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BY

SOIL EROSION AND ITS CONSERVATION

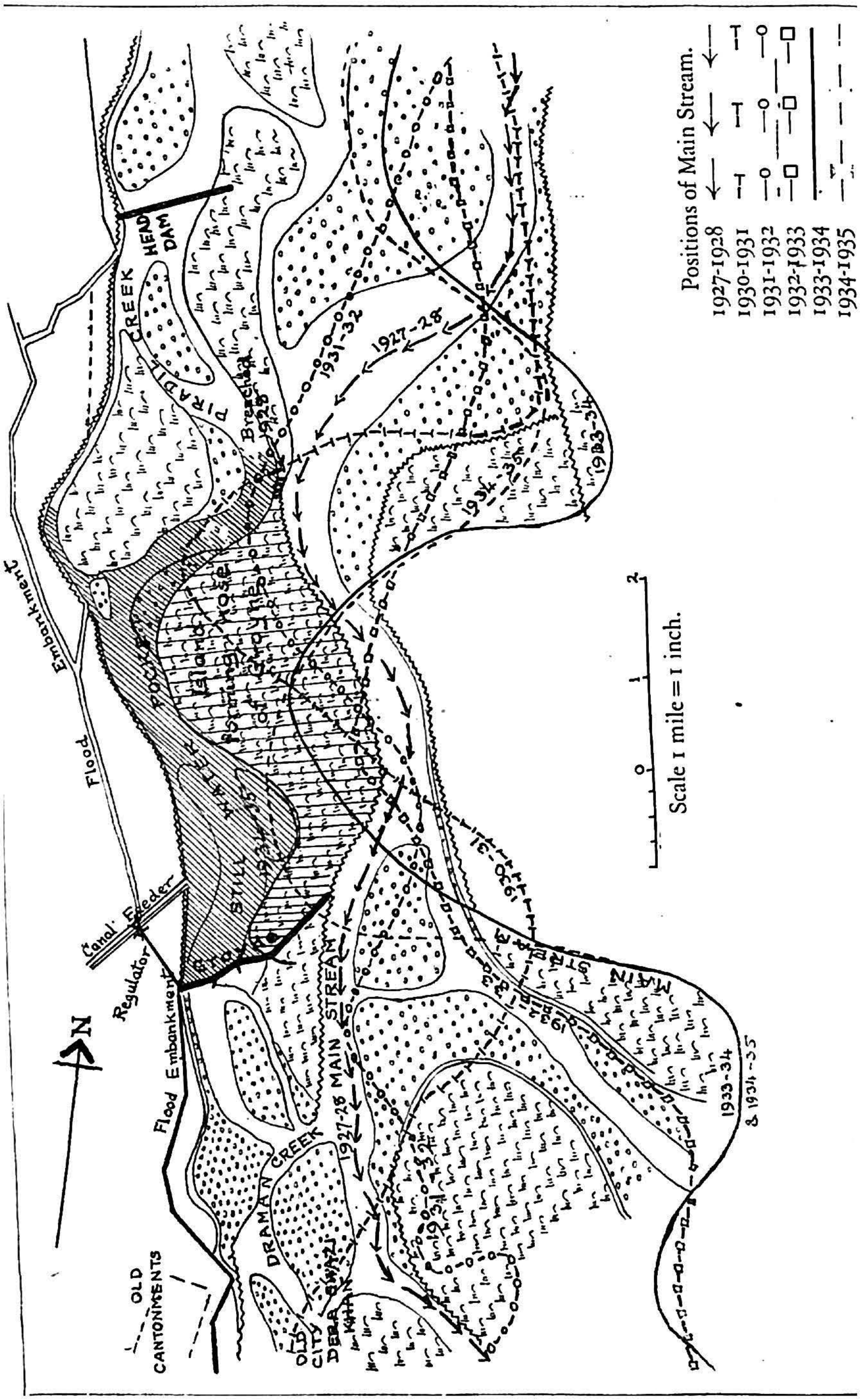
By PHILIP CLAXTON

EVER since the mountains were formed and the earth received her frame, running water has taken up the tale of soil erosion. Pushing out deltas from the base of the hills, torrents have gradually formed great plains, and, nothing daunted, have essayed even continents. Nature meanwhile clothed both mountain and plain with verdure, grass, scrub and forest, which in turn slowed down erosion and established a balance of economy, till man appeared on the scene. Not considering his place as a mere moment in the long vista of time over which nature had worked, he set about to upset the balance of soil erosion and conservation, till today soil erosion and conservation present us with problems that truly are formidable.

