WORKING PAPER 13

Pakistan Country Series No. 4

Remodeling of Outlets in Three Pilot Distributaries

The Farmer- Managed Irrigation Project in Sind Province Pakistan

Bakhshal Lashari
Hammond Murray-Rust

INTERNATIONAL WATER MANAGEMENT INSTITUTE

FUTURE HARVEST
IWMI is a Future Harvest Center
Supported by the CGIAR

Working Paper 13

Remodeling of Outlets in Three Pilot Distributaries Under the Farmer Managed Irrigation Project in Sindh Province, Pakistan

Bakhshal Lashari

Hammond Murray-Ruest

International Water Management Institute

Extended Project on Farmer Managed Irrigated Agriculture Under The National Drainage Program (NDP)

IWMI receives its principal funding from 58 governments, private foundations, and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR). Support is also given by the Governments of Pakistan, South Africa, and Sri Lanka.

The authors: Dr. Bkhshal Lashari, Senior Researcher IWMI
Dr. Hammond Murray-Rust, Principal Researcher IWMI

Lashari, B., and Murray-Rust, D.H. 2000. *Extended Project on Farmer Managed Irrigated Agriculture Under The National Drainage Program (NDP): Remodeling of Outlets in Three Pilot Distributaries Under the Farmer Managed Irrigation Project in Sindh Province, Pakistan. Lahore, Pakistan: International Water Management Institute (IWMI) 35p. (IWMI working paper 13).*

farmer-managed irrigation systems / irrigation canals / distributary canals / hydraulics / performance / design / water delivery / water users / participatory management / construction / operations / maintenance / Pakistan / Sindh Province / Mirpurkhas / Bareji / Sanghar / Heran / Nawabshah / Doro Naro / Nara

ISBN: 92-9090-204-3

Please direct inquiries and comments to: IWMI 12 Km, Multan Road, Chowk Thoker Niaz Baig, Lahore 53700 Pakistan.

CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

The authors of this report express their profound thanks to the following members of the IWMI field teams who collected all kind of the data presented in this report.

Mr. Niaz H. Sial, Mr. Ghulam Mustafa Talpur, Mr. Nizamudin Bharchoond, Mr. Asghar A. Memon, Mr. Ghulam Mustafa Ujjan, Mr. Ghulam Mujtaba Dhamrah, Mr. Munwar H Memon, Mr. Zahid H Julbani, Mr. Ghous Bux Laghari, Mr. M. Hashim Memon, Mr. Aftab A Khushak, Mr. A. Rahman Soomro, Mr. Waqar Khokhar, Mr. Pahlwan Magsi, Mr. Habib Ahamdani and Mr. Mukhtiar Ali Chandio.

Special thanks go to Professor G.V. Skogerboe former Director of IWMI Pakistan for his valuable suggestions during the first phase of the project.

We also convey our gratitude to Dr. Yameen Memon, Team Leader IWMI Hyderabad, for his encouragement and continuous discussion on completing this report.

Special thanks are due to Mr. Mashooque Ali Talpur field irrigation engineer, Mirpurkhas, who helped in using the SIC model and determining the design parameters of the pilot distributaries.

The authors are indebted to the SIDA and NDP staff for cooperation in discussing the issues of design and actual discharges.

The study forms part of the Farmer Managed Irrigation in Sindh Province, which is funded by the Government of Sindh with assistance from the World Bank.

Special thanks are due to Miss Sofia Saeed for editing this report and also thanks to Mr. Tabrez Ahmad for formatting the report.

SUMMARY

The Farmer Managed Irrigation Project in Sindh under the National Drainage Program selected three distributaries on which Farmer Organizations were created. The International Water Management Institute took responsibility of this pilot project, which addresses the issue of remodeling of outlets to achieve equitable water distribution.

Field studies revealed that there was considerable inequity in water distribution both at the head of secondary canals and between watercourses along each canal. Following discussions about what design discharge should be selected for each of the pilot canals the cross-sections of secondary canals and the elevation and dimension of each watercourse outlet were calculated. Revised discharges were calculated on the assumption that each canal would receive the same average discharge as had been measured in the first phase of the pilot project.

Recommendations are made for the implementation of a remodeling program that fully involves the Farmer Organizations. They should participate in the design of the outlets, help in construction of canals and outlets, participate in the commissioning of the canal to check that actual discharges meet the designed discharges, and undertake a program of monitoring for equitable water distribution. This process has to be undertaken jointly with the Area Water Board staff.

1 RATIONALE FOR REMODELING OUTLETS ON PILOT DISTRIBUTARIES

The Farmer Managed Irrigation Project in Sindh Province, Pakistan has two major objectives:

- To test the viability of farmer's organizations in managing distributaries, minors and Watercourses so that more efficient and equitable allocation of water can be achieved;
- To make recommendations on future extensions from the results of the pilot projects in the remainder of Sindh

The International Water Management Institute (IWMI)1 has been involved in this program since July 1995, first in conjunction with the Department of Agricultural Engineering and Water Management of the Government of Sindh and since April 1999 with the Sindh Irrigation and Drainage Authority (SIDA). IWMI took responsibility to help establish farmer organizations on three pilot distributaries that assessed whether the design of the distributaries and their outlets was suitable to achieve proper sharing of water among all members of the organization.

This is the first effort in Sindh to transfer responsibility for water allocation and distribution among farmers at secondary canal level. Previously farmers were only responsible for implementing warabandi water turns at watercourse level. There are two main reasons why remodeling of outlets is necessary:

- The transfer occurred at the same time as the implementation of the Left Bank Outfall Drain program (LBOD) which involved redesign of some main canals and associated secondary canals to accommodate changes in water allocation through improved surface and sub-surface drainage.
- All secondary canals, whether remodeled or not, are expected to receive an equal share of water delivered into the canal system which exceeds the official design discharge, and must be able to share this surplus equitably.

The standard practice in Sindh is to design canals so that they not only distribute water equitably among all watercourses but are also in regime. This means that no net scouring or sedimentation occurs over the course of a year. The design criteria used to achieve regime are well known and incorporated in the formulae derived by Kennedy (1895) and Lacey (1930).

Observations from the three pilot distributaries indicated that due to a combination of intentional changes and natural deterioration it was not possible to achieve either equitable water distribution or stable regime conditions. It was therefore agreed that IWMI would undertake an assessment of redesign requirements for SIDA as part of the project commitments.

To undertake this study IWMI undertook a series of activities to provide sufficient information to determine the revised design conditions. These included:

- Re-surveying the sample canals and outlet structures
- Undertaking field studies of actual discharges
- Calibration of the canals for use in the SIC model
- Discussions with SIDA officials about policy towards changing design discharges
- Computer calculation of revised design conditions.

[1] Formerly known as the International Irrigation Management Institute (IIMI)

2 DESCRIPTION OF THE PILOT DISTRIBUTARIES

In consultation with various Departments of the Government of Sindh it was decided to select three pilot distributaries that would represent different conditions encountered elsewhere in the province, and particularly those found elsewhere in the LBOD project area. The three selected distributaries are shown on Figure 1. All three canals are in the command of canals served from the Left Bank of the Indus at Sukkur Barrage.

a) Bareji Distributary, Mirpurkhas District

Bareji Distributary offtakes from Jamrao Canal at RD 408[2]. It was originally designed and commissioned in 1932 to irrigate a command area of approximately 20,000 acres (8,000 hectares) through 31 outlets. The canal was designed according to the standard conditions and criteria in force at that time in Sindh, and had a design discharge of 64.28 cusecs (1.82 m3/sec).

In 1984 the canal was remodeled because portions of the tail end of the command area were transferred from Bareji Distributary to canals served by Mithrao Canal. A total of seven outlets command area were transferred so that remodeling was required. The new command area was established as 14,531 acres (5,880 ha) served by 24 outlets. As a result of these changes the length of the distributary was reduced from 62,250 feet (18,978 m) to 39,300 feet (11,981 m) and the design discharge reduced to 41.0 cusecs (1.16 m^3/sec). The design parameters of distributary and its outlets are provided in Annex-I, Tables 1 & 4.

Under the LBOD Project, along with other distributaries of Jamrao Canal, the Bareji Distributary was again remodeled in 1994/95 and a large increase in water allocation was given to significantly increase the discharge capacity of Jamrao Canal. Most canals had their original design discharge doubled or more and Bareji was no exception: the new design discharge was established as 109 cusecs (3.09 m3/sec). There was no change in the number of outlets or command area, but obviously the capacity of existing outlets was changed to deliver the increased discharge.

During the LBOD remodeling the cross-sections and longitudinal section were carefully redesigned to deliver the new design discharge, the details are provided in Annex-I, Table 2. The regulator at the head of Bareji Distributary was rebuilt to carry the new design discharge, new berms and bridges were constructed, and other infrastructure changed.

Individual outlets were not redesigned. Instead, they were replaced by pre-cast outlet structures that could be modified after installation to have the appropriate width and depth of the orifice or flume. Because the new Jamrao II canal paralleling the original Jamrao canal was not commissioned until early in 2000 the new design discharge could not be delivered anyway, so there was no real pressure to deal with the outlet dimensions during the period of remodeling the distributary. The expectation is that when the new design discharge is delivered then new outlet structures will be sized according to calculations undertaken at that time.

A re-survey of the distributary was made in 1997/98 as part of the IWMI project. The results of this survey show that there are significant deviations from the 1994/95 design drawings, and when the new design discharge is actually delivered significant physical remodeling will be required again. The details of survey are provided in Annex-I, Table 3.

[2] RD denotes Reduced Distance and equal to 1000 feet. In Pakistan it is measured in feet from the head of the canal downstream.

