MATHEMATICAL MODELING OF IRRIGATION SYSTEMS FOR PADDY FIELDS

Ha Woo Chung , Seung Woo Park , Nam Ho Lee
Prof. Assoc. Prof. Res. Assoc.

Department of Agricultural Engineering
Seoul National University

INTRODUCTION

The amount of daily water requirements of paddy rice often exceeds normal precipitation during some parts of the seasons, and supplemental irrigation is needed. To suffice high water requirements, huge sum of capital has been invested year after year to the development and maintenance of irrigation water resources and delivery facilities, which are instrumental to the recent level of high rice yield per area despite of minor drought spans during past several years.

The agricultural water use is estimated up to the two-thirds of the total water resources being used. However, competative water demands from domestic and various industrial sectors have been rapidly growing. Thus, it is important to conserve the vital resources through the efficient utilization of the available agricultural water resources.

The efficient water use for a given irrigation system requires the accurate evaluation of the water demand and the adequate water allocation within the system. The water demand varies with weather, soil, crop, and irrigation depths. These factors vary with time and space. The accurate estimation of such variability is important to water allocation schemes.

The objectives of this study are

(1) to develop a simulation model to depict the physical behavior of an irrigation system.
(2) to apply the simulation model for typical irrigation district
(3) to evaluate the respones of the simulation model to different irrigation schemes.

SCHEMATIC OF IRRIGATION SYSTEM

A typical irrigation district consists of irrigation water resources, irrigation canals, field blocks,and drainage system.The water resources may be a reservoir, weir, pump station, or their combinations. The irrigation canals consist of mains and laterals, and delivers the water from the water resources to field blocks. Field blocks consist of the field plots of various sizes, each of which is the target area of irrigation. Excess water from individual fields is flown to drainage ditches and eventually to the stream. At some districts, supplemental water resource facilities like weirs or pump stations are located at downstream location to collect the return flow from irrigated areas upstream and divert the water for downstream field blocks.

IRRIGATION NETWORK MODEL

A mathematical model (IRRINET) simulating an irrigation network is developed to depict not only the water balance for a series of field blocks but the flow charateristics fo delivery canals and drainage ditches. It uses daily or hourly time increment and simulates the flow characteristics of canal segments and stream reaches and the water balance at the fields. It also defines the irrigation efficiencies such as delivery efficiency, system efficiency and field efficiency. The delivery efficiency is the ratio of the volume of water to field blocks to the volume of water supplied to the delivery canals. The system efficiency is the ratio of the consumptive use at field block to the volume of water supplied to the irrigation system. And the field efficiency is the ratio of the consumptive use to the volume of water supplied to a individual field block.

In case more than one field block are used in IRRINET, certain parameters must be given, which include the intake rates for individual field block in forms of fractions of the water to each block or hydraulic variables like the openning at intakes.Intakes rates may vary with different irrigation procedures and the irrigation efficiencies change with the procedures. Since the model allows the spatial and temporal variations of the intake rates at different locations of the canal segments, the model may be used to identify an irrigation scheme best suited for a given irrigation system by comparing the efficiencies.

Other input data for IRRINET include irrigation system network parameters, geometric and soil conditions, weather data, and irrigation operation parameters. The network parameters are those related to the segmentation of delivery canals, field blocks, ditches and streams, and their linkage. The geometric conditions include the mean geometric conditions for each segment of the system. The soil conditions may be expressed using infiltration and seepage parameters for individual field blocks. The weather data include the potential evapotranspiration and rainfall. The irrigation operation parameters include the average irrigation depths at individual field blocks, and delivery losses for canal segments. The detail information for the model are available in the reference (Lee, 1989).

MODEL APPLICATIONS

In order to evaluate the applicability of IRRINET to a real irrigation system, a test site was chosen and the time variations of the water levels along the delivery canal and the irrigation depths at individual field plots were measured during the irrigation seasons from 1985 to 1988. The test site is the Banweol irrigation district, Main water resource for the district is an irrigation reservoir, but two diversion weirs, and a pumping station are also used as supplemental resources. The acreage of the irrigation area is 405 ha and the length of mains and laterals is 6.7 km.

Irrigation System Approximation

To cope with the physical features of the Banweol district and the measuring stations installed for the study, the irrigation system was schematized. The whole irrigation acreage was divided into thirteen field blocks for each of which corresponding delivery canal and drainage ditch segment are linked and stream reaches divided. Intake points were placed accordingly at the location similar to real situations.

Parameter Calibration

For parameter calibration for the model, daily reservoir release rates, discharge measurements along mains, irrigation depth at selected field plots during 1986 were used. The model parameters to be calibrated were 1) the intake rates from mains and laterals to individual blocks, 2) the seasonal ponding depths at fields, and 3) the retention depths and delivery losses at mains and laterals.

