mitted to our complete confidence. But in that one moment we have known the real meaning of science, we have experienced its highest value; unless such knowledge and such experience were possible, science would be without meaning and therefore without truth.

References and Notes

1. Perhaps this statement is not quite true. The system of thought against which Huxley was especially concerned to defend science was theology, and some theological systems rest, not on common sense, but on immediate and fundamental judgments or revelations which are definitely stated to be confined to the elect. Such systems have not the truth characteristic of science. The value of their propositions is determined wholly by principles analogous to the second and not at all by those analogous to the first.
2. I have heard this term used wickedly to denote the form of science which, at the end of the 19th century, was closely associated with the name of Sir Robert *Ball*.
3. E. Rostand, *La Princesse Lointaine*.
4. O. Wilde, *The Decay of Lying*.

Natural and Cultural Aspects of Floods

Paul B. Sears

Nature makes floods, but man makes flood hazards. Although there is no known way to prevent floods, much can be done to minimize flood damage. Protection, not prevention, therefore, is the real problem. Effective protection can come about only from improved land use and management, based on a better understanding, by the general public, of the relation between water, land, and ground cover.

Ordinarily water which has been evaporated from the ocean and moved inland by air falls on land and returns to the sea through stream channels cut by the flow of water. When the amount is too great for the channel to carry, the water rises and spreads out over the land. This we call a flood.

Stream channels swing back and forth as time goes on, producing level plains on each side. These are called floodplains, for the very good reason that they are flooded when the channel cannot handle all the water that is present.

Modern Flood Settings

Like many others of my vintage, I have been observing floods off and on for more than a half-century and have read about many that I have not seen. As far as I can recall, these floods, whether in Arkansas, California, Florida, Mexico, New England, Ohio, Oklahoma, or Utah, had one feature in common. They took place where earth-forms and vegetation gave clear warning that man should be on guard.

Not all floods take place, however, in what can technically be considered flood plains within stream valleys. Thus at Bellevue, Ohio, the citizens long considered themselves unusually fortunate in that they could dispose of their sewage by simply poking a hole in the underlying limestone. Waste, poured into this hole, vanished. That is, it vanished until March 1913—a month of rapidly melting snow and excessive rainfall. Then the good people of Bellevue suddenly found themselves immersed and mysteriously so. They had been taking advantage of an underground river which flowed beneath them through tunnels cut in the limerock. This stream, suddenly overloaded, relieved the pressure by surging upward through the vents they had made in order to get rid of municipal waste.

Another type of destructive flood that does not involve a valley, properly speaking, occurred near Arcadia, Florida, during the rainy season of 1918. Here the Army had established a flying center, known as Dorr Field, in a rather extensive, treeless area. This seemed logical enough at the time. Much of the space was grassy prairie, the rest low-growing scrub palmetto, which could be scraped away by gangs of workmen. There were no troublesome pine trees to be reckoned with, and the whole area was quite flat.

All went well until the rains came. Then, suddenly, the whole post was transformed into a shallow lake, and much valuable property was submerged.

Had the engineers bothered to consult any local naturalist, all of the trouble might have been avoided, for prairie growth is the characteristic vegetation in areas that are regularly flooded during rainy season. Surrounding these prairies, and separating them from the pine flatwoods on slightly higher ground that is never flooded, is a zone of scrub palmetto, covered occasionally by high water. Thus, Dorr Field was bound to be submerged at times.

Today, nearly 40 years later, the growing economy of Florida is pressing upon these same treeless stretches that form the low backbone of the peninsula, not many feet above sea level. This pressure extends to the lower lying marshes and swamps known as Everglades, naturally filled with water the year round. The demand for more pasture and horticultural space is being met by vigorous efforts to drain away both seasonal and permanent water into the surrounding seas. This means, at times, an abnormal load of water moving through almost level land and across the densely populated and highly developed seaside margin of the state. The problem thus created is obvious, and the cultural element in it, equally so.

Lower mountain slopes in California, Utah, and Colorado provide a somewhat different example. Mountains wear away through the ages, of course, and lowlands are built up by virtue of this process. But the process becomes catastrophic when the mountainside vegetation that normally restrains the violence of moving water is destroyed by fire, excessive grazing, or the plow. When this occurs, not only does water pour down in abnormal volume, but rocks of incredible size are converted into rolling missiles, that wipe out homes and schools, orchards and roads.

An excellent example of this phenomenon can be observed in the Wasatch Mountains north of Salt Lake City. Here are two steep watersheds, side by side. One has been protected from the time of settlement, since it provides a municipal water supply. Its vegetation is intact, and neither rain nor melting snow has caused flood or brought down sediment in excess of the geologic norm. Next to it is Parrish Canyon, whose sides have been cleared and heavily pastured. Here, in 1928 and subsequently, surprisingly small amounts of rainfall on the upper slopes have gathered headway, bringing down

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masses of earth and rock to debouch on the valley margin below, with results disastrous to roads, homes, public buildings, and fertile acres.

The mood of national remorse during the 1930's made it possible for the Government to acquire this watershed and take stabilizing measures, using CCC workers to terrace and replant the steep slopes. This has worked so well that, as one technical man said: "The people below have now rebuilt. They have more confidence in what we have done than we do ourselves. We can't promise no more floods, even with the slopes protected by plant life."

