# INCREASING FLEXIBILITY IN CANAL WATER DISTRIBUTION BY IMPROVING OPERATIONAL RULES AND SELECTIVE AUTOMATION (TWO CASE STUDIES)

by

**Zaigham Habib, Gaylord Skogerboe and Kobkiat Pongput**
IIMI Pakistan

## 1. ABSTRACT

The concept of productive irrigation has recently been introduced in a small part of the old, huge and traditionally supply-based Indus Basin Irrigation System (IBIS). This approach tries to solve the water shortage problems of about two hundred fifty thousand ha of command area out of 16 million ha of the total IBIS command because more water is available for these canals. But more than that, it provides an environment to evaluate and compare different aspects of the old and new setup and to address some of the generic issues of the IBIS network. The new approach has bestowed changes: 1) in the concept of water supply by shifting it from fixed and continuous to optimum but variable; 2) in design to provide more and better control structures; and 3) in water regulation and distribution practices by demanding better/effective planning, operations and communication.

This study presents the analysis of hydraulics, operational behavior and the implementation scenarios from two systems of North West Frontier Province (NWFP). The Upper Swat Canal (USC) system is more than 80 years old and is going through rehabilitation and extensions by adding Pehur High-Level Canal (PHLC) from the Tarbella Reservoir to address the new targets. In the history of the Indus Basin, for the first time computers have been used for the complete design of the system, proposed operations has been addressed and analyzed before finalizing the design by using hydraulic models but still there are issues to be resolved. The Chashma Right Bank Canal has been planned and designed as a crop-based supply system, but is facing operational problems due to conceptual, as well as, physical constraints.

The analysis has been carried out by using hydraulic models, SIC and CANALMAN. In both cases, the hydraulic parameters of roughness, velocity and time lags are evaluated along with the physical constraints like canal capacities and freeboard. The impact of the operations of cross and head regulators on the hydraulic parameters and water distribution is quantified using both the steady state and unsteady state computations.

For Upper Swat Canal, a complex algorithm, which is a combination of manual control radial gates and automatic control AVIO & AVIS gates, has been designed. The response of both systems has been analyzed using two hydraulic models, SIC & CANALMAN. For the Chashma Right Bank Canal (CRBC), use of Decision Support Systems (DSS) to make crop-based operational plans and consequently to optimize the gate operations has been presented.

Finally, the expectations from the control agencies are discussed in the context of new demands for their services.

## 2. CONTEXT OF THE STUDY

The concept underlying the design of Chashma Right Bank Canal (CRBC) and Pehur High-Level Canal (PHLC) is acknowledged as a major shift in water supply targets by moving from *protective to productive irrigation in Pakistan.* As a result, changes have been introduced in water allocation, system design, and distribution with reference to the common and established procedures followed throughout the Indus Basin Irrigation System (IBIS) network. In the past, canal systems were designed as supply-based, with a minimum of manual control structures to meet the water requirements for yearly cropping intensities of

50% to 90%. The rationale behind was to irrigate the maximum area by making available good quality canal water over a thinly spread population at that time, while still keeping the operational expenditures of the system as low as possible. With the passage of time, cropping intensities have increased to 100-140%, while the average yield remains quite low. Insufficient water supplies are generally considered as the major cause of low agricultural productivity.

The division of Indus River waters according to the Water Apportionment Accord between the four provinces of Pakistan provides the North West Frontier Province (NWFP) with options to extend its irrigation network. The water storage available upstream of the CRBC and USC systems makes it possible to introduce the concept of *"modernization"* by providing *"higher water allowances"* and *"more demand oriented operations".* The consequent changes in different concepts are briefed below.

### 2.1 Conceptual change in water allocation

For both systems, surface water has been allocated for higher cropping intensities, in the range of 150% to 200%. A bigger percentage of high delta crops have been recommended. The supply patterns are planned to follow the crop water requirements that can vary in a wide range, from 2.57 to 8.6 cusecs/1000 acres for CRBC and from 2 to 17 cusecs/1000 acres for PHLC canals (ref: PC-1 of the projects). The authorized yearly volumes for different sections of the system are computed on this presumed crop demand considering canal water as the only source of water supply.

