Report No. R-39.3

PILOT PROJECT FOR FARMER-MANAGED IRRIGATED AGRICULTURE UNDER THE LEFT BANK OUTFALL DRAIN, STAGE-I PROJECT

MONITORING AND EVALUATION OF IRRIGATION AND DRAINAGE FACILITIES FOR PILOT DISTRIBUTARIES IN SINDH PROVINCE, PAKISTAN

Volume Three
Dhoro Naro Minor, Nawabshah District

Interim Report
by

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1. INTRODUCTION

1.1. BACKGROUND

The Dhoro Naro Minor[1] and its command area located in Nawabshah District is part of the three pilot projects selected from the LBOD project area to assist farmers in undertaking Operation and Maintenance (O&M) of the combined irrigation and drainage facilities. This is being achieved through assisting farmers to organize themselves into Water Users Associations (WUAs) at the watercourse level and into a Water Users Federation (WUF) at the minor level. The experience gained from this pilot command area would help in identifying and developing an appropriate institutional process, along with legal requirements, for effective implementation on a broader scale for all of the distributaries in a canal command area.

The expectation is that the WUAs and WUF would eventually be accountable for the water received at the head of the minor canal, responsible for water distribution among the members, collection of water charges, along with operation and maintenance (O&M) of the combined irrigation and drainage facilities in the minor command area. They may also adapt revised procedures on water allocation, distribution and water charges collection with the agreement of their members. The WUF would be expected to enter into an agreement between their own members and the Sindh Irrigation and Drainage Authority (SIDA) for implementation of the concept.

1.2. OBJECTIVE

The main objective of the pilot project is to test the viability of farmers' managing parts of irrigation systems, more specifically Dhoro Naro Minor, so that more efficient and equitable distribution of water can be achieved and to make recommendations related to future extensions on the basis of results from this pilot project.

1.3. ACHIEVEMENTS

The pilot project has achieved good progress in the implementation of proposed activities. The project has assisted farmers to organize themselves into Water Users Associations (WUAs) on all of the watercourses and using these WUAs as the foundation, a Water Users Federation (WUF) has been formed at the minor level.

A Joint Management Agreement (JMA) is being developed between the Sindh Irrigation & Drainage Authority (SIDA) and the WUF. Under this agreement, the WUF would undertake operation of the irrigation and drainage system, assessment and collection of water charges, improve water management practices, and carry out other necessary activities, including the maintenance of irrigation and drainage facilities in each pilot area.

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[1] In the Province of Sindh, a small distributary is often called a minor, which is the case for Dhoro Naro Minor.

1.4. MONITORING AND EVALUATION ACTIVITIES

As the main purpose is to involve farmers in operation and maintenance of the combined irrigation and drainage systems. This has never been successfully accomplished before in the country. Therefore, there is a strong need and justification for monitoring the process employed and its impact, so that changes can be made to make the process more useful for all concerned and to the country. The M&E would help in at least two major ways:

(i) allow the SIDA and WUF to adjust their activities to the needs and constrains of the irrigation and drainage management turnover project; and

(ii) provide policy-makers and planners with up-to-date information about the consequences of appropriate management changes for planning new projects that could be extended to other distributary/minor command areas.

The Monitoring & Evaluation activities were initiated in December 1996. The main objective was to document the on-going situation before the management turnover of the minor to the WUF. Field data collection was started in April 1997 (kharif season). This is an interim report that summarizes the results and findings of the M&E activities undertaken until December 1997 in the Dhoro Naro Minor command area.

2. THE DHORO NARO MINOR

2.1. LOCATION

The Dhoro Naro Minor command area is a plain piece of land 17 km in length and about 6-8 km in width. The total Gross Command Area (GCA) and total Culturable Command Area is 15,067 acres and 13,382 acres, respectively. The head of the minor starts from Nawabshah City and the tail ends near Gupchani Town. The total length of the minor is 10.39 km. The minor feeds an area of about 3,489 acres on the right side and 10,042 acres on the left side. In the west, there is a Gujrah Branch Canal, from which the minor offtakes. A location map of the project area is shown in Figure 2.1 and a command area map of the minor is presented in Figure 2.2.

The command area is at the intersection of Nawabshah and Sanghar Districts; therefore, from an administrative point of view, it is divided into two districts, but from an irrigation point of view it comes under the Nawabshah District. The Nawabshah-Sanghar main road runs on the left side of the minor and it again divides the left side command area into two portions and makes a triangular piece of land between the minor and road.

2.2. SALIENT FEATURES

The salient features of the Dhoro Naro Minor are given in Table 2.1.

Table 2.1 Salient features of the Dhoro Naro Minor.

