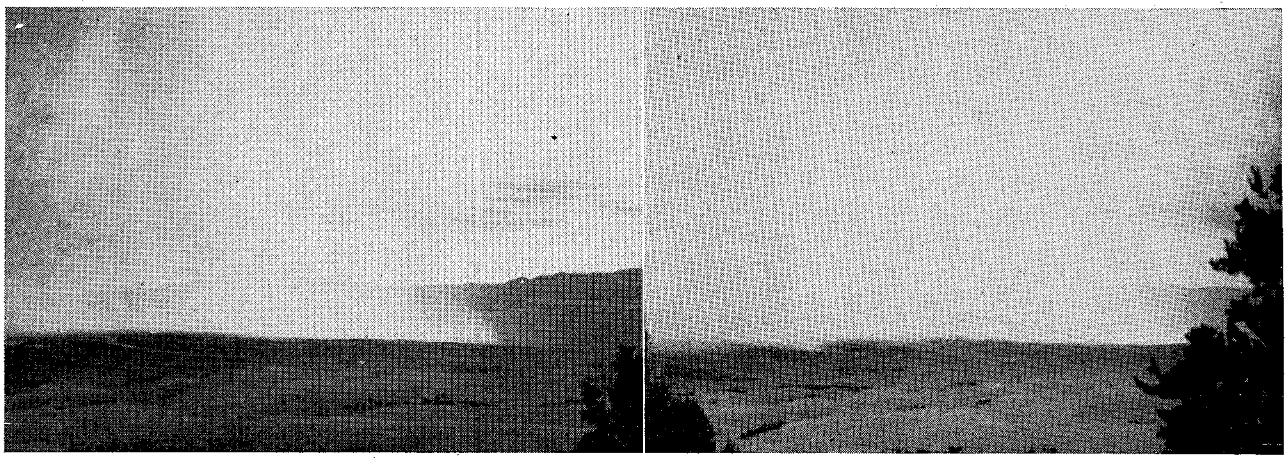


Typical summer storm starts in high-desert country; three minutes later creeks begin to flow.

by RICHARD H. JAHNS

Desert floods

Not many people see them—
but those who do never forget them

IT WAS a 15-foot wall of water, moving toward us about as fast as a man could run. We had crossed the wash only a few minutes before, when already we could hear the roar of the flood not far upstream. It passed us with a rush, making such a commotion that you couldn't hear a man yelling right into your ear. It was about midnight and too dark to see much in detail, but the front of the water was nearly vertical, and huge granite boulders and chunks of trees kept dropping over its edge. This edge was much higher in the center than along the sides of the wash, and it didn't seem possible that water could have such a slope. The whole business moved on down the channel, giving us the feeling that nothing could stop it this side of Glendale."

As he spoke of the great débris wave that poured from Blanchard Canyon during southern California's New Year's flood of 1934, this resident of La Canada Valley seemed scarcely disposed to believe what he had actually seen.