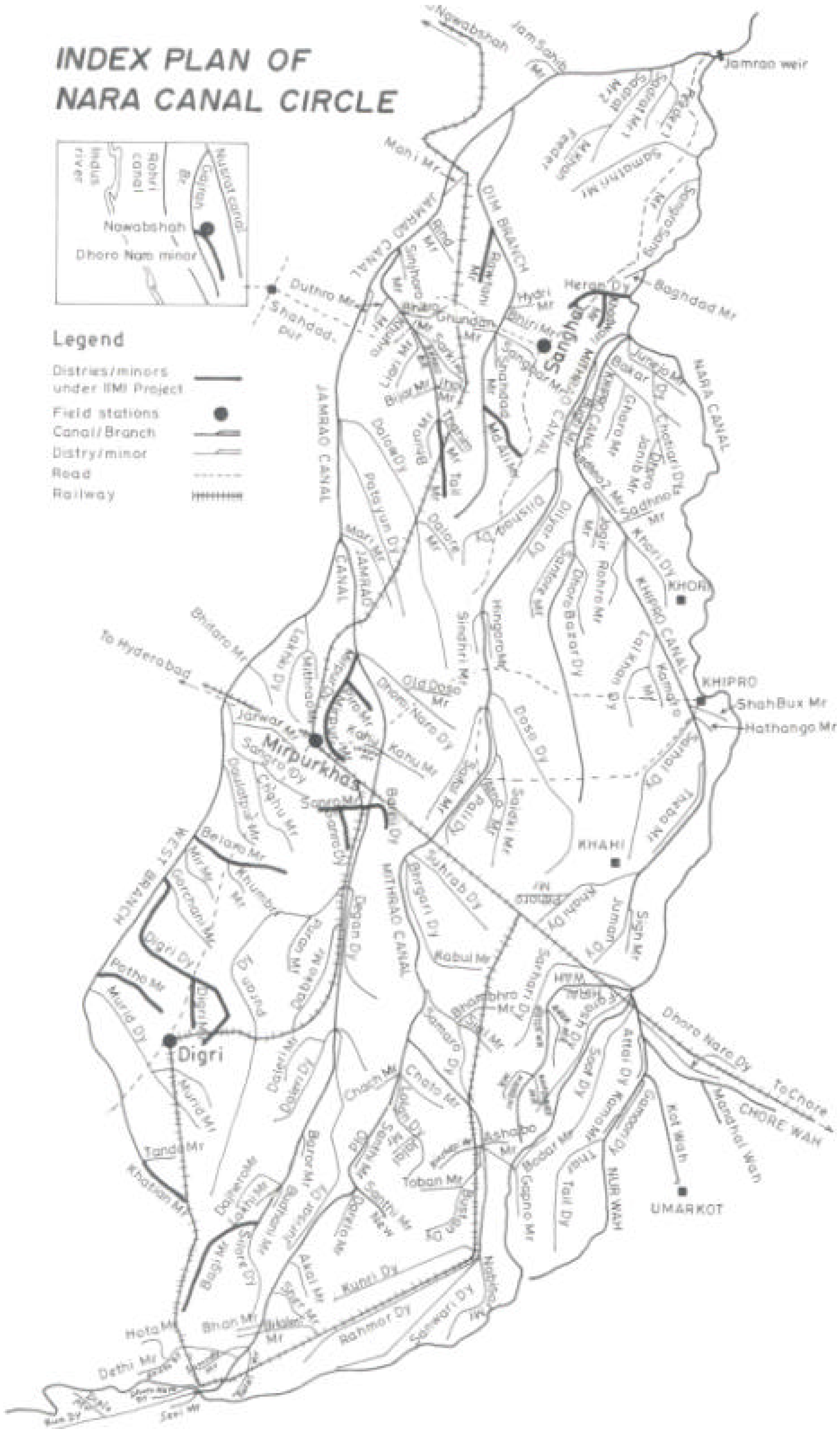

Figure 1. Index plan of Nara Canal Circle.

b) Heran Distributary, Sanghar District

Heran Distributary offtakes from Nara Canal just upstream of the Cross-regulator that controls discharges into Mithrao canal. It therefore has a favored location because there is always sufficient head available at the headgate to permit plenty of water to be delivered.

Like Bareji Distributary, Heran Distributary was constructed in 1932. However, it has not been remodeled since then, and the original design conditions are still in force at present time. The command area is some 15,400 acres (6,235 ha) served by 24 outlets along Heran Distributary and 7 along Khadwari Minor which offtakes at RD 10. The total length of Heran Distributary is 32,000 feet (9,756 m), while Khadwari Minor is 17,000 feet (5,182 m). The design discharge of Heran Distributary is 62.5 cusecs (1.77 m^3/s).

The designed conditions of Heran Distributary are shown in Annex II, Table 1 and outlet dimension data is shown in Annex II, Table 2.

Conditions in 1997/98 were in many instances significantly different from the original design, again largely due to wear and tear of the canal system and adaptation of outlets to meet higher than anticipated water deliveries. The dimensions measured at the time of the IWMI survey are present in Annex II, Table 1.

c) Dhoro Naro Minor, Nawabshah District

Despite its name, Dhoro Naro Minor is more or less the same size as both the other canals in the pilot project study. It offtakes from Gajrah Branch of Rohri Canal. It is also a tail of Gajrah Branch canal command area, which means that it is close to the tail of the command area of Rohri Canal, and therefore more susceptible to water shortages.

The canal was also designed in 1932 and has not been remodeled since. The original design conditions, which are presented, in Annex III, Tables 1 and 2 are still valid today. The canal has a command area of 13,500 acres (6,235 ha) with 25 outlets. There is no minor branching off from Dhoro Naro. The design discharge for the canal is 52.8 cusecs (1.50 m^3/sec).

Just as the other two canals there have been significant changes since the canal was first constructed. The canal condition that existed at the time of the IWMI survey in 1997/98 is shown in Annex III, Table 1.

3 HYDRAULIC PERFORMANCE OF THE PILOT DISTRIBUTARIES

Part of the IWMI activities in the three pilot distributaries included monitoring of hydraulic performance. This was included in the study to better understand the current water distribution conditions and determine what would be required of farmer organizations to achieve the objective of more equitable water distribution.

Monitoring commenced in April 1997 and has continued on and off until the present time. The main focus has been on daily water delivery at the head of each distributary, daily water levels and discharge readings at new gauges installed at the head and head of the middle and tail reaches of the distributary, and periodic monitoring of watercourse discharges.

A separate study has been conducted on water distribution equity in the pilot project area (Murray-Rust and Lashari, 2000) and so only a summary of the conditions experienced in the three pilot distributaries is presented in this study. The summary only refers to the water conditions experienced close to the time of the surveys of physical conditions. Data for more recent periods is found in the IWMI Quarterly Reports for the Pilot Project (IWMI 1999 and 2000) although any significant deviations are reported below.

Each distributary shows that there are significant deviations from designed conditions in terms of discharges actually delivered. Each of the canals studied has a different pattern of water deliveries, and thus may indeed represent the range of conditions experienced in other locations in the province.

a) Bareji Distributary

Water Deliveries to Bareji Distributary show that there is a relatively steady discharge into the canal irrespective of the season or the actual demand for water. The highest discharges occurred in July and August 1997, which is during the period of peak demand for water while there was a slight decrease in discharge during the cooler months of November, December and January. However, each month the actual discharge exceeded design by significant amount, typically in the range of 50-75% above design except for January when demand is low and canal closure occurs (see Figure 2 and Annex-IV, Table 1).

It is obvious that if actual discharges were so much higher than design discharge then the original outlet design would be unable to pass all of the available water, let alone pass it in an equitable manner. It is clear that numerous modifications to outlets will have to be made to accommodate the higher discharges.

Figure 3 (Annex-IV, Tables 2&3) shows the average Delivery Performance Ratio (DPR) for each watercourse along Bareji Distributary in both Kharif and Rabi seasons: DPR is the ratio of actual discharge to design discharge. So any value greater than 1.0 indicates that actual discharge exceeds the design discharge (Bos et al., 1993). It is obvious from Figure 3 that virtually all of the watercourses get more than their designed discharge, a condition that would be expected if the discharge at the head of the distributary is also greater than design.

However, there is a highly inequitable distribution of water: four watercourses get less than design while four others get more than twice their share. There is no head-tail trend. The pattern observed in Figure 3 probably results from several factors:

- some watercourses have a high degree of waterlogging and therefore do not want much water;
- some outlets have been enlarged to obtain more water;
- some outlets use the new structures built in 1994/95 which were intended to meet a design discharge of 109 cusecs at the head of the canal;
- some outlets are higher than the canal bed and must use lifting machines to get water into the watercourse.

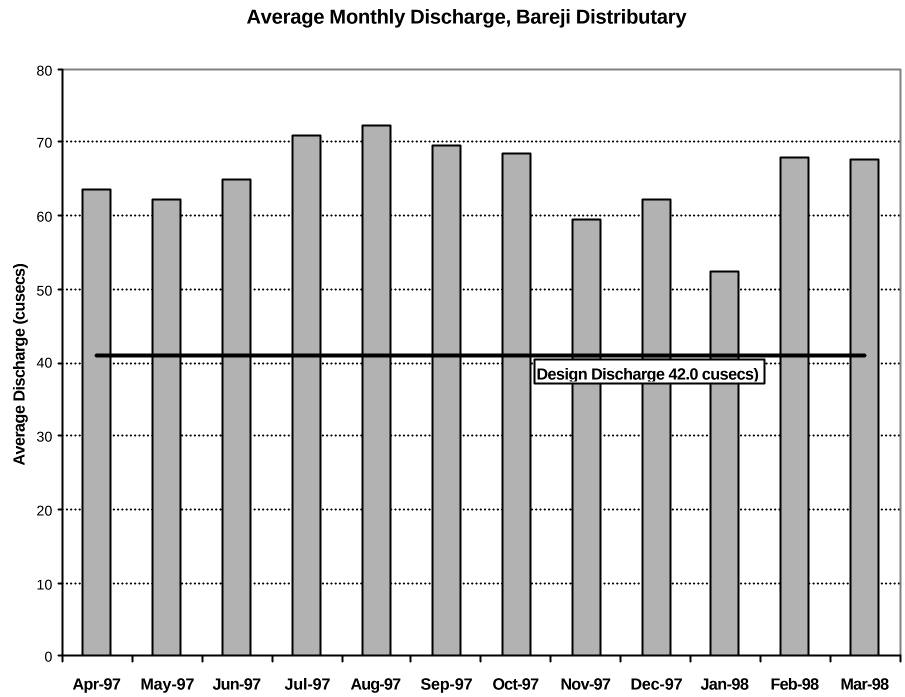

Figure 2. Average monthly discharge, Bareji distributary.

