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EROSION: A REAL MENACE IN THE SOUTHWEST¹

By B. P. FLEMING

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THAT erosion by wind and water is the principal factor in giving character to the topography of the Southwest is familiar to any one who has lived or traveled in this region. Accelerated erosion by winds and water due to man's comparatively recent occupation of the Southwest is not so generally recognized as responsible for profound changes in topography. Nevertheless, it is generally admitted and believed that the problem of erosion in the Southwest had its beginning coincident with our Anglo-Saxon occupation of this region. Marked vegetative changes have occurred on the vast ranges used for grazing. Box canyons and deep arroyos are now found where some of the early settlers located their home ranches, river beds have risen and adjoining areas of once fine agricultural lands have become water-logged and alkali.

Arroyo floods and the debris swept along the

arroyos by these floods and deposited at the mouth of the arroyos in the form of great delta fans are responsible for the loss of many thousands of acres of lands in the river valleys, while the choking of culverts and flood passages beneath bridges by arroyo debris greatly increases the problem of maintenance of railroads and highways.

Many of us are inclined to the view that the melancholy results of accelerated erosion, which are so evident in many parts of our Southwest are to some extent, if not wholly, due to man's occupation and exploitation of this region. In confirmation of this view we have the evidence of old settlers and the physical evidence which we are free to interpret ourselves. In the valleys below Elephant Butte Reservoir we have probably one of the oldest inhabited regions of the Southwest. It has supported some sort of civilization for much over 300 years. Prior to the coming of the white man, it was occupied by the villages of the pueblo type Indian. Some of

¹ Address at the thirteenth annual meeting of the Southwestern Division of the American Association for the Advancement of Science, Las Cruces, New Mexico, May 1 to 4, 1933.

their villages exist to this day. They were built almost always on the edges of the mesa above the flood plain of the Rio Grande, a turbulent stream which, prior to its curbing by storage, wandered at will back and forth across the valley, occupying this year a channel on this side of the valley, but next year one perhaps against the mesa on the other side.

The Indians had great respect not only for the capricious behavior of the Rio Grande, but for the menace of arroyo floods. It is not likely that they deliberately would locate a village in the path of one of the latter, yet, even within the memory of living man, villages, dating from no one knows how far back, have been overwhelmed and partially buried beneath the debris of neighboring arroyos. These arroyos are probably of recent origin or at least they have become menacing in recent times. It is a common story in this region that on the mesa to the east of Dona Ana in the Mesilla Valley of the Rio Grande, where now even a goat has difficulty in foraging a living, it used to be the custom of the natives to harvest a hay crop. Near the town of Las Cruces, New Mexico, is an arroyo which some day may engulf the town, but which 20 years ago had a bed six to eight feet lower than to-day, as is proven by adobe buildings partially buried in the sands it has brought down.

These are some of the more immediate and easily recognizable effects. What is the cause? Can it be that rainfall is heavier and more intense? Undoubtedly climate does change in cycles of both primary and secondary frequencies, but there is no evidence that the past 50 years has been one of the major cycles of heavy rainfall. Rather, is the cause not to be sought in that disturbance of the delicate balance of nature brought about first by uncontrolled and excessive grazing, second by the wide-spread destruction of predatory animals which feasted on rabbits and rodents, and all resulting in such rapid destruction of native grasses and herbage by cows, sheep, goats, rabbits and rodents, to say nothing of grasshoppers, that this sparse but nevertheless protective blanket of native vegetation no longer was effective in preventing surface erosion, no longer was the retentive top soil and root growth effective in retarding run-off, and in an ever-descending spiral we have the effects of erosion widening and deepening.

Private interests and the state and federal government have expended vast sums of money in the construction of irrigation projects in the Southwest. These projects, which are centers of civilization and Anglo-Saxon culture in the vast expanses of desert, are now viciously attacked by all those natural forces released when in any manner nature's delicate balance is destroyed. Reservoirs established across torrential streams for the impounding of flood waters are rap-

idly filling with silt brought in by the main stream and by side arroyos; river beds below the reservoirs are slowly rising, due to the absence of scouring floods, which, prior to the building of the reservoirs, washed on down stream the debris from side arroyo inflows. Rising river beds mean rising water table with added menace from water-logging and seepage of river bottom lands, and added difficulties in finding and maintaining artificial outlets for surface drains which protect the irrigable land from seepage. It is no uncommon thing, therefore, to find great irrigation projects threatened by the effects of erosion, not only from the effects of direct overwhelming of lands by arroyo floods and debris, but the more insidious and equally fatal effects of silt in reservoirs, distributaries and river channels.

