MANAGING IRRIGATION SYSTEMS TO MINIMIZE WATERLOGGING AND SALINITY PROBLEMS

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE - PAKISTAN

SEVENTH PROGRESS REPORT

ON

MANAGING IRRIGATION SYSTEMS

TO

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SEVENTH PROGRESS REPORT

1. INTRODUCTION:

This Progress Report on the Project "Managing Irrigation Systems to Minimize Waterlogging and Salinity Problems" cover the half yearly period ending June 30, **1992.**

During the report period the field data collection activities at the tertiary level for the Rabi (winter) season were carried forward at the three research locales on the Upper and Lower Gugera Branches of the Lower Chenab Canal (LCC) and on the Fordwah Sadiqia Canal System.

A programme of investigation and data collection for the Kharif (summer) season was initiated for the same field sites.

The work on the performance at main system level of the Fordwah Branch initiated earlier was finalized by the end of April **1992.** Related to this aspect, the conduct of a massive desiltation program during the annual canal closure period was closely watched and its impact was taken up for monitoring.

The past work at the tertiary level on the Fordwah Sadiqia Canal System was analysed in detail to assess the interaction between surface and groundwater use as influenced by the variability of canal supplies, and the availability and quality of groundwater. Consideration was also given in this study to the socio-economic factors.

With the acquisition of the needed hardware and software, a start was made during the report period on the use of the Geographic Information Systems (GIS).

The report period also marked the initiation of management interventions in association with a parallel research project, which aim to improve the performance of the canal systems. These interventions represent an activity under Phase II of the project.

This Progress Report following the format of the earlier Reports, describes all the above activities in greater detail.

2. PROGRESS:

2.1 Data Collection and Analysis

The field research activities under the Project, complemented with other IIMI-Pak research activities were continued at the three selected locations in the Punjab. These consisted of the follow through of the Rabi season program and the initiatiori of the activities for the following Kharif season starting from April. In addition, special activities were carried out at the main system and tertiary levels. A brief description of these activities are given in the following sections.

2.1.1 Upper and Lower Gugera Sites

The Rabi season (Sept to March) data collection program and the scope of its coverage was presented in the last progress report. For the ensuing Kharif season, the intensity of data collection at the tertiary level was somewhat reduced in the Lower Gugera location on the Junejwala Minor, (3 watercourses in place of 6) and a watercourse was added in the Upper Gugera on the Mananwala Distributary to ascertain in particular the changes that had taken place in soil salinity from an earlier survey. At both, the Upper and Lower Gugera sites, the data collection program for the Kharif season includes besides the monitoring of canal performance, the collection of information at the watercourse and field levels. At the watercourse level, information to be collected comprises the availability of irrigation supplies both from surface and groundwater sources, water table depths, soil salinity and cropping for the selected watercourses. At the farm level information is being collected for water budgeting as well as on crop yields.

As a means for measuring the small irrigation streams in the field, a new RBC flume was tested in the field and compared to the traditional cut throat flume. The results were found to be quite satisfactory and therefore, a number of flumes were locally fabricated with slight modifications. Considering, however, that the RBC flume is less easy to carry, a smaller model was developed and its testing was taken up.

The past hydraulic data, pertaining to Mananwala Distributary and Karkan Minor, was critically examined for discrepancies and corrections made where necessary. The rating curves for Mananwala head and some outlets were checked and modified in this connection.

The analysis of the data from the Upper and Lower Gugera sites, focused on tubewells, canal water supplies and salinity and the position is detailed below:

Tubewells

The analysis of tubewell data for Mananwala Distributary, Karkan minor, Pir Mahal Distributary and Junejwala minor was taken up. The objectives of this analysis are multiple :

First to understand how farmers have been reacting to the inadequacyof canal watersupply by installing tubewells and operating them according to their needs;

Second to detect the impact of groundwater quality on the operation of private tubewells;

Third to try to understand the conjunctive use of surface water and groundwater, at watercourse and farm level, and the main factors influencing it (soil salinity, groundwater quality, economic factors, cropping pattern, etc);

Finally to compare the results for the selected distributaries and minors with results obtained previously on Lagar Distributary (Johnson and Vander Velde's work).

The data have been processed and their basic analysis has been completed for all the distributaries and minors command areas. Further analysis. however, has been focused up to now on Mananwala Distributary command area, where the longest series of IIMI data are available. The first basic results for Mananwala are presented below.

In Mananwala area, private tubewell development has been important during the last decade, similar to what has been found in Lagar command area. The total number of tubewells in 10 sample watercourses has jumped from *20* in 1980 to 190 in 1991 (nearly 10 times more). At the end of 1991, the total density of tubewells in terms of Cultuiable Command Area (CCA) was close to 8 tubewells per 100 hectares. Differences exist between watercourses (from 4 tubewells per 100 ha of CCA in watercourses 87R to 12 tubewells in watercourse 71R) but no head to tail trend was found.

To estimate the total quantity of groundwater used by farmers, operational data of private and public tubewells have been computed as monthly tubewell water supplies. The comparison between the different figures show the following results.

1. Groundwater extraction is higher during the Kharif season than during the Rabi season. However, the difference between the Rabi and the Kharif groundwater supply is larger for the head and tail watercourses than for the middle reach watercourses.