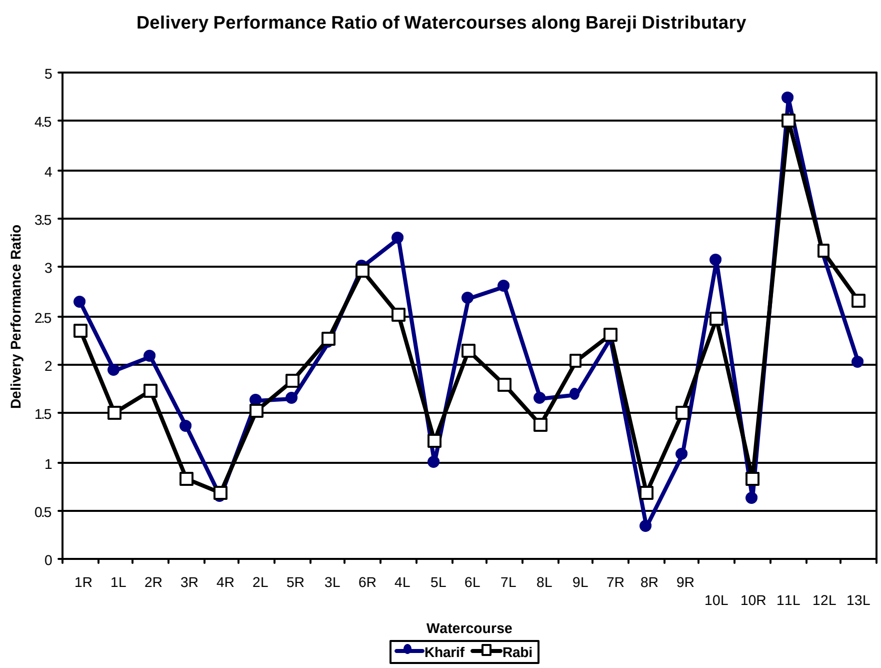

Figure 3. Delivery performance ratio of watercourses along Bareji distributary.

All in all it is clear that without substantial remodeling of the outlets along Bareji Distributary it is impossible to obtain equitable water distribution.

b) Heran Distributary

The pattern of water deliveries into Heran Distributary is rather different to that of Bareji Distributary (Figure 4 and Annex-V, Table 1). During the summer months when demand is high there is a very high level of water delivery, and average actual deliveries exceed design discharge by 175-190%. During the cooler winter months, however, deliveries into the canal are reduced to more or less design levels. This does not imply any water shortage is likely in this period, because demand is very much lower than design discharge in the winter. We can therefore conclude that there is no problem in getting adequate water at Heran Distributary but that the head regulator is managed somewhat more than at Bareji. This is probably because there is waterlogging in parts of Heran Distributary command area, and if too much water is issued into the canal during periods of low demand then the waterlogging will become progressively worse.

A bimodal pattern of water distribution such as that observed at Heran Distributary means it is impossible to expect outlets to have an equitable pattern of water delivery. Figure 5 (Annex-V, Table 2) shows that every watercourse obtains more than design discharge, that there is high variability in DPR values for head end watercourses, and also shows a slight head-tail difference with tail end watercourses only just getting more than design discharge.

However, in general, the pattern of water distribution in Heran Distributary is more equitable than in Bareji, with less difference in the DPRs of the most favored and least favored watercourses. Overall Heran and Bareji both show a pattern of water distribution typical of canals that have plenty of water, such as those of the Lower Swat Canal (Murray-Rust et al., 1996).

Like Bareji it is clear that remodeling of outlets is required to obtain a more equitable pattern of water distribution.

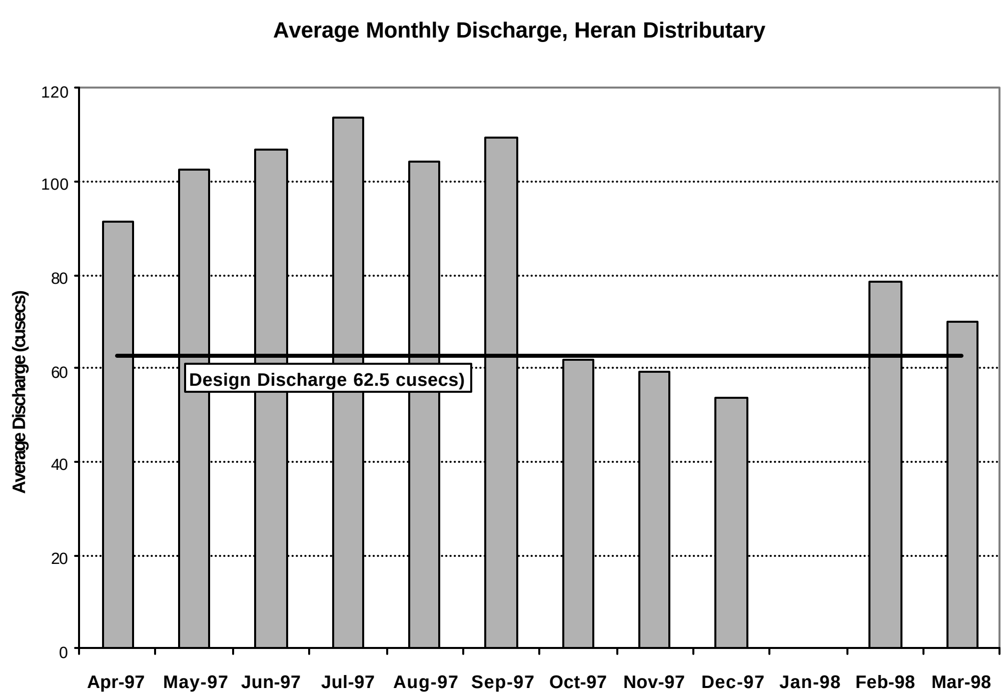

Figure 4. Average monthly discharge, Heran Distributary.

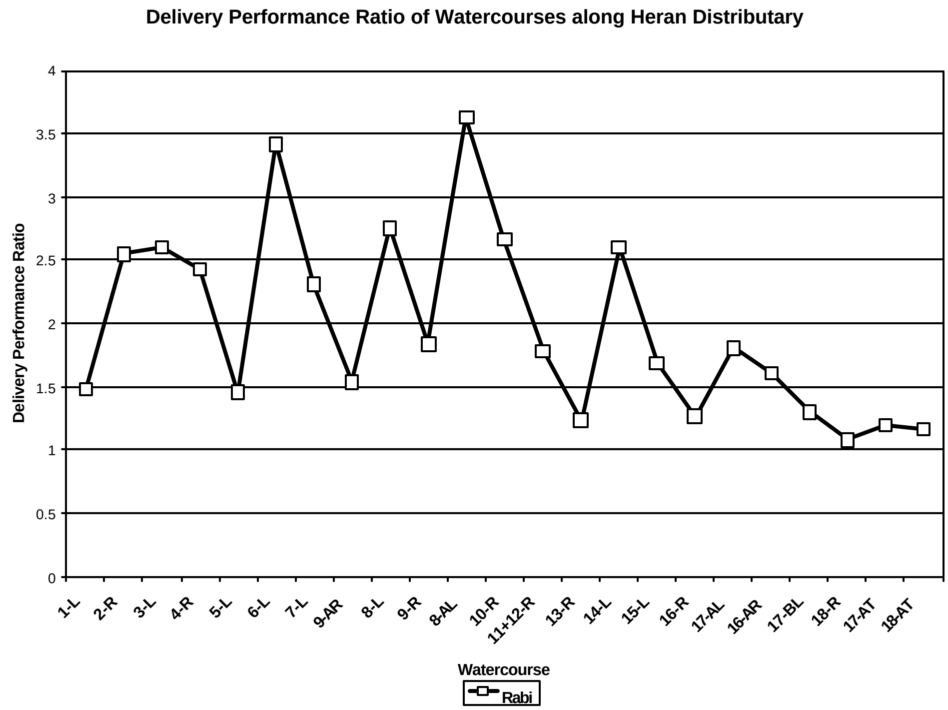

Figure 5. Delivery performance ratio of watercourses along Heran Distributary.

c) Dhoro Naro Minor

At Dhoro Naro Minor we find a very different water distribution pattern during the measurement period. Firstly, actual discharges are very close to design discharges, and even when they are above design they only exceed the target by approximately 10-25%. It is also noticeable that the canal gets less water when demand is higher, and more water when demand is less (Figure 6 and Annex-VI, Table 1). This appears to be the consequence of Dhoro Naro being towards the tail of Rohri Canal command. When demand is high upstream canals take more water, and there is consequently less available for downstream areas. When demand in upstream canals declines then more water passes to the tail end areas.

Given this pattern of water deliveries in the head we should be able to observe whether design conditions are also met at the watercourse level. Ideally, with head discharges close to design we should also expect to have reasonably equitable water distribution if outlet structures are also close to design conditions.

Figure 7 (Annex-VI, Tables 2&3) shows that there is also a highly inequitable pattern of water distribution at Dhoro Naro, with a strong head-tail difference. None of the tail end watercourses obtain design discharge while all head end watercourses exceed it substantially. The inequity is worse in Kharif when water supplies are slightly lower but demand is higher.

The pattern of inequity at Dhoro Naro is much more like the patterns observed in previous studies elsewhere in Pakistan where discharges at the head are at or close to design discharge (Bhutta and Vander Velde, 1994).

