inland and coastal sources of beach nourishment are local, as are also the sand losses from the system.

Inman and Brush (1974) have identified five such littoral cells in coastal southern California. The identification of these natural coastal sediment units provides a basis for studying the coastal sediment system in large enough scale to treat all upcoast (upstream) influences on local conditions.

In studying the sediment system in each littoral cell, and quantifying sediment budget factors, the first step in the CIT study has been to treat upland sedimentation processes and the flux of sediments yielded from geologically erosional areas, in each of the five littoral cells.

UPLAND SEDIMENTATION PROCESSES

The Caltech study has led to the development of detailed estimates of upland catchment sediment yields throughout the coastal drainages in southern California (Taylor 1981).

While these study results help considerably in quantitatively defining the coastal sediment system in this area, they do not treat some important questions pertaining to upland sedimentation processes. Through this study, however, there has been a sharpening of focus on needed follow-on research. This research can contribute substantially to regional management practices as well as basic understanding of upland sedimentation processes.

Field information and data indicate that throughout the coastal drainages in southern California, there are six dominant processes active in sediment erosion and transport. Three of the processes involve the independent movements of particles; and three are mass movement processes. Individual particle movements include dry 'ravel' (miscellaneous particle movement down slopes), and rainsplash and rill and channel hydraulic transport, which are wet processes.

Mass movements include soil creep, which is essentially a dry process, sediment flows under wet conditions, and landslides that can be initiated by both wet and dry conditions.

[1]Presented at the Symposium on Dynamics and Management of Mediterranean-type Ecosystems.

[2]Member of Professional Staff, Environmental Quality Laboratory, California Institute of Technology, Pasadena, Calif. 91125.

Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982.

While all of these six processes appear to be active in the coastal drainages of southern California, the relative importance of each process must vary from one location to another. As an example, qualitative information indicates that soil creep is quite active in the Palos Verdes area but that sediment flows in this area are rare, Whereas in the San Gabriel mountains there is only scanty evidence of soil creep, but sediment flows are common.

In identifying the relative importance of individual processes a practical description would include:

1. Mass scale of process
2. Characteristic distance of movement
3. Time scale of process
4. Temporal and spatial frequency of occurrence.

A more complete description would also include:

5. Conditions of occurrence
6. Mechanics of movement.

The first four items are sufficient to quantify a particular process. The latter two items provide understanding of why and how the process takes place.

In Table 1, general estimates based on limited field data and observations in the southern California region are given regarding items 1,2, and 3 for each of the six sedimentation processes identified. With available data, it is not possible to accurately estimate item 4 and thereby estimate the relative importance of individual processes for the region. The first area of research to be identified, then, is the need for quantitative field studies that will define the relative importance of the six dominant sedimentation processes in affecting sediment yield.

Douglas L. Morton[3] of the U.S. Geological Survey has initiated studies of this kind in mapping recent mass movements in the western Transverse ranges. Radbruch and Crowther (1973), also, have prepared a map classifying local areas as to their relative susceptibility to surface mass movements. This map was prepared during a 3-month period with a very limited data base, and it was intended by its authors only as a first-order approximation, to differentiate between areas of most mass movement and least mass movement. While this map is neither quantitative nor detailed, it presents a useful first step.

In addition to these studies there need to be complementary studies of some of the basic mechanisms of the six sedimentation processes. Such studies would involve both laboratory and field-type investigation. A primary research topic in this category is the mechanics of sediment flows. Sediment flows are common in coastal drainages in southern California, especially in the northern part of the study area. Sediment flows vary over a wide range in volumetric magnitude, frequently causing property damage and jeopardizing human safety, below burned catchments. The mechanics of these flows are not well understood, e.g. conditions that initiate movement; flow velocities as a function of material size, water content, and channel characteristics (slope, etc.); and amplification

Table 1--Characteristics of Dominant Sediment Erosion and Transport Processes in Southern California.

