Some Recent Land Drainage Investigations at Iowa University of Science and Technology, Ames, Iowa, U. S. A.

DON KIRKHAM

Iowa State University of Science and Technology, Ames, Iowa (USA)

There are only 2,000 acres (800 ha.) of classified sodic soils in Iowa (SCHAFER [16]) but sodic and non-sodic soils have many drainage problems in common; I will review some of our recent drainage research work.

A first property of the soil which must be known before drainage ditches or tile lines can be placed rationally is the hydraulic conductivity of the soil. 'SIGMOND shows, in his book on alkali soils ('SIGMOND [17], page 97.), an infiltrometer still of value in studying soil permeability. Recently, FLANNERY and I developed a simple core permeameter for use in field work (FLANNERY and KIRKHAM [2]) when we were consultants on land reclamation work in Turkey. In designing this permeameter, the principal thought was to make the equipment as simple as possible, both to fabricate and to operate. The permeameter is now in use in Uruguay, Colombia, Korea, Turkey, the U. S. A. and elsewhere. The permeameter is very simple to operate. A person needs only to measure the time „t" of fall of two centimeters of water on top of the core and multiply the reciprocal of this time by two. Thus, hydraulic conductivity equals (2/t) cm/min., if the measured time is in minutes.

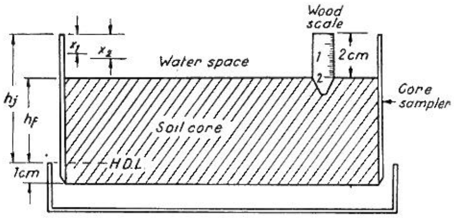

Fig. 1.

The FLANNERY and KIRKHAM [2] soil core permeameter ring unit. (See original article for other parts of the equipment)

Some recent developments, in the theory of water movement in soils, may now be mentioned. Figure 2. shows a series of pictures of the falling water table in a model simulating tile drainage (GROVER, LIGON and KIRKHAM [3]). Our problem was to learn whether the rate of fall of the water table was different for tiles in the internal part of the system than it was for tiles at the edge of the system. The figure shows no detectable differences in water table height on the inside of the external drain lines. In drainage experiments this means that an extra one or two drain lines are not needed at the edge of an experiment.

Much of our work has been purely theoretical. For example, we have determined the theoretical pressure distribution and the flow line distribution for a number of idealized drainage situations. Generally, research workers have obtained flow solutions by use of the approximate theory of DUPUIT-FORCHHEIMER (D. F.) (see HARR [4]). We have not used this D. F. theory except to compare it with our approach. In Figure 3. a correct flow net is shown for drainage of steady excess irrigation water for tube drainage. Superposed on this figure, is the 60% streamline as computed by the D. F. theory. The 60% D. F. streamline lies far from the correct 60% streamline over the last third of the streamline path.

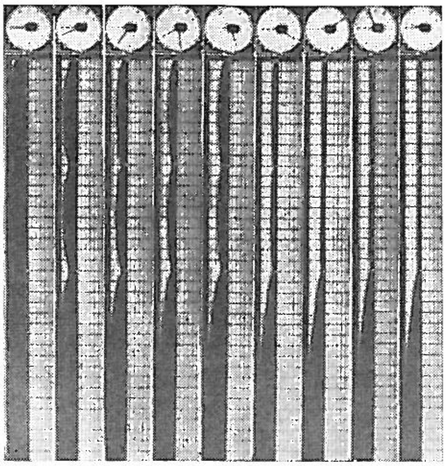

Fig. 2.

Water table shapes near edge and internal drain lines (GROVER, LIGON and KIRKHAM [3])

Leaching of soil by ponded water is a means of removal of undesired salts. Some years ago, I (KIRKHAM [5]) and others (see LUTHIN [15], pp. 164—165) worked out the theory for the movement of ponded water into drain tubes when there was an impervious layer below the drain tubes. The drainage rate is extremely small compared with that over the drain tiles. Thus, there

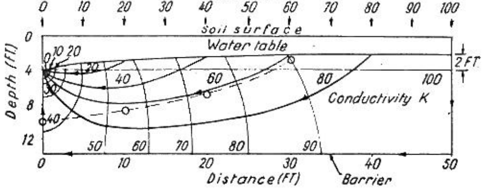

Fig. 3.