Writing for the United States of America, Paul Sears, a distinguished botanist, an economist and an agriculturist of no mean skill, gives us these interesting remarks in his book *Deserts on the March*. "Since 1900," he says, "the United States has moved to the forefront in the study of the relation of plant and animal to their environment between the individual living thing, to the soil and the atmosphere. Man has found that the landscape presents more than the mere plant and the physical texture of the soil, for both should be regarded in a totality, each as a factor in relation to other factors. When we enter a forest or a meadow we should see not merely what is there, but what is happening there. We should have a glimpse of continuity, analysis, integration and destiny, subject, as they may be, to management and control."

But while the U.S.A. and other countries of the West have been moving forward in the study of nature's economical balance in the relation between plant, animal and environment, and have been reaching methods of management and control to restore it, the East awaits solutions on a much wider scale. There we have very large areas of bare hills and mountains that may never have been covered with verdure, and of torrents which pour down their sides and need to be managed and controlled if soil erosion and the annual recurring waste is to be arrested.

The writer would therefore transfer the thoughts of Paul Sears to the East, where these problems, soil erosion and conservation in relation to the living thing and landscape, apply even more strongly: as he knows from many years' experience in a corner of the earth—Dera Ghazi Khan on the Punjab-Baluchistan frontier—remote it is true, but presenting the problems in their acutest form. On one side was the river Indus, a veritable sea, 8 miles broad between flood embankments and discharging anything between 20,000 and 700,000 cubic feet per second. On the other side were torrents descending from the bare and often rocky Suleiman range of mountains, bringing down anything from 20,000 to 100,000 cusecs. heavily laden with clay when in spate. The inundation canals in his charge were wedged between these enormous forces of nature, and


Positions of Main Stream.
1927-1928
1930-1931
1931-1932
1932-1933
1933-1934
1934-1935
Scale 1 mile = 1 inch.
0
1
2
N
Flood Embankment
Flood Embankment
Canal Feeder
Regulator
OLD CANTONMENTS
OLD CITY
DERA
DRAMAN CREEK
MAIN STREAM
1927-28 MAIN STREAM
PIRADIL CREEK
HEAD DAM
1927-28
1931-32
1933-34
1934-35
MAIN STREAM
1933-34
& 1934-35

while he had to extract supplies from the one he had to protect his work against attack from the other.

Naturally his first study had been the river, but having found a solution there he came to apply it to the torrents. He will therefore give the river solution first and then demonstrate how it was applied to the torrents later.

The Still Water Pocket.—For management and control he could deal only with the side-creeks, which are in themselves very large, but which hold the meanderings of the river in check. On the side-creek all active flow could be brought to a comparative standstill by what he termed the still-water pocket. Earth, sand and brushwood, all the materials ready to hand, could then control the situation. To illustrate this Fig. 1 is given to reproduce the conditions as they were actually presented in 1928-35 at a point 4 miles above the old city of Dera Ghazi Khan, washed away by similar conditions in 1910, eighteen years earlier. This time the city was not in question, but the fate of a canal and many miles of adjoining flood embankment. The attack was threatened through the Piradil creek into which the main stream would soon breach. The lower end of the Draman creek was already the main stream, but were it to enter the creek from a higher point through the Piradil creek, as it threatened to do, many miles of canal and flood embankment would be in extreme danger.

The figure (1) shows how the situation was handled. The Piradil creek was closed at the head and again lower down near the outfall by sand and earth dams protected with brushwood. The lower dam was then extended in an upstream direction over the highland of the island, a comparatively cheap work, so as to form a groyne enclosing a pocket. By this means the whole of the island was pressed into service and became a huge nose. So long as the island lasted the groyne was effective, and the pocket remained a still-water pool, shown blue.