Sediment Movement Process	General Time Scales	General Mass Scales	General Distance of Movement
Ravel	seconds [1]0(100s)	Millionths of a Kilogram $0(10^{-6}$kg)	meters $0(10^{0}$m)
Rain splash	tenths of a second $0(10^{-1}$s)	Millionths of a Kilogram $0(10^{-6}$kg)	centimeters $0(10\text{-}^{2}$m)
Rill and Channel Transport	minutes $0(10^{2}$s)	Millionths of a Kilogram to Thousands of Kilograms $0(10^{-6}\text{-}10^{4}$kg)	kilometers $0(l0^{3}$m)
Creep	years $0(10^{7}$s)	Hundreds of Thousands to Tens of Millions of Kilograms $0(10^{5}\text{-}10^{7}$kg)	centimeters per year $0(10^{-2}$ m/yr)
Landslides	seconds $9(10^{0}$s)	Kilograms to Tens of Millions of Kilograms $0(10^{0}\text{-}10^{7}$kg)	tens of meters $0(10^{1}$m)
Sediment Flows	seconds $0(10^{2}$s)	Kilograms to Tens of Millions of Kilograms $0(10^{0}\text{-}10^{7}$kg)	hundreds of meters $0(l0^{2}$m)

[1]0( ) means “on the order of . . .,” i.e. approximate value within plus or minus a half power of ten of the indicated number.

[3]Personal communication.

or diminution of flow volume along the path of movement. This is a second area of needed research.

Superimposed upon the set of six basic sedimentation processes, in southern California, are the effects of the regular occurrence of fire. In general, fire increases the short-term sediment yield in a catchment, but specific effects vary depending on local conditions.

Fire effects on sedimentation processes were first studied statistically in southern California by Rowe and others (1954). This study included sub-regional estimates of fire effects on catchment sediment yield. Since this study in the early 1950's, a lot more field data have been obtained. It would now be profitable to do a more detailed statistical analysis of fire effects data. Such a study could provide improved estimates of effects of fire on catchment sediment yield. Also, in specific areas there may be sufficient field data to begin to identify the relative effects of fire on one or more of the six regionally dominant sedimentation processes.

A fourth research question identified in the Caltech study deals with the routing of sediment in primary and secondary channel systems on upland catchments. Of particular interest is the quantitative relation between storm hydrology and the delivery of sediment from hillslopes to the channel system versus the movement of sediment in the channel system and its delivery to the mouth of the catchment.

Limited field observations suggest that during dry or moderate rainfall years, more material is delivered by the channel system to the mouth of the catchment, and thus there is channel aggradation and temporary storage. Conversely, during wet years and particularly during severe storm periods, there is significant channel scour, indicating that more material is delivered to the mouth of the catchment than is brought into the channel system from the hillslopes. This wet/dry channel cycling may be due in part to the loss of riparian vegetation and consequent streamlining of the channel during severe floods. On catchments where this channel unloading takes place during severe storm years, the volume of storm debris may be significantly increased depending on conditions during the intervening years since the last major event. Results from this study could assist in assessing annual flood potential on individual catchments.

SUMMARY AND CONCLUSIONS

In summary, the environmental system in coastal southern California involves the continual relocation of surface geologic materials. Under natural conditions erosion from upland catchments delivers an average of some 12 million m^3/year (6 million m^3 of fine material, 5 million m^3 of sand, and 0.8 million m^3 of gravel and boulders) to alluvial fans, inland valleys, plains and coastal areas. Sand-sized material delivered to the shoreline is moved up or downcoast at net rates generally between 100,000 and 1,000,000 m^3/year, in the five littoral cells. This longshore movement forms and nourishes beach areas. Eventually this sand is lost through natural processes, to offshore areas.

The first key element in this coastal system is the inland erosion and delivery of sediments from upland catchments. Through studies at Caltech over the past few years, wherein aggregate estimates of regional and sub-regional sediment yield have been obtained, four areas for further more-detailed research have been identified, as follows:

1. Field studies are needed to quantitatively identify the relative importance with regard to sediment yield of the six sedimentation processes common in this area.

2. Pioneering studies on fire effects by Rowe and others (1954) should be updated and improved upon with currently available data.

3. Laboratory and field studies should be undertaken to study the mechanics of sediment flows.

4. There should be a research investigation of wet/dry-year cycling of sediment storage in the primary and secondary channel systems on upland catchments.

Results obtained from the four areas of research identified could contribute substantially in improving upland management practices, as well as enlarging our understanding of regional sedimentation processes in coastal southern California.

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