Problems of Irrigation.

By Prof. B. H. WILSDON.

THE introduction of irrigation in an arid country, along with its obvious blessings, brings in its train diverse problems, as do most other of man's disturbances of Nature's equilibrium. The consequences may give rise to problems of such urgency that, unless solved, large tracts of land, after a period of fertility productive of an ever-increasing density of population, must lapse into saline desert or into waterlogged marsh infested with malaria. Difficulties will be at their worst in flat country devoid of drainage.

Terrain, soil and sub-soil, climate, the design of irrigation channels, the method of distribution of water, and the habits of the cultivator, must all be factors which contribute to the permanent success or ultimate disaster of irrigation projects. Only by the systematic study of their interactions can it be hoped to secure control of effects. Control is perhaps too strong a word to use when the complex reactions which follow the apparently simple engineering feat of digging a canal for irrigation are properly considered, but for the possibility of disaster we have object lessons in the ruined irrigation systems of Mesopotamia and the Punjab, which must once have supported flourishing civilisations.

In the Punjab an average flow throughout the year of about 25,000 cubic feet of water a second is maintained by irrigation works by which some $10\frac{1}{2}$ million acres of crops are matured in land previously desert or precariously cultivated. These figures omit the great areas which are now coming into cultivation as a result of the new irrigation works on the Sutlej, and greater areas, which will be irrigable when the Sukkur barrage on the Indus is completed.

Of the $10\frac{1}{2}$ million acres irrigated in the Punjab, the area threatened with waterlogging has been estimated at $3\frac{3}{4}$ million acres.[1]

The new areas now being brought under irrigation are probably more liable to damage than those in the Punjab, since, in general, soils become heavier and the fall of the land flatter as we proceed south.

The need for research has been recognised, but not too soon. As a matter of Imperial interest, the question has been under examination for some time by a special committee appointed by the Committee for Civil Research. The report of this body will be awaited with interest. In the Punjab, the ominous rise of the water-table in many irrigated tracts, the abandonment of an increasing acreage of once fertile land through actual waterlogging and the spread of saline soil, could not be longer ignored. Some preliminary steps have already been taken in an attack by scientific methods upon the analysis of the factors, and in attempts at control, by the formation in the Punjab under the Irrigation Department of a research organisation. A laboratory equipped for the study of the hydrodynamic and physico-chemical problems which await solution is nearing completion, and a staff of computers for statistical investigations has been at work for some time. Already some light has been thrown on the gravity of the problem, and indications of the most feasible methods of control by administrative methods or engineering works have been secured. A brief account of the results obtained and the problems now more clearly defined may, it is hoped, reveal subjects of scientific interest to workers in many fields whose active interest would be of valuable assistance to those called upon to face the situation.

Fortunately, due to the foresight of a former chief engineer of the Punjab—Sir Thomas Higham—extensive records have been kept for nearly thirty years of the depth of the water-table in selected wells scattered more or less uniformly throughout the irrigated tracts. This valuable collection of data, with records of rainfall maintained by the Irrigation Department at sub-divisional stations, and the recorded volume of irrigation water admitted to canal distributaries, enables statistical estimates to be made, not only of the present and future rate of rise of a water-table but also of the relative responsibility of rainfall, drainage, and the irrigation load for the effects observed.[2]

The method of analysis adopted has been that developed by R. A. Fisher[3] of the Statistical Department of Rothamsted Experimental Station in the examination of the relation between rainfall distribution during the growth of a crop and its yield. This method was necessary, as there is every reason to expect that rainfall or irrigation in excess of the normal will not have the same effect on the water-table at different seasons of the year since the quantity of water lost by evaporation, and able to affect the water-table, must depend intimately on the prevailing temperature and humidity. Moreover, well measurements have only been recorded on two dates in the year, in June and October, and the latter are not very trustworthy on account of the after-effects of flooding due to the previous monsoon. The method adopted was therefore to correlate the constants determining a polynomial curve fitted to the distribution of rainfall and irrigation in the year previous to the well observations, with the fluctuations of the spring levels after correction for secular trend. Typical regression curves are reproduced in Fig. 1. The ordinates represent the effect in the following June of unit departures from the average depth of irrigation on the rise of the water-table.