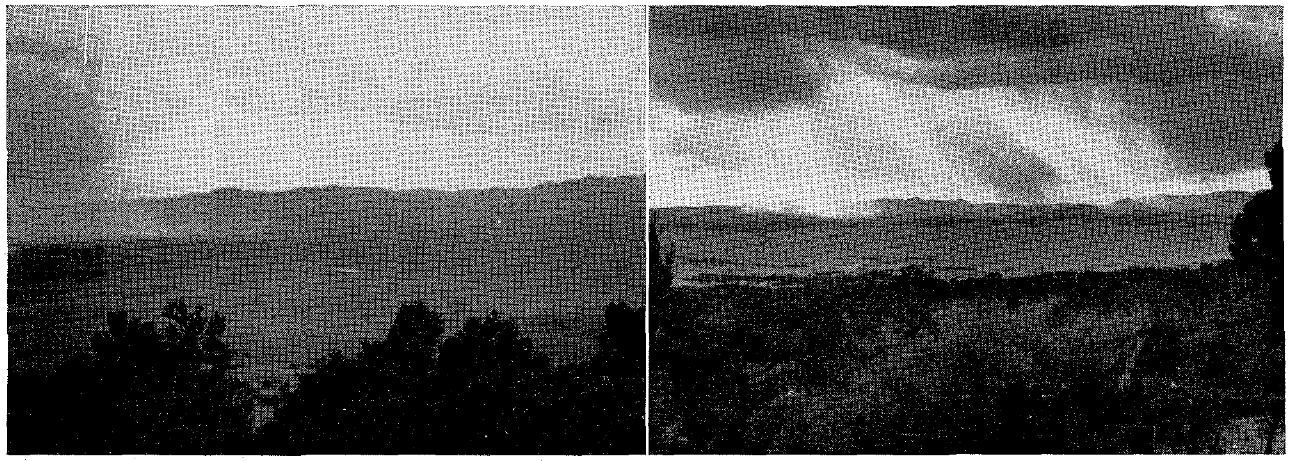
Anyone who happened to be out of doors in this area on that particular New Year's Eve, had a rare opportunity to observe one of the principal features of the desert flood—the débris wave—and to see that previous reports of such things as "vertical walls of water," "thunderous roaring," and "irresistible force" were not just the dubious products of overactive imaginations. Such eye witnesses often are later troubled with doubts, and the nightmarish qualities of such floods may well cause them to question the intrinsic reliability of their own observations.

Few persons *do* see such things, it is true, and yet spectacular floods are quite characteristic of arid and semiarid country. They are even responsible for many familiar features in the desert landscape. The infrequency of such floods, their most common occurrence in sparsely populated areas, and the unpleasantness of the weather generally associated with them cause many to pass unobserved. Few have been described in detail, and rarely do conditions permit their inclusion in the photographic record.

The word "desert" is used here in its most general sense—which of course is contrary to that preferred by organizations like the Los Angeles Chamber of Commerce and the New Mexico Boosters. Much of the southwestern United States is arid or semiarid country, and ranges from such true deserts as the Colorado, Papago, Gila, and Mojave to areas of intense cultivation and considerable settlement. Development of the latter generally is founded upon the introduction of water from nearby mountain areas or from more distant rivers. Much of the desert country is characterized by profound contrasts of landscape and climate. Ranges in altitude are great, and commonly occur within short distances. Deep, precipitous canyons drain rough, mountainous country in some places, and high, rolling tableland in others; in turn they debouch onto relatively flat-floored valleys. Bold mountain scarps that rise to heights of 4,000 feet or more are by no means rare.

Temperatures are high, in both winter and summer, and daily and longer-term temperature ranges are great. Strong winds are common during certain seasons. Annual precipitation and humidity are low except in the highest mountains and near the southern California coast. On the other hand, heavy rainfall in the most arid regions results from single storms in some years. Much of the country is so dry that all streams are intermittent, and indeed rarely flow, but elsewhere the desert areas are traversed by large rivers fed from distant sources. Nearer the coast are mountain masses that capture enough moisture from the air to supply small perennial streams of their own.

Whether wet or dry, the stream courses are everchanging in their appearance, and it even seems that the longer the periods of their inactivity, the more catastrophic are the changes wrought by the following floods that traverse them. Even the permanent streams vary considerably in their behavior from one season to another. In his *Southern Sierras of California*, Charles Francis Saunders speaks feelingly of the changing moods of



Six minutes later storms begins to move off; 15 minutes later storm has passed, sun is shining.

the Big Tujunga, in the San Gabriel Mountains of southern California:

> During storms, and for days afterward, it goes thundering and gnawing at its banks, ripping out trees, undermining rocks and cracking them together till the sparks fly, rolling great boulders around like marbles. The stream may then be a hundred feet across and twenty deep, and the sound of its fury may be plainly heard a mile away; but with the passing of the rainy season its passion is forgotten, and in July, following its tortuous course for miles, I found it in tenderest and most lovable mood. Now it would be rippling past gravelly beaches open to the sun, now idling in the still shadows of cottonwood and willow; now, slipping round a corner, it would widen out and sparkle through a setting of sedgy mead under perpendicular white cliffs, suggesting a miniature Yosemite and returning echoes to my call; again dropping musically by proper little cascades from rocky shelf to shelf, it would gather comfortably in drowsy lins of restfulness.

