Water Resources Division
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January 12, 1965

Memorandum

To: Mr. Frank E. Clark, Chief, General Hydrology Branch
　　　Thru: Area Hydrologist PCA

From: Valmore C. LaMarche Jr., WRD, Menlo Park California

Subject:　　　PUBLICATIONS - Report. "Slope denudation and sediment yield in the San Gabriel Mountains, California", by Valmore C. LaMarche Jr., for the Annual Review.

The subject paper is being submitted for approval for publication in the annual volume entitled Geological Survey Research.

Enclosed are the original manuscript and one copy of each of 3 Illustrations together with the manuscript routing sheet.

　　　　　　　　　　　　　　　Valmore C. LaMarche Jr.

Enclosures

cc: Area Hydrologist, PCA

Slope denudation and sediment yield in the San Gabriel Mountains, California

By Valmore C. La Marche Jr.
Menlo Park, California

Abstract. Slope denudation has deeply exposed the root system of a 1,400 year-old limber pine In the San Gabriel Mountains. The estimated denudational rate is equivalent to an average sediment yield of 4 acre-feet per square mile per year. Sediment yield from nearby small drainage basins, calculated from 40 years of reservoir sedimentation records, approaches this long-term average rate.

Debris-laden flood waters from rugged mountain watersheds In southern California have repeatedly threatened adjacent valley areas. Numerous studies related to sediment sources and movement have accompanied watershed treatment and Installation of flood - and debris - control structures (Sinclair, 1954). Prediction of future sediment yield from the" watersheds is based on records of reservoir sedimentation obtained mainly since 1925. It is interesting to compare those recent sediment-yield data with an independent estimate based on actual reduction of the level of the ground surface within a major, watershed.

Evidence of long-continued ground surface decline is provided by the deep exposure of roots of old limber pines (*Pinus flexilis*) on Mt. Baden-Powell, in the northern San Gabriel Mountains (Fig. 1). Here. limber pines and lodgepole pines (*Pinus contorta*). accompanied by scattered shrubs, form an open subalpine forest at altitudes above 9,000 feet. The trees grow on a rocky soil that forms a thin mantle over the highly fractured gneissic bedrock. The old limber pine are concentrated on the crest and northwest slope of a ridge that extends northeastward from the summit. The root systems of several old trees along the ridge-crest how been deeply exposed by slope denudation. Measurements of root exposure and increment cores for tree-ring dating were obtained from one of these pines In order to estimate the local denudational rate.

The tree is now perched over the precipitous (45°) southeast slope of the ridge (Fig. 2). This slope is in the drainage of the East Fork of the San Gabriel River. Two major lateral roots extend parallel to the ridge-crest, but in opposite directions. A third rout extends directly down the gentler (20°) northwest slope, which is drained by a tributary of Rock Creek, a northward-draining ephemeral stream. Thus, the tree straddles the-main east-west drainage divide of the San Gabriel Mountains. The main stem of the tree is nearly vertical. This indicates that, despite its precarious situation, the tree has not been shifted or tilted. The widespread system of exposed lateral roots outlines the approximate shape of the ground surface as it existed when the root system developed. Reconstruction of this original slope profile (Fig. 3) shows that the ridge-crest has shifted westward and that 8 to 10 feet of soil and rock have been removed from the steeper slope within the lifetime of the tree.

The time that has elapsed since the root system developed can be estimated by counting the annual rings exposed in cores taken with a standard increment borer. A 24 inch-long core from one me stem contains approximately 1,000 rings. The total radial growth is estimated as 36 Inches. If the early growth rate was between 2 and 4 inches per 100 years, the 12 inches of missing growth record represents 200 to 600 years. This leads to an age estimate for the tree of 1,400 (± 200) years. A root core was also obtained. The root axis is only I inch from the bare upper surface of the 1 foot-high root. The root has the same form and mode of origin as the buttress roots of other old pines (La Marche, 1963). The innermost ring was formed about 1,100 years ago and the upper surface of the root was first exposed from 100 to 200 years later.

Combining the age of the tree with the depth of exposure yields an estimate of the average denudational rates in the vicinity of the tree during the past 1,400 years. On the steep, southeast slope, 8 to 10 feet of vertical lowering of the ground surface corresponds to a denudational rate of from 5.8 to 7.1 feet per thousand years. On the opposite slope 2 to 3 feet of denudation took place, at the rate of 1.4 to 2.2 feet per thousand years. Two lines of evidence show that the rapid retreat of the steeper slope is not due to a local catastrophic event, such as a rockfall or slide. First, several old trees along the ridge-crest, over a distance of a thousand feet, show similar asymmetrical root exposure. Second, the buttress forms of all of the living lateral roots suggest that denudation has been a continuing, gradual process.