2. Groundwater use for irrigation purposes is high at the head and at the tail of the Distributary. In August 1990, for example, groundwater extraction ranges from 0.35 l/s/ha to as high as 1.2 lls/ha versus 0.08 l/s/ha to 0.13 l/s/ha for the middle watercourses. The high percentage of area under cotton crop (instead of rice) would be one of the main factors explaining the low use of groundwater at the middle reach of the distributary.

3. It was difficult to find a clear relationship between water quality and the time a tubewell has been operated. The main reason for this is that farmers are facing different constraints in different parts of the distributary command area. At the tail of the distributary, farmers face a low groundwater quality having a negative impact on their crops. However, because of the scarcity of canal water there, farmers are completely dependent on groundwater and thus irrigate a lot with groundwater of poor quality. At the head, it is mainly the high percentage of vegetables in some watercourses as well as the importance of the rice crop that explain the high level of groundwater utilization

A tubewell owner survey was started in most of the field stations to complement the collection of operational data. This survey is focused on the management of the tubewells by farmers and their behavior related to the sale of private tubewell water. Already finished in Hasilpur, the collection of the data is still under progress in Mananwala, Farooqabad and Pir Mahal field stations.

Canal Water Supplies

The next step in the analysis is to analyze the canal water supply and compare the total irrigation water supply to the crop water requirements. This analysis was taken up and results are expected shortly.

In 1988/1989 the soil salinity was determined in 3 watercourses in the command areas of Mananwala and Pir Mahal Distributary as part of the data collection programme. The results of this and the data collected on quantity and quality of the irrigation water applied to farms were used in a computer model to predict the development of salinity as a result of the application of marginal and hazardous groundwater. This was reported upon by Kijne and Vander Velde in the Fourth Progress Report.

This Kharif season we have gone back to the same watercourses to check whether the trend that was predicted has indeed taken place over time.

2.1.2 Fordwah Sadiaia Site!;

In this research locale. the field work on the main system pertained to the modelling of the Fordwah Branch on which a start had been made from Oct 1991. This was essentially completed by March 1992.

At the tertiary level, the Rabi 1991/92 program of investigations was carried forward and a programme for the Kharif season was initialed. While the earlier selected watercourses (5 Nos) and farmers (30 nos) were retained for further data collection, the scope for Kharif was enlarged by the addition of four watercourses, and by the selection of 30 additional farmers on the 5 watercourse to include non-tubewell owners.

The economic component of the project was further extended with the following objectives:

to evaluate the economic effects of unsuitable canal water supplies coupled with the use of tubewells;

to quantify the economic consequerices of salinity;

to see how the costs of O&M of tutiewells influences their operation

The results of the Socio-Economic Survey were used extensively for analytical purposes. In addition to this, a tubewell questionnaire was prepared that is being used in all the field stations.

Hvdraulic Performance of the Fordwah Branch

Two Research Associates from Delft University finished their work at the end of Rabi 1991/1992. and wrote up on their research findings in a (draft) report, entitled : "Water Management in the Fordwah Branch, Bahawalnagar Circle". Their study is based on the irrigation operations in this main canal during the Rabi season.

The main findings of their report that were disseminated in a seminar on April 26, attended by the Chief Engineer IRI and the Chief Engineer Bahawalpur Zone and his sub-ordinating officers, are as follows :

Rating tables for the structures in main canal and at the head of distributaries are outdated, rendering it difficult to monitor the actual discharges in the system

The bed of the Fordwah Branch has been silted up badly; differences of the existing bed level with the design bed level of more than a meter were observed.

As a result of the siltation a number of structures have submerged flow conditions; downstream water levels are now influencing the discharge at structures

There are large fluctuations in discharge in the main system that can amount to 3 m^3/s a day

Existing hydraulic data were used as an input for the Delft developed MODIS model and verified in the field. Results indicated that the model predicted water flows accurately. However the use of the model as a package to assist the ID in its daily operation is not feasible at present.

Conjunctive Use of Surface and Groundwater

In the analytical work, the subject which has received considerable attention is the conjunctive use of the surface and groundwater in situations representing wide variations in the equity and reliability of surface supplies and the access to groundwater and differences in its quality. This has particular relevance for secondary soil salinization and also for reclamation of saline lands.

Some of these findings from the analysis of the data are:

All farmers interviewed were mixing groundwater with surface supplies either to augment the supplies or to contract the deterterious effects of low quality tubewell water.

The total Relative Water supply were in the same range for all watercourses monitored (0.8 to 0.9), indicating that farmers tend to spread the irrigation supplies over an area as large as possible to realize greater production.

Groundwater use has been resorted to by the farmers to overcome the paucity and rigidity in canal supplies. The share of tubewell water in the total irrigation supplies ranged from 20% at the head of Fordwah to 84% at the tail of Azim.

There is an active tubewell water trade and all non-tubewell owners reported the purchase of tubewell water with the traded water 20 to 40% of the total volume of groundwater pumped in a watercourse.

The results of the work on Conjunctive Use would be brought out shortly in a publication entitled: "The Appropriateness of Canal Water Supplies: The Response of the Farmers. A case study in the Fordwah/Eastern Sadiqia Area, Punjab. Pakistan', by Pierre Strosser and Marcel Kuper, July 1992, IIMI-P)."