He also points out, however, that most of the streams "prove on inspection to be, during eight or nine months of the year, little more than floods of sand littered with cobbles, where lizards bask and snap up flies and top-knotted quail toe about dry-shod."

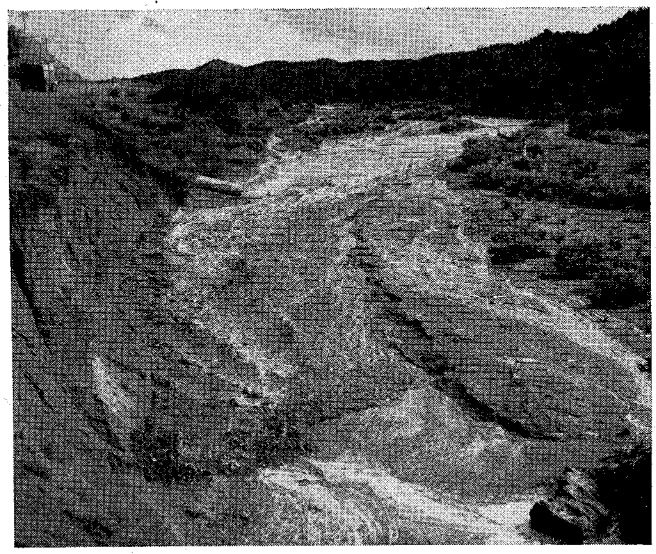
Desert floods typify a land of contrast. In most areas they are rarities as measured by human standards. Geologically, however, they are common and recurrent features, and represent the chief mechanism for the erosion of the mountain ranges and deposition of sediment in the lowland areas. These floods usually result from torrential downpours of the cloudburst type, which develop either from cyclonic storms or, more commonly, from thunderstorms. The cloudbursts ordinarily are irregular in distribution, affect rather small areas, and involve short-time precipitation of exceptionally high intensities. A downpour at Opid's Camp, in the western San Gabriel Mountains, seems to hold the all-time record of slightly more than one inch of precipitation in a period of 60 seconds during the early morning of April 4, 1926. Reports of half an inch in five to ten minutes are by no means rare, and doubtless cloudbursts of even greater intensity have gone unrecorded in more remote regions.

The distribution and duration of a typical summer thunderstorm in the "high-desert" country of southwestern New Mexico are shown in the pictures above. This small storm generated a cloudburst of the type known as a "saddle-blanket shower," in tongue-in-cheek testimony of the oft repeated statement that such a blanket would cover the wetted area. Thunder clouds gathered over a period of about 35 minutes during the early afternoon of an August day in 1942, and suddenly precipitation began over a well defined area of not more than four square miles. The storm shifted in a rather irregular path, but in general travelled slowly from northwest to southeast. Within a few minutes of the original downpour, water began to course down several of the dry creek beds. Within 15 minutes the storm had passed, but some of the creeks continued to flow for as long as half an hour.

In many regions where there is some cover of vegetation and where stream gradients are not very steep, cloudbursts of moderate intensity result in rather quiet, "orderly" floods. In one such flood the waters of a creek, which "came down" as a result of a thunder shower in the Black Range of southwestern New Mexico, were nearly free of debris, and did not disturb the coarse gravels or even the low bushes in the stream bed.