Palliative measures, such as attempts to control arroyo floods by detention reservoirs at the mouths of the arroyos or along their courses, are generally futile. No structure, except at prohibitive expense, can be erected to withstand and impound arroyo floods. Impounding reservoirs soon would be filled with debris, which would have to be removed from time to time at prohibitive expense to maintain the integrity of the reservoir. Any one familiar with these conditions knows that the control of arroyos and the prevention of the disastrous effects of erosion must be effected at the source, namely, in impounding run-off on the watersheds, where the floods arise and where most of the products of erosion originate.

The engineering problems involved in the control of arroyos are numerous and baffling. If it were a question only of controlling water, the problem would be greatly simplified. However, arroyos bring down enormous quantities of silt, sand and coarser materials, some of which may be boulders of many hundred pounds' weight. The ease with which arroyos move relatively enormous boulders probably can not be accounted for on the basis of velocity alone. A research problem of great interest would be to determine whether arroyo water, because of its excessive silt and sand content, might not have an increased specific gravity, enabling it to transport, through added buoyancy, material which otherwise it could not move. This same effect of possible increase in specific gravity of water due to excessive turbidity may account for the occasional difficulty found in the clogging of irrigation ditches by sand. For example, some two or more years ago, the Rio Puerco injected into Elephant Butte reservoir enormous quantities of a yellowish mud which persisted in suspension or possibly in colloidal form for nearly a year subsequent to the flood. This yellowish mud was carried with irrigation water to all parts of the irrigation system, and during this time more difficulty was experienced

with deposits of sand in certain of the distributaries than had ever been noted before.

From the engineering standpoint, it would not be difficult to design safety valve reservoirs on some of our larger arroyos, similar to those on the Dayton flood control project, which would prevent the occurrence of serious floods on the lands and improvements at the mouths of the arroyos, but it is probable that such reservoirs soon would be filled with arroyo debris which would destroy their effectiveness and require constant maintenance.

There also arises the puzzling problem of what degree of protection arroyo flood control works should provide. Obviously, 100 per cent. protection would be an expensive if not impossible goal at which to aim, because an extensive rain storm of more than average intensity and duration on the watersheds of some of our arroyos would be followed by floods which would overtop and probably destroy any man-made thing in their paths. Something less than complete protection would be the only practicable aim of the engineer in the design of a system of control works, and whether the expense would be justified would have to be determined by the value of property to be protected and by the acquiescence of property owners in a scheme for limited protection only. The most simple method of checking arroyo action is the construction of large numbers of small and inexpensive dams of brushwood or boulders or other local materials along the course of the arroyo and its various tributaries, for the purpose of destroying grade. These, however, merely would tend to check the final emergence of the coarser arroyo debris into the larger river channels, would in no way check the floods, but would merely minimize their peaks. They would have nothing whatever to do with the further erosion of denuded hillsides, and would not diminish the quantity of fine silts and sands ultimately carried into river channels or reservoirs. The first line of defense must always be the native vegetation, if it can be encouraged to reestablish itself on the mesas and the steep slopes bordering the drainage channels. We can never prevent rapid run-off from the steep slopes of the mountains and foothills, but on the flatter mesas which border the irrigated valleys we can minimize the tendency of the run-off to pick up and carry debris by encouraging the reestablishment of the native shrubs and grasses which in former times we know did minimize erosive action.

Here, however, we find ourselves hopeless and helpless. The vast areas which border the valley of the Rio Grande, for example, both above and below the storage reservoir, are areas on which neither the irrigators nor the Bureau of Reclamation can exercise control. Those who use these areas for grazing

may, from an enlightened sense of self-interest, practise methods of grazing which will tend to maintain the ranges at least in their present condition, if not to improve the growth of vegetation by limitation of herds or by alternate methods of pasturing and rest of certain areas. Such methods, however, are possible only where the stockman or sheepman controls enough grazing area individually to make it worth while and possible to practise advanced grazing methods or perhaps artificial re-seeding. Where open competition exists, as it does on great areas of unfenced range, each strives to secure as much pasture as he can before his neighbor arrives. There is not the slightest effort at control or conservation, and great areas are denuded of all vegetation and perhaps irrevocably ruined. Such areas soon show the most melancholy effects of erosion, great gullies appear, where formerly were gentle swales, the gullies and box canyons thoroughly drain the underground water from adjacent areas and the cumulative effects are soon apparent in absolutely arid adjacent areas, which formerly supported a good growth of grass.