Such curves represent the result of heavy computations. More than three hundred individual well records are included, each of which is suitably weighted for the area of which it is taken as representative. Secular change was eliminated from the record of well fluctuations by fitting an exponential curve, departures from which were correlated with the rainfall and irrigation distribution.

The available record varies from 20 to 27 years in the cases examined. The unit of time was taken as five days, for each of which it was necessary to compute the rainfall from about fifty rain-gauge

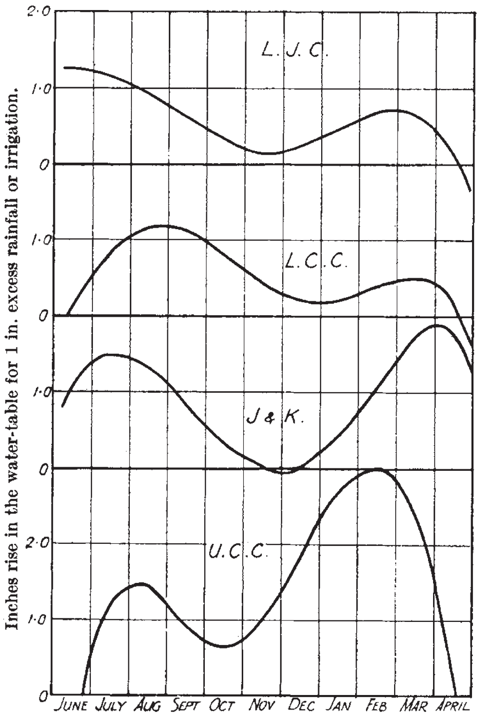

FIG. 1.—Typical regression curves showing the effect of rainfall or irrigation on the rate of rise of the water-table.

L.J.C.—Lower Jhelum Canal. Area, 2096 sq. miles; recorded wells, 80; perennial irrigation.
L.C.C.—Lower Chenab Canal (Upper); 2030 sq. miles; recorded wells, 54; perennial irrigation.
J. & K.—Jaurian and Kasoki distributaries. Area, 65·2 sq. miles; recorded wells, 6; the water-table is high and a considerable proportion is irrigated by wells.
U.C.C.—Upper Chenab Canal. Area, 2486 sq. miles; recorded wells, 83; the water-table is high throughout the area and a large proportion receives irrigation only in the summer season. A large area of rice is grown.

stations and the records of many canal distributaries. The correlations are undoubtedly significant according to statistical criteria, the percentage of the total variance accounted for by the regression being more than 60 per cent in the mean for the cases illustrated.

There is a marked uniformity in the regressions for the monsoon period, July to September. Roughly we see that a depth of water added to the surface of the soil as irrigation or rain produces an effect on the water-table, detectable six months afterwards, of from one to one and a half times its amount. This indicates that from one-third to one-half of the water must reach the water-table from the surface, since the porosity of the soil may be assumed to lie between 30 and 40 per cent. The effects of irrigation during the winter months are more diverse, as might be expected. There is, in addition to the monsoon maximum, an obvious tendency to attain another maximum effect during February and March. This is most marked in the Upper Chenab Canal, which differs very considerably in its agricultural regime from the others.

The winter 'hump' in the regression curve has afforded an instructive insight into agricultural practice, and has been traced very conclusively to wasteful irrigation. The most important application of the results has been in guiding administrative action in insistence on economy. It is obvious from the curves that great effects are possible through economy, or avoidance of waste, during the monsoon, and, on certain canals, during February and March. The total closing of certain canals for periods during the monsoon has been tried and would already seem to have produced promising results without undue interference with agriculture. The effects in future years of the policy now adopted will be awaited with great interest.

Fig. 2 shows the mean observed annual rates of rise of the water-table, averaged from 54 separate well records over a tract of about 2500 square miles in the Lower Chenab Canal. The exponential correction for trend is also shown, as well as the fluctuations calculated by means of the derived regression equation from the recorded irrigation and rainfall. The fit of the observed and calculated fluctuations in the rate of rise is remarkable.