Description	Detail
Name of the minor	Dhoro Naro
Total number of outlets	25
Lined watercourses	16
Unlined watercourses	9
Length of minor	10.39 km
Design discharge	51.62 cfs
Culturable command area (CCA)	13,382 acres
Grass command area (GCA)	15,067 acres
Off take RD	91.40 (Gajrah Branch Canal)
No. of private tubewells	14
No. of saline tubewells	8
Disposal channels	7
No. of inlets	5
Name of subdrain	WN 1 AR
Name of branch drain	Gajrah Branch Drain
No. of water users	504
Tenants (share croppers)	694
No. of villages/ hamlets	147
No. of households	2,468
Population	19,822
Major communities	Jamali, Khaskheli, Syed, Zardari, Brohi, Arain, Gupchani, Shar, Mughari, Keerio, etc
Languages of the area	Sindhi, Siraiki, Punjabi, Balochi & Brahvi

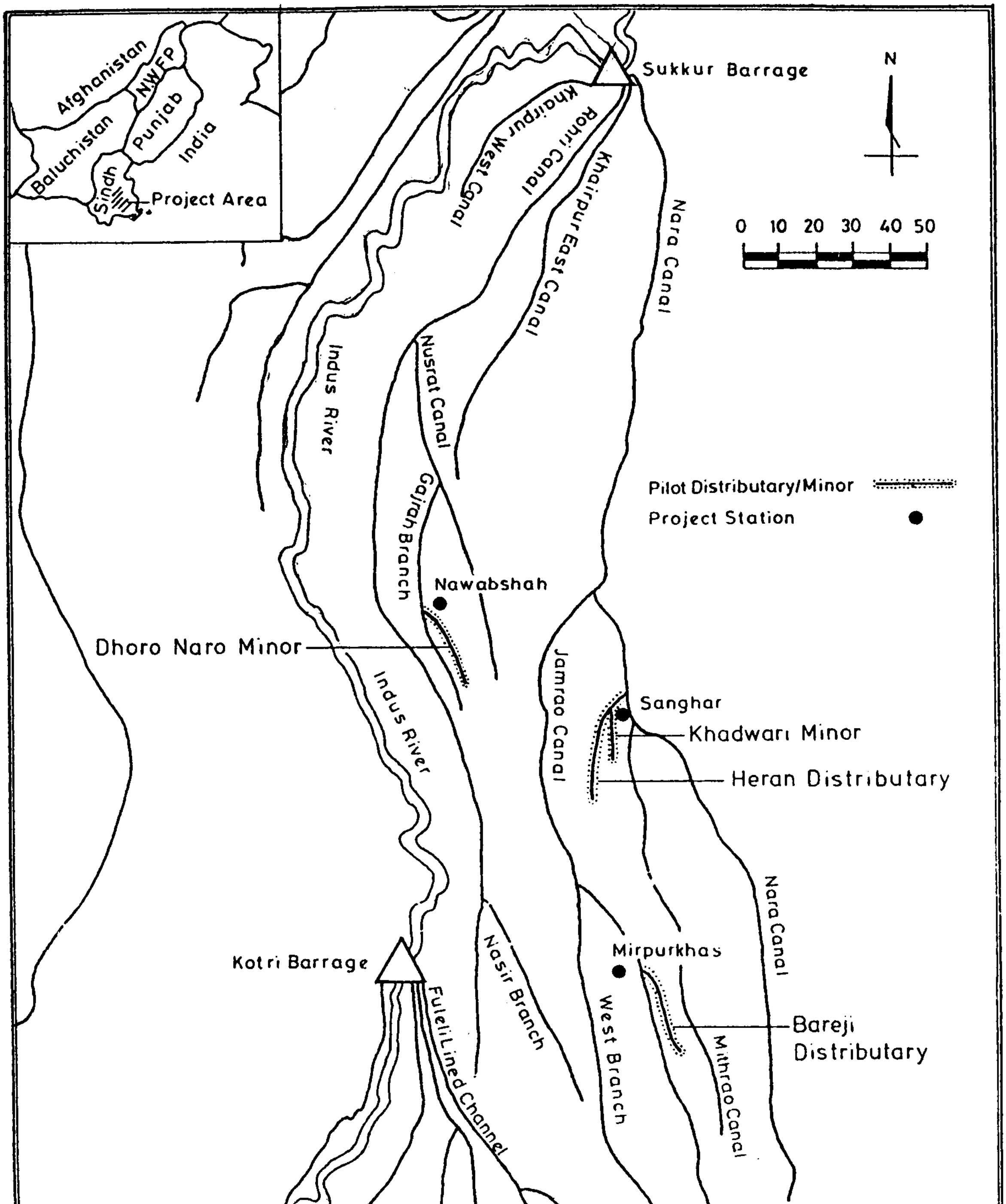

Figure. 2.1 Location map of the three distributaries In Sindh Province.