Correct flow net for ditch drainage and a 60% D. F. streamline. The D. F. (dashed streamline) fall below the theoretically correct flow net 60% (KIRKHAM and WARRICK [13]) will be a high leaching of salt over the tiles and practically none midway between the tiles. To remedy this situation, one should not maintain ponded water on the surface, but should apply successive rinsings. An even better way is to apply water at the midway position between the drains.

When there is artesian pressure from below, and also surface water, as shown in Figure 4, then the leaching is even more difficult than when an impermeable layer is present. Figure 5. shows actual laboratory sand-tank tests of streamlines moving upward from the artesian basin and also streamlines moving down from ponded surface water. The circled points are the theoretical streamlines. Still another situation is indicated in Figure 6, a situation I met with in Egypt. Here, underlying the soils to be leached, are highly porous shells. Figure 6, however, shows gravel. The actual flow lines for the situation of Figure 6. are shown in Figure 7. The highly permeable layer of gravel or shells makes the leaching simple, since the water can go practically vertically downward rather than having to move long horizontal distances.

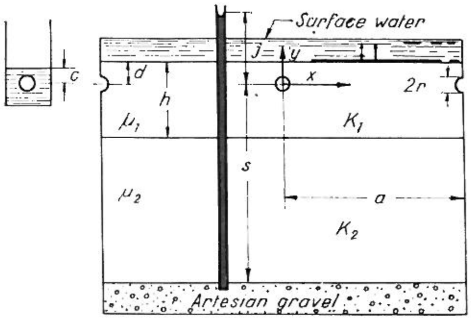

Fig. 4.

Surface water, for leaching, in the presence of artesian pressure. ($s + j$ = standpipe height of water above artesian gravel (for other symbols see the original paper (KIRKHAM [6]))

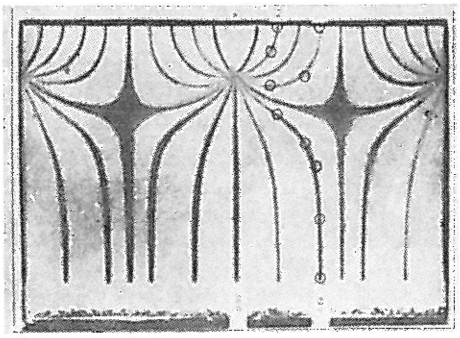

Fig. 5.

Laboratory test of leaching when there is artesian pressure. (Laboratory streamlines, Harding and Wood; theoretical points, KIRKHAM [10])

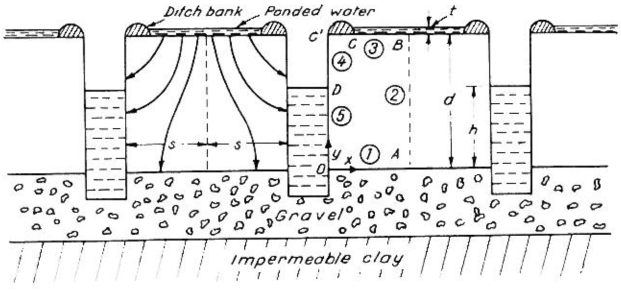

Fig. 6.

A leaching situation as found in Egypt. (For symbols see the original paper (KIRKHAM [8]))

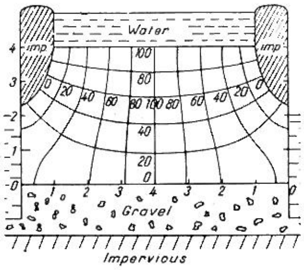

Fig. 7.

Theoretical flow net for Figure 6. (KIRKHAM [8])

A situation which is quite different from that of ponded water is theoretically the case of steady rainfall being removed steadily by ditches or drain tiles. In irrigation practice, the steady rainfall is replaced by steady intermittent irrigation applications. It has been shown (CHILDS [1]) that these successive equally spaced irrigation charges are equivalent to steady state rain as far as the water table average height is concerned. A few years ago I (KIRKHAM [7]) solved the problem of the steady-state rainfall on the assumption that friction of the downward moving water could be ignored in the water table arch. At the 1960 International Soil Science Society Meetings I showed (KIRKHAM[9]) how this solution could be improved to give an upper theoretical design limit for the water table height. Shortly thereafter, TOKSOZ, a Turkish drainage engineer, who has since studied with me, coauthored a paper (TOKSOZ and KIRKHAM [19]) showing how this rather involved theory could be reduced to engineering charts. The theory has been checked against field data (KIRKHAM [7]; TALSMA and HASKEW [18]).