It is argued by those who advocate state control of the present public domain that turning over these lands to individuals to have and to hold by sale or lease will not only restore the native herbage but will be a source of revenue to the state. The writer is not convinced that enlightened self-interest of the cattle and sheep men is sufficient safeguard to the vast interests menaced by further erosion on the great watersheds of our southwestern rivers, a considerable proportion of the areas of which is public land. On the vast land grants which dot the Southwest overgrazing and resultant erosion seem quite as apparent as on the public domain. If the cattle and sheep industry is in a state of depression it is easy to practise conservation of forage, systems of deferred grazing, the protection and development of overgrazed areas. Let the cattle and sheep industry enter a boom period and it is questionable if those who owned or controlled the watersheds of our great rivers and the myriads of arroyos and smaller streams would practise such conservation methods as would be likely to deny to them the participation in quick profits that general overstocking for a short time would bring.

The interests of those whose living and whose properties are in the river valleys are too serious and too extensive and mean too much to the state to be left to the mercies of private interests in control of the ranges and the quality of whose enlightened self-interest alone would determine whether the valleys eventually shall be overwhelmed by the effects of erosion or whether its effects shall be stayed by proper and intelligent control and use of the remaining public domain. Nor should the revenues accruing to the

state be allowed to influence the matter. Even though considerable, they always will be insignificant compared to the irreparable damage which will follow a failure to stay the effects of erosion.

Expenditures for administration and grazing control, expenditures for fencing, re-seeding, arroyo control, wells and tanks, expenditures rather than revenues should and must be the expectation for years to come from an enlightened and really intelligent effort to remove the menace of erosion. Do any of our Southwestern states wish to add to their already overburdened budgets an immense and continuing expense for rehabilitating vast areas of lands which now reflect the unenlightened public lands policy of the federal government for the past seventy years? Is it not the duty of the federal rather than the state government to evolve a plan and bear the expense for the restoration of its public domain and to remove the menace of accelerated erosion which its public lands policy has brought about and which now threatens private and public developments in the Southwest?

When erosion is brought under control, it will be time enough to consider revenues and the finer points of state *versus* federal supervision of what then will be land worth arguing about. The Forest Service has proven its capacity for organizing a system and a force for controlling conditions that affect erosion in the national forests and on the range lands included within their boundaries. Expand their duties, give them authority and funds to make a start at least in controlling erosion on the public lands which form the watersheds of our principal rivers. Every year wasted in fruitless discussion of state *versus* federal control sees more silt deposited in our reservoirs, higher river beds, more land seeped, more surface soil washed off the ranges, more progress made toward that not distant time when American civilization in the Southwest must give way before the relentless forces released when nature's balance was disturbed on the watersheds of this region.

If nothing is done soon to restore the conditions on the ranges which existed 60 to 70 years ago, one can see an unending, expensive and almost hopeless struggle to prevent the obliteration of farming communities such as those along the Rio Grande. The Bureau of Reclamation has announced as a policy that it can not and will not attempt to protect farm lands on its Rio Grande project from the effects of arroyo floods. It has a difficult enough problem in attempting to protect its canals, drains and other works from being overwhelmed by the debris brought down by arroyos, without carrying its policy of protection to adjoining farm lands. A glance at a map of the Rio Grande project, with its slender thread

of green agricultural lands hugging the banks of the Rio Grande while vast areas of mesa and mountain land stretch away on either side, certainly will impress one with the utter futility of attempting to do anything in the way of protection or control at the mouth of the arroyos. Out on those stark denuded areas which border and drain into the river, a wide-spread storm of even average intensity would bring down a volume of water and debris sufficient to carry away everything in its path, sweep out or submerge the mightiest of man's puny efforts at protection and leave desolation where now is a highly cultivated and flourishing community.

Let us cease "fiddling while Rome burns," and with an awakened consciousness of what erosion means, not alone now but to the future of this Southwestern country, forget the selfish interests of the stockmen, sheepmen or any other group whose pretensions to a place in the sun clash with the public's interests in the physical preservation of the public domain. Let us renounce any thought of revenue either for the state or the nation at large until a program of erosion control, actively carried out, begins to show results; then we can begin to consider whether New Mexico or other Southwestern states might not well benefit from leasing and other privileges on the grazing lands within their borders.