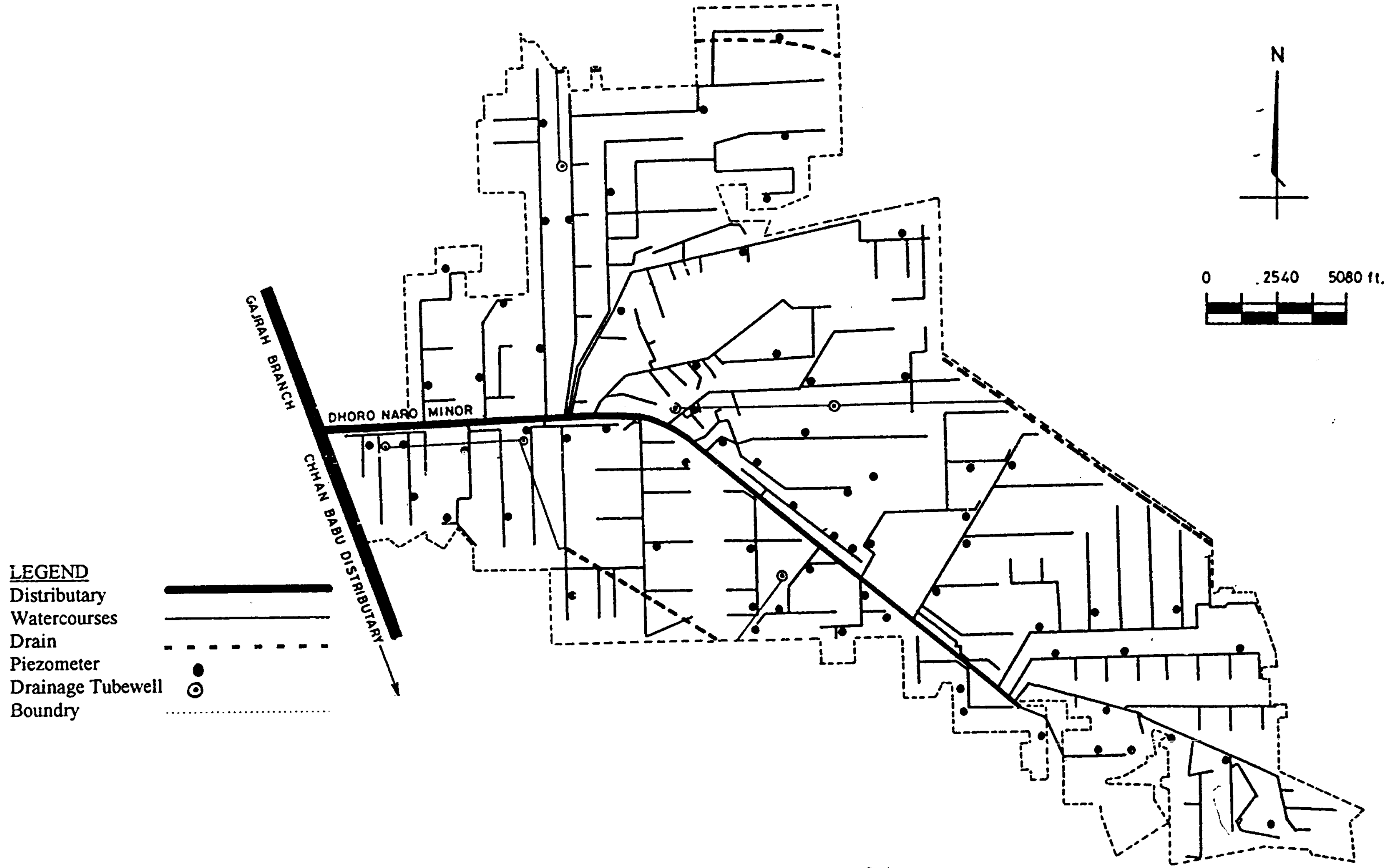

Figure 2.2 Layout plan of The Dhoro Naro Minor Command Area.

2.3. CLIMATE

The climate of this command area is extremely hot in the summer season, mostly in June and July, but is cold during winter. In the summer season, days remain very hot, sometimes temperatures pass 50 degrees centigrade, but in the night, mostly fast winds blow from the South; hence, nights are charming in the open air, while inside the house the atmosphere remains hot. The climate is suitable for all major crops such as cotton, wheat, chilies, sugarcane, oil seeds, bananas, etc.

2.4. IRRIGATION SYSTEM

Agriculture is the mainstay of the Sindh Province. With such a peculiar type of natural vegetation, varying climatic conditions, and very scanty rainfall, but good soil, man has been practicing agriculture in Sindh since times immemorial.

The main source of irrigation water for the pilot project area of the minor is canal irrigation. But, at the same time, some private tubewells are available which are being used during periods of water shortage. The water of tubewells is being utilized by mixing with canal water because tubewell water salt concentrations are relatively high.