Old-Time Floods

Turning now to floods of the more conventional river-valley type, antiquity furnishes us with at least two vividly contrasting patterns—those of the Nile and the Tigris-Euphrates. The Nile, flowing through a broad and gentle valley far downstream from its sources, rises and falls in orderly fashion as an aggrading stream, leaving a coating of nutrient material that enhances the agricultural value of the valley without producing devastation.

The twin rivers, on the other hand, flow less than half the distance covered by the Nile and arise in mountainous terrain rather than in swampland. As a result, floods are likely to be violent and to come without warning. The only safeguard is to be on the alert during the season of melting snows and heavy rainfall—a circumstance which is believed to have had something to do with the early development of astronomy and the calendar in Mesopotamia, Moreover, the terror of flood is a familiar feature of near-Eastern tradition and folklore.

Such an area is vulnerable to deforestation in the upper reaches of the valleys. This would not only augment the violence of moving water but would greatly increase the load of silt brought down by it. The accumulation of this silt through the millenia imposed a burden on the otherwise efficient irrigation system of the Tigris and Euphrates. This greatly lowered its efficiency, even before its destruction by invaders in the 13th century.

In former times, in the lower Mississippi flatlands, it was possible to take advantage of conditions not unlike those in the Nile Valley. Levees were built at right angles to the stream, to moderate its force while allowing it to spread out, rather than attempting to confine it to channel. Livestock and people were moved to high ground, returning after the spring flood to find the fields enriched. But, today, the pressure of population for space makes such a leisurely give-and-take impossible, as it has long been on the crowded, level plains of eastern China and India.

Industrialization and Floods

The flood problem in New England, a highly urbanized industrial area, shows an interesting combination of geologic, climatic, and human elements. In order to reach Long Island Sound, Connecticut rivers have cut channels through whatever material is in their way. Where this material is soft, the swinging channels have cut wide flood-plains. But in many places the streams have cut down through hard volcanic rock. At such places we have narrow gorges with little or no flood-plain. These gorges choke the flow of high water, backing it up still higher on the broad flood-plains upstream.

When New England was settled, mills were built close to the stream channels, because of the need for water power. Homes, however, were built on high ground, safe above flood level. With the shift to steam and electricity, water was needed for processing and for waste disposal, so factories expanded in the old locations along the channel. Because the flood-plains were relatively level, roads and railroads were built along them. And as population increased, residence and business construction came down into the flood-plain, too.

These developments all served to increase flood hazard by occupying space which, throughout geologic history, had been subject to frequent occupation by high waters. The hazard has been further increased by structures which block the channel itself, by bridges of types which constrict the channel, and by lumber- and junk-yards full of loose material that can be washed down against bridges, converting them into dams.

It is often said that deforestation causes floods. This is a half-truth. Water flows faster, and in greater amounts, off of cleared land than off of forested land —up to a certain point. When rainfall exceeds the critical amount, especially on shallow soils such as we have in New England, not even forests will hold it back. Actually, with some two-thirds of its acreage in forest, New England is in pretty good shape as far as natural cover is concerned. On the other hand, an increasing amount of land along the valleys has no vegetation at all, since it is covered with waterproofed buildings, roads, parking lots, and sidewalks. It is safe to say that the water which falls on such places contributes directly to floods.

Flood Protection

A means of flood protection often mentioned is the storage of water in reservoirs. To be any good for this purpose, reservoirs must either be empty, like those above Dayton, Ohio, or have plenty of empty reserve space, like those in the Muskingum Conservancy district. These conditions are hard to meet in New England, where choice reservoir sites are already being used mainly to store up water for use. Additional reservoir sites are in the wide flood-plains now occupied by urban and industrial developments, which could be moved only at great cost.

To make matters worse, we are rapidly destroying an excellent source of natural storage by filling in swamps and marshes above the river mouths. Until now the only objections to this filling have come from nature lovers, who prize the plants and animals that make swamps and marshes so interesting. It is time for us to begin to weigh carefully the damage that may result in times of heavy rainfall if there are no spongy basins to hold part of the excess water.

Finally, since floods come from falling water, it is essential to remember that rainfall figures represent averages. The amount and intensity of precipitation at any given place are unpredictable, varying within wide limits. Fifteen inches or more of rain in 3 days would be expected, statistically, only once in 1000 years or more, yet we had such rains twice in one season last year.

All this adds up to the fact that water makes flood-plains and has the first right to them. Any competition with water for this space must be regarded as a calculated risk, to be taken with eyes open. Storage of surplus water and proper ground cover help reduce the risk but cannot eliminate it. In short, all available evidence justifies the view of Leopold and Maddock in their excellent book, *The Flood Control Controversy*. High waters cannot be prevented, but they can be intelligently dealt with. Water problems are complex, both from the natural and the cultural standpoint. Each situation must be studied on its merits; there are no blanket solutions guaranteed to work everywhere. The surest safeguard lies in better understanding, on the part of each citizen, of the facts of his environment—physical, biological, and social. The ecologist, as teacher, citizen, and investigator, must contribute to this understanding. Perhaps in this way we can come to realize that ecological hazards do exist and, thus, come to accord them the same respect that we now give to hazards in law, engineering, and economic matters.