The positions of the main stream in the attack which followed should be noted, for it would take too long to comment on each position separately, but it will be seen how the main stream was thrown into great loops which beat against the island, and did its best to tear a way through.* This was all to the good, so long as erosion remained on that side, the right side, because from our knowledge of river behaviour the eroded material would re-form as shoals lower down, *on the same side*—in this instance the lower Draman branch, which was the main stream. It took five years to fill this up, but filled it was, and the river was diverted into the Ghazi Ghat creek on the left side that had meanwhile been developing. What engineers had failed to do in the fight from 1900 to 1910 to save the city, at a cost of 22 lakhs (2,200,000 rupees), was accomplished in the fight from 1928 to 1933 at a cost of one lakh only. This is noteworthy in demonstrating the power of the Still-water Pocket Principle, which, as we shall see, was applied later to the control of the torrents.

These torrents had been harnessed to some extent by the peasant, after they had left the hills, in a system of "basin irrigation," close to the foot-hills, as bolstered up by the Record of Rights, applied under the

* *Vide*, Paper 5319, "Influence of Silt on River Behaviour," by Philip Claxton, published in *Journal of Institution of Civil Engineers*, London, for 1942-43.

supervision of Government officials. Both the basin system and the Record of Rights will need our attention, being in themselves outstanding attainments, though imperfect without engineering direction.

Taking basin irrigation first, a sketch (*vide* Fig. 2), will help us to picture it and follow its working.

The system is the same as that followed in Egypt, though applied under very different circumstances. Here the torrent spate must be caught at a moment's notice, for the fields are served under critical conditions. Each field is enclosed by the peasant with substantial embankments or "bunds" made with the scoop or drag, so that the oxen pass over the bund each time the earth is scooped up after being ploughed over, if necessary, from both sides. The result is a perfectly constructed and consolidated work. The clay, however, of which it is constructed, brought down by torrents, is treacherous because of unequal contraction and expansion. The peasants swarm out on seeing rain clouds over the hills and man the bunds, and have to be very much alive watching for the slightest leakage, which must be jumped on and closed immediately. When one field is filled to a depth of some 3 feet, the inlet is closed and the water cut into the next lower field. With the rich silt brought down in the water, one such filling is enough to plough and sow the field as soon as it has dried off sufficiently, and to mature the crop.

In the Fig. 2 the distribution of the water to the fields will be as follows: The right and left branches will flow separately or together: if separately, one branch will be closed till the other has received its share; if together, each will draw off proportions calculated very roughly by the bed width of the torrent, the groynes being extended into the torrent bed to one-third to two-thirds or whatever the proportions may be in the Record of Rights.

Consider now the right branch. All water will be stopped at dam *a* and passed into watercourse No. 1 till it reaches dam *b*. Here it will be stopped and passed into field 1 by the cut shown. When field 1 is filled dam *b* will be cut and the cut into field 1 will be closed. The same process of filling will be repeated at dam *c* and field 2, and finally the dam *c* will be cut and field 3 filled. When nearly full—allowing for the water that has yet to flow from the head of the watercourse—dam *a* will be cut, and the next lower fields will be watered in the same way in turn on the general principle first come, first served. The same procedure applies to the torrent's left branch.

The Record of Rights.—Now, the shares of water for the branches and watercourses, the order of the fields, and from which watercourses they are to be served, and how, are laid down in great detail in the Record of Rights. This is a record, prepared and attested by Government authority, of the rights of the people, either in land or water, and their obligations for the construction and maintenance of the works, jointly or independently, and constitutes a sort of title deed for a village. Individual proprietors rely on the entry in the Record of Rights as upon title deeds, and in the Collector's and other courts of law the entries are presumed to be correct, unless the person contesting them can prove to the satisfaction of the court that they are wrong.