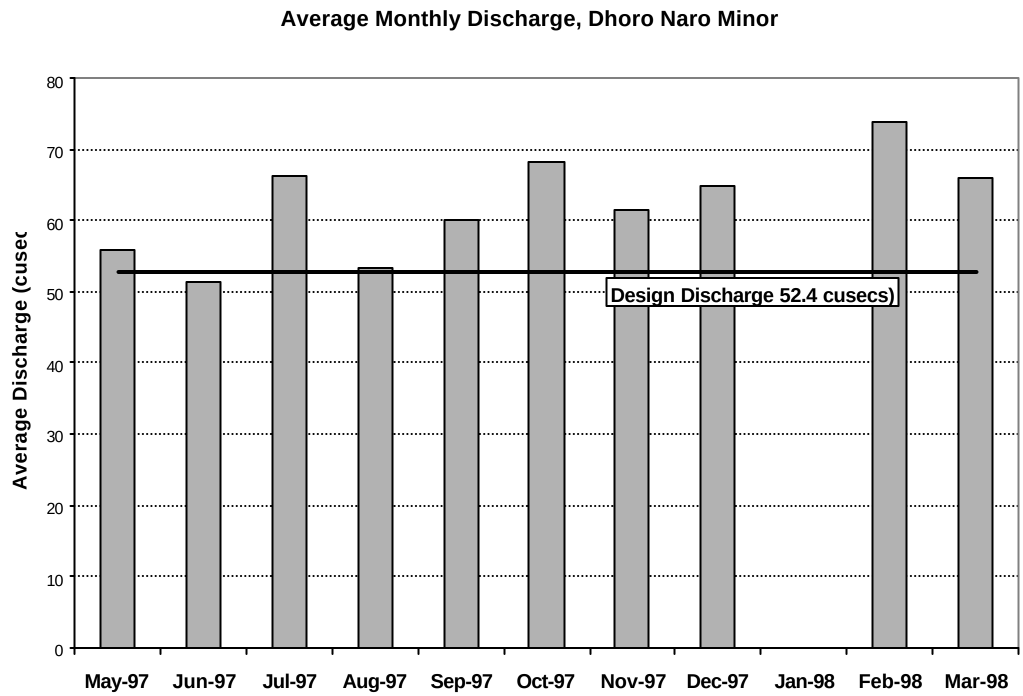

Figure 6. Average monthly discharge, Dhoro Naro Minor.

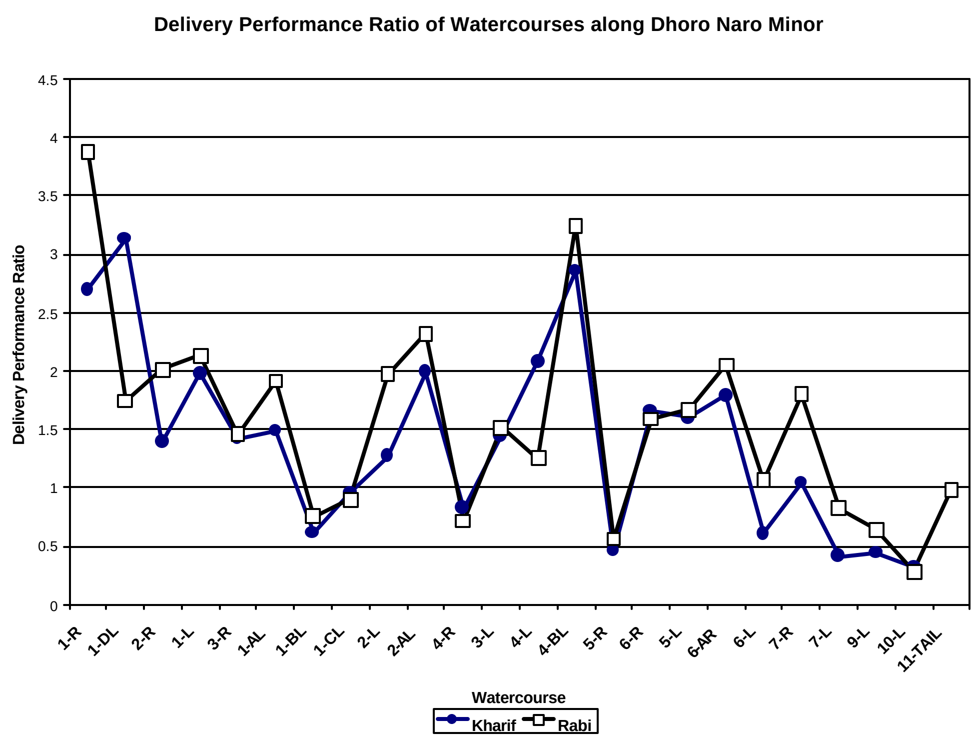

Figure 7. Delivery performance ratio of watercourses along Dhoro Naro Minor.

4 DETERMINING THE DESIGN PARAMETERS FOR REMODELING

In a new irrigation system it is easy to determine the design parameters. Once the overall water allocation for the system has been determined and the boundaries of each watercourse mapped out, then the design for each watercourse outlet is a simple calculation because the water allocation per 1000 acres is applied equally to all areas.

In remodeling, however, it is impossible to ignore changes that have occurred since the scheme was originally constructed and operated. Typical changes that may need to be taken into account include:

- Loss of command area due to roads, village expansion, etc;
- Loss of command area due to waterlogging and salinization;
- Informal transfer of land from one watercourse command to another due to topography or social factors;
- Legal increases in watercourse discharges for orchards;
- Splitting of watercourses;
- Additional sanctioned outlets.

Further, and much more complicated, is the expectation of water users to obtain at least as much water in the future as they are currently getting, even if current levels of discharge greatly exceed design levels. This is the situation found in both Bareji and Heran Distributaries.

Before design can be started, a set of policy decisions must be made to determine the design discharge for each distributary. As these decisions have not been finalized by SIDA this report considers three alternatives for remodeling on the basis that the original command area of each watercourse will be irrigated. The three alternatives are:

- The official design discharge established in 1932 (Heran and Dhoro Naro only);
- The average annual discharge measured during the period 1997/98 under the Pilot Project for Farmer Managed Irrigation in Sindh (i.e. the current status quo);
- The proposed design discharge for those canals remodeled under LBOD (Bareji only).

Using these design discharges it is relatively easy to calculate the dimensions of the canals and the outlets. This was done using the Lacey Formula.

A second assumption was made, again following existing design guidelines, that all outlets would be Adjustable Proportional Modules (APM) except for 20% of outlets closest to the tail, which would be Open Flumes (OF). It has been clearly demonstrated over the years that this combination of outlet types provides the best way to achieve equitable water distribution along the length of a distributary canal.

The results of these calculations are presented for the three canals in Annexes 7 to 9. For each canal three sets of data are presented:

- the canal cross-sections at 5000 feet intervals for both the original design and existing discharge levels;
- the proposed dimensions of each outlet for the expected design discharge (i.e. 109 cusec design discharge for Bareji as per the LBOD remodeling program, 60 cusecs for Heran and 51.6 cusecs for Dhoro Naro);
- the dimensions that would be required to distribute existing discharges equitably in existing dimensions of the distributary, calculated using the SIC model.

From the data provided in these appendices it is then possible to proceed with remodeling once the appropriate design discharge has been chosen. Given the ease of using computers to recalculate all of the canal dimensions it is possible to determine outlet dimensions for any other design discharge should there be a change in policy towards water allocation at the Area Water Board level.

However, remodeling under the Pilot Program of the Farmer Managed Irrigation Project in Sindh also requires the participation of water users, an issue that is addressed in the next section.

5 INVOLVEMENT OF WATER USERS AND OTHERS IN REMODELING OF OUTLETS

It is essential that water users be involved in any process of remodeling because they have to agree to the changes made and feel that they are partners of the physical infrastructure. In the circumstances present in Sindh this is even more important because Farmer Organizations are being established who will take over full operation and maintenance responsibility for secondary canals and watercourses.

Clearly there has to be a high level decision made concerning the overall discharge into each canal at the Area Water Board level because it is not possible to let each canal bargain for a different level of discharge.

a) Water User Involvement in Design

Once the target discharge is established for each secondary canal, then the design must be discussed with the Farmer Organization members so that they fully understand the expected pattern of water distribution that will occur once remodeling has been completed. If discussions do not take place at this stage in an open atmosphere then there will be suspicion that one group will receive more than another, and this suspicion may later result in damage to infrastructure.

Before the establishment of Farmer Organizations there was no effective communication between staff of the Sindh Irrigation Department and water users. Now such channels of communication have been established and it is possible to have a much more participatory involvement of the water users. By holding design meetings with the water users everybody is involved and cannot complain of any underhand deals.

b) Water User Involvement in Construction

It has been shown in other locations that if water users are involved in the reconstruction of infrastructure they are much more likely to accept that the outlet is constructed according to the agreed design. In the Gal Oya Water Management Project the newly established farmer organizations were able to undertake earthwork and some basic construction for which they were paid under a series of contracts awarded by the Irrigation Department (Uphoff, 1986).

Not only did this mean that the quality of the work was higher than if a disinterested contractor had done it, but it also earned some income for the farmer organization that they could use for other purposes. It is noteworthy that these farmer organizations, which function at secondary canal level and have representation at the equivalent of the Area Water Board level, are continuing to function effectively after 20 years.

c) Water User Involvement in Commissioning of Remodeled Canals

An important element of remodeling is testing the canal once it has been completed to ensure that it functions properly. The case of Kalpani Distributary in Northwest Frontier Province is a clear example of the need to check actual discharges as soon as construction is completed (Murray-Rust and van Halsema, 1998). It is just not acceptable to assume a canal will function properly: it must be verified.

Once remodeling has been completed then a joint program of verification can be implemented whereby both Irrigation Department staff and water users test the discharge of each watercourse and of the secondary canal at selected locations.

If both parties are satisfied that the actual discharges are close enough to design conditions then the structures can be formally turned over to the water users with an agreement and understanding that the infrastructure does what it is designed for.

Where there are major deviations from designed conditions, structures have to be adjusted accordingly.

d) Operation and Maintenance

Once the remodeled canal is turned over to the Farmer Organization routine operation and maintenance activities can be undertaken. The most important elements are the periodic checking of discharges of different outlets along the lines of the old "H" register that is rarely undertaken these days, and the checking of cross-sections of the secondary canal. With recent moves that involve the Army of Pakistan in checking outlet dimensions it is important for the Farmer Organization to maintain a proper Outlet Register that shows what the dimensions of each outlet should be.

The Farmer Organization must pay particular attention to the discharge received at the head of the secondary canal. If incoming discharges are too high or too low it becomes impossible to maintain equitable water distribution.

Data on water levels and discharges have to be sent to the Area Water Board, where conditions in all canals can be monitored. It is important that these data are also made available to constituent Farmer Organizations so that they can verify that water distribution is equitable between secondary canals and within their own area of responsibility.

With such routine activities it is possible to foresee a situation whereby equitable water distribution becomes a straightforward task.

6 CONCLUSIONS

Assuming that the range of conditions experienced in the three pilot distributaries is representative of overall conditions in Sindh, then it is clear that there is a great deal of work to be undertaken before equitable water distribution can be re-established.

Current conditions are clearly inequitable. Actual discharges at the head of secondary canals show big variations from design, with some canals getting a lot more while others getting less than design. Along distributaries there are large variations in the DPR for different watercourses.