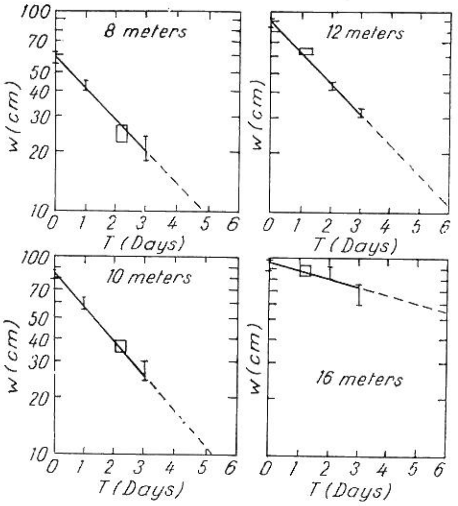

Fig. 8.

Water table elevation w above the levels of tile drain centers, as measured midway between adjacent drains, versus time t, after an 11.2 mm rain of Dec. 2, 1950, for a silty very fine sand in the North-East Polder of the Netherlands; drains are 1 meter deep and at spacings 8, 10, 12 and 16 meters; rectangles and vertical lines are field data (with standard deviations); straight lines are theoretical; dashed lines are extrapolated. (Data from KIRKHAM and DE ZEEUW [12])

So far we have talked of the leaching of ponded water and of the height of the water table arch to be expected for steady rainfall or steady state applications of irrigation water. Now, we come to a report of our work on non-steady water tables; i.e., how rapidly does a water table fall after it has once been established and the application of rain or irrigation water has been discontinued? A basic factor in the formula is the height z at any distance x from a ditch of the irrigation water. This height z has been given theoretically and tested experimentally by LIGON, KIRKHAM and JOHNSON [14].

Theory of the fall of water tables on tube drained land has recently been developed and tested against field data obtained in the Netherlands. Figure 8. shows the maximum height w above the level of the drain axes where the drain tubes are at 8, 10, 12 and 16 meters spacings and where an impervious layer was at 1 meter depth (86 cm) below the drain tiles. A fair fit of the theoretical and field data is seen.

Our work at Iowa State University has not been confined to the study of seepage in tile and ditch-drained lands. We have also considered flow into wells (KIRKHAM [11]) and into auger holes (ZASLAVSKY and KIRKHAM [20]). Our work has also dealt with water flow in soils (work not cited here) under unsaturated conditions.

Summary

Drainage is fundamental in ameliorating sodic soils. This paper reviews some work done at Iowa State University, Ames, Iowa, U. S. A., on the science of land drainage, as follows: (1) Very simple apparatus is described for measuring the soil hydraulic conductivity for drainage. (2) Theoretical formulas, which check either laboratory or field experimental data for falling water tables, and steady state water tables, are presented and discussed. (3) It is shown that leaching of salts by maintaining a steady ponded-water condition over the salted soil is not as effective, when the soil is underlain by an impervious layer, as applying a number of rinsings with the same volume of water

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О некоторых последних исследованиях, связанных с почвенным дренажом, проведенных в Айовском Государственном Университете Науки и Техники

ДОН КИРКХАМ

Государственный Университет Науки и Техники, Айова, США

Резюме

Дренаж является основой успешной мелиорации засоленных почв. В работе приводятся некоторые данные исследований, проведенных Государственным Университетом в Айове, связанных с дренированием некоторых территорий.

1. Приводится описание очень простого прибора при помощи которого можно измерить водопроницаемость почвы.

2. Представлены и обсуждены теоретические формулы, которые дают возможность контролировать полевые и лабораторные данные, относящиеся к изменению уровня грунтовых вод (постоянного и понижающегося).

3. Показывает, что если в засоленных почвах имеется водонепроницаемая прослойка, то постоянное покрытие водой, с точки зрения промывки почвы от солей, не столь эффективно как промывание той же нормой воды, но поданной в несколько раз.