Slope denudation can be related to sediment yield. If the rock debris produced by a drainage basin is derived directly from the component slopes then the annual sediment yield is obtained simply by multiplying the annual depth of denudation by the total drainage area (neglecting possible changes in bulk density). Although sediment storage on lower slopes and flood plains may reduce not sediment yield, and accelerated channel erosion can cause high yields, it is clear that sustained sediment yield depends on denudation of the slopes that make up met of the area of a typical mountain watershed.

Conversion of the denudational rates cited above to estimates of annual sediment yield gives figures in the range of 3.7 to 4.5 acre-feet per square mile for the steep slope in the San Gabriel River drainage and 0.9 to 1.4 acre-feet per square mile for the slope an the opposite side of the divide. Denudational rates along the ridge-crest am thought to be representative of the" on the adjacent slopes, as demonstrated by results of similar studies elsewhere. Thus, these estimates of long-term average sediment yield can be compared with the measured sediment production of nearby watersheds.

Modern rates of debris production of drainage basins in the San Gabriel Mountains are relatively well known. Lustig (1964) gives data for 6 basins ranging from about 3 to 82 square miles in area. The average annual sediment yield during the past 30 to 40 years ranges from 1.27 to 4.00 acre-feet per square mile. He finds that sediment yield is highly correlated with several topographic variables. In general, sediment yield per unit area of drainage increases with increasing average slope angle and with decreasing drainage basin size. Schumn (1963, p. 3) cites a sediment-yield figure of 29.95 tons per acre per year for the 1.06 square-mile Halls Debris Basin. This is equivalent to about 5.5 acre-feet per square mile.

Although none of the basins includes the Mt. Baden-Powell area, the overall similarity in topography, bedrock, climate and soils should be reflected in a similar response to erosional processes. Thus, the long-term sediment yield calculated from direct evidence of ground surface lowering is within the present range of values expected for the steep headwater part of a small drainage basin in this region. It is concluded that the 40-year record of reservoir sedimentation In the San Gabriel Mountains gives sediment-yield values that approach the probable long-term average.

References

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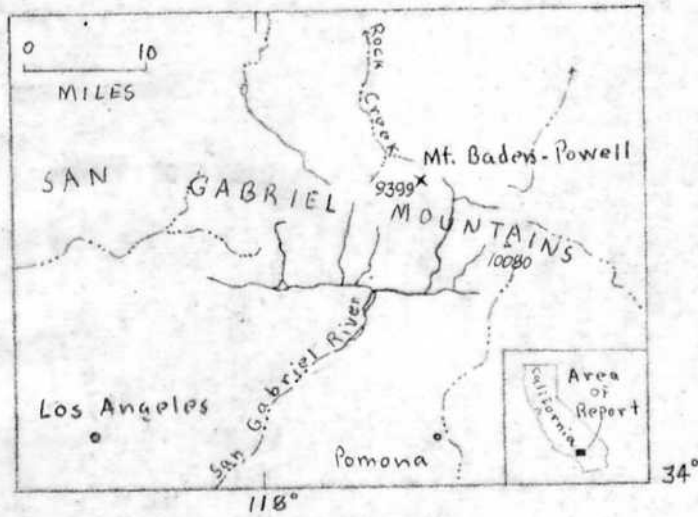
Figure 1.

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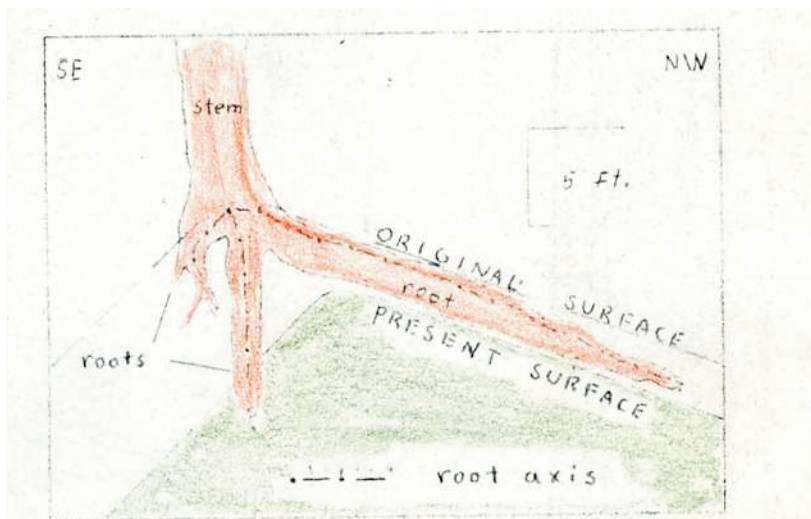San Gabriel Mountains, California"

Figure 3.

in " Slope denudation and sediment yield
in the San Gabriel Mountains, California"

Figure 2.- Stereoscopic view of exposed root system
of 1400 year-old limber pine.

V.C. LaMarche, Jr., Slope denudation and sediment
yield in the San Gabriel Mountains, California