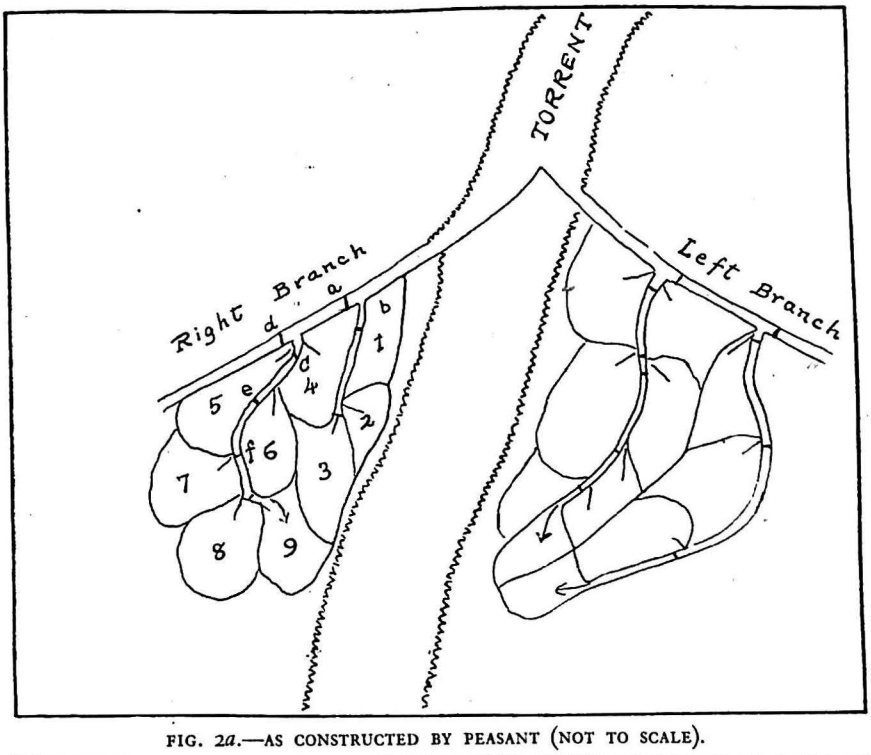


FIG. 2*a*.—AS CONSTRUCTED BY PEASANT (NOT TO SCALE).

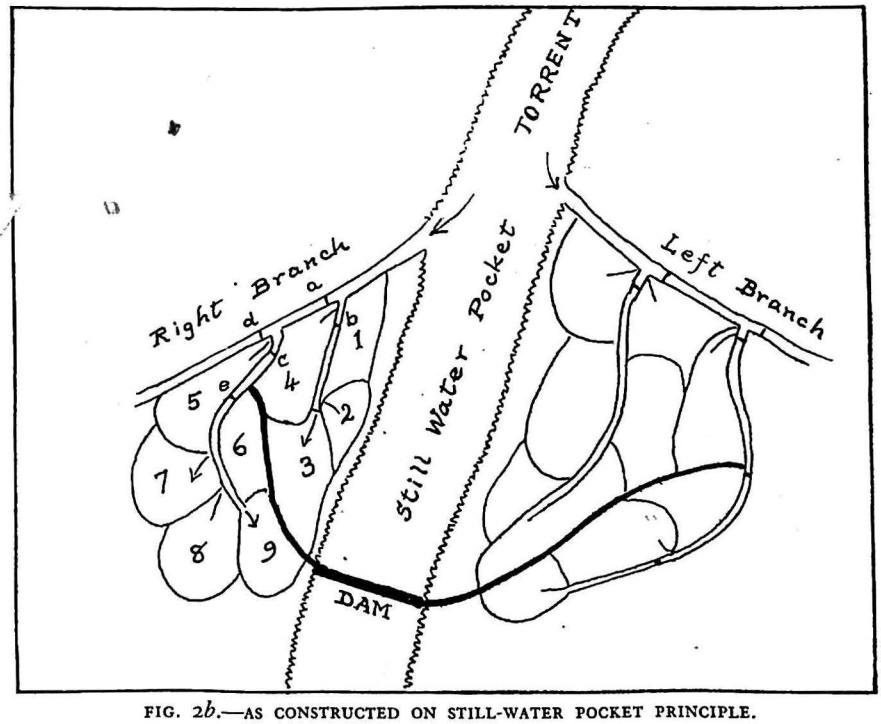


FIG. 2*b*.—AS CONSTRUCTED ON STILL-WATER POCKET PRINCIPLE.

The Collector has powers under the Minor Canals Act to enforce the observance of the Record of Rights. For instance, the order for filling the fields is first come, first served; but a field when once served must wait its turn till all the others have been served. The one rule was observed with half an eye on the other, and where powerful interests were involved it needed all the power of the Collector to enforce the second rule. Again, to induce the shareholders to construct a common work he had to issue notices for the attendance of each man. If after that a man failed to attend his share was completed for him by contract, and the amount was recovered later as an arrear of revenue. Again, on application made, or after personal inspection of the site, the Record of Rights might be corrected, subject to appeal on proceedings as in court.