In some contrast was the flow of a larger stream a few miles to the north. The waters, derived in greater abundance from the same storm, formed a débris-laden front that traveled down the valley at a rate of about five miles per hour. As shown on page 12, they coursed down a channel whose bottom was marked by sun-cracked and hoof-printed mud, only partly dry. The front of the wave was distinctly higher and steeper on one side of the channel than on the other, apparently because the water there was more heavily freighted with stones, fragments of vegetation, and other detritus. As more and more solid matter was picked up from the bottom and from caving banks of the wash, the forward progress of the water in contact with the bottom was slowed distinctly. Relatively clear water, traveling faster at positions higher in the wave, constantly flowed over the débris-rich portion as a sort of waterfall, only to be in turn slowed by additional débris picked up from the dry stream bed. In this way an essentially vertical wall of water was maintained to a height of about eight inches. Some of the relatively clear water at the surface of the flow reached the front of the wave as series of low, relatively fast-traveling ripples, most of which were 50 feet to more than 200 feet apart.

As the water approached the observation point, a separate lobe began to develop, and to travel more



In torrent of silt-choked waters well-defined waves gnaw at bank of this arroyo near Santa Fe, N.M.

rapidly than the remainder of the front (right below). This lobe was marked by a distinctly lower frontal wall, evidently a reflection of a relatively lower content of solid matter. This in turn may well be ascribable to the course of this lobe over mud and gravel of the stream bed that was still wet from a previous flood, and that hence contained relatively little loose material. Upstream from the front of the flood waters, the surface of the flow rose gently for a distance of at least 150 feet, where the water had an average depth of about four feet. The general flood crest fell rather rapidly, however, and within an hour the water was only three inches deep and fairly free from solid matter.

Damaging Flood Waves

Though fascinating to watch, neither of the floods noted above was particularly unusual, as neither overtopped the banks of the arroyo in which it flowed. On other occasions both of these streams have developed damaging flood waves in response to much more severe storms. Their banks were overtopped, meadow and pasture lands were gutted and rilled, some boulders were strewn on their surfaces, dwellings and other buildings were broken into by the flood waters and partly banked with débris, and there was some loss of life.

A rather energetic series of flood waves was observed in June 1948, north of Santa Fe, New Mexico, where a large arroyo drains an area underlain by soft, fine-grained rocks. The flood waters hence contained no boulders, but instead formed a reddish-brown, mud-choked torrent. The soft banks of the arroyo were vigorously attacked, and from time to time great masses of the bank material dropped into the rapidly moving waters. Large and distinct waves marked the flood. These were spaced 25 feet to more than 100 feet apart, and in general were three inches to two feet high. Most appeared to travel by the same rolling mechanism as that described above for a less tumultuous flood. In the last stages of the flow, individual waves were travelling over moist ground with very little surface water.

Of somewhat different aspect are the rare floods of the most arid, desert parts of the Southwest. These generally stem from sudden and violent storms on steep, rough slopes with little vegetation, and the waters rush down dry canyons in which all sorts of detritus may have accumulated for years. Thus an abundant supply of boulders, rubble, and other débris usually is incorporated with the flowing water to form flood waves that may contain as much as 90 percent solid matter. These are known as mudflows or débris flows. They behave as viscous liquids, and hence travel much more slowly than clear water. Some mudflows contain more solid matter than others, the ratio of liquid to solids depending largely upon such local conditions as topography, stormwater supply, and type of rock.

I was fortunate enough to witness a rather spectacular mudflow in the extremely dry country about 30 miles northeast of Parker, Arizona, in January 1943. A cloudburst of unusual magnitude was indicated by a formidable display of lightning and thunder in a very heavy overcast that enveloped a part of the nearby mountain range. No rain fell at the mine I was visiting, but within an hour there was a great roar in an adjacent steep-walled canyon, which emptied onto a valley flat at the base of the range. At first dull and punctuated only now and then by booming sounds, this roar became almost deafening even before the flood appeared.