### 2.2 Change in water distribution patterns

There are two important aspects of Crop Based Irrigation Operations (CBIO):

The maximum flow for a command area is much higher than the traditional flows. The design report of PHLC mentioned: "The irrigation distribution system will be doubled in capacity through enlarging and partially lining canals, and replacing or modifying old canal structures."

Discharge in the main network (main canal and branch canals) vary between a wider range while the secondary and tertiary channel will normally be operated at full supply levels. The design report for PHLC states that the minimum discharge occurs throughout the canal system between November and March, when the main system flow is about half of its maximum. The distribution canal network is designed to operate on proportional flow, with no control gate below the distributary canal head. The moghas are designed to operate over a relatively narrow range of discharge in the parent canal. Effective distribution is dependent on the distributary canals flowing full or near full, in order that the proportional outlets can operate correctly. All rabi season water will be diverted to separate halves of the project on a week-on week-off rotation.

### 2.3 Change in the design and operation of control structures

The main canal control structures should be able to feed the secondary system for the entire flow range without introducing instabilities. A number of upstream control gate structures have been provided in CRBC, while in PHLC canals a host (about fifteen) of downstream water level control gates have been added to provide more flexibility.

The tertiary system should be able to draw the crop water demand over the entire season.

The compatibility and integrated regulation should be assured at different levels of the system.

## 3. SYSTEM DESCRIPTION

### 3.1 Chashma Right Bank Canal

The Stage I of Chashma Right Bank Canal (CRBC) started operating in 1987, Stage II was fully operational in 1994 and Stage-III is under construction. The design canal capacity is 4800 cusecs (147 m^3/sec), which will irrigate 570,000 acres of land. All three stages are planned for operating according to the crop water requirements for 150% cropping intensities and for a fixed cropping pattern in the command area. The crop demand during the year will vary from 40 cumecs to 137 cumecs. The available natural surface slope is 1 in 14000, so it was not possible to provide many cross regulators; however the distributary head regulators rating with escapes are provided to manage the variable flows.

### 3.2 Upper Sawat canals

The system was constructed in 1914 as a supply-based, run of the Swat River system. It supplied water to a command area of 111,700 ha according to a fixed water allowance of 4.5 cusecs per 1000 acres. The present rehabilitation project will enhance the capacity of the Machai Branch and the system at its tail, Maira Branch Canal.

<u>Machai Branch Canal</u>: The canal was designed as a gravity flow system with a capacity of 37 cumecs. Due to the natural topography of the area, the canal is having many natural tunnels, aqueducts, siphons and notch falls; all of them are unregulated structures. Two gated regulators have been provided at the head and the tail of the canal. The Machai Branch will be rehabilitated to carry 67.6 m^3/sec flow, while 12 cross-regulators with radial gates will be added throughout the canal length, all other structures will remain intact.

<u>Maira Branch Canal</u>: Maira offtakes from Machai at RD with a discharge of 11 m^3/sec and serves an area of 34,500 ha. The canal will be rehabilitated to convey 28 cumecs of water at its head and will be regulated through 5 downstream control gates. The mode of supply to the command area will be crop-based.

<u>Pehur High Level Canal</u>: This 26.2 km long canal will offtake from Tarbella Reservoir through a tunnel and supply about 28.11 cumecs of water to Machai Branch at RD 242. The PHLC is designed as a parabolic, lined canal, which will finally feed about 20,000 ha of direct command with a demand based mode of supply. Seven downstream control gates will regulate the canal.