All these duties fell on the writer when he was ultimately transferred to torrents, and he can speak from inside knowledge. But his object now is to present a system fostering the spirit of self-help and having the seeds of soil conservation, when without this system soil erosion would have been rampant. Where interests and conditions are so conflicting and varied that the wisest counsels are baffled, the fact that Dera Ghazi Khan had a system that actually worked is the remarkable thing. It can offer economists and agriculturists some points, and gives the engineer his chance. Armed with these two weapons, the Still-water Pocket of Control, acquired at the river, and the Record of Rights picked up from the peasant, the engineer might set out as David with stone and sling to slay Goliath, Silt Erosion. If a system in the shape of basin irrigation had gone so far in the hands of the peasant alone, he could surely go further with engineering skill, and what is more powerful than the Still-water Pocket of Control? The principles of the Still-water Pocket had only to be demonstrated to be better understood and applied.

Now, even the best that modern skill can do in the uplands, such as re-afforestation, terracing and buttressing, still leaves some overflow that may be dealt with in the lowlands by the basin system we contemplate. Here, however, the lowlands only are to be considered where operations in the uplands are altogether out of the question. Vast areas in the East come under this category, and it is for these principally that the basin system is presented. When we enter into this world of re-creation we sense even more "the continuity-analysis, integration and destiny" that should exist, of which Paul Sears speaks; and our purpose is to bring the factors under management and control more completely than he envisaged.

But, lest the writer appear to be talking of vague generalities, he wishes to recall some of the prominent instances by which the Record of Rights and the Still-water Pocket worked together. These he hopes will cover most of the conditions under which torrents are encountered and suggest the many ways in which they may be managed and controlled with the help of the Record of Rights.

Confining himself to the principal torrents of Dera Ghazi Khan, he would present them in order:

Vihoa—discharging up to 17,000 cusecs. in spate.

The peasants dammed this frequently, but with no success. The

reason was that they feared water pressure more than velocity, and instead of a pocket presented a dam protruding out into the torrent in the form of an inverted V, with the idea of securing their share as prescribed by the Record of Rights as a fraction of bed-width. This of course was quickly underscoured by the high velocities set up. With tact and firmness we brought down the site of the dam half a mile (*vide* Fig. 2*b*) to form a pocket in which no off-takes of any watercourses were allowed. The flanks of the dam were carried up at an angle of about 45°, following the banks of the fields as they zigzagged till safe ground was reached. To the astonishment of the peasant this work stood, and as the pocket was heavily silted up, grew stronger each year till it was well-nigh impregnable.

Sanghar—up to 30,000 cusecs. in spate.

This torrent, the largest of them all, had a very narrow foreshore from gorge to river in which there was small scope for basin irrigation. We therefore confined ourselves to the gorge where groynes diverted the water into right and left channels by means of boulders brought down by the torrent, strengthened with brushwood. The peasant, as usual, built his groyne out so as to invite attack, until we induced him to adopt the loop, which was all the pocket we could obtain under the conditions. The result was that the peasant had not to construct his works so often. On the left of the torrent an unauthorized break-away was dealt with by a retired dam in the place of the one at the head built by the peasant.

Lower down the important town of Taunsa was heavily attacked and the authorities were helpless, but a groyne was suggested. An island strewn with boulders and overgrown with brushwood offered a fairly permanent objective in midstream, and by building a groyne across to it a more or less stable pocket would be formed with a nose naturally protected with boulders and brushwood. The pocket would soon silt up and grow stronger from year to year, diverting flow to the other side. This work was, however, outside our sphere and was left to the town and district authorities.

Sori—up to 15,000 cusecs.

Two breaks-away were brought under control by Still-water Pocket dams. In one the dam had actually been cut to give a share to lower fields allowed by the Record of Rights. These fields were transferred to other sources of supply, a harsh measure, but the only alternative was a masonry or pipe outlet in the dam which the peasant might have built at his own cost. This is a contingency Government might provide for, as many low fields can be served only by masonry or pipe outlets or masonry distributors.