If we assume that the rise of the water-table, falling off exponentially as it appears to do, will continue unchecked, it is calculated that the water-table as a whole will rise another 13 feet above its level in 1927. This must result in a very considerable portion of the area becoming water-logged. By a similar calculation for the Lower

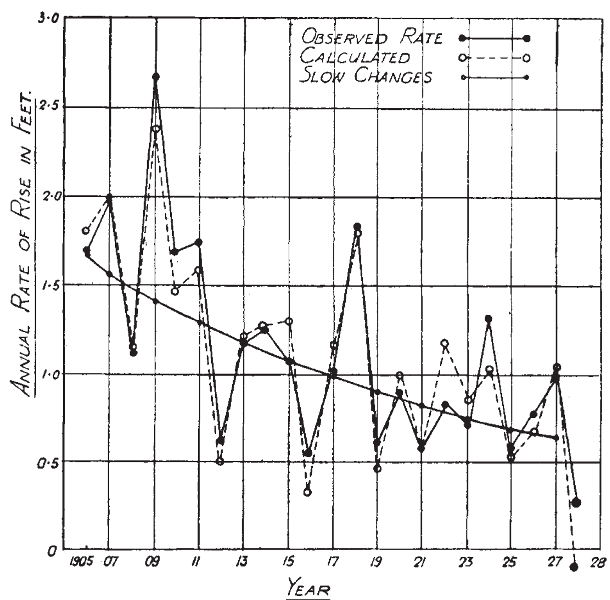

FIG. 2.—Lower Chenab Canal. Calculated and observed rates of rise of the water-table.

Jhelum Canal, in which the water-table has exhibited a remarkable rate of rise, the corresponding final equilibrium is calculated to be 56 feet above its present level.

A second line of investigation, on which work is still in progress, has been directed to the elucidation of the causes for such exceptionally rapid rises of the water-table as have been recorded in the Lower Jhelum Canal since the introduction of irrigation. Much of the area is easily commanded by inundation canals, but the higher areas are served by high level channels from the head works at Rasul and Mangla. Tradition states that the tract was once irrigated even in the higher areas, but that "God became angry" and the land waterlogged. The existence in high areas of abandoned wells which show signs of use, the curbs of which lie at levels still many feet above the present water-table, confirms this tradition. The map (Fig. 3) shows the Rivers Chenab and Jhelum. At Kirana, near the district headquarters of Sargodha, occurs an outcrop of Pre-Cambrian rocks associated with the Delhi and Aravalli series. Similar rocks are found at Chiniot where the Chenab passes through a gorge, and at Shahkot and Sangla farther south. To the north-west lies the Salt Range where rocks ranging from Tertiaries to Lower Carboniferous lie unconformably over the Aravalli Cambrians. It is a remarkable fact that the principal incidence of waterlogging and the areas in which the rise of the water-table has been most rapid, lie to the north-east of a line roughly joining these outcrops with the Dehli ridge. This suggests the possibility that the deep Indo-Gangetic alluvium is traversed by a submerged ridge along this line which might act as a weir to head up the subsoil drainage. Such a rock mass would account for the sensitivity of the water-table upstream.