There are water shortages at the tail of the minor, as well as on the tails of the watercourses. Despite the fact that there is water shortage, there is also water wastage. The water wastage is mainly due to unreliable water supply, seepage losses, field application water losses, deep percolation, evaporation due to an arid and hot climate, unlined watercourses, and over and frequent irrigation.

2.5. DRAINAGE SYSTEM

In the command area of the pilot minor, the vertical drainage systems (tubewells) are being installed to lower the watertable to the required level for agricultural production. There are seven (7) tubewells discharging saline water. This saline water enters disposal channels that discharge into Subdrain WN 1 AR. The subdrain discharges the total drainage effluent into Gajrah Branch Drain. The details about the drainage system in the pilot command area are shown in Tables 2.2 and 2.3.

Table 2.2. Drainage tubewells in the Dhoro Naro Minor command area, Nawabshah.

Serial No.	Name of Tubewell	Type of Tubewell	Design Discharge (cfs)	Area to be Drained (Acres)	Motor Hp	Running Hours (hrs/day)	Name of Disposal Channel	Length of Disposal Channel (km)
1	GAJ-16	Saline	1.5	320	10	16	DC GAJ-16	3.75
2	EN-142	Saline	1.5	320	10	16	SDC EN-142	0.048
3	EN-154	Saline	1.5	320	10	16	DC EN-154	0.102
4	EN-155	Saline	2.0	320	15	16	DC EN-155	0.824
5	EN-134	Saline	2.0	320	15	16	DC EN-134	1.055
6	EN-143	Saline	2.0	320	15	16	DC EN-143	4.84
7	EN-144	Saline	2.0	320	15	16	DC EN-144	0.184

Source: WAPDA, LBOD, Nawabshah Where: DC = Disposal Channel; SDC = Sub Disposal Channel

The details about the surface drains located in the pilot command area are shown in Table 2.3. Font 7

Table 2.3. Drainage profile of surface drains of the Dhoro Naro Minor command area, Nawabshah.

Name of Drain	Total Length of Drain (km)	Total Length of Drain in Command Area (km)	Designed Discharge (cfs)
Subdrain WN-1AR	5.70	5.18	7.90
Gajrah Branch Drain	46.6	8.53	132.0

Source: WAPDA, LBOD, Nawabshah "Deh" is a small village.

2.6. GROUNDWATER

The saline tubewells are being installed under the LBOD project at about 200 feet below ground level. The water quality of the saline tubewells was observed for East Nawabshah District by using an electrical conductivity meter, which registered 17,000 ppm (Dhoro Naro Minor command area comes into East Nawabshah). The water samples collected from the piezometers installed in the minor command area have a Total Dissolved Solids (TDS) ranging from 345 ppm to 3750 ppm.

2.7. CROPS AND LAND USE

The crops being cultivated in the command area of the minor during the Rabi season are wheat, mustard, vegetables and grass. In the kharif season, the crops are sugarcane, cotton and grass. There are some gardens of mangoes and lemons in the command area. Also, berseem and juwar are the most common grasses cultivated in the command area.

Average cropping intensity in the pilot project area was observed to be 59 % and 54 %, respectively, for the rabi and kharif seasons. The cropping intensity and cropping pattern is shown in Tables 2.4 and 2.5, respectively.

Table 2.4 Cropping intensity in Dhoro Naro Minor command area.

Year	Rabi	Kharif
1995-96	58.88	54.00
1996-97	59.27	59.50
1997	-----	47.60
Average:	59.1	53.70

Table 2.5 Cropping pattern in Dhoro Naro Minor command area.

Rabi		Kharif	
Crop	Percentage	Crop	Percentage
Wheat	42.3	Cotton	37.0
Sugar Cane	3.6	Sugar Cane	3.6
Oil Seed	5.1	Fodder	6.0
Fodder	5.8	Orchards	3.8
Vegetables	2.3	Vegetables	1.8

2.8. IRRIGATION PRACTICES

Normally, two methods of irrigation are being followed by the farmers in the command area of the minor, which are basin irrigation and furrow irrigation. The basin method of irrigation is practiced for the crops of grain, fodder, sugarcane, cotton and wheat. The furrow irrigation method is practiced for vegetables only, but now, it is also being used for the cotton crop.

3. RESULTS AND DISCUSSION

The results of the monitoring and evaluation activities undertaken in the Dhoro Naro Minor command area since April 1997 are given below. These pertain to phase I of the monitoring and evaluation representing the conditions "before" the irrigation management turnover.

3.1. IRRIGATION DELIVERY SYSTEM

3.1.1. Operations of Irrigation Delivery System

The most important operational objective of an irrigation delivery system is considered to be the provision of reliable and equitable irrigation water supplies to the secondary and tertiary units in the whole of the command area. Keeping this in view, operations of the Dhoro Naro Minor were monitored to determine the nature and extent of fluctuations occurring in canal water supply and their impact on watercourses. To undertake this, discharges were measured twice a week simultaneously at the head regulator as well as at all of the outlets (watercourses). Details of the discharge measurement data are given in Annex A.