Vidor—up to 15,000 cusecs.

This torrent was directly above the new City of Dera Ghazi Khan, and with the country falling rapidly towards it (1 in 100 at the gorge, flattening down to 1 in 1,000 at the city) the fear in the lay mind was that it might change direction and overwhelm the city. As it was, two side channels had developed, the Jabria to the north, and the Phular to the south-west. Torrents debouching from a gorge behave in this way because the heavy detritus pushed forward by the nose tends to silt up

the centre delta and to break away at the sides. In this instance the side channels drew off large supplies to lands not entitled to irrigation, and the centre delta did not get its share. The Phular was brought back to its legitimate area by a Still-water Pocket, and it was proposed to do the same for the Jabria, bringing back the discharge to the original point of distribution. Danger to the city through the central delta was remote, as this delta obliterated forward development, but the fears prevailed and the city authorities let the matter drop. All we could do was to build a Still-water Pocket dam across the Jabria at a lower point and disperse the supply over lands not entitled to receive it.

Kaha—up to 17,000 cusecs.

We did little in the upper reaches except enforce Still-water Pocket principles, but lower down the overflow was considerable and swept over the country, breaching our canals and disorganizing irrigation. We therefore impounded this overflow in a lake known as the Hamuwala lake, which is somewhat different to the Still-water Pocket, as all floods could be contained within its greater capacity. The lake was formed merely by strengthening the right banks of the canals in the vicinity, and blocking the water at the south end by a spur running up into the steeply sloping ground. A masonry inlet into the canal was provided at the root of the spur and minor inlets higher up. The canal then drew off supplies as required for its own irrigation.

Compare this with a proposal for feeding Iraq in the Middle East by impounding the flood waters of the Tigris and Euphrates rivers in a much larger lake formed by joining the two rivers where they come close together above Baghdad.* As this has already been discussed in that journal it needs no further comment here.

Lower down other minor torrents brought down water with injurious salts in solution which could not be freely utilized for basin irrigation, and much of it reached the canal (Kadra). Here a good deal of it was intaken into the canal by a device and the rest escaped across the canal. Mixed with the sweet supply of the canal the water was useful for irrigation.

The above measures give but the salient features of torrent management and control, but they represent the many ways in which torrents may be fitted into basin and canal irrigation. Our attention, however, is now directed to its inter-relation with plant, living thing and environment. Such an inter-relation cannot often be realized in the highlands, but in the lowlands it may, as here, by the Record of Rights and Still-water Pocket.

Such a scheme applies in a particular way to the Middle East, but there political difficulties, it is said, bar the way; and soil conservation has been left severely alone. Engineers moreover are handicapped, for they must treat the separate countries as water-tight units, instead of having the whole field of resources at their command. No project can be developed to its full capacity under these conditions.

The writer now has in mind the wider range which Government

* *Vide* Paper 5480 published in the Journal for 1945-46 of the Institute of Civil Engineers, London.

projects in India/Pakistan were working up to in order to solve problems hitherto thought to be impossible. For instance, the irrigation of the Montgomery Bar was one such, till exchanges of supply right across three rivers were considered. Starting with the Jhelam a supply was passed into the Chenab, and as much taken off higher up from the Chenab, and passed by a Level Crossing across the Ravi. Again, formerly irrigation from the Sutlej was confined only to the Sirhind canal taking off at Rupar, but later Bikanir as well as the rest of the Sutlej valley was brought into the picture, and three new barrages built lower down, having regard to the distribution of supply as demands arose in Sindh at the Sukkur barrage. Or again, to extend irrigation in the Delhi-Hirsar areas it was suggested to carry water from the Sarda river in Oudh to the Ganges tract, and take off as much from the Ganges across the Jumna. The Talukdars of Oudh at the last moment objected to the project and it was dropped, but whether the Talukdars have benefited is doubtful, for serious waterlogging on the canal of their adoption has taken place.

If the Middle East took this development of project-building to heart they would be well advised. The political difficulties are admittedly great, but is not the danger of working in water-tight units greater, since it perpetuates these difficulties? If a project in which all could share were devised, the political difficulties might be eased and possibly eliminated.

