CHAPTER I

INTRODUCTION

Border irrigation is a controlled surface flooding method of water application. The field is divided into a series of long strips called borders that are separated by low ridges. The borders have a uniform downfield gradient and are level crosswise. Normally the direction of the strip is in the direction of the greatest slope, but sometimes borders may be placed nearly on the contour. Water is turned onto the upper end of each strip and slowly flows towards the lower end in a thin sheet (Fig.1).

Efficient water application in border irrigation depends on the knowledge of the hydraulic characteristics of water flowing over the border. The fluid flow phenomenon of border irrigation is a case of spatially varied unsteady open channel flow with decreasing discharge. This flow phenomenon is affected by several variables that must be determined before proper design criteria for borders can be established. The dominant variables are entrance stream size, infiltration, slope of the land surface, and hydraulic resistance. If a functional relationship is established between the dominant variables, border irrigation can be described by the water front advance, water storage and depletion, and tail water recession phases. The efficiency

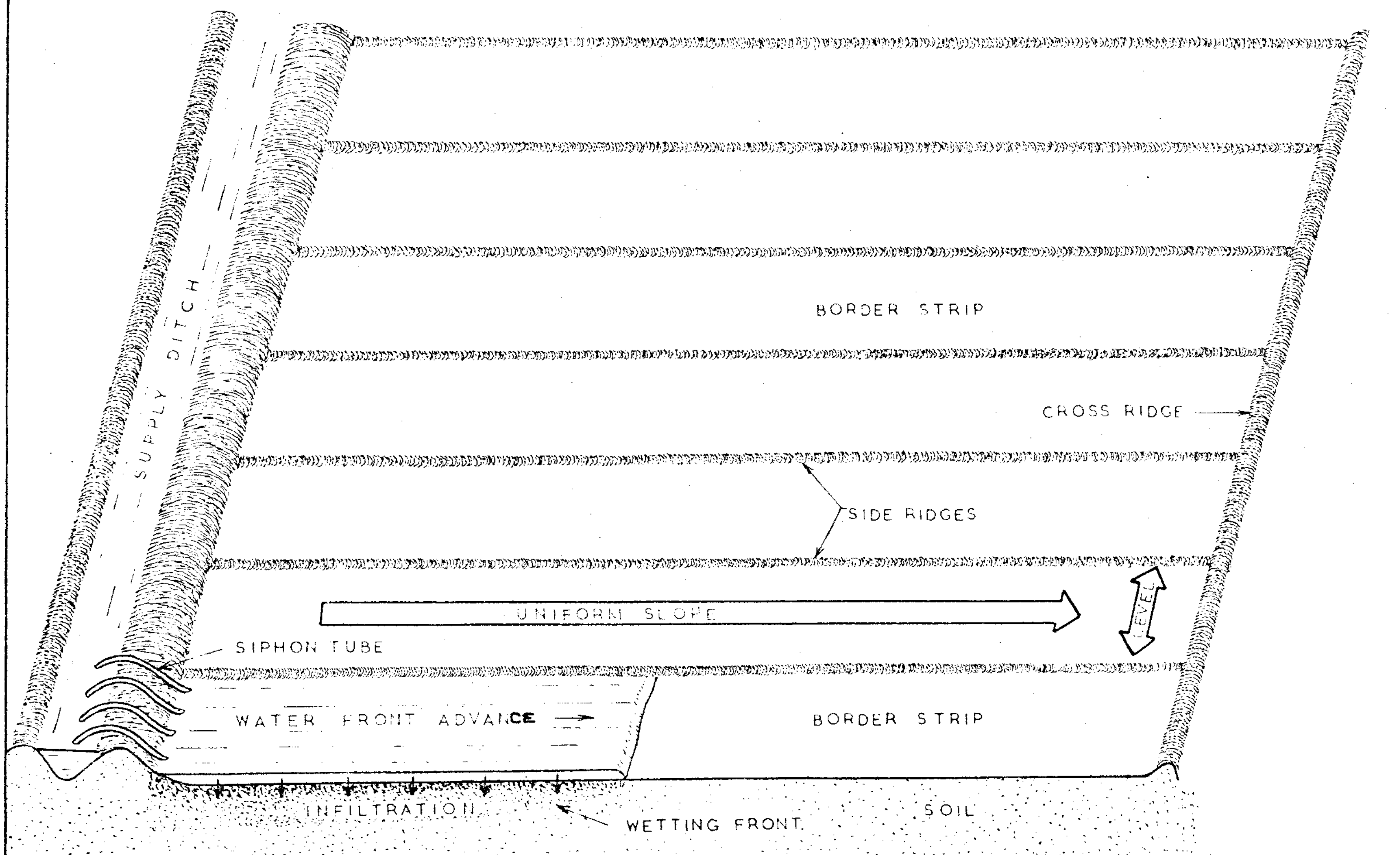

FIG1. PERSPECTIVE SKETCH OF BORDER IRRIGATION SYSTEM

of the system is related to the uniformity of application and water application efficiency.

If the irrigation system is properly designed, a physical environment is provided so that a nearly uniform depth of moisture penetration is attainable throughout the border. Uniformity of water application requires uniformity of infiltration opportunity time. The infiltration opportunity time is the period of time for which the irrigation water stands at a given point on the field. It is demarcated by the times when water advances to and recedes from a point. Thus the time-distance relationships of water front advance and tail water recession are major factors in determining border irrigation efficiencies.