2.2 Special Investigations

Apart from the regular and continuing investigations at the selected field research sites, a number of discrete investigations were taken up or initated during the report period. These are detailed below:

2.2.1 Annual Canal Closure Maintenance & Reuair

During the annual canal closure period in January this year, the Punjab Government had mounted a massive effort for canal desilting by mobilizing the local farming communities and students. Apart from the Irrigation Department, which carries out its own desiltation program within the meager budget, other Provincial Departments were called in to give a helping hand. As this represented a novel approach, IIMI-Pakistan decided to study the operation in some depth with particular reference to the processes involved in planning coordination and implementation. For this purpose intensive observations and interviews were conducted using a modified 'participant observation' technique on a few selected channels in the Upper Gugera (Lagar Distributary. Mittu Minor, Kotla Sub-Minor of the Mananwala Distributary) and information of general nature was gathered from other field stations. Attention was also given to the evaluation of the impact of this program soon after the completion of the works and also on a longer time frame. The analysis of the data and information was undertaken and a draft report, initially for internal use, was prepared. This is intended to be recast as a publication of wider dissemination and especially for the benefit for the Irrigation Department.

2.2.2 Impact of Salinity on Wheat Production

With particular reference to the wheat crop sown during the last Rabi season, a Pakistani Ph.D candidate at the University of Illinois, Urbaiia-Campaign (see 2.4), carried out a major data collection program on the Mananwala and Pir Mahal Distributaries starting from March 1992. This work is intended to contribute to a thesis on 'Sustainability of Indus Basins Impact of Groundwater Salinity on Agricultural Production 1970-90: Damage Assessment and Future Public Policy.'

For data collection the sample comprised of 198 fields of as many farmers. The sample was divided into two equal halves for both distributaries. In each distributary, fields were further divided into three equal groups to represent three reaches, i.e., head , middle, and tail. Fields in these reaches were similarly sub-divided into head, middle, and tail along the selected watercourses. Then fields in each location were selected through a random process.

For primary data collection, as part of this particular effort, field interviews were designed and conducted by using the standard questionnaire. The information related to the following variables was obtained : (i) irrigation and drainage practices; (ii) quality of soils and water; (iii) crop management practices and levels of input use; and (iv) yield levels and profitability of crop culture. The standard procedures for data collection was followed. Soil and water quality tests were carried out to test for their EC, SAR, RSC, and pH. Soil samples were collected from four different depths, 0-15 cm, 15-30 cm, 30-60 cm, and 60-100 cm. Wheat yield samples were collected (using one-square meter ring) to ascertain the yields. Detailed wheat yield analysis is also being carried out to check for average number of tillers per unit of area, average panicle weight, average number of grains per panicle, 1000 grain weight, and grain to straw ratio etc.

Field work for this investigation was planned to last for five months, March through July 1992. The process of primary data collection was divided into two phases. In the first phase, wheat yield cuts and soil samples were obtained from the randomly selected farmers in the sample. In the Mananwala area, these samples were obtained from April 22 through May 4, and in Pir Mahal from April 24 through May 4 1992. Several personal interviews with the farmers were conducted during this period but most of these interviews have been conducted in May and June. Almost all interviews were essentially complete by the end of June.

The chemical analysis of water and soil samples were undertaken in the Department of Soil Science at the University of Agriculture, Faisalabad. These were scheduled to be completed by the end of July.

Secondary time-series data collection has also been undertaken. Data on the related variables from the SCARP Monitoring Organization (SMO) of WAPDA, and Soil Fertility Institute, Lahore, are to be compiled to test for changes in the soil and water quality over an extended period of time.

2.2.3 Land Reclamation Orierations bv PID

The Punjab Irrigation Department (PID) has been carrying out a regular programme of land reclamation through its Directorate of Land Reclamation (DLR) with the primary objective of leaching the salts from saline soils. For this purpose, extra water supplies are provided through 'reclamation shoots' (pipe outlets) during the Kharif season for three years and the farmers are encouraged to use prescribed leaching practices and follow certain cropping patterns and crop relations.

Early in the year, it was decided to study the reclamation operations of the DLR both from the management stand point (to be treated by the Management Specialist) and from the technical stand point (physical impact on soils and crops).

For proceeding with the study, contact was established with the DLR and documentation obtained on the reclamation operations and on the institutional and legal framework. Field visits were also made with the Director, DLR and his staff to locations where reclamation operations have been carried out. These interactions highlighted some of the issues which needed clarification: how the reclamation shoots are sanctioned and operated, whether additional supplies are obtained or whether adjustments are made to the existing supplies, how these special deliveries are handled through the traditional warabandi system and how the farmers as a group in the watercourse perceive this exercise. It was also important to know how the linkages between DLR's staff and the PID staff actually operate in the field. A study of these aspects was considered to be a pre-requisite before the organizational and operational constraints of the DLR could be documented.

To follow through with the study, it was prcposed to undertake monitoring activities, through farmer interviews at a few selected sites in different stages of the reclamation process during the Kharif season.

It is expected that this study could help to define management interventions in collaboration with the DLR which could address the emerging problems of secondary salinization.

2.4.4 Salinity Prevention Flows

Results of the past investigation have indicated that the incidence of secondary salinization is related to the paucity of good quality canal water. The redirection of canal water to areas which are chronically short, could therefore, help to mitigate the problem by the leaching down of the salts. Whether this is possible or not, at different time of the year when the demand may be slack, is a subject worth investigation.