Seasonal average values for the model parameters were estimated from a trial and error method, in which initial values were given and simulation results compared with the observed values and new sets of parameter values tried. The calibrations were repeated until a reasonable set of parameters was obtained that resulted in daily flow conditions and irrigation depths closed to the observed.

Model Validation

Using calibrated parameters based on the field data of 1986, daily flow rates along irrigation canals and daily water depth fluctuations at field blocks were simulated for 1987 and 1988 irrigation seasons. Simulated flow rates at irrigation canals were compared to the measured values at specified canal segments. The results are shown in Fig. 1. The simulated daily flow depths at the specified segment of irrigation mains were in good agreement with the field data.The daily water depths at field blocks, were determined using the average value of the daily water depth at individual field plonts. The results are summarized in Fig. 2, which indicates the simulation results were also in agreement with the data. These indicate that IRRINET may be used to adequately describe the behaviors of the irrigation system.

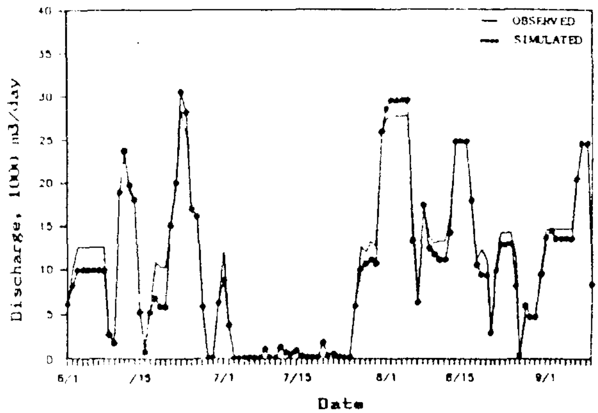

Fig. 1 Observed and simulated water depths, 1988

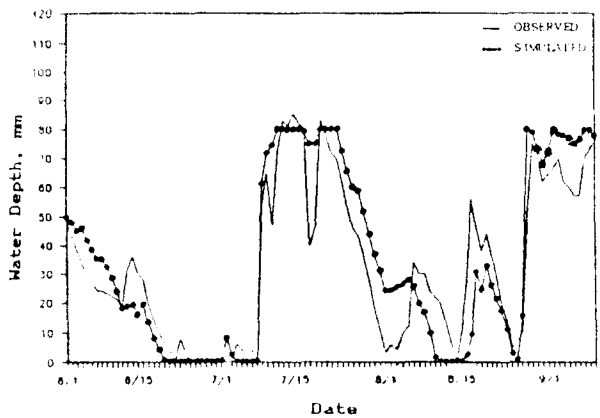

Fig. 2 Observed and simulated water depths, 1988

Irrigation Efficiency

In order to demonstrate the applicability of IRRINET to the identifications of appropriate irrigation schemes for the given irrigation district, different schemes were assumed and the simulated irrigation efficiencies compared. The seasonal averages of irrigation efficiencies among three different cases of the water intake rates at individual field blocks were compared.

The conventional intake rates at the irrigation district were found to be higher at upstream field blocks and become lesser along the way. This allocations were partly due to the tendency that farmers at upstream areas diverted water when irrigation water was released through the canal. The excess water from the upstream areas returned to the stream and was diverted at the weirs downstream. As a result, total irrigation efficiencies became lesser for the district.

IRRINET may also be used as a decision support system for irrigation operations. (Koch and Allen, 1986; Labadie and Sulivan,1986) Research has been initiated to apply IRRINET to the real-time operations

(Labadie, 1986) of an irrigation district. With a few additional measuring facilities along th canal, the disctrict will be operated using the results from IRRINET. And the preliminary results are promising.

CONCLUSIONS

In order to identify an irrigation scheme that may improve the irrigation efficiencies at irrigation districts, a mathematical model that can simulate the behaviors of the irrigation system was developed and tested with the field data. The results indicate that the model simulated the flow rates at the canals and the water fluctuations at field blocks that are very close to the field observations. The model was used to simulate irrigation efficiencies for three different irrigation schemens based on the intake rates. It was found that irrigation efficiencies may be improved by 5 percent by simply adjusting intake rates from the canals to the fields along the way. The model may be used to identify irrigation efficiencies without little change in present irrigation facilities.

REFERENCES

Koch,R.W. and R.L.Allen 1986, "Decision Support System for Local Water Management", ASCE, 112(WR4), pp.527-541.

Labadie,J.W. 1986, "Real Time Control of Water Resource Systems", Computer Application in Water Resource, Proc. of the Specialty Conference in Buffalo, New York, ASCE, pp.489-498.

Labadie,J.W. and C.H.Sullivan 1986, "Computer Decision Support Systems for Water Managers", ASCE, 112(WR3), pp.299-307.

Lee,N.H. 1989, "Simulating Daily Operation of Water Management Systems of Irrigation Districts", Unpublished Ph.D Dissertation,Seoul Nat'l Univ., Republic of korea, pp.150.