Improved design criteria are needed for border irrigation systems. Although analysis of surface irrigation systems and some preliminary rational equations describing such systems have been proposed, these developments have not been adequately tested and confirmed by field experiments. Particular solutions of some of the general solutions proposed are also necessary to make them suitable for application under prevailing field conditions. The variables that influence the behaviour of border irrigation systems have not been adequately evaluated. There have been no previous dependable investigations on this subject in India, within the knowledge of the author. Hence an attempt is made in this thesis to evaluate the variables under field and laboratory conditions and to develop design criteria for border irrigation systems that utilize measureable characteristics of the site.

Need for study

One of the greatest opportunities for increased agricultural production in India lies in more efficient use of irrigation water. Water is one of the most costly factors of production in irrigated farming. This valuable resource must be wisely used. Water lost by surface runoff, deep percolation, evaporation and permeable conveyance channels generally exceeds the water available for crop use. Non-uniform or excessive application of water is not only a waste of water but it may also depress yields. Further, the excessive water applied to the soil may cause a rise of the water table leading to unfavourable soil conditions for plant growth. Excess water that evaporates leaves salts on the soil surface. An accumulation of salts is detrimental to crop growth. It implies that judicious application of water is essential for high yields of the crop and also to maintain a favourable salt balance.

Irrigation farming accounts for large portion of India's agricultural production. The area under irrigation in India is about 31 million hectares. This is approximately