The benefits of a common interest would undoubtedly go a long way to solve the political difficulties, but we would propose the further step of giving the people themselves a hand in their own affairs by electing their own Record of Rights. As we have studied the system of basin irrigation governed by the Record of Rights and directed by the Still-water Pocket, the perspective completely changes. From "Deserts on the March" we pass to "Deserts as Pools of Water." In the one the landscape was quite unprepared for the extremes of drought by soil erosion, and flood by torrents uncontrolled, but in the other the basin system of irrigation, brought about by the Record of Rights and Still-water Pocket gives us soil conservation, and the extremes of drought and flood brought about by soil erosion disappear.

Lest this change seems to be an empty dream the writer has drawn attention to the basin system of irrigation based on the Record of Rights alone, to which he had actually been introduced in Dera Ghazi Khan. If this system had gone so far there without engineering direction, he has shown how much further it may go with this direction armed with the Still-water Pocket principle.*

Advancing from here he would suggest what might be possible at this moment in the Middle East. Starting with the Still-water Pocket in its larger capacity as a storage lake or reservoir as applied at Hamuwala, he has suggested a reservoir for Iraq by joining the rivers. Such a reservoir would not only completely absorb all floods, and distribute water through barrages under control, but would secure a surplus with

* *Vide*, Paper 5480, "The Still-water Pocket Principle," by Philip Claxton, published in 1945-46 by The Institution of Civil Engineers, London.

which Iraq could bargain with other countries. Thus, Syria could take off all the water she needs for irrigation from the Euphrates from a higher point near Aleppo. The canal from here, keeping to the higher land, must pass close to Homs, from where Palestine could pump a supply over the Baalbeck ridge for the development of hydro-electric power in the Jordan valley and the Dead Sea. Some of the ridge would be dug through, but there would be plenty of power generated at the fall into the Jordan valley to pump its own supply, once the pumps had been primed up by an independent plant; or power could be obtained for this purpose at the Euphrates off-take itself. The power available would be enormous, supplying not only the needs of Palestine but also of Arabia. Thus all the countries would come into the picture. As in America there is a Tennessee Valley Authority, so in the Middle East there might be a Euphrates-Tigris Authority. The one demonstrates that collaboration is possible between the local community and the Government with the best prospect of success, as the other will doubtless demonstrate the same result for the Middle East, and should also overcome many of its political difficulties. As in America the individual keeps his self-respect and initiative, so also in the Middle East the individual will keep his. Such collaboration has the most likely chance of success.

Note how Iraq presents the thin end of the wedge, for the first step concerns only her as a unit, and the major political difficulties are thereby by-passed. But having taken this step, the other steps may be left to the better judgment of the people, politicians and engineers standing aside, content to offer suggestions leading the people in the right direction. All that they need to be careful about is to make sure that the first step is in the right direction.

For instance, it would not be in the right direction if to check floods an escape, as shown on the bird's-eye view, were dug to the Thar Thar Depression.* There the supply, one of Iraq's most valuable assets, would be lost, whereas we want it conserved. Nor can it guarantee total immunity against floods, but only a mitigation of them. Apart from the Tigris floods, those from the Dyala river have been left out of consideration.

In the alternative scheme the bund for the Tigris-Euphrates reservoir has been re-aligned to include the Dyala. The cost will be no greater, except for the regulator for the lower reaches of the river itself.

Meanwhile, basin irrigation on the Record of Rights and Still-water Pocket principles should go forward independently over all the Middle East along the higher lands of the foothills, leaving the lower lands to canal irrigation. It would be excellent training for the larger irrigation schemes, for thereby the peasant, hitherto indifferent to irrigation, would acquire the sense for it, and would do far better than if he had no preliminary training.

Here we must leave basin irrigation in the hope that it will bring about the economical inter-relation of plant, animal and environment

* The Colonial Development Department states it is now being dug. The Inspector General of Irrigation in Iraq informs me that conservation of all the sources of supply is the ultimate object of his schemes.—P. C.

that is so desirable. If man has not been altogether responsible for disturbing nature's balance in the East, he will have the greater honour for creating it where the march of deserts has never been disputed.

To those interested in the methods of water control suggested here, the author will be glad to supply full engineering details with illustrations. *Vide* also Papers 5319 and 5480 cited above, of the Institution of Civil Engineers, Great George Street, London, S.W.1.