3.1.1.1. Irrigation Supplies at Head Regulator

Average monthly discharge values at the head regulator for the kharif season of 1997 are presented in Figure 3.1. The average monthly discharges are not very different from one month to the other except for the months of June and July. In the month of June, the average discharge was found to be significantly lower than the other months. Whereas in the month of July, the average discharge was found to be considerably higher than the other months. These fluctuations represent the conditions of peak demand (high temperatures coupled with rice cultivation) and the peak flows (snow melt and onset of the rainy monsoon season).

Taking fluctuations of the irrigation supply into consideration, the average temporal coefficients of variability were calculated for each month of the kharif season. They are presented in Figure 3.2. Except for the month of June (0.24), they were within the acceptable range, being in the fair to good category according to Molden and Gates (1990), criteria. The results show that the fluctuations observed at the head regulator over time were in an acceptable range. Therefore, irrigation supplies at the head regulator of the Dhoro Naro Minor are rated as satisfactory.

3.1.1.2. Irrigation Supplies at Outlets (Watercourses)

The distribution of water among the outlets is the main concern of the farmers/ water users. To take this important aspect into account, the distribution among the outlets/ watercourses was evaluated using "equity" as the indicator, which indicates the ability of a system to distribute water uniformly over space. The uniformity of spatial distribution of water is usually influenced by a number of potential factors: (i) deferred maintenance (ii) sedimentation: (iii) excessive withdrawals by outlets: and (iv) illegal water abstractions.