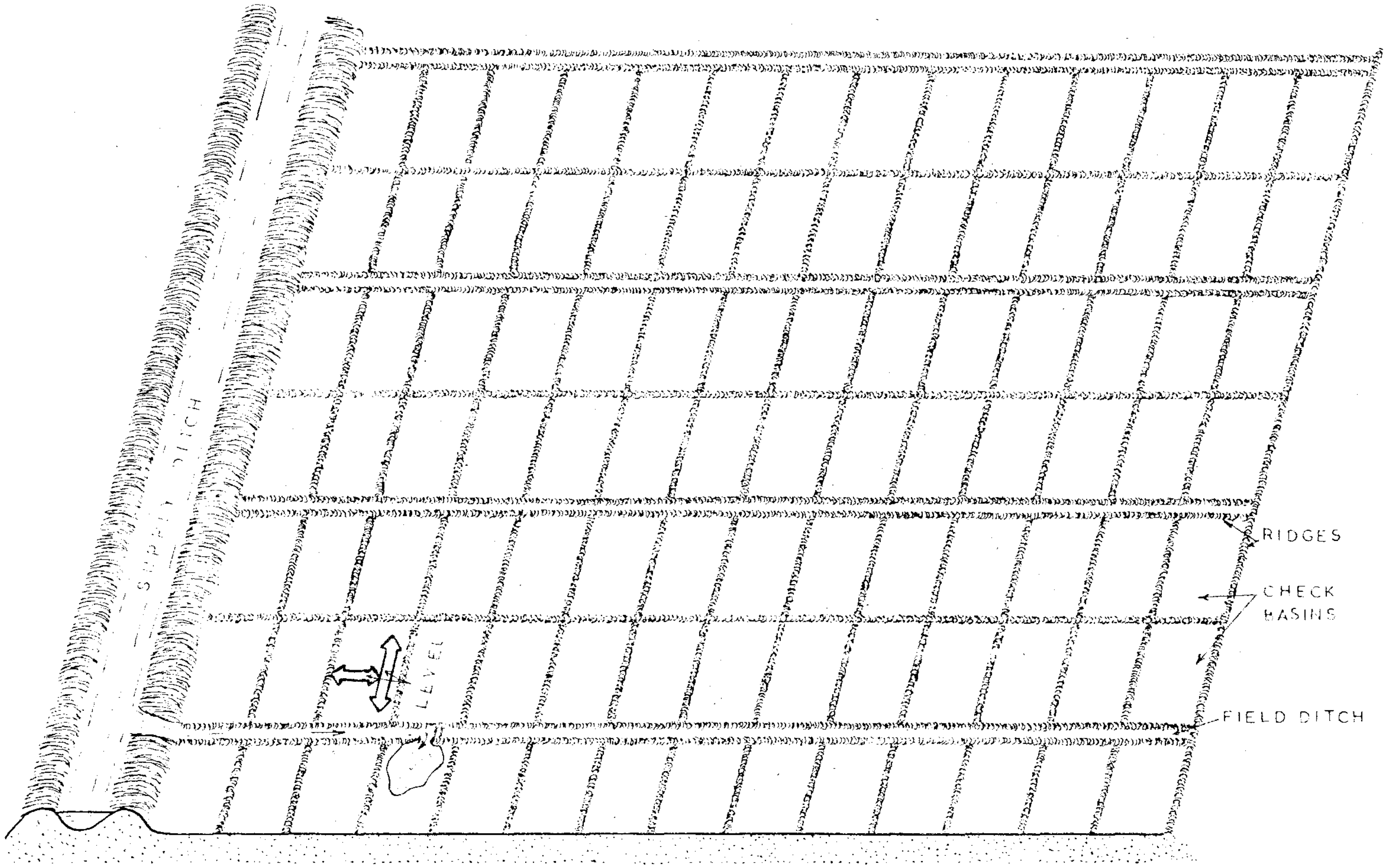

FIG.2. PERSPECTIVE SKETCH OF CHECK BASIN IRRIGATION SYSTEM.

22 per cent of the agricultural area. Seven and one - half million hectares are sown under wheat, barley and other close growing fodder crops. The check basin method of irrigation (Fig. 2) is commonly practised in India. In this method water is applied to small relatively level plots surrounded by ridges. Water is conveyed to the field by a system of supply ditches and field ditches. There is usually one field ditch for every two lines of check basins. The disadvantages of the method are comparatively lower irrigation application efficiencies since irrigation streams applied to check basins are difficult to control and inefficient utilization of land and labour. Further, the land under field ditches and ridges sustains crop of low yield compared to the crop in the basin. The area of land covered by ditches and ridges is proportionately much larger than in border irrigation. Another disadvantage of check basins is that the network of ridges interfere with the use of animal and tractor drawn implements.

The border method of irrigation is the most suitable for close growing grain crops such as wheat, barley, and fodder crops. If properly designed border irrigation systems are introduced to the area under these crops, irrigation efficiency may be substantially increased. The method is suitable to most soil types, except those having very low and very high infiltration rates. Field trials in India have shown that border irrigation is suitable in most areas of the country (67). However, successful operation of the border method requires that the system be properly designed. Proper grading of the land surface is also necessary.

The border method has a number of advantages. These include : 1) ridges can be constructed economically with simple farm implements, 2) one man can irrigate a large area that contains several borders, 3) uniform distribution and high water application efficiencies are possible , 4) large irrigation streams may be used efficiently , 5) operation of the system is simple and easy, and 6) adequate surface drainage is provided if outlets are available.

Research on the hydraulics of border irrigation and the subsequent improvement in efficiency of water application have great potential for making a significant contribution to irrigated agriculture in India. If it is assumed that an improvement of only ten per cent in water application efficiency could be made on the estimated 7.5 million hectares of land under close growing crops an additional 40 to 50 million hectare-centimetres of water per year would be available. This is a significant quantity of water that could be used for irrigating about 8 lakh hectares of additional lands without developing new water facilities.