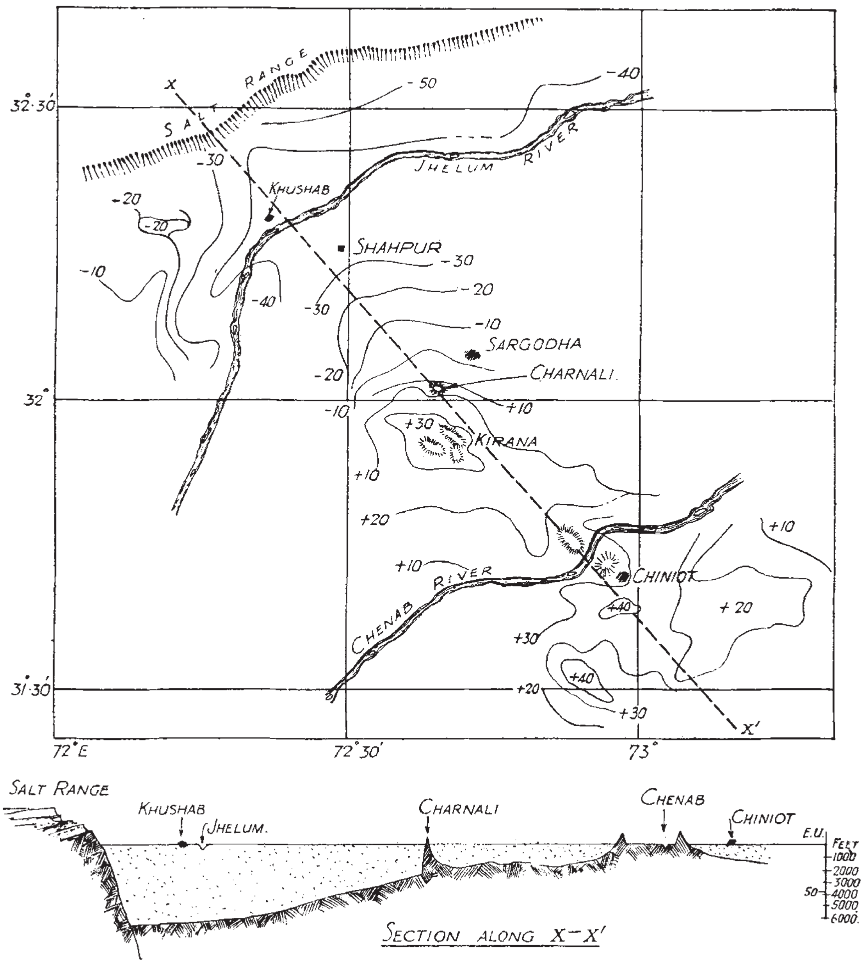

FIG. 3.—Gravity survey in the Chenab-Jhelum doab.

It was thought worth while to substantiate this hypothesis by a gravity survey. A survey party has now been in the field for three successive cold seasons, using an Eötvös torsion balance. The work, which has been carried out in the field by Dr. N. K. Bose, is not yet completed, but detailed results of the first two seasons' work will be published shortly. Fig. 3 shows a rough reproduction of the isogams with the omission of all detail; a section along the line X – X' is also shown. Observations have been made at more than two hundred stations in the area. The greatest depth of the alluvium is calculated to be about 5000 feet. No other determinations of the depth of the Indo-Gangetic alluvium are available for comparison; rock has never been reached by boring in the alluvium proper. Extension of the results now obtained would probably be secured, at considerably less trouble than is entailed in work with the torsion balance, by the recently developed methods of seismic sounding. It is to be hoped that this will prove possible in the future.

It is clear that the comparatively shallow sub-soils found to the south-east of the tract illustrated must affect considerably its drainage, but no quantitative estimate is yet possible. The rapid rise of the subsoil rock at the base of the Salt Range is a subject of considerable geological interest, but no stratigraphical conclusions as regards the type of the unconformity should be based on Fig. 3.

Other problems associated with irrigation must be mentioned only cursorily. Satisfactory hydrodynamic theories on which may be based equations for the flow of water in a deep soil are still to be sought. Even the comparatively simple case of the discharge of a tube well in a deep soil, unprovided with the conveniently situated impervious layer always found in theoretical descriptions, is open to obvious objections. The most illuminating model of such cases appears to be that of surface disturbances in an infinitely deep and highly viscous fluid. This analogy has been studied mathematically by Bose.[4]

The design of channels is determined primarily by the amount of silt which they must carry and discharge on the irrigated fields if the system is to remain working. The transport of silt by water in turbulent flow, both as it affects the intake from the river at the headworks, and the regime of the canal, still awaits scientific description. With the problems which arise in the design of irrigation works, in which model experiments, under properly adjusted conditions of dynamical similarity, alone enable three dimensional problems to be solved, enough will have been said to indicate the scope awaiting the application of mathematical and physical research.