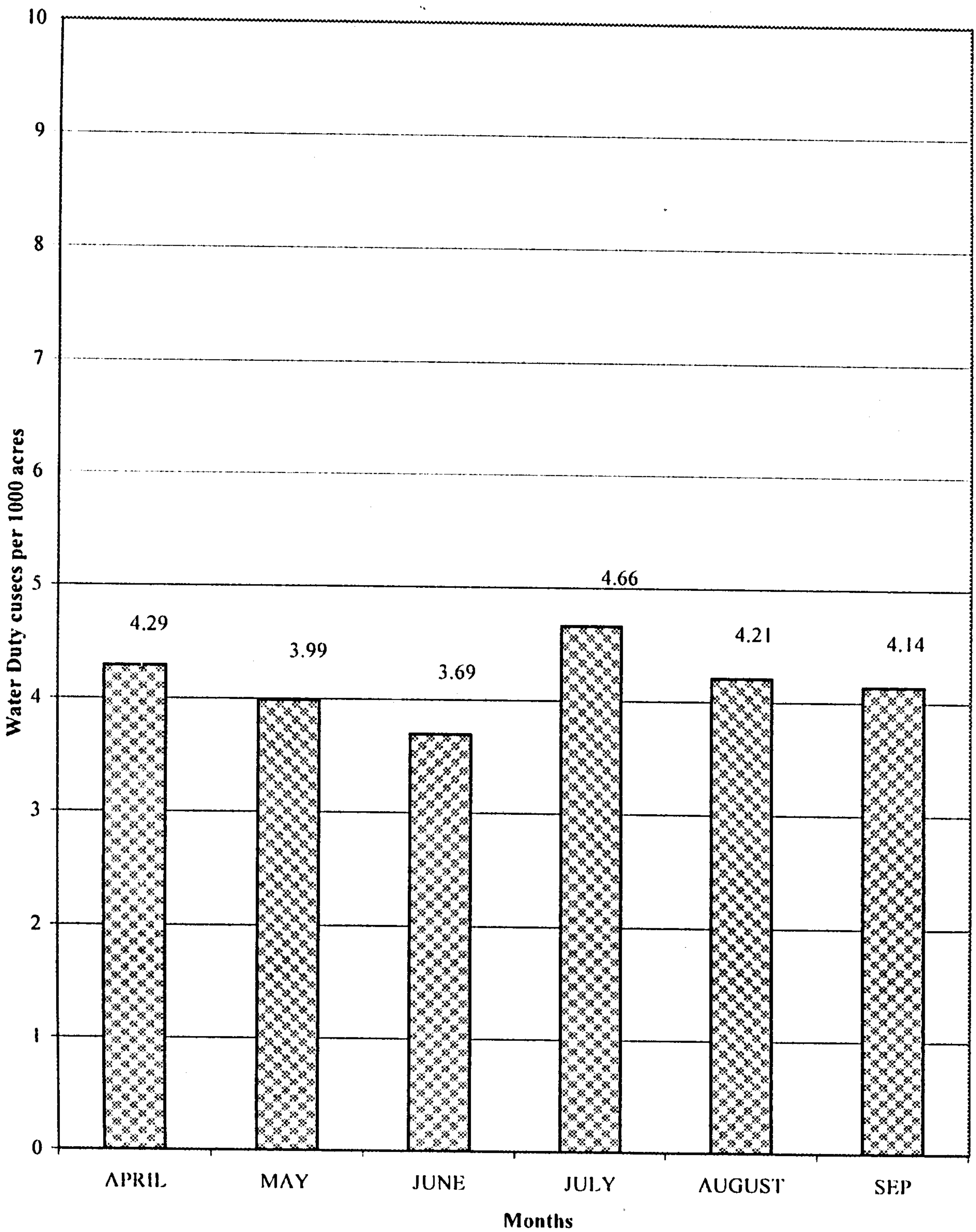

Figure 3.1 Monthly average discharge entering the Dhoro Naro Minor for Kharif 1997.

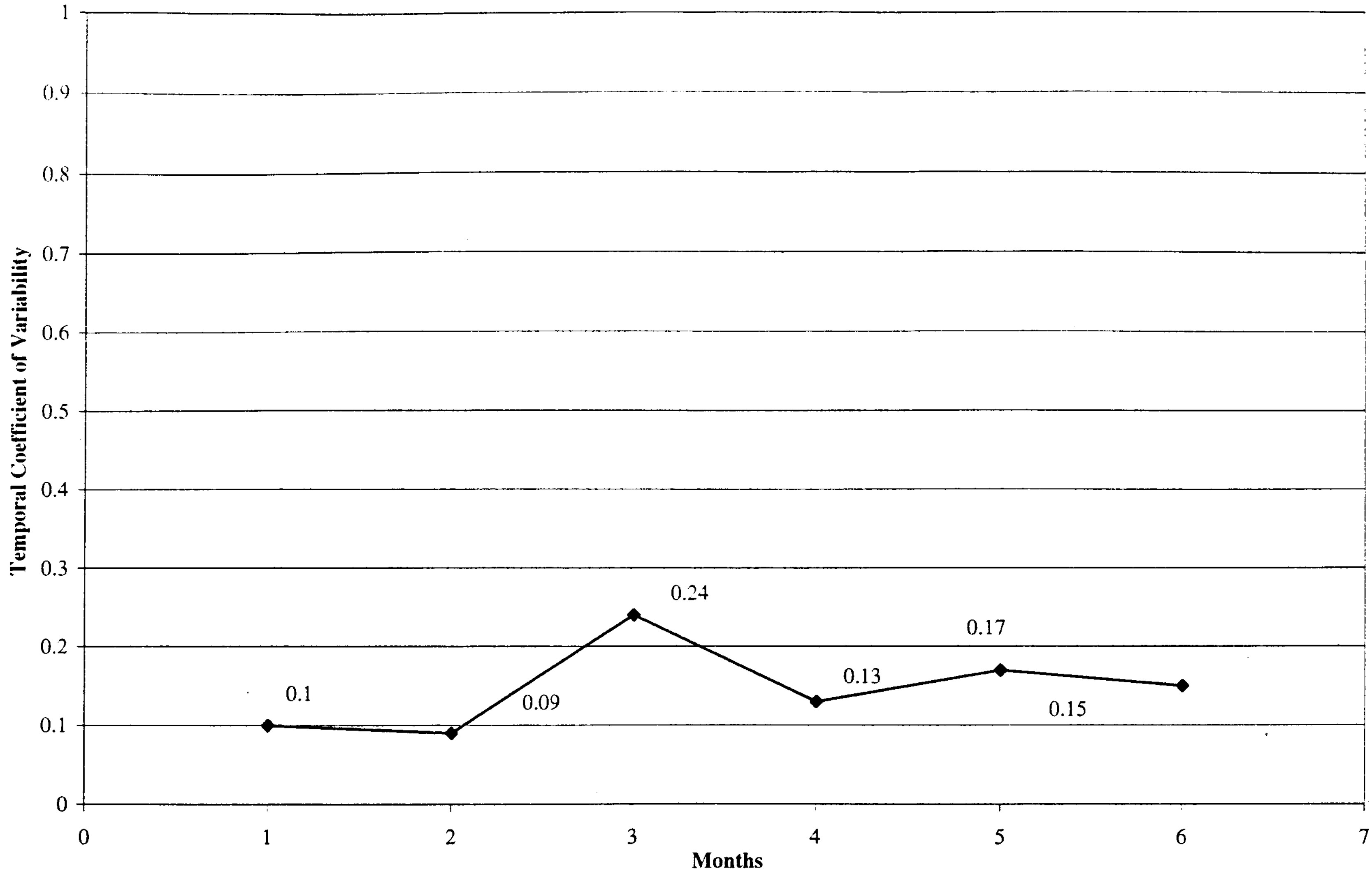

Figure 3.2 Temporal Coefficient of Variability at head regulator of the Dhoro Naro Minor for Kharif 1997.