Irrigation Requirements

In the arid and semi - arid regions of India the winter crop, called "RABI" , is usually grown after an irrigation so that necessary soil moisture is available for germination of seed and growth of seedling. This irrigation, called the pre-sowing irrigation, is applied after the seed bed is prepared and when the land surface is thoroughly pulverized and smooth. Subsequent irrigations are given at optimum time intervals during the active growth of the crop. The total number of irrigations required for cereal crops usually vary from four to six.

The variables influencing the hydraulic characteristics of flow in borders vary considerably in the different irrigations required to raise a crop. Considerable difference in soil bulk density prevailing at the time of pre-sowing irrigation and that during the post-emergence irrigations usually cause substantial difference in infiltration characteristics between the two. For the different post-emergence irrigations also, infiltration rates may vary from one irrigation to the other due to the crop and other factors. In the pre-sowing irrigation the hydraulic resistance offered to the flow of water over the border is only due to the roughness of the ground surface. But in post-emergence irrigations the resistance offered is due to the roughness of the ground surface and also due to the retardance offered by the vegetation. The relative importance of the two factors causing resistance in post-emergence irrigations vary from one irrigation to the other. The degree of resistance may also change during different post-emergence irrigations because of the changing vegetative characteristics of the plant. The characteristics of flow are profoundly affected by the slope of the border. Border slopes vary owing to the prevailing topography of the area and soil properties. Considerable variations in entrance stream sizes are also necessary depending on crop needs for water, available stream size, variability in soil and crop characteristics, and the slope and length of the border.

Scope of the Present Investigations

Mathematical models to describe the hydraulic characteristics of flow in borders were developed and/or adapted. The variables involved in the hydraulics of border irrigation were evaluated on the basis of data obtained from field and laboratory studies. Field studies were conducted over a period of three years. The studies included the evaluation of the variables during the different post-emergence irrigations of a wheat crop and also the hydraulics of pre-sowing irrigation. The land slope was kept constant in the post-emergence irrigation experiments, while the stream size and vegetative retardance factors were varied. In the pre-sowing irrigation experiments in the field as well as in the laboratory, the land slope and stream sizes were varied while the soil surface conditions and other physical properties were kept constant. Actual field conditions during pre-sowing irrigation were simulated in the laboratory.

Post-emergence irrigation studies were intended to provide values of infiltration and hydraulic resistance and also to evaluate the characteristics of the water front advance and tail water recession in borders as influenced by the dominant variables. In the pre-sowing irrigation study in the field a comparative study was made of the infiltration measurements by the conventional cylinder infiltrometer method and from the water front advance data. Effect of slope and other dominant variables on the hydraulic characteristics of flow were evaluated from the field and laboratory studies under pre-sowing irrigation conditions.

The experiments conducted under the present study were intended to provide criteria for the design of efficient border irrigation systems based on measureable characteristics of the site. Development of instruments and techniques to evaluate the dominant variables and also the characteristics of border flow were additional objectives. Suitability of laboratory studies to predict the behaviour of the irrigation system in the field were also investigated. Adaptation of flow pattern and relationships to flow of water in furrows should be possible by addition of a shape factor to the variables studied in borders.

Limitations

The field studies on the hydraulics of post-emergence irrigations were limited to one soil and one variety of crop. A different soil was used in the pre-sowing irrigation studies. Although the textural class of both soils in field studies was sandy loam, other physical and chemical properties varied considerably. Only pre-sowing irrigation was simulated in the laboratory. The soil used in the laboratory studies was sandy clay loam. The effective length of test section was limited to 60 metres in the field and 9 metres in the laboratory.

Specific Objectives of Study

In view of the above discussion, the specific objectives of the present investigations may be listed as follows:

1. To provide analytical formulation of the hydraulic characteristics of flow in borders
2. To develop instruments and techniques to measure the dominant variables influencing border flow

and to evaluate border irrigation systems ;

3. To evaluate the hydraulic characteristics of flow in irrigation borders under pre-sowing and post-emergence conditions,

4. To ascertain the suitability of mathematical equations to predict flow characteristics in borders ;

5. To evolve improved design criteria for border irrigation systems ;

6. To examine the suitability of laboratory models for simulating field conditions.