For this purpose, the availability of canal supplies on a selected canal system will be studied, using the records of the Irrigation Department. The procedure for securing the data was outlined and its collection would be taken up during the later half of the year.

2.2.5 Other Investioations

A study was initiated by the Management Specialist to obtain more field data on the operation of the 'warabandi'. The potential for farmer-managed water distribution at the watercourse level is to be assessed with a view to finding out ways in which farmers can be involved in solving salinity related problems. Another important issue under investigation is the operation of equity criterion embodied in the 'warabandi' system.

Field data through interviews with farmers and agency staff collected during 1991, and extensive literature survey on institutional aspects of Pakistan's irrigation, were used to finalize a publication titled, "Institutional Factors Affecting Irrigation Performance in Pakistan" (Bandaragoda and Firdousi). This will be coming out soon as Pakistan Country Paper No. 4, under the aegis of the project.

Following the short and informal survey by French researchers, mentioned in the last Progress Report, a reconnaissance survey was undertaken by a Ph.D candidate from Cornell University (see 2.4), to address, for the first time the gender issue in irrigated agriculture. The purpose of the survey was to address the following issues:

1. The degree of women's involvement in agriculture and irrigation;
2. Influence of women in the decision making process in both agricultural & household work; and
3. Impact of salinity and waterlogging an the work load of rural women.

The field work for this investigation was undertaken starting from February 1992. by interviewing 87 women in the IIMI Research sites in the Upper and Lower Gugera Branches: the Mananwala, Distributary, Pir Mahal Distributary, Junejwala Minor and an area irrigated by a Rasool tubewell.

After analyzing the results of the field work, a report entitled: 'Beyond the Chardar and Chardiwari: Women in the Irrigated areas of Punjab' was brought out in June 1992.

2.3 Consultancies

The consultancy of Ch. Nooruddin, former director of the Land Reclamation Directorate, of the Punjab Irrigation Department, was concluded early in the year upon his submission of the Final Report entitled: "Mechanisms for Coping with Salinity and Waterlogging Problems".

The consultancy of Ms. N. Gijsen was continued in the report period during which she assisted with the acquisition of the needed software and hardware for the GIS system to be activated. She also undertook a critical review of the field data collected at the various locales and determined its suitability for spatial depiction at various levels in the Irrigation System {Distributary, Watercourse, Farm). Suggestions for data management on relevant basic maps were also presented by her, along with a list of research topics in an internal discussion paper (For details refer to section 2.5 Geographic Information System).

During the first two weeks of May 1992, Mr. J. Wind, an ITC staff member was invited, as a consultant, to install the software for the GIS system and to provide training on the use of GIS (See also section 2.5 Geographic Information System).

2.4 Fellowships

The fellowship of the two Junior Research Associates, Anton van Essen and Casper van der Feltz, from the University of Delft. was successfully completed by the end of April 1992. Before their departure, they completed a draft of their report ontitled: Water Management in the Fordwah Branch, Bahawalnagar Circle *(see* also section 2.1.2)

From mid-February 1992, an internship was offered to Ms. Kanchan Basnet, a Nepali national who had obtained a B.Sc from the University of Agriculture in Faisalabad and had recently completed her M.Sc in Irrigation Engineering at Cornell University. She investigated the role of women in irrigated agriculture in the Punjab giving attention to the impact of waterlogging and salinity on their work load. In this work she had the advantage of knowing the local language while interviewing the rural women. On completion of her internship, Ms. Basnet left on July 2, 1992, leaving behind a report based on her work (See also section 2.2.5).

A pre-doctoral fellowship for a period of 5 months was awarded to Mr. Akmal Siddiq, a Pakistani national starting from early March 1992. Mr. Akmal, a Ph.D candidate at the University of Illinois, Urbana-Campaign, had worked with CIMMYT earlier and in examining the wheat yield trends in Pakistan had hypothesized that the salinity in the irrigation waters due to increasing use at groundwater may be a factor which was off-setting yield increases in wheat despite the mounting use of other inputs. His work was therefore, meant to test this hypothesis. With IIMI Pakistan he carried out field work on wheat production in sample areas an important element of which was the determination of yields by crop cutting and the salinity in the soils and irrigation waters. For relating to change over time, the collection of secondary data was also organized as part of the study. The result of the work by Mr. Siddiq would be prssented in his thesis to be submitted to the University of Illinois (*see* also section 2.2.2).

2.5 Geographic Information Systems (GIS)

Following her consultancy report for IIMI on the Applications of Remote Sensing and Geographic Information Systems in Irrigation Management (October 1991), and in keeping with the recommendation for a PC based image processing/G S system, specifically the Integrated Land and Water Information System (ILWIS) developed by the ITC of the Netherlands, Mrs. Nanny Gijsen assisted towards purchase of compatible computer hardware. The configuration comprised an 80486 processor based PC with dual monitor display and a large format digitizing tablet. A color inkjet printer is included to make hard copies for reports. Antecedent of hardware emplacement, Mrs Gijsen prepared a discussion paper outlining the suitability of IIMI's data archives, with emphasis on the pertinent research topics. It was concluded that iricorporation of accurate base maps would be essential towards assimilation of distributary, watercourse, and farm level details. From amongst a wide range of research topics, following were recommended as having immediate relevance:

Comparison of measures of irrigation performance with maps of salt-affected areas or cropping intensity, confirmed through grounc truth and satellite observation.