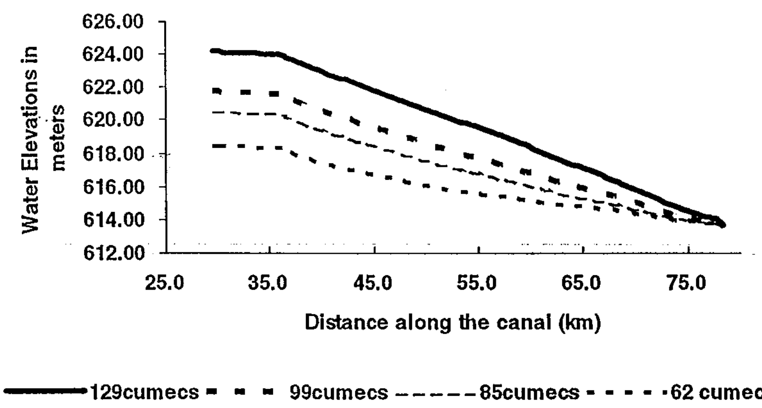
## 4. NEW SCENARIOS OF MANAGEMENT AND OPERATIONAL CONTROL

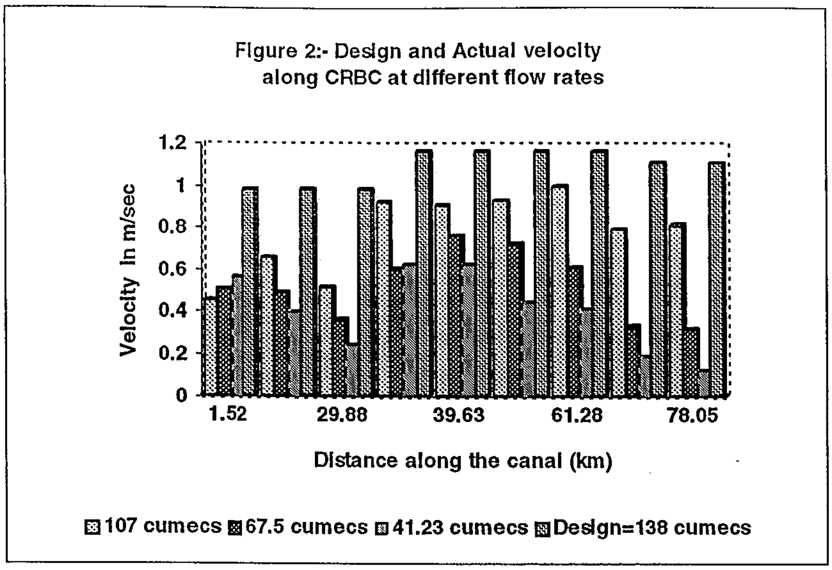
The characteristics of the regulating and control facilities provided in these two systems and their design function are briefly described in Table 1 and 2.

Table 1. Characteristics of the regulating and control facilities of CRBC

| Control or regulating facility | Designed function | Impact on the canal |
|---|---|---|
| Canal lining | Provide strength, save water, feed maximum command | Functions are mostly achieved, although the seepage rate is more than expectations.<br>The maintenance expenditures are much higher than the Indus Basin average.<br>Lining quality is not always according to the standards. |
| Escapes & regulatory structures at the tail of Stage-I & II | Operate the main canal at higher than demand discharge by escaping extra water back into the Indus.<br>Feed the high crest level secondary canals. | The most effective facility used for the partial operation of the system when only a small percentage of the total inflow is delivered by maintaining the water levels to a prescribed level. Figure 1 shows water surface profiles for different flow rates.<br>As a consequence of this operation, velocity reduces drastically upstream of the regulators, allowing deposition of the sediment, see Figure 2. |
| Sediment ejectors | Silt ejecting vans & lower gates for escapes to flush-out silt deposition. | Effect only locally.<br>Not functioning properly. |
| Distributary head regulators & bigger canal capacity | To increase the responsiveness to crop-demands | The maximum deliveries are achieved but the appropriate operational procedures and practices are not developed yet.<br>The ground water is not used in the command area.<br>Over-supply is leading towards waterlogging in the areas where efficient drainage is not available. |