The flood was an awesome sight. A dark reddish-brown mass of water-lubricated débris moved—very slowly, it seemed—down the last tortuous part of the canyon. It formed a curving, but extremely steep wall, which must have been about 35 feet high at the point where it burst from the narrow mouth of the canyon. Masses of rock more than 30 feet in maximum dimension cascaded down this front and quickly disappeared from view beneath its base. The entire mass moved much like wet concrete, and its tremendous bulk and leisurely pace gave it an appearance of almost irresistible force.

Flood waters course down bed of New Mexico creek; one lobe advances more rapidly than rest of front.

A feature of peculiar fascination was a series of dust clouds that rose from the sides of the flow, where dry soil and rocks of the canyon walls were sheared off by the moving mass. It was not unlike puffs of dust rising from the hopper of a rock crusher.

Patches of soil, mats of brush, branches and even trunks of cottonwood trees, and boulders of many sizes floated along the upper surface of the flow, and in the more turbulent places they bobbed up and down or even were briefly tossed into the air. Evidently these masses were very buoyant in the heavy, sludge-like "liquid" of water and ill-sorted débris, and were held up also by the almost solid mosaic of rock fragments between them and the bed of the wash. Waves more than eight feet high traveled slightly faster than the front of the débris flow itself, and succeeded one another at intervals of 50 to 100 feet.

After the initial wall of the flow had passed, the roaring noise diminished perceptibly in volume, but by no means was it less than a roar. The part of the flow that succeeded the front became progressively richer in water, and behaved more and more like an ordinary stream. Each succeeding wave, however, obviously was more heavily freighted with solid fragments.

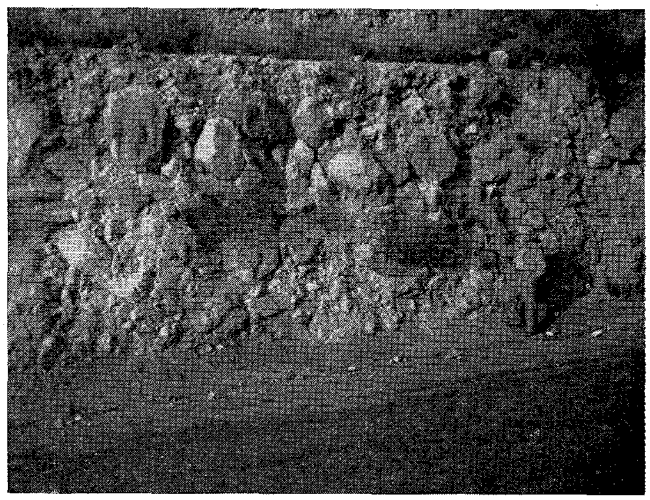
It was impossible to follow the initial flow as it spread out along the valley floor, but inspection a short time later indicated that it had come to a halt about a mile from the canyon mouth. Evidently it had fanned out somewhat and had stopped when enough water had soaked into the dry sand and gravel of the valley floor to reduce internal lubrication materially. In this, its final position, the front was very steep and about 15 feet in average height. The top of the flow, which dried within a matter of a few hours, was studded with boulders, most of them several feet in diameter. It was also marked by large wrinkles, generally six inches to more than two feet high, that lay essentially parallel to the margin of the flow.

The steep front of the original flow had been breached in several places by later flows of more liquid material, and each of these had in turn been "dried up" and hence halted a short distance beyond. Perhaps each of these successive flows was represented by one of the huge, débris-laden waves that had been seen in the canyon proper. It was interesting to note that nowhere was any stream of water issuing from beneath the halted mudflow, nor was there evidence of free water at any other point examined. Digging beneath the outer margin of the principal flow disclosed patches of essentially dry sand and gravel that evidently had been incorporated into the flow from the surface over which it traveled.

In desert floods there appear to be all gradations between the mudflow, with a maximum proportion of solid particles lubricated by some water, to relatively clear water with much greater velocity and tremendous cutting power. The latter is much more common along the lower courses of large, well defined lines of drainage, especially those with perennial streams. It also occurs in conjunction with mudflows—either preceding or succeeding them, or both. The timing of the two are easily evaluated.