Spatial linkage between land use/land cover and soil type.

Relate soil deterioration with primary and secondary level salinization.

Salinity variations along the length of the secondary and tertiary water distribution network.

Compare information on cropping intensity from Satellite imagery with Irrigation Department. and IIMI field data sets.

ILWIS GIS installation at IIMI-Pakistan was performed by an ITC staff member, Mr. J. Wind, who also conducted a two-week training course participated by four locals and one IIMI-Sri Lanka staff member. The first week emphasized basic principles of GIS and image processing, whereas the second week concentrated on various applications of the data collected by IIMI.

Proceeding successful system installation, fcrmal data entry has concentrated on the Hasilpur research area for which reliable base maps were available. The continuing entails of rigorous digitizing for spatial details and tagging of appropriate attributes will be followed by overlay analysis to abet management interventions in the area.

As per recommendation of the senior ITC staff member, Mr. W. Siderius, in his Mission Report on "The use of Remote Sensing for Irrigation Management with emphasis on IIMI Research concerning Salinity, Waterlogging and Cropping Patterns," IIMI-Pak has inducted Mr. Gauhar Rehman, a civil engineering cum GIS specialist, as a regular member of the national staff. His appointment, effective June 1, is meant to provide effective support to the ongoing IIMI operations within Pakistan in terms of decision support and management interventions constructs as perceived within a GIS.

2.6 Management Interventions

Following the Retreat, to elicit the collaboration of the Punjab Irrigation Department, in taking up promising management interventions, to which reference was made in the last Progress Report, a start was made on two of the identified management interventions 1) Delivery Accountability, and 2) Computer-Assisted Decision support, which are closely inter-related. Some additional research activities on these topics are being supported under a Cooperative Agreement between USAID and IIMI of Sept. 18, 1991.

Under the first activity, as per decisions taken in working group meeting of IIMI-ID, held at Faisalabad on 6 February 1992, a programme of wate' measurement training and calibration of head structures was launched in Bhagat Sub-division of Lower Gugera Canal Division. The objectives of the activity were two-fold. Firstly to hold training sessions to build capability among the participants to measure discharge of channels by current meter. Secondly to calibrate structures with different flow conditions, i.e. modular and submerged flow. The program was executed in two stages. The first stage was implemented March 1 - 4, 1992. and second was completed April 20 - 23. The first stage activity was centered around training of irrigation staff in use of current meter and measurement of discharge at actual stage (higher than design discharge). The second stage involved measurement of discharges of submerged structures at different percentages of design discharge and training of irrigation staff in development of rating tables. Some seven irrigation officials attended this whole activity and by the start of second stage they were able to measure discharges independently.

It was observed that actual performance of modular structures and submerged structures is quite different from the theoretical performance envisaged (ID discharge tables and regulation rules). Proper management of water distribution within the canal and its offtakes is impossible without the day to day actual measurements and calibration of control structures in terms of discharge and water level. The water measurement at control points frcm time to time will help the ID in identification of problems now being faced in the improvement of equity among distributaries and equity among outlets (turnouts) of a distributary. Group discussions were also held for seeking feedback from the participants. The use of computer software was demonstrated in the development of rating tables for head structures. It was concluded that some of the submerged structures can be made modular with little adjustment of crest widths and raising of crest levels. Sufficient working head is available to incorporate this alteration. It was mentioned that the ID has to purchase a set of current meters for utilizing this built up capability and to calibrate the system as a whole.

The results of this research activity were discussed in ID/IIMI working group meeting held on 23 June 1992 at IIMI' Lahore office. The ID has agreed with the recommendations formulated as a result of the completion of this activity. The ID has promised to implement these recommendations in letter and spirit and for that ID would prepare a work p'an for the same in consultation with IIMI Pakistan. It was also decided to repeat this ID/IIMI joint water measurement programme in LCC West circle, adjoining IIMI research area. It was also decided to discuss these recommendations with the participants at a seminar to be jointly organized by PID and IIMI Pakistan. The seminar is proposed to be held at Faisalabad, the regional office of Chief Engineer Irrigation Zone. The activity of joint ID/IIMI water management programme was decided for implementation in LCC Circle around September 1992.

The second management intervention has been termed as Management Support for Canal Operation and Maintenance and its overall aim is the completion and pilot testing of a Management Support Package that will enable Provincial Irrigatioii Departments (PIDs) to optimize the benefits of limited maintenance budget for improving canal system performance. This will include the establishment of tested procedures on computer modelling of canal hydraulic conditions for accurately predicting the impact of different operational and maintenance inputs on water distribution equity and reliability. The establishment of low input operations mcnitoring programs and development of techniques for establishing priorities for optimal maintenance inputs are also a part of the research study.

IIMI is presently working with two flow siniulation models as components of the Decision Support Package (DSP) Study. One model, named Rajbah (I), has resulted from a synthesis of earlier IIMI canal modelling activities in Pakistan and elsewhere in the IIMI system. This model has proven to be especially suitable for secondary (distributary) canal applications.