The discharge at each outlet from the Dhoro Naro Minor was measured at the same time as the discharge measurement at the head regulator. Eight measurements were taken every month. The data was normalized. The resulting average monthly discharge value for each outlet is presented in Figures 3.3 through 3.7.

The results show that three outlets located in the head (1R, 1DL and 3R) and three located in the middle reach (4R, 4BL and 4AL), were drawing exceptionally high discharges during the months of May and June. Whereas, almost all of the outlets located in the tail reach were drawing lower discharges when compared with their old design discharges. This trend continued throughout the kharif season, though some other outlets also drew more water later in the season.

From the results, it is quite clear that there was a large variation in amounts of water being drawn by different outlets. A major cause of this problem is "tampering" of outlets. This phenomena was found to be very common. Most of the outlets were found tampered. Therefore, irrigation supplies at the outlets of the Dhoro Naro Minor, particularly for those located in the tail reach, are rated as unsatisfactory.

The data were analyzed to determine the spatial coefficient of variability for each month. The results are shown in Figure 3.8. The spatial coefficient of variation ranged from 0.48 (48%) in the month of April to 1.13 (113%) in the month of June. The water distribution uniformity among the outlets was in the "poor" category according to Molden and Gates (1990).

Temporal coefficients of variability at outlets were also determined to see the fluctuation in supply at outlets over time. These are presented in Figure 3.9. The temporal coefficient of variability varied from 0.24 (24%) in the month of August to 0.81 (81%) in the month of June. The irrigation water supplies at the outlets over time were found in the "poor" category according to Molden and Gates (1990). This implies that the supplies were highly variable over time.

Based on the results presented above, it is concluded that the distribution uniformity of water among the outlets was very poor both in space and time.