Rectifying this situation is not easy but it can be undertaken if a proper process of remodeling is established that uses the Farmer Organizations as allies in the process rather than enemies.

It has to be a joint process because the Farmer Organizations do not have the technical skills to redesign canals and outlets in the correct manner and therefore require the inputs of the SIDA staff. However, SIDA staff must view the Farmer Organizations as their clients and treat them accordingly. The process of remodeling must be open and transparent so that there is no room for suspicion or interference by influential.

The actual redesign is a simple process once the design conditions have been established and agreed upon by all concerned. With the aid of computers the systems can be redesigned to accommodate any discharge at the secondary canal level, and allowances can be made for special conditions along a secondary canal that are agreed upon by the Farmer Organization.

It should be fully understood that remodeling goes well beyond mere design. It requires the involvement of water users in all stages of the intervention: planning, design, construction, testing, operation and maintenance, and in monitoring of conditions after remodeling has occurred.

REFERENCES

Bhutta, M.N., and Vander Velde, E. J. 1992**.** *Equity of water distribution along secondary canals in Punjab, Pakistan.* Irrigation and Drainage Systems, 6(2):161-177.

Bos, M. G., Murray-Rust, D. H., Merrey, D. J., Johnson, H. G., and Snellen, W. B. 1994. *Methodologies for assessing performance of irrigation and drainage management.* Irrigation and Drainage Systems, 7(4):231-261.

Gerald Lacey. 1930. *Stable channels in alluvium,* Proceedings, Institution of Civil Engineers, London, Vol. 229, pp. 259-384.

International Water Management Institute. 1999-2000. *Quarterly Progress Reports.* Farmer-Managed Irrigated Agriculture Project, under National Drainage Program.

Murray-Rust, D. H.; Lashari, B.; Memon Y (2000). *Water Distribution Equity in Sindh Province, Pakistan*. Pakistan National Program. International Water Management Institute (IWMI),

Murray-Rust, D. H.; Van Halsema, G. 1998. Effects of construction defects on hydraulic performance of Kalpani distributary, NWFP, Pakistan. Irrigation and Drainage Systems, 12(4):323-340.

Murray-Rust, D. H.; Vander Velde, E. J.; Habib-ur-Rehman. (Eds.) 1997. *Water management in NWFP.* Peshawar, Pakistan; Wageningen, The Netherlands: NWFP Agricultural University; Wageningen Agricultural University. V, 367p.

Murray-Rust, D. H.; Vander Velde, E. J. 1994. Changes in hydraulic performance and comparative costs of lining and desilting of secondary canals in Punjab, Pakistan. Irrigation and Drainage Systems, 8(3):137-158.

Robert G. Kennedy (1895). The prevention of silting in irrigation canals, Proceedings, Institution of Civil Engineers, London, Vol. 119, pp. 281-290.

Uphoff, N. 1992. Learning from Gal Oya: Possibilities for participatory development and post-Newtonian social science. Ithaca, NY, USA: Cornell University. x, 448p.

ANNEXURES

Annex-I

Table 1. Design dimensions of Bareji Distributary, Mirpurkhas for the year 1984.

Distance [RD]	Bed level [ft]	Width [ft]	Depth [ft]	Standard Specifications				
				Berm Width [ft]	Bank Width [ft] IP	Bank Width [ft] NIP	Side Slopes	Free Board [ft]
0	54.19	12	2.5	10	12	5	0.5:1	2
5	53.34	11	2.5	10	12	5	0.5:1	2
10	52.49	10.5	2	10	12	5	0.5:1	2
15	51.64	7	2	10	12	5	0.5:1	2
20	50.79	7	2	10	12	5	0.5:1	2
25	49.94	6	1.4	10	12	5	0.5:1	2
30	49.08	3.5	1.2	10	12	5	0.5:1	2
35	48.23	3.5	1.15	10	12	5	0.5:1	2

Table 2 Design dimensions of Bareji Distributary, Mirpurkhas for the year 1994

Distance [RD]	Bed level [ft]	Width [ft]	Depth [ft]	Berm Width [ft]	Bank Width [ft] IP	Bank Width [ft] NIP	Side Slopes	Free Board [ft]
0	54.2	23	3.3	10	12	12	0.5:1	1.5
5	53.8	21	3.1	10	12	12	0.5:1	1.5
10	53.1	19	2.9	10	12	12	0.5:1	1.5
15	52.7	17	2.5	10	12	12	0.5:1	1.5
20	52	14	2.3	5	12	12	0.5:1	1.5
25	51.3	13	2.1	5	12	12	0.5:1	1.5
30	50.5	10	1.8	5	12	12	0.5:1	1.5
35	49.7	6	1.4	5	12	12	0.5:1	1.5

Table 3 Existing (1999) dimensions Of Bareji Distributary, Mirpurkhas.

Distance [RD]	Bed level [ft]	Width [ft]	Depth [ft]
0	51.87	19.0	4.63
5	51.27	15.0	4.23
10	51.14	11.5	3.66
15	50.21	7.5	3.79
20	49.30	6.0	4.0
25	48.53	3.5	4.37
30	48.44	3.9	4.46
35	47.04	4.0	4.46

Where: RD is reduced distance and equal to 1000 ft
IP is inspection path and NIP is non-inspection path

Table 4. Design dimensions of outlets for Bareji Distributary, Mirpurkhas for the year 1984.

W/C.No.		Distance	CCA	Qd	H	B	Y	HL	H	MMH	Type of	R.L of
IIMI	IPD	(RD)	Acres	[cfs]	[ft]	[ft]	[ft]	[ft]			outlet	crest
1-R	240/1	0.5	254	0.7	1.30	0.20	0.50	-	0.8	0.6	APM	53.16
1-L	229/1L	0.5	685	2.01	2.70	0.25	0.80	2.1	1.9	1.42	APM	51.72
2-R	240/1AR	1.75	248	0.72	1.20	0.32	0.40	0.3	0.8	-	APM	53.05
3-R	239/2R	4.9	829	2.32	2.20	0.40	0.66	0.6	1.5	1.15	APM	51.36
4-R	239/2A	4.9	294	1.89	2.00	0.32	1.08	0.2	0.9	0.69	APM	51.56
2-L	228/1L	5.7	806	2.26	2.00	0.32	0.92	2.3	1.1	0.81	APM	51.81
5-R	240/2R	6.7	601	1.74	2.10	0.40	0.72	-	1.4	1.04	APM	51.55
3-L	228/1A	11.5	670	1.88	2.10	0.50	0.40	2	1.7	1.27	APM	50.48
6-R	240/3R	11.5	481	1.29	1.30	0.32	0.75	-	0.6	0.39	APM	51.22
4-L	228/2L	12.1	144	0.4	1.50	0.20	0.25	1.1	1.3	0.93	APM	50.96
5-L	227/1AL	12.1	1590	4.43	2.60	0.63	0.80	-	1.8	1.35	APM	49.80
6-L	227/1L	13.1	661	1.84	1.90	0.32	0.72	1.63	1.2	0.9	APM	50.50
7-L	226/1L	14	523	1.44	1.90	0.25	0.72	1.4	1.2	0.9	APM	50.37
8-L	226/2L	17.3	583	1.63	2.00	0.25	0.80	0.9	1.2	0.9	APM	49.74
9-L	225/1L	20	547	1.54	1.20	0.35	-	1	1.2	0.19	OF	50.21
7-R	239/3R	22.9	136	0.39	1.60	0.20	0.24	0.9	1.4	1.02	APM	48.38
9-R	238/2R	25.1	451	1.27	1.00	0.40	-	0.2	1.0	0.14	OF	48.51
8-R	238/1R	25.1	777	2.25	1.80	0.40	0.76	0.6	1.0	0.78	APM	48.76
10-L	225/1AL	25.4	722	0.91	1.35	0.18	-	-	1.4	-	OF	-
10-R	237/1R	29.2	807	2.26	1.30	0.17	-	0.1	1.3	0.17	OF	47.49
11-L	225/2L	30.3	339	0.52	1.30	0.20	0.41	0.3	0.9	0.66	APM	48.71
12-L	224/1L	33.5	354	0.58	1.00	0.18	-	0.05	1.0	0.14	OF	47.56
11-R	236/1AR	36										
13-L	224/2L	39.31	646	1.53	1.00	0.48	-	-	1.0	0.14	OF	47.16

Annex II

Table 1. Design and existing dimensions of Heran Distributary, Sanghar.

Distance (RD)	Designed (1932) Width [ft]	Existing (1997/98)		
		Depth [ft]	Width [ft]	Depth [ft]
0.50	15.00	2.80	18.00	4.40
4.40	15.00	2.70	18.00	4.08
10.00	15.00	2.50	11.67	3.52
16.70	10.00	2.30	9.58	3.64
18.77			9.00	3.49
24.99	7.00	1.90	9.00	3.40
29.89			7.00	2.55
30.95	5.00	1.30	6.50	2.32

Table 2. Design dimensions of outlets for Heran Distributary, Sanghar for the year 1932.

W/C No.	Distance [RD]	CCA [Acres]	Discharge [cusec]	H [ft]	B [ft]	Y [ft]	HL [ft]	MMH [ft]	RL Crest [ft]
1-L	2.64	233	0.84	1.60	0.20	0.55	0.20	0.89	76.71
2-R	4.39	228	0.54	2.00	0.20	0.28	-	1.29	76.20
3-L	6.95	310	0.99	2.30	0.20	0.52	0.90	1.33	75.38
4-R	7.18	952	2.46	2.00	0.40	0.77	0.50	0.92	75.58
5-L	9.29	454	2.50	2.00	0.40	0.46	0.32	1.15	72.00
6-L	10.10	520	1.45	1.50	0.40	0.50	0.30	0.75	75.58
7-L	10.10	575	2.09	2.50	0.25	0.92	1.30	0.78	74.58
8-L	11.90	421	1.55	2.10	0.25	0.73	1.20	1.00	73.33
9-AR	11.09	457	1.55	1.30	0.50	0.46	0.30	0.63	74.31
9-R	13.02	854	3.16	2.10	0.40	1.05	1.30	0.53	73.00
8-AL	16.70	291	1.08	2.00	0.20	0.66	2.10	0.67	72.22
10-R	17.35	582	2.17	2.00	0.32	0.69	1.50	0.66	72.11
11+12-R	18.77	1167	4.52	1.60	0.80	0.85	0.61	0.56	72.20
13-R	20.81	517	1.93	1.90	0.32	0.78	1.40	0.56	71.43
14-L	21.83	304	1.13	1.80	0.20	0.73	2.20	0.80	71.30
15-L	25.00	316	1.15	1.80	0.20	0.78	2.00	0.15	70.58
16-R	26.06	759	2.83	2.20	0.32	1.10	0.90	0.83	69.93
17-AL	26.73	588	2.66	1.80	0.40	0.65	1.30	0.89	70.16
16-AR	29.90	500	1.85	1.20	5"+1/4"	-	0.40	-	-
17-BL	30.95	491	1.85	1.60	0.40	0.66	0.80	0.70	69.36
18-R	30.95	522	2.19	1.20	6"+1/4"	-	-	0.19	-
18-AT	32.01	633	3.12	1.50	6"+1/4"	-	0.24	0.27	69.76
17-T	32.01	589	2.38	0.24	4"+5/8"	-	0.24	0.27	69.26
17-AT	32.01	416	2.27	-	-	-	-	0.27	69.26

Annex-III

Table 1. Design and existing dimensions of Dhoro Naro Minor, Nawabshah.