A word may be added on the agricultural problems which are inseparable from questions of irrigation. Excessive irrigation and its evil effects have been mentioned, and may be regarded as a Scylla, between which and the Charybdis of the development of salinity, a safe course must be steered. With sparse rainfall the salts carried in irrigation water may accumulate in the soil, so that a too parsimonious economy of water, or reversion to well-irrigation without adequate replenishment of the water-table with fresh water, must result in a continuously increasing salinity of soil and ground water. It would appear that the only permanent solutions which can be looked for in the flat alluvial plains now considered, will be a combination of irrigation and drainage; in fact, it would be safe to state that any modern system of irrigation in alluvial plains must be designed at the outset with full provision for adequate drainage.

Very much therefore remains to be done in designing effective remedies for existing systems and in the physical and chemical questions of reconditioning damaged soils.

[1] Lindley, *Punjab Irrigation Branch Papers* No. 31.
[2] Wilsdon and Sarathy, *Punjab Irrigation Research Memoirs*, vol. 1, Nos. 1 and 2.
[3] R. A. Fisher, *Phil. Trans.*, B, **213**, 309; 1925.
[4] N. K. Bose, *Punjab Irrigation Research Memoirs*, vol. 2, 1929.

Obituary.

SIR GEORGE WATT, C.I.E.

THE death of Sir George Watt removes a figure who did valuable work for India, from which he retired nearly a quarter of a century ago. He will be always remembered for his "Dictionary of the Economic Products of India". Few would dispute the very great value on Indian economic development which has resulted from this publication.

Watt was born at Old Meldrum in Aberdeenshire in April 1851, the third son of John Watt. He married in 1873 Jane, elder daughter of Robert Simmie, who was Customs and Excise Officer at Lossiemouth. A son, Dr. R. H. Watt, and two daughters survive him. Watt was educated at the Grammar School and Marischal College, Aberdeen, and then went to the University of Glasgow in 1871, graduating M.B. and C.M. He had obtained distinction in botany, and this led to his appointment in 1872 as professor of botany in the University of Calcutta, a post he held for twelve years. In 1882 he was appointed scientific and medical officer on the Burma-Manipur Boundary Commission. His work and enthusiasm were beginning to attract the notice of the Government of India, and in 1883 Watt was appointed to the charge of the Indian Section of the great International Exhibition held in Calcutta in that year. The following year he received the definite appointment of assistant secretary for scientific purposes to the Revenue and Agricultural Department of the Government of India. In 1885 he went home and held charge of the Imperial Indian Economic Court of the Indian and Colonial Exhibition, an exhibition which fired the imagination of the public school youth of the day.

By this time Watt appears to have convinced himself of the grave existing need for a better knowledge of, and comprehension of, the value of the enormous number of what, *faute de mieux*, were termed the economic products of the country. He was able to impress the Government of India with his views, and in 1887 was appointed Reporter on Economic Products to the Government, a new post. It has been said that Watt had been turning his attention to this question of the economic products of the country and he had commenced in 1885 collecting material for the compilation of a dictionary on the subject. With his official apointment he was able to take up this project seriously and by 1894 the nine fine volumes of the "Dictionary" were completed. The work was a standard one and, unfortunately, owing to the unexpected demand, went out of print at an early date.

When Watt compiled the "Dictionary" there was no Agricultural Department to the Government of India, no Pusa and no Forest Research Institute at Dehra Dun. Watt's project was invaluable but, with no idea of belittling his magnificent work, it should be stated that the "Dictionary" would never have seen the light of day had it not been for the loyal, intelligent, and enthusiastic assistance accorded to him by collectors and deputy commissioners of districts and their staffs, and by the forest officers throughout the country; and the latter, owing to their training in scientific method and deduction, were perhaps in a better position to submit reports in a readily utilisable form. Many, if not most, of the inquiries originated with Watt, and circulars were issued asking for co-operation in instituting investigations and often in carrying them to a conclusion, where practicable, out in the districts. There is little doubt that Watt's initiative in this respect aroused the interest of many junior officers in this matter of economic products.