Initially the recalibration of Rajbah (I) was taken up for the Lagar Distributary for which extensive and detailed hydraulic data were available and which was supplemented with a hydraulic survey before the annual canal closure in mid January 1992. This involved distributary flow simulations under different operating scenarios.

The survey work of Pir Mahal Distributary (Bhagat sub-division, Lower Gugera division, LCC-East Circle), selected for further field testing of the Decision Support Package was completed, and it was taken UP for study using the Rajbah (I) model. For flow simulation, this distributary was divided into four reaches, each reach terminating at a point of channel bifurcation. During Annual Closure, 1992, the Punjab Irrigation Department desilted the distributary from head to tail, the first 60% of channel with the help of machinery, and depth of excavation involved was as much as one meter.

IIMI-Pakistan undertook a full hydraulic survey of pre and post-desiltation conditions. Sufficient data are now available to study various maintenance options through simulations and to predict likely performance outcomes. Pre-desiltation conclitions have been simulated, and work has begun on post-desiltation simulations. The results of predicted flow conditions are very satisfactory.

Development work continues to make the basic Rajbah (I) model more user friendly (menus, linkages between model components) and to generate graphical output in a simple way. These activities also include the incorporation of a suitable formula for seepage losses linked to a capability to vary seepage coefficients for varying canal reach conditions, and a suitable routine to allow users to choose between working in metric and English units.

Recently IIMI-Pakistan also obtained access to a second hydraulic model, SIC (Simulation of Irrigation Canals), from its Headquarters that is more developed in terms of linkages and "user friendly" interface compared to Rajbah (I). SIC is available for use because of an IIMI collaboration with CEMAGREF (France) on the development and application testing of hydraulic models. A MOU between the two organizations is being negotiated to enable SIC to be more widely used and distributed by IIMI within a DSP or for other purposes to irrigation agencies in various countries where IIMI is working. An advanced version of SIC is expected to becorne available to IIMI Pakistan shortly. Meanwhile, an initial test application of SIC was taken up on the Chasma Right Bank Canal, on which IIMI is investigating the possibility of introducing crop-based operations.

In carrying through this research activity. IIMI has recognized the importance of having PID personnel with canal operations experience and knowledge associated at an early stage with the development of the DSP and agreement has been reached for two executive engineers of the PID to work with IIMI one or two days per week. Also in the process of the DSP development, IIMI is utilizing the services of a PID engineer who has been granted a leave of absence and a Pakistani Systems Analyst.

A further outcome of this Study will be a report on 'guidelines' for improved management of canal operations and maintenance for use by the operating staff of the Irrigation Departments. It is proposed to convene a Workshop to demonstrate the practical application of the DSP as developed.

3. REPORTS

During the period under review. the following reports were prepared, some for internal discussion only, others submitted as IIMI-Pakistan Country Paper, Discussion Paper, or to edited international journals:

AHMAD, N. CH. *1992.* Mechanisms for Coping with Salinity and Waterlogging Problems. Internal Report

ASGHAR, C. M.; **BHATTI. M. A.** and **KIJNE. J.** W. *1992.* Management of Salt Affected Lands for Crop Production in Punjab of Pakistan. - International Symposium on Strategies for Utilizing Salt Affected Lands, Bangkok, Thailand, Feb 17-25, 1992

BANDARAGODA, D. J. and **FIRDOUSI, G. R.** *1991.* Institutional Factors Affecting Irrigation Performance in Pakistan, Research and Policy Priorities, Country Paper # 4

BASNET, K. *1992.* Beyond the Chadar and Chardiwari: Women in the Irrigated Areas of Punjab, June 1992. Internal Report

BHATTI, M. **A.** and **KIJNE. J.** W. *1992.* Irrigation Management Potential of Paddy/Rice Production in Punjab of Pakistan. Paper for International Workshop on Soil and Water Engineering for Paddy Field Management, January 1992, Thailand

BHATTI. M. A. and **KIJNE. J.** W. *1992.* Management for Increasing Productivity for Irrigation Water in Pakistan. To be submitted for discussion at workshop.

BHATTI, M. **A.** and **KIJNE, J.** W. *1992.* Mariagement of Groundwater Abstraction in Gugera Branch. 5th International Drainage Workshop on Subsurface Drainage on Problematic Irrigated Soil: Sustainability and Cost Effectiveness, Feb 1992.

BHUTTA, M. **N.** and **VANDER VELDE. E. J.** *1992.* Equity of Water Distribution along secondary canals in Punjab, Pakistan. To be published in Irrigation and Drainage Systems.

BHATTI, M. **A.** *1990.* Irrigation Management at Farm. Paper presented at IPR 1990, Discussion Paper No. 1, June 1992

ESSEN, A. T. VAN and **VAN DER FELTZ. C. F. C.** *1992.* Water Management in the Fordwah Branch, Bahawalnagar Circle, Punjab, Pakistan. Draft Report, April 1992.

KIJNE. J. W. and **VANDER VELDE, E. J.** *7992.* Salinity & Irrigation Operations in Punjab's Pakistan: Are There Management Options?, Workshop on INDIA-IIMI Collaborative Research in Irrigation Management, New Delhi, February 13-14, 1992.