Distance (RD)	Designed (1932)		Existing (1997-98)	
	Width [ft]	Depth [ft]	Width [ft]	Depth [ft]
0.00	15.5	2.3	16	3.99
5.50	15	2.3	17	4.30
5.90			19	3.73
10.50	13	2.2	15	3.13
11.48			17	2.91
14.50	11	2.1	13	2.72
16.73			13	3.15
24.50	9	1.7	11	3.05
28.86			10	3.20
31.50	7.5	1.6	5	2.68
32.28	7.15	1.4	6	2.06
33.78			5	3.21

Table 2. Design dimensions of outlets for Dhoro Naro Minor, Nawabshah for the year 1932.

W/C. No.	Distance [RD]	CCA [Acres]	Q_d [Cusec]	B [ft]	H [(ft]	Crest level [ft]	Type of Outlet
1-R	2.000	327	1.4	0.17	2.2	96.37	OF
1-DL	3.750	388	1.45	0.27	1.8	96.13	OF
2-R	5.700	436	1.59	0.15	2.15	95.89	OF
1-L	6.959	563	1.62	0.13	2.4	95.72	OF
3-R	8.987	406	1.45	0.21	1.55	95.45	OF
1-AL	10.250	574	1.76	0.17	2.1	95.3	OF
1-BL	11.000	898	4.3	0.64	1.6	95.25	OF
1-CL	11.000	988	2.56	0.36	1.75	95.25	OF
2-L	11.100	695	2.02	0.27	1.7	95.26	OF
2-AL	12.960	485	1.44	0.13	2.3	95	OF
4-R	12.980	1167	3.46	0.51	1.6	95.03	OF
3-L	13.660	560	1.76	0.15	2.3	94.96	OF
4-L	14.946	351	1.01	0.09	2.1	94.77	OF
4-BL	15.276	454	1.43	0.21	1.6	94.73	OF
5-R	18.801	445	1.17	0.13	2.1	94.62	OF
4-AL	18.942	83	0.24	0.09	0.7	94.25	OF
6-R	22.076	216	0.83	0.10	1.5	94.26	OF
5-L	24.170	631	1.88	0.25	1	93.83	OF
6-AR	24.386	179	0.57	0.17	1.7	93.55	OF
6-L	27.526	851	2.41	0.33	1.9	93.55	OF
7-R	29.500	353	1.02	0.11	1.6	93.13	OF
7-L	31.590	688	2.01	0.29	1.2	92.91	OF
9-L	31.795	729	2.11	0.25	1.8	92.64	OF
10-L	32.275	820	2.38	0.55	1.2	92.67	OF
11-T	32.275	288	0.98	0.26	1	92.7	OF

Annex-IV

Table 1. Actual discharges at head regulator of Bareji Distributary Mirpurkhas.

Month	Average (Q) [Cusec]	Month	Average (Q) [Cusec]
April 97	63.5	October 97	68.59
May 97	62.2	November 97	59.52
June 97	64.8	December 97	62.26
July 97	71.0	January 98	52.37
August 97	72.2	February 98	67.93
Sept 97	69.5	March 98	67.65

Table 2. Water delivery performance ratio at each outlet of Bareji Distributary, Mirpurkhas for kharif 1997.

W/c No. IWMI	W/c No. IPD	Design Q [Cusec]	May	June	July	Aug	Sept
1R	240/1	0.7	2.52	2.58	2.52	3.00	2.52
1L	229/1L	2.01	1.85	1.84	1.86	1.82	2.36
2R	240/1AR	0.72	2.09	2.09	2.09	2.03	2.07
3R	239/2R	2.32	1.41	1.28	1.53	1.58	1.01
4R	239/2A	1.89	0.66	0.69	0.67	0.59	0.59
2L	228/1L	2.26	1.96	1.95	1.32	1.31	1.64
5R	240/2R	1.74	1.73	1.72	1.75	1.28	1.76
3L	228/1A	1.88	2.13	2.10	2.31	2.19	2.39
6R	240/3R	1.29	1.76	1.73	4.03	4.35	3.11
4L	228/2L	0.4	5.27	4.00	2.24	2.46	2.53
5L	227/1AL	4.43	1.01	1.06	0.82	0.99	1.10
6L	227/1L	1.84	2.77	2.85	2.64	2.51	2.63
7L	226/1L	1.44	2.41	2.96	2.86	3.01	2.72
8L	226/2L	1.63	1.26	1.13	1.91	2.07	1.87
9L	225/1L	1.54	1.55	1.67	1.68	1.54	1.98
7R	239/3R	0.39	1.85	1.16	3.06	2.82	2.48
8R	238/1R	2.25	0.27	0.26	0.20	0.49	0.49
9R	238/2R	1.27	1.02	0.94	0.95	1.02	1.39
10L	225/1AL	0.91	3.00	3.32	2.62	2.78	3.66
10R	237/1R	2.26	0.74	0.68	0.60	0.83	0.25
11L	225/2L	0.52	2.54	4.69	4.94	6.68	4.80
12L	224/1L	0.58	3.49	2.41	3.69	2.67	3.50
11R	236/1AR						
13L	224/2L	1.53	1.81	2.32	1.73	2.62	1.63

Table 3. Water delivery performance ratio at each outlet of Bareji Distributary, Mirpurkhas for rabi 1997/98.

W/cNo. IWMI	W/c No. IPD	Design Q [Cusec]	Oct	Nov	Dec	Feb	Mar
1R	240/1	0.7	2.19	2.26	3.02	2.43	1.87
1L	229/1L	2.01	2.51	1.42	1.09	1.31	1.15
2R	240/1AR	0.72	2.07	1.71	1.97	1.63	1.30
3R	239/2R	2.32	0.85	0.71	0.45	0.94	1.23
4R	239/2A	1.89	0.52	0.29	0.40	0.99	1.22
2L	228/1L	2.26	1.50	1.51	1.45	1.67	1.50
5R	240/2R	1.74	1.77	1.67	1.68	2.19	1.86
3L	228/1A	1.88	2.49	2.07	2.02	2.39	2.32
6R	240/3R	1.29	3.08	3.57	2.97	2.78	2.42
4L	228/2L	0.4	2.24	2.32	1.66	3.16	3.23
5L	227/1AL	4.43	0.91	0.59	1.48	1.68	1.47
6L	227/1L	1.84	2.30	1.70	1.68	2.48	2.56
7L	226/1L	1.44	2.90	1.32	1.65	1.58	1.47
8L	226/2L	1.63	1.53	1.65	1.56	1.08	1.09
9L	225/1L	1.54	2.22	1.54	1.36	2.83	2.20
7R	239/3R	0.39	2.86	2.55	1.92	1.65	2.55
8R	238/1R	2.25	0.53	0.72	0.75	0.74	0.63
9R	238/2R	1.27	1.73	1.80	1.66	1.02	1.29
10L	225/1AL	0.91	2.94	3.50	1.78	2.67	1.46
10R	237/1R	2.26	0.38	0.81	0.87	0.81	1.26
11L	225/2L	0.52	6.13	4.24	4.09	3.93	4.10
12L	224/1L	0.58	3.43	2.15	4.71	2.49	3.02
11R							
13L	224/2L	1.53	1.58	2.55	2.77	1.99	4.37

Annex-V

Table 1. Actual average discharge at head regulator of Heran Distributary, Sanghar

Month	Discharge [cusec]	Month	Discharge [cusec]
Apr 97	91.3	Oct 97	62.0
May 97	102.5	Nov 97	59.4
June 97	107.0	Dec 97	53.5
July 97	113.7	Feb 98	78.4
Aug 97	104.4	Mar 98	69.9
Sept 97	109.6		

Table 2. Water delivery performance ratio at each outlet of Heran Distributary, Sanghar for kharif 1997.

WC	Design Q [cusec]	April	May	June	July	August	Sept
1-L	0.84	0.94	0.84	1.54	1.36	2.73	1.48
2-R	0.54	1.62	1.90	2.31	2.20	3.06	4.21
3-L	0.99	2.19	3.02	3.11	2.72	3.20	1.37
4-R	2.46	2.21	2.31	2.40	2.54	2.26	2.84
5-L	2.50	0.96	1.20	1.35	1.28	1.86	2.07
6-L	1.45	4.05	4.59	4.66	3.96	1.66	1.59
7-L	2.09	1.71	2.19	2.30	2.25	2.54	2.85
9-AR	1.55	1.32	1.47	1.57	1.53	1.71	1.63
8-L	1.55	2.28	2.73	2.84	2.94	2.91	2.82
9-R	3.16	1.57	1.90	1.92	1.77	1.89	1.98
8-AL	1.08	3.09	3.72	3.93	3.96	3.10	3.98
10-R	2.17	2.30	2.26	2.65	2.87	2.97	2.95
11+12-R	4.52	1.56	1.61	1.66	1.75	2.17	1.93
13-R	1.93	1.09	1.34	1.22	1.31	1.20	1.23
14-L	1.13	2.14	2.48	2.64	2.79	2.74	2.81
15-L	1.15	1.55	1.89	1.59	1.75	1.62	1.69
16-R	2.83	1.23	1.43	1.28	1.33	1.01	1.31
17-AL	2.66	1.47	1.85	1.86	1.93	1.74	1.98
16-AR	1.85	1.26	1.56	1.75	1.69	1.36	2.01
17-BL	1.85	0.98	1.38	1.36	1.41	1.33	1.34
18-R	2.19	0.91	1.06	1.07	1.22	1.12	1.09
17-AT	2.38	0.94	1.37	1.13	1.35	1.07	1.30
18-AT	3.12	0.96	1.27	1.06	1.26	1.19	1.23
1-AL KM	1.02	2.12	2.16	2.49	2.56	2.11	2.75
1-L	.83	2.67	2.87	3.55	3.41	2.40	2.95
2-R	2.06	0.83	0.94	1.30	1.30	1.00	0.86
3-L	1.28	1.55	1.20	1.27	1.52	1.43	1.46
4-R	2.62	0.93	0.91	0.94	1.30	1.00	1.15
5-T	1.64	1.59	1.43	1.52	1.83	1.81	2.45
6-T	1.06	1.02	0.94	1.05	1.56	1.03	1.40

Annex-VI

Table 1. Actual average discharge at head regulator of Dhoro Naro Minor, Nawabshah.