The mudflow deposits are characteristically poorly sorted and stratified, consisting as they do of a jumbled mass of sub-angular fragments. In contrast, the deposits of more ordinary flood waters are sharply bedded, and are composed of rather well sorted particles of sand, silt, and gravel. Where desert-flood sediments are exposed in cross section, they commonly comprise interlayered deposits of the two general types.

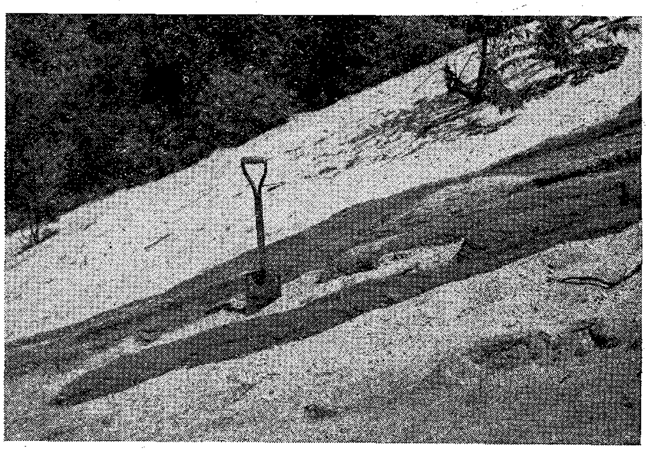
The desert landscape is constantly being modified and adjusted by floods of varying degrees of intensity. Complex, generally steep-walled canyons are carved into the bold mountain masses, and broad, fan-like accumulations of rock waste are built outward from their mouths where the streams spread onto the flatter valley floors. The alluvial fans that fringe the southern margin of the San Gabriel Mountains are excellent examples of these accumulations, and many others border the mountain ranges of the Mojave Desert and areas far to the north and east. These fans are characteristically cone-like in form, with slopes that gradually steepen upward toward the mouths of the canyons from which they were built.



This jumbled mass of granite boulders is a typical mudflow deposit in the alluvial fan near Pala, Calif.

The fan materials are coarsest nearest the canyon mouths, and become progressively finer-grained as traced away toward the central parts of the valleys. The fans themselves generally coalesce along mountain fronts to form an apron-like deposit of coarse detritus. As time goes on, their surfaces are continually modified by flood waters, and they show abundantly the effects of this trimming, rilling, and incising. Ordinarily, for example, a mudflow is never reactivated, once it has come to a stop; instead, subsequent flood waters gradually form trenches and channels in it, and at later times their own mudflows course through these channels before coming to a halt farther down the slope.

The surfaces of some alluvial fans are marked by



Sand flows duplicate mudflows in all but violence.

Avawatz Mountains — typical desert mountain range.

perennial streams, whereas others are not wetted by flowing water for periods of months or years. Few real changes are made in the general appearance of any of the fans, however, except during times of extraordinary floods. It is then that large mudflows debouch from the canyon mouths, or tumultuous streams with relatively little solids cut actively into the surfaces of the fans. The amount of material transported during a single flood can be very great. During the New Year's flood of 1934, for example, the waters of Pickens Creek, with a drainage basin of only 1.6 square miles, probably laid down at least 70,000 cubic yards of detritus in La Canada Valley. This is sufficient material to cover the Caltech campus to a depth of about 18 inches.

Similar rapid deposition takes place on much larger scales, too. The great mudflow fan from Agua Tibia Creek, in northern San Diego County, California, was once built so rapidly across the valley of the San Luis Rey River that it formed an effective dam. A lake was developed on its upstream side, and remained there until the river could cut headward through the lower part of the fan and drain the valley once again. The fan is shown in the photograph below, right; the mouth of Agua Tibia Creek appears just beyond the reservoir near the upper right-hand corner. The San Luis Rey River flows from the center foreground away from the observer and out of the picture near the upper left-hand corner. The steep-walled canyon cut by this river is clearly shown near the center of the photograph.