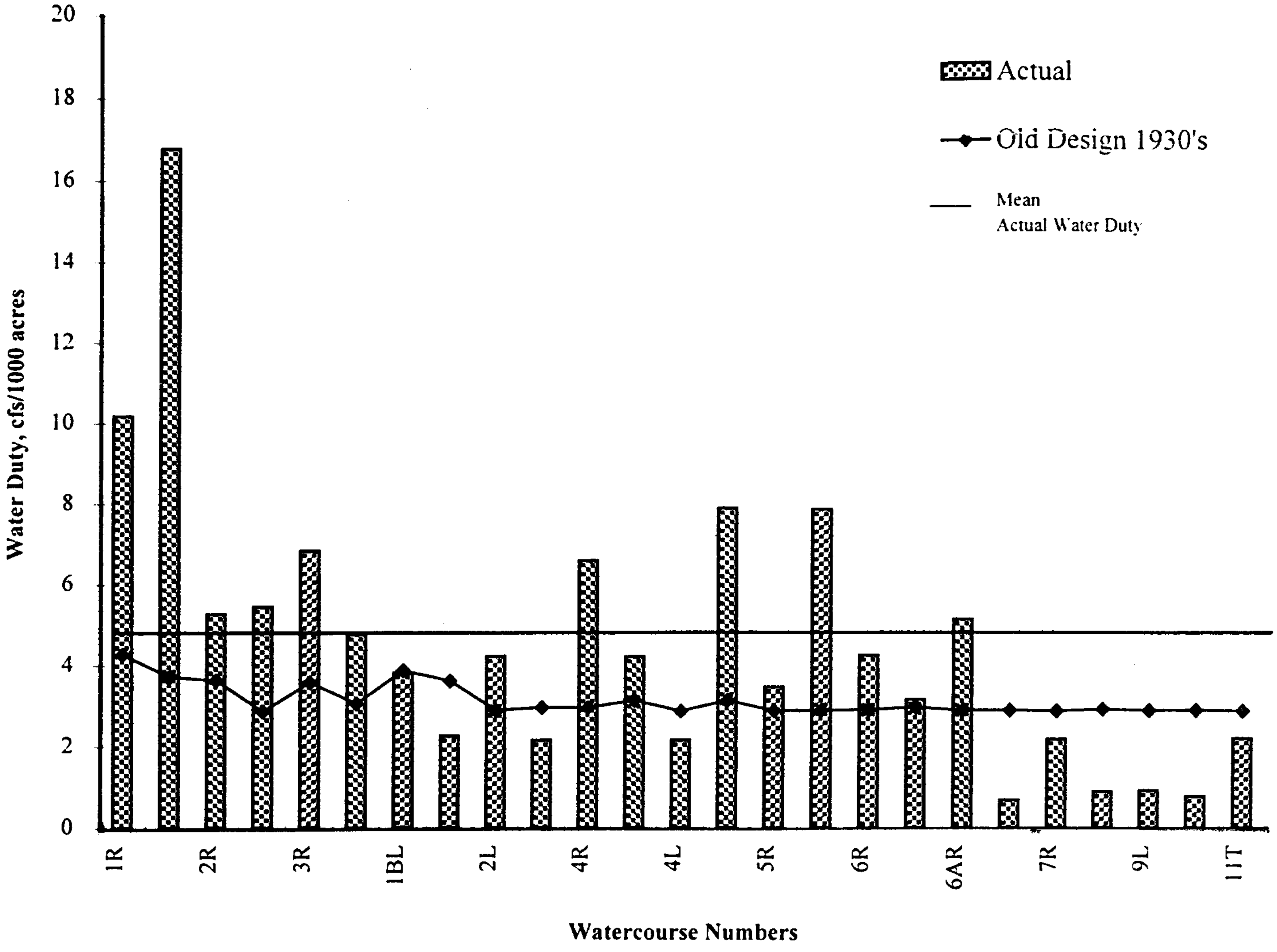

Figure 3.3 Normalized water discharge of outlets from Dhoro Naro Minor for May 1997.

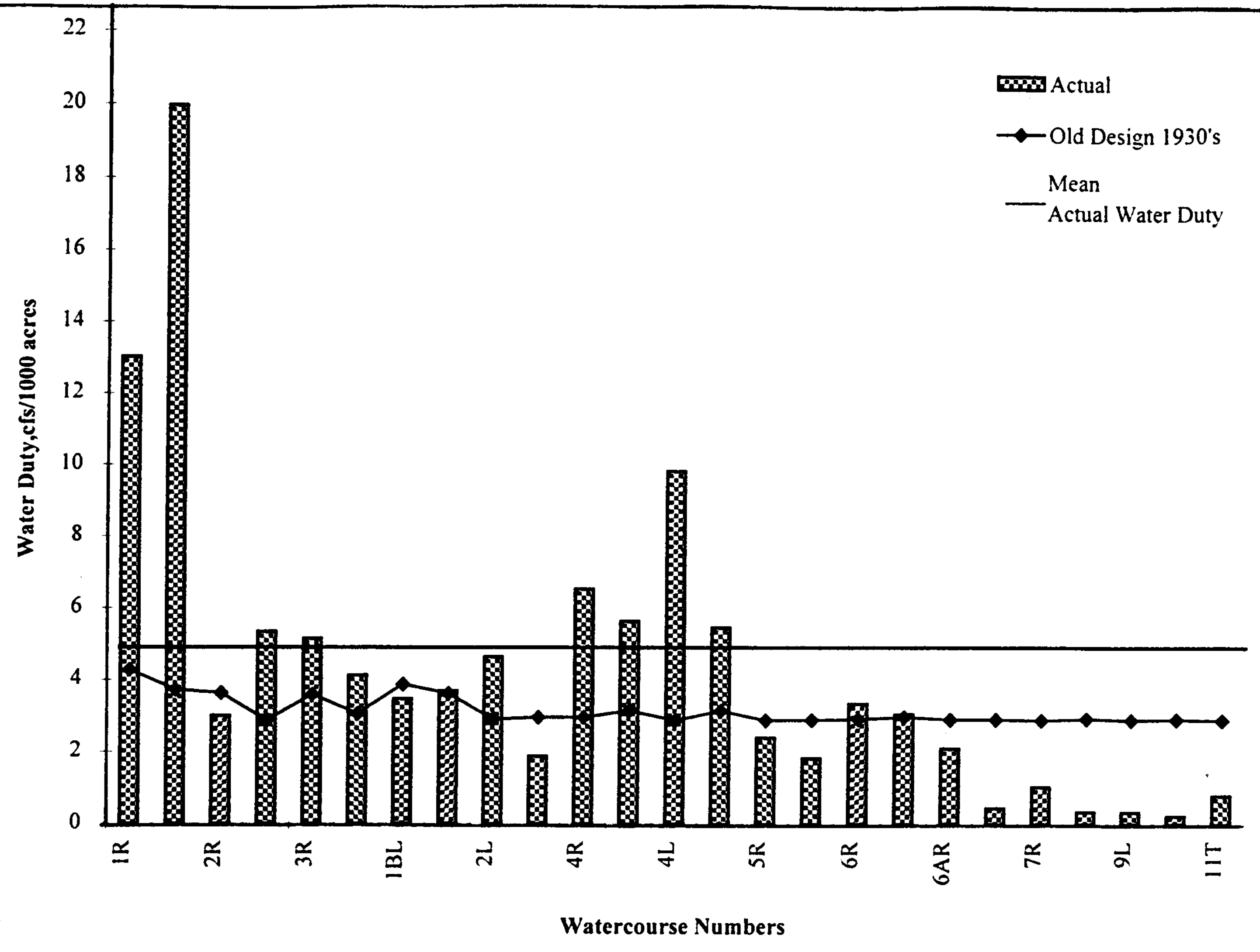

Figure 3.4 Normalized water discharge of Outlets from Dhoro Naro Minor for June 1997.