Month	Discharge [Cusec]	Month	Discharge [Cusec]
May-97	55.97	Oct-97	68.26
Jun-97	51.38	Nov-97	61.40
Jul-97	66.30	Dec-97	64.77
Aug-97	53.37	Feb-98	73.90
Sep-97	60.04	Mar-98	65.92

Table 2. Water delivery performance ratio at each outlet of Dhoro Naro Minor, Nawabshah for kharif 1997.

W/c No.	Design Q [Cusec]	June	July	August	Sept
1-R	1.4	3.04	1.93	2.45	3.37
1-DL	1.45	4.65	2.50	2.82	2.56
2-R	1.59	0.82	1.62	1.39	1.74
1-L	1.62	1.86	2.34	2.21	1.50
3-R	1.45	1.43	1.68	1.71	0.88
1-AL	1.76	1.35	1.81	1.39	1.39
1-BL	4.3	0.70	0.61	0.65	0.50
1-CL	2.56	1.02	1.08	0.83	0.90
2-L	2.02	1.60	1.08	1.12	1.28
2-AL	1.44	1.52	2.57	1.85	2.02
4-R	3.46	0.92	0.79	0.88	0.70
3-L	1.76	1.79	1.94	1.04	1.02
4-L	1.01	3.41	2.86	0.96	1.09
4-BL	1.43	1.73	3.48	2.95	3.26
4-AL	1.17	4.05	9.99	10.14	12.37
5-R	0.24	0.13	0.41	0.51	0.78
6-R	0.83	0.87	1.64	1.75	2.37
5-L	1.88	1.02	2.12	1.61	1.66
6-AR	0.57	0.66	2.46	1.80	2.23
6-L	2.41	0.16	0.65	0.70	0.93
7-R	1.02	0.36	1.52	1.12	1.17
7-L	2.01	0.12	0.56	0.41	0.57
9-L	2.11	0.11	0.78	0.31	0.58
10-L	2.38	0.08	0.50	0.31	0.39
11-TAIL	0.98				

Table 3. Water delivery performance ratio at each outlet of Dhoro Naro Minor, Nawabshah for rabi 1997/98.

W/c No.	Design Q [Cusec]	Oct	Nov	Dec	Feb	Mar
1-R	1.4	4.18	4.22	4.58	4.44	1.96
1-DL	1.45	1.80	1.76	2.03	1.76	1.36
2-R	1.59	1.71	1.93	2.11	1.94	2.37
1-L	1.62	2.06	1.98	2.25	2.19	2.17
3-R	1.45	1.16	1.12	1.26	1.46	2.29
1-AL	1.76	2.02	1.69	2.05	1.86	1.94
1-BL	4.3	0.76	0.68	0.57	0.66	1.11
1-CL	2.56	0.50	0.86	1.17	1.11	0.85
2-L	2.02	1.55	1.24	2.00	2.18	2.90
2-AL	1.44	2.07	2.15	2.52	2.88	1.99
4-R	3.46	0.31	0.50	0.70	1.24	0.84
3-L	1.76	1.18	1.19	1.47	1.64	2.08
4-L	1.01	1.09	1.10	1.27	1.54	1.28
4-BL	1.43	2.88	3.14	3.72	3.94	2.54
4-AL	1.17	10.72	11.19	12.06	13.17	8.66
5-R	0.24	0.47	0.35	1.02	0.80	0.17
6-R	0.83	1.52	0.66	0.58	3.18	2.00
5-L	1.88	1.72	0.87	1.43	2.32	2.01
6-AR	0.57	1.14	1.88	3.41	2.28	1.56
6-L	2.41	1.41	0.72	0.82	0.78	1.59
7-R	1.02	2.11	1.48	1.27	2.43	1.72
7-L	2.01	1.58	1.04	0.47	0.12	0.90
9-L	2.11	1.30	0.51	0.42	0.05	0.93
10-L	2.38	0.28	0.14	0.23	0.19	0.57
11-TAIL	0.98	2.12	0.58	0.54	0.53	1.15

Annex-VII

Table 1. Proposed dimensions for different discharges of Bareji Distributary, Mirpurkhas.

S.No.	Distance [RD]	Q=70 cusecs		Q=109 cusecs	
		B,ft	D,ft	B,ft	D,ft
1.00	0.00	18.45	2.75	22.32	3.10
2.00	5.00	17.21	2.50	21.76	2.75
3.00	10.00	14.91	2.30	19.28	2.50
4.00	15.00	12.00	2.00	14.00	2.30
5.00	20.00	11.74	1.85	12.87	2.20
6.00	25.00	11.15	1.70	12.47	2.00
7.00	30.00	5.29	1.40	9.26	1.30
8.00	35.00	4.23	1.20	6.48	1.20
9.00	39.31				

Table 2. Proposed dimensions of outlets of Bareji Distributary, Mirpurkhas (Q=109 cusecs).

W\C	Distance [RD]	Proposed Q [cusec]	Depth [ft]	H [ft]	Hs [ft]	Y [ft]	B [ft]	Type of outlet
Head	0	109.00	3.10					
1L	0.50	5.40	3.07	1.84	0.92	0.92	0.84	APM
1R	0.50	1.88	3.07	1.84	0.92	0.92	0.29	APM
2R	1.75	1.94	2.98	1.79	0.89	0.89	0.31	APM
3R	4.90	6.24	2.76	1.65	0.83	0.83	1.14	APM
4R	4.90	5.08	2.76	1.65	0.83	0.83	0.93	APM
2L	5.70	6.07	2.73	1.64	0.82	0.82	1.12	APM
5R	6.70	4.68	2.71	1.62	0.81	0.81	0.88	APM
3L	11.50	5.05	2.44	1.46	0.73	0.73	1.11	APM
6R	11.50	3.47	2.44	1.46	0.73	0.73	0.76	APM
4L	12.10	1.08	2.42	1.45	0.72	0.72	0.24	APM
5L	12.10	11.91	2.42	1.45	0.72	0.72	2.64	APM
6L	13.10	4.95	2.38	1.43	0.71	0.71	1.13	APM
7L	14.00	3.87	2.34	1.40	0.70	0.70	0.90	APM
8L	17.30	4.38	2.25	1.35	0.68	0.68	1.08	APM
9L	20.00	4.14	2.20	1.32	0.66	0.66	1.06	APM
7R	22.90	1.05	2.08	1.25	0.63	0.63	0.29	APM
8R	25.10	3.41	1.99	1.19	0.60	0.60	1.02	APM
9R	25.10	6.05	1.99	1.19	0.60	0.60	1.80	APM
10L	25.40	2.45	1.94	1.17	0.58	0.58	0.75	APM
10R	29.20	6.07	1.41	1.35			1.46	OF
11L	30.30	1.40	1.29	1.27			0.36	OF
12L	33.50	1.56	1.23	1.16			0.38	OF
11R	36.00	1.88	1.10	1.01			0.46	OF
13L	39.31	4.11	1.00	0.99			0.66	OF

Table 3. Calculated outlets dimension of Bareji Distributary, Mirpurkhas following SIC model.

W\C	Distance [RD]	Proposed Q [cusec]	Depth [ft]	H [ft]	Hs [ft]	Y [ft]	B [ft]	Crest Level [ft]	Type of outlet
Head		71.57	2.48	0.00					
IL	0	3.83	3.18	1.91	0.95	0.95	0.56	54.08	APM
1R	0.5	1.26	3.18	1.91	0.95	0.95	0.19	54.08	APM
2R	0.5	1.26	2.71	1.62	0.81	0.81	0.24	53.89	APM
3R	1.75	1.77	2.88	1.73	0.86	0.86	0.30	53.44	APM
4R	4.9	4.23	2.88	1.73	0.86	0.86	0.72	53.44	APM
2L	4.9	4.12	2.97	1.78	0.89	0.89	0.67	53.21	APM
5R	5.7	3.18	2.97	1.78	0.89	0.89	0.52	53.01	APM
3L	6.7	3.43	3.02	1.81	0.91	0.91	0.54	52.64	APM
6R	11.5	2.35	3.01	1.80	0.90	0.90	0.38	52.63	APM
4L	11.5	0.71	2.37	1.42	0.71	0.71	0.16	52.35	APM
5L	12.1	7.96	2.33	1.40	0.70	0.70	1.87	52.33	APM
6L	12.1	3.34	2.43	1.46	0.73	0.73	0.74	52.11	APM
7L	13.1	2.63	2.37	1.42	0.71	0.71	0.60	51.96	APM
8L	14	2.96	2.77	1.66	0.83	0.83	0.54	50.93	APM
9L	17.3	2.81	2.37	1.42	0.71	0.71	0.64	50.18	APM
7R	20	0.69	2.32	1.39	0.69	0.69	0.16	50.16	APM
8R	22.9	4.11	1.80	1.08	0.54	0.54	1.42	49.49	APM
9R	25.1	2.32	1.77	1.06	0.53	0.53	0.82	49.48	APM
10L	25.1	1.72	1.71	1.02	0.51	0.51	0.64	49.36	APM
10R	30.3	2.15	1.23	1.10			0.47	48.80	OF
11L	33.5	0.95	1.18	1.06			0.27	47.65	OF
12L	36	1.02	1.06	0.95			0.20	46.94	OF
11R	39.31	4.12	1	0.90			0.66	46.27	OF
13L		2.76	1	0.90			0.30	45.67	OF

Annex-VIII

Table 1. Proposed dimensions of Heran Distributary, Sanghar.