KIJNE, J. W. *1991.* Sustained Development, Irrigation Management or Crop Production, IPR Nov 1991, Discussion Paper # 5, June, 1992.

KIJNE, J. W. and **LEVINE, G.** *1991.* Opportunities for Management Interventions in Irrigation Systems in Pakistan, IPR October 1991, Discussion Paper # 3, Jun 1992.

KIJNE. J. W. and **VANDER VELDE. E. J.** *1990.* Salinity in Punjab Watercourse Commands and Irrigation Systems Operations: The Imperative Case for Improving Irrigation Management in Pakistan - IPR Dec 1990, Discussion Paper # 2, June 1'392

MURRAY-RUST, D. H.; VANDER VELDE. E. J. and BHUTTA. M. N. *1992.* Cost and Benefits of Selective Canal Maintenance: A Case Study from Pakistan. To **be published in international journal.**

VANDER VELDE. E. J. and JOHNSON. R. L. *7992.* Tubewells in Pakistan Distributary Canal Commands, Lagar Distributary. Lower Chenab Canal System, Punjab. Working Paper 21.

4. WORKPLAN

Following on the discussion of the Workplan for 1992, in the Sixth Progress Report, the main components of the workplan for the remainder of 1992 include:

1. To provide further support to the Punjab Irrigation Department in the introduction and testing of three management interventions.

The first one. on Delivery Accountability, includes training of PID staff in other (Sub-) Divisions in flow measurements and making rating curves, but also aims to instill in staff an awareness of how the information can be used for better management of the system. A workshop will be held for the latter purpose.

The second one, on Computer-assisted Decision Support. involves training of and collaboration with two PID engineers in the further development and use of the Decision Support Package (DSP) for flow management and canal maintenance. A start will be made during the next report period with field testing of the DSP, in close collaboration with PID staff.

The third management intervention, on Salinity Mitigation through Leaching, involves continuation of a study of current practices with respect to sanctioning, delivery and application of so-called leaching shoots, in close collaboration with Directorate of Land Reclamation of the PID. It also includes developing methodologies, including modifications of current warabandi, which would make it possible for PID to deliver flows to areas with the greatest need for leaching, during slack periods of demand. The testing of these methodologies has to await the next period that flows exceed demands, which in some of the study areas could be during the next transition from Kharif to Rabi.

2. To produce outcome from the computer-based geographic information system (GIS), which has been in operation since early June. It will find its first application in producing base maps of many of the parameters with geographic reference ihat have been collected in the sample areas of IIMI's studies. Considering the expressed interest of the Government of Punjab in installing a sub-surface drainage system in the southern part of the Fordwah/Eastern Sadiqia area, with financial support from the World Bank (and the Bank's insistence that further research should precede such a construction), priority will be given to the analysis through GIS of data and information available with IIMI for the study area in that region. Inequity in distribution of amounts of water and of quality of irrigation water have been observed in our study area (see Annex - 1). Farmers have responded by installing tubewells, and by de facto conjunctive management of groundwater and surface water at farm level. GIS will be used to document the extent of conjunctive management by farmers, in an attempt to convince PID staff that in the distribution of canal water more attention should be paid to water quality, to ensure equity in amounts of water and of water quality, in order to prevent build-up of salts in rootzones of irrigated lands. One component of the workplan therefore, is the development of a management intervention that allows PID at the several levels of the system to manage flows of water such that conjunctive management of surface and groundwater is optimized system-wide.

3. To publish reports on IIMI's findings under the Waterlogging and Salinity Project. This issue was discussed in some detail in the previous Progress Report, and has been vigorously pursued since then. Additional reports will be published during the next report period, as was mentioned at several places in the text of this report.

5. FINANCIAL REPORTING

IIMI-PAKISTAN
MANAGING IRRIGATION SYSTEMS TO MINIMIZE WATERLOGGING AND SALINITY PROBLEMS
EXPENDITURE STATEMENT

AS AT JUNE 30, 1992

	BUDGET $	ACTUAL EXPENSES 1989 $	ACTUAL EXPENSES 1990 $	ACTUAL EXPENSES 1991 $	ACTUAL EXPENSES 30-JUN-92 $	TOTAL $
SALARIES	1,529,000	135,464	300,005	398,072	205,546	1,039,087
TRAVEL	90,000	14,392	23,388	23,616	12,754	74,150
S$SERVICES	356,000	44,615	73,947	85,698	46,575	250,835
EQUIPMENT	155,000	21,381	12,707	20,262	22,780	77,130
LEASEHOLD	20,000					
CONTINGEN-CIES	77,000					
	2,227,000	215,852	410,047	527,648	287,655	1,441,202

EXECUTIVE SUMMARY

The Appropriateness of Canal Water Supplies: the Response of the Farmers.

A case study in the Fordwah/Eastern Sadiqia Area, Punjab, Pakistan'

by

Pierre Strosser and Marcel Kuper

In 1989 IIMI initiated research for the Waterlogging and Salinity Project in three different sites in the Punjab. Extension of the research to an area with a different agro-ecological zone, served by its own distinctive irrigation system was advocated, and in late 1990, IIMI started a study in the Fordwah/Eastern Sadiqia area. The area is located in the south-east of the Punjab, bounded by river Sutlej, Cholistan desert and the Indian border.