Figure:-1 Water Surface Elevations along CRBC at different flow rates






## Table 2. Characteristics of the regulating and control facilities of Upper Swat Canals

| Control or regulating facility | Designed function | Impact on the canal |
|---|---|---|
| Addition of 12 cross-regulators along with gated secondary canals and untagged direct outlets | To regulate the supply to distributaries & direct outlets at low flows | All of the distributaries will be able to draw their share for the whole flow range;<br>Some of the direct outlets will need further regulation ( e.g. gates at their heads). |
| Parabolic lining of PHLC | To provide strength, reduce the seepage, modernization | High maintenance standards are expected. |
| Downstream control regulation and pipe outlets in PHLC | To introduce demand-based canal supplies & to optimize production.<br>Maximum stability and responsiveness to downstream demand. | Simulation studies show that the first objective will be achieved without any constraint.<br>Hydraulic model's computations indicate enough stability provided by downstream control gates. Figure 3 shows a scenario of un-stability when the discharge demand in the last reach of Pehur is dropped from 12 to 0 cumecs. |
| The downstream control gates, gated secondary canal, and un-gated direct outlets in Maira Branch | To ensure crop based supplies.<br>To achieve the target of equitable water distribution.<br>To optimize the use of water drawn from Tarbella. | The branch canal will function as a live storage for secondary & tertiary system, which will maintain a supply level unless either the float gates in branch canal are readjusted or the gates of secondary distributaries are operated. Analysis indicates that the refusal gates at the heads of direct tertiary outlets from Maira canal will help to manage the supply during low demand periods.<br>The equity and proportional supplies are realized by the designed size and planned rigid operations of the tertiary outlets. |
| The wide functional range of the structures in three branch canals | Provides the technical ability to different reaches of the branch canals to deliver water to the gated secondary canals | Model studies indicate that the given function will be achieved, but as a consequence, velocity and sediment transport capacity of the given reach will decrease drastically. |
| A big escape and on-line storage in the head reach of Maira Branch canal | To ensure security in case of sudden drop in downstream demand, rains, etc. | Both of these facilities provide an important tool to handle the sudden changes and extra supplies. Figure 4 shows the functioning of the escape when a big wave of 29 m^3/sec comes from Machai Branch Canal. |

From the above tables, it is clear that both systems indicate a transitional phase from the supply driven to the demand driven irrigation in Pakistan. The control components in both systems are a combination of old and new; some of their compatibility problems are obvious at this stage. The quantitative increase in the good quality canal water supply, more responsiveness to the command area demands, and the new control techniques like parabolic lining and downstream control gates are major features of the intervention. The PHLC is a multi-objective system at the moment and many targets are set by the project like optimization of production, optimization of Tarbella Reservoir water and equity; a working combination of these targets is still to be seen.

Towards the water management aspects in the irrigation network, the utility of escapes to flush out extra water back to the source has emerged as an important management tool in the operations of CRBC Stage-I & II. This experience has been used in the PHLC system and a big escape is provided at the confluence of three branch canals (i.e. PHLC, Machai and Maira). However, proper consideration still needs to be given to the sediment transport capacity of the canals, especially when operated at low flows or used as live storage. The simulation analysis of Maira indicates a substantial change in velocity and hence the sediment transport capacity. The silt ejectors provided in CRBC have not proved their functionality so far and no clear solution is proposed for PHLC canals. Hence, this is the area where further investigation is required to evaluate and test technical as well as managerial solutions. The improved operations of both of these systems would be a crucial factor determining the successfulness of the crop-based or demand-based concepts. For both systems, only well designed and integrated operations can achieve complex supply objectives and compete with the physical limitations of the network.

## 5. CONCLUSIONS

The multi-criterion supply objectives have been mentioned for these productivity oriented irrigation systems; there is a need to define the link between these objectives or set the priorities.

The schemes will supply more water and enhance the cropping intensities in general. An assessment and review of water and land sustainability over some time period could substantially add to the "productive" vision of the systems.

The concept of new targets and facilities is available in design documents, but not thoroughly discussed in the concerned professional circles, which can delay the operation of the system as crop-based or demand-based.

The inherited peculiarities of the system, like the conveyance of sediment load entering or moving in all Indus-fed canals, must be taken into accounts in order to make new interventions successful.