On the other hand, we should not be unaware of the vast problem inherent in suitable control of range conditions brought about by the dispersion of the range area into state, government, railroad, land grant and private holdings. If there were no consideration other than this involved, the simplest solution would be for the government to cede its remaining public lands to the state, whereupon the latter under its police power would proceed in the public interest to dictate upon what conditions, where and to what extent grazing might be permitted either on public or private holdings, so that erosion would be stayed and a progressive improvement in vegetative cover be brought about that eventually might restore to some extent primitive conditions on the watershed areas.

We generally are too apt to be guided in our decisions on public policies by the question of revenue. There will be no revenue in our range lands for anybody unless erosion is checked, and if erosion is not checked, if exploitation and not conservation is to be the policy of the next seventy to one hundred years, future archeologists, roaming over this region, may discover deep beneath what will then be the valley floor of the Rio Grande, concrete structures bearing the letters U. S. R. S., which being interpreted will remind the lawmakers of that distant time that our government once undertook a far-sighted policy of reclamation by irrigation. It advanced millions for

the construction of great irrigation works, which the people who settled in the valley of the Rio Grande of that time painfully paid for. It neglected, however, to realize that nature intended this region to be a desert and it made no provision to protect these people from the relentless forces of nature which pressed in on them from every side. The

winds covered up with sand what the waters failed to wash away. A permanent civilization in these river valleys of the Southwest must be founded upon control of the desert, just as methodically as we control the torrential rivers. The sooner this fact is realized, the sooner will our lawmakers have achieved a permanently successful reclamation policy.

CUTANEOUS SENSATION¹

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THIS is really a very elementary problem with which you all have had first-hand experience. You know the distinctly different qualities of the sensations of warmth and cold aroused by sudden changes in the temperature of the skin, and the very different sensation of touch which is evoked when a thermally indifferent object comes in contact with the skin. If the heat and cold are sufficient to damage the skin, if the object is applied with crushing force or if it is sharp and penetrates the skin a fourth sensation entirely different from all the others is aroused, and this you call pain. What happens in the skin in each instance, and how are the disturbances which are set up there propagated to the brain, and how do they then make themselves felt in consciousness?

In spite of the primitive nature of this problem it has not by any means been solved. I shall leave out of account entirely the most difficult part; how when these propagated disturbances reach the brain they give rise to conscious sensation, which appears to be something of an entirely different order than neural activity. I can not understand how such a thing as a sensation of warmth makes its appearance as a result or as a concomitant of the activity of certain nerve cells in my brain. I can only admit the fact and leave to the future, perhaps the far distant future, the problem presented by the relation of brain and mind.

But the first part of the problem can be solved. It should be possible to determine which of the several different types of sense organs situated in the skin are sensitive to warmth, cold and touch, respectively, and which respond only to those painful stimuli which carry a threat of injury. It should be possible also to determine how the disturbances, when once set up in the sense organs, are propagated to the spinal cord and brain. It is to some relatively new information on this subject that I wish to direct your attention to-night.

When mechanical, thermal and chemical stimuli of

sufficient intensity are applied to the skin they evoke sensations of pain, and it was formerly thought that excessive stimulation of any cutaneous receptor was painful. But this view was quite generally abandoned when it was found that there were separate warm, cold, pain and touch spots in the skin. For more than forty years it has been known that the skin is not uniformly sensitive. This can easily be demonstrated by marking off with a rubber stamp one square centimeter on the front of the forearm and subdividing this into square millimeters. If this area is then explored for touch by taking a not too stiff hair and pressing the end of it against the center of each of these millimeter squares in succession it will be found that touch is felt in only about one out of five of the squares. That is to say, there are about twenty points in each square centimeter on the front of the forearm which are acutely sensitive to touch. It is quite generally believed that these points are the only ones that are sensitive to touch, in spite of the fact that if a stiff hair is used the contact can be felt in every square millimeter. This can be explained as due to the pitting produced by the stiff hair causing a deformation of the skin which extends to and stimulates a true touch spot.

By appropriate means it is possible to identify points which are acutely and specifically sensitive for cold, others for warmth, and still others for pain. Not every psychologist will admit the absolute specificity and fixed identity of these sensory spots, but all will admit their existence. And, entirely apart from any of the implications of the punctiform theory, the number of these touch, pain, warmth and cold spots in a given square centimeter of skin may be taken as the best available index of the receptivity of that particular region in terms of each of the four varieties of cutaneous sensation.

One of the chief stumbling blocks in the way of the punctiform theory has been the failure to establish a definite relation between these spots and the sense organs in the skin. Yet if the theory is true such a relation must surely exist. For the sake of

¹Lecture before the Northwestern University chapter of Sigma Xi, on December 9, 1932.