This (semi-)arid area is served by two main canals, i.e. Fordwah and Eastern Sadiqia Canal, both off-taking from Sutlej at Suleimanki headworks. The system combines both perennial and non-perennial canals in its command area; the latter receiving water only in Kharif. When the system was designed (1930) some canals were made non-perenniai, for fear of waterlogging in the riparian tract along Sutlej.

Fordwah Branch off-takes from Fordwah Canal and part of its service area was selected as study area, downstream from RD 245 (Chishtian Sub-division). Of the 14 distributaries two were studied in more detail, i.e. Azim distributary and Fordwah distributary, and along these distributaries four sample watercourses were chosen (Azim 63, Azim 1'l 1, Fordwah *62* and Fordwah 1301. In addition, Fateh distributary, off-taking from Malik Branch of Eastern Sadiqia Canal was monitored, and a sample watercourse (Fateh 1841 selected. As such, a transect is taken perpendicular to the Sutlej going from the river towards the Choiistan desert. The irrigation system was studied at all levels, from main system level (Fordwah Branch), via distributaries to the watercourse level. Data was collected for one full year, comprising Kharif 1991 and Rabi 193111992.

In this paper, the evaluation of the canal water supplies and the farmers' response are reported.

The discharge at the onset of Kharif is substantially below design at the upstream boundary of the study area. This is due in part to the lower than design discharge at the head of Fordwah Branch, and partly to the higher discharges of the head distributaries off-taking from Fordwah Branch during the beginning of Kharif. This enables farmers in these favored areas to prepare their lands for the rice and cotton crops. The ID responds *to* the water shortage by implementing a rotation between distributaries within the sub-division. The distribution of water between distributaries is not equitable, with Azim receiving only 60% of its share of water during Kharif against Fordwah's 90%. ID quotes the better groundwater quality in Azim command area as a reason for Fordwah's preference. A better degree of organization among farmers in Fordwah command area is another reason.

During Rabi, water is distributed among the five perennial distributaries with non-perennial canals acting as escapes. A rotation is implemented among the three sub-divisions in Fordwah Division resulting in a highly variable discharge at the head of the study areas, ranging from 40 to 180% of design, which in turn leads to the non-perennial canals carrying substantial discharges during Rabi.

The operational preference for Fordwah during Kharif at the cost of Azim has a marked impact on the performance of both distributaries, with Fordwah experiencing 26% dry days at the tail during Kharif and Azim 55%. The situation is compounded by the poor physical condition of the distributaries because of siltation in the head reaches, leading to higher water levels. Head-end moghas draw more water than they should due to substantial changes in the dimensions of moghas since the design of the system. In Kharif 1991, a DPR of 1.3 was measured for the head reach of Azim and Fordwah, whereas for example watercourses at the tail of Azim receive only 16% of the supplies they are entitled to. Illegal irrigation, as evidenced by cuts and breaches, 'contributes to a deficient inter-distributary equitability.

The deficiencies of canal supplies at main an3 secondary level affect farmers differently depending on their location within the system. Farmers in sample watercourses in Azim reported 6 to 24 water turns lost during Kharif, while watercourses in the Fordwah command area lost 4 to 12 turns. This wide range in number of turns lost within the same watercourse is partly due to the rigidity of the warabandi (water distribution schedule). In addition, in Azim farmers reported theft of water turns by powerful farmers as a contributing factor to their losing water turns.

Generally, farmers responded to the constraints of the canal water supplies by developing a large number of private tubewells, with site specific differences in tubewell intensity. Fordwah 62 had sufficient canal water supplies, diminishing the incentives to install tubewells, while for Fateh 184 groundwater quality discouraged farmers in using groundwater for irrigation. Tubewell densities range from 28 per 1000/ha of CCA (Fateh 184) to 80 to 95 tubewells per 1000/ha of CCA in the other watercourses.

As was to be expected from the observed differences in canal water availability, utilization rates of tubewells vary widely, from less than 5% to as much as 45%. Pumping rates in Azim command area are much higher than in Fordwah. Usually tubewells in command areas of tail watercourses pump more water than those located in command areas of head reach watercourses. Groundwater quality limits the utilization of tubewells in Fateh 184. Moreover, distinctly higher utilization rates are found for electric tubewells than for diesel and PTO driven tubewells. because of the substantially higher O&M costs for the latter two types.

At watercourse level, the total Relative Water Supplies are of the same order for all sample watercourses, with the contribution from groundwater ranging from 84% for Azim 11 to 12% for Fateh 184. During the season, the proportion of tubewell water in total irrigation water supplies changes with crop water requirements. As has been observed elsewhere, seasonal applications by individual farmers vary greatly, e.g for cotton ranging from 400 to 1000 mm, depending on tubewell ownership, quality of groundwater, excess to canal supplies and operating cost of the tubewells.

Another response by farmers to the inflexible canal water supplies is wide-spread water trading mainly of tubewell water. All non-tubewell owners purchased tubewell water, with the farmers in the Fordwah command area being far more active than those in Azim, contributing to the reported lower degree of cooperation between farmers in the command area of Azim. The amount of water traded ranges from 20 to 40% of the total tubewell water pumped for the watercourses in Fordwah compared with 5 to 10% in the Azim command area. Even in Fateh 184, in spite of the lower groundwater quality, water trading is more active in Fateh than in Azim command area.