Playa Lakes

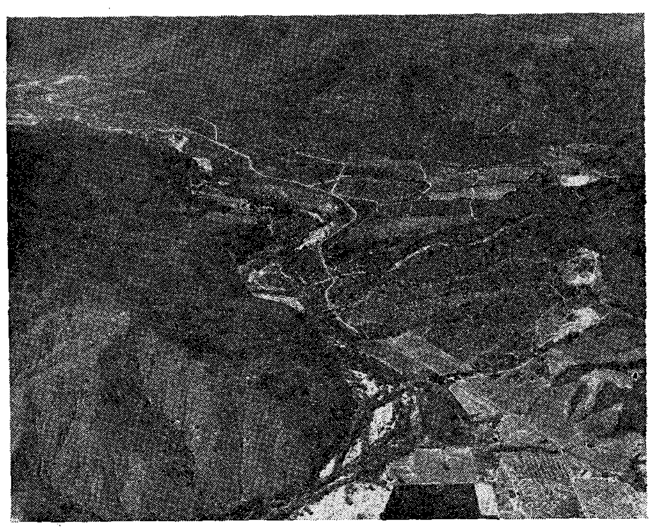
In some desert regions the drainage is internal, and flood waters from mountain ranges flow into lakes, rather than ultimately into the ocean. These playa lakes, most of which ordinarily are dry, are particularly numerous in the Mojave Desert region of southeastern California. They are underlain by thinly bedded silt and clay, but here and there are layers of coarse detritus that represent particularly energetic and long-lived mudflows derived from adjacent mountain masses. Indeed, at least one geologist has shown that individual boulders probably can be skated across the wetted surfaces of playa lakes by unusually brisk winds.

The flooded playas typically have only a few inches of water, even after heavy rains, but some storms are so severe, so widespread, or so long lasting that they introduce extraordinary quantities of water into desert drainage systems. Such a series of storms in 1938 contributed more than eight feet of water to Soda Lake and Silver Lake, in San Bernardino County, California. During this storm, mudflows were rather widespread through much of the Mojave region, but in addition the waters of some rivers contained so little débris that they were able to cut energetically into canyon walls and damage highways, railroads, and buildings.

It is fortunate that most vigorous desert floods occur in regions of little or no settlement. Others, however, constitute unwelcome visitations to populous areas, where they inflict great damage and even loss of life. The relation of floods to human activities in such areas is a difficult and complex problem, but suffice it to say here that such floods will course down the surfaces of alluvial fans and valley plains in the future, just as they have in the past; they will appear on the thickly settled fans that fringe the San Gabriel Mountains and Peninsular Ranges of southern California, just as they will occur in the more arid regions farther east. There is nothing in the records to suggest that future floods will become more frequent or less frequent, as viewed over a long period of time. Their effects, however, will become more and more troublesome as human settlement of any given desert or semi-desert area is continued.

As laconically expressed by the Mississippi Valley Committee, "The ideal river, which would have a uniform flow, does not exist in nature." Departure from this ideal reaches its maximum in arid country. The floods may be less frequent, but many spell an awful finality for those works of man that lie in their path.

A resident of a flood-ravaged valley may not be compellingly interested in knowing whether the wreckage of his home was accomplished by a mudflow that filled it with débris or carried it bodily for a few city blocks, or by a torrential stream that undermined it or simply chewed it to bits; yet these possibilities might well have been considered before he chose a location for his dwelling. He might have studied it with respect to the channels on the surface of the fan, the positions of large boulders and other deposits of previous mudflows, and the general topography and amount of vegetative cover in the nearby mountains. Much of the fan surface may have been modified by the effects of settlement, to be sure, but critical scrutiny from a high place, or even a study of aerial photographs generally will disclose the details of the natural drainage pattern. After all, it is a grand experience to witness a débris flow—but not in your own back yard!



Mudflow fan in San Diego County, near Pala, Calif.