S.No.	Distance [RD]	Q=62cusecs	
		B,ft	D,ft
1.00	0.00	17.05	2.15
2.00	5.00	16.36	2.15
3.00	10.00	12.67	2.00
4.00	15.00	10.64	1.85
5.00	20.00	8.72	1.70
6.00	25.00	7.96	1.65
7.00	30.00	4.71	1.30
9.00	39.31		

Table 2. Proposed dimensions of outlets of Heran Distributary, Sanghar.

W\C	Proposed Q [cusec]	Distance [RD]	Depth [ft]	H [ft]	Hs [ft]	Y [ft]	B [ft]	Crest Level
Head	62.00	0.00	2.15					
1-L	0.86	0.50	2.15	1.29	0.65	0.65	0.23	74.94
2-R	0.54	4.40	2.15	1.29	0.65	0.65	0.14	74.38
3-L	1.16	7.00	2.12	1.27	0.64	0.64	0.31	74.03
5-L	1.69	8.79	2.10	1.26	0.63	0.63	0.46	73.78
4-R	2.46	9.29	2.10	1.26	0.63	0.63	0.67	73.71
Gate (KWM)	10.62	10.00	2.00	1.20	0.60	0.60	3.13	73.67
6-L	1.45	10.00	2.00	1.20	0.60	0.60	0.43	73.67
7-L	2.09	10.00	1.95	1.17	0.59	0.59	0.64	73.70
9-AR	1.43	11.09	1.95	1.17	0.59	0.59	0.44	73.55
8-L	1.55	11.90	1.92	1.15	0.58	0.58	0.49	73.45
9-R	3.16	13.07	1.85	1.11	0.56	0.56	1.05	73.32
8-AL	1.08	16.70	1.82	1.09	0.55	0.55	0.37	72.82
10-R	2.17	17.35	1.82	1.09	0.55	0.55	0.74	72.73
11+12-R	4.52	18.77	1.75	1.05	0.53	0.53	1.63	72.57
13-R	1.93	20.81	1.70	1.02	0.51	0.51	0.73	72.31
14-L	1.13	21.83	1.70	1.02	0.51	0.51	0.43	72.16
15-L	1.15	24.99	1.65	0.99	0.50	0.50	0.45	71.74
16-R	2.83	26.05	1.60	0.96	0.48	0.48	1.17	71.62
17-AL	2.04	26.72	1.50	0.90	0.45	0.45	0.93	71.58
16-AR	1.85	26.82	1.50	0.90	0.45	0.45	0.84	71.57
17-BL	1.85	29.89	1.40	0.84	0.42	0.42	0.93	71.19
18-R	2.19	30.95	1.30	0.78	0.39	0.39	1.23	71.10
Tail	3.07	32.00	1.15	0.69	0.35	0.35	2.08	71.04

Table 3. Calculated outlets dimension of Heran Distributary, Sanghar following SIC model.

W\C No.	Discharge [cusec]	B [ft]	Y [ft]	Type of outlet
1-L	1.58	0.16	1.23	APM
2-R	0.99	0.10	1.21	APM
3-L	2.14	0.25	1.11	APM
5-L	3.11	0.34	1.17	APM
4-R	4.53	0.47	1.21	APM
Gate(kwm)	19.55	2.10	1.18	Gate
6-L	2.67	0.29	1.18	APM
7-L	3.85	0.41	1.18	APM
9-AR	2.63	0.31	1.11	APM
8-L	2.85	0.34	1.11	APM
9-R	5.82	0.70	1.09	APM
8-AL	1.99	0.28	0.97	APM
10-R	3.99	0.54	1.01	APM
11+12 R	8.32	1.20	0.97	APM
13-R	3.55	0.68	0.80	APM
14-L	2.08	0.32	0.93	APM
15-L	2.12	0.44	0.76	APM
16-R	5.21	0.90	0.86	APM
17-AL	3.76	0.81	0.74	APM
16-AR	3.41	0.89	0.65	APM
17-BL	3.41	0.65		OF
18-R	4.03	0.77		OF
17-AT	5.65	1.15		OF
18-AT	5.87	1.20		OF

Annex-IX

Table 1. Proposed dimensions of Dhoro Naro Minor, Nawabshah.

S.No.	Distance RD	Q=52.6 cusecs	
		B,ft	D,ft
1.00	0.00	16.71	2
2.00	5.00	16	1.9
3.00	10.00	15	1.8
4.00	15.00	10	1.55
5.00	20.00	8	1.45
6.00	25.00	7	1.35
7.00	30.00	5.5	1.20
9.00	39.31	2.5	0.9

Table 2. Proposed dimensions of outlets of Dhoro Naro Minor, Nawabshah.

W\C	Proposed Q [cusec]	Distance [RD]	Depth [ft]	H [ft]	Hs [ft]	Y [ft]	B [ft]	Crest Level [ft]
Head	52.6	0.00	2.00					
1-R	1.40	2.00	1.97	1.18	0.59	0.59	0.42	96.37
1-DL	1.45	3.75	1.95	1.17	0.59	0.59	0.44	96.13
2-R	1.59	5.70	1.90	1.14	0.57	0.57	0.51	95.89
1-L	1.62	6.96	1.88	1.13	0.56	0.56	0.52	95.72
3-R	1.46	8.99	1.85	1.11	0.56	0.56	0.48	95.45
1-AL	1.76	10.25	1.80	1.08	0.54	0.54	0.61	95.30
1-BL	4.30	11.00	1.70	1.02	0.51	0.51	1.62	95.25
1-CL	2.86	11.00	1.70	1.02	0.51	0.51	1.08	95.25
2-L	2.02	11.10	1.65	0.99	0.50	0.50	0.79	95.26
2-AL	1.44	12.96	1.65	0.99	0.50	0.50	0.57	95.00
4-R	3.46	12.98	1.60	0.96	0.48	0.48	1.43	95.03
3-L	1.76	13.66	1.55	0.93	0.47	0.47	0.76	94.96
4-L	1.01	14.95	1.55	0.93	0.47	0.47	0.44	94.77
4-BL	1.43	15.28	1.55	0.93	0.47	0.47	0.62	94.73
5-R	1.28	18.801	1.55	0.93	0.47	0.47	0.55	94.62
4-AL	1.17	18.942	1.50	0.90	0.45	0.45	0.53	94.25
6-R	0.24	22.08	1.45	0.87	0.44	0.44	0.11	94.26
5-L	0.53	24.17	1.42	0.85	0.43	0.43	0.26	93.83
6-AR	1.88	24.39	1.40	0.84	0.42	0.42	0.95	93.55
6-L	0.57	27.53	1.35	0.81	0.41	0.41	0.30	93.55
7-R	2.40	29.50	1.30	0.78	0.39	0.39	1.35	93.13
7-L	1.02	31.59	1.20	0.72	0.36	0.36	0.65	92.91
9-L	1.83	31.795	1.15	0.69	0.35	0.35	1.24	92.64
10-L	2.11	32.275	1.05	0.63	0.32	0.32	1.63	92.67
Tail	2.38	32.279	0.88	0.53	0.26	0.26	2.40	92.70

Table 3. Calculated outlets dimensions using SIC model for the Dhoro Naro Minor, Nawabshah.

W\C	Proposed Q [cusec]	Distance [RD]	Depth [ft]	H [ft]	Hs [ft]	Y [ft]	B [ft]	Type of Outlet
Head	70.00	0.00	2.95					
1-R	2.26	2.00	2.34	1.40	0.70	0.70	0.53	APM
1-DL	2.34	3.75	2.45	1.47	0.74	0.74	0.51	APM
2-R	2.56	5.70	2.16	1.30	0.65	0.65	0.67	APM
1-L	2.61	6.96	2.32	1.39	0.70	0.70	0.62	APM
3-R	2.35	8.99	2.61	1.57	0.78	0.78	0.46	APM
1-AL	2.84	10.25	2.94	1.76	0.88	0.88	0.47	APM
1-BL	5.40	11.00	2.54	1.53	0.76	0.76	1.11	APM
1-CL	4.61	11.00	2.54	1.53	0.76	0.76	0.95	APM
2-L	3.26	11.10	2.54	1.53	0.76	0.76	0.67	APM
2-AL	2.32	12.96	1.59	0.96	0.48	0.48	0.96	APM
4-R	5.58	12.98	1.59	0.95	0.48	0.48	2.32	APM
3-L	2.84	13.66	1.47	0.88	0.44	0.44	1.32	APM
4-L	1.63	14.95	1.73	1.04	0.52	0.52	0.60	APM
4-BL	2.30	15.28	1.49	0.89	0.45	0.45	1.06	APM
5-R	1.89	18.80	1.70	1.02	0.51	0.51	0.71	APM
4-AL	0.39	18.94	1.70	1.02	0.51	0.51	0.15	APM
6-R	0.85	22.08	1.53	0.92	0.46	0.46	0.38	APM
5-L	3.03	24.17	1.67	1.00	0.50	0.50	1.17	APM
6-AR	0.84	24.39	1.67	1.00	0.50	0.50	0.32	APM
6-L	3.97	27.53	1.63	0.98	0.49	0.49	1.58	APM
7-R	1.64	29.50	1.75	1.05	0.52	0.52	0.59	APM
7-L	3.24	2.01	1.06	0.954			1.199	OF
9-L	3.40	2.11	1.06	0.954			1.259	OF
10-L	3.84	2.38	0.85	0.765			1.977	OF
Tail	1.34	0.83	0.85	0.765			0.689	OF

IWMI Pakistan
Regional Office
12km
Multan Road
Chowk Thoker Niaz Baig
Lahore 53700
Pakistan

Headquarters
127, Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Mailing Address
P O Box 2075
Colombo
Sri Lanka

Tel.
94-1-867404, 869080

Fax
94-1-866854

E-mail
iwmi@cgiar.org

Website
www.iwmi.org

INTERNATIONAL WATER MANAGEMENT INSTITUTE

FUTURE HARVEST
IWMI is a Future Harvest Center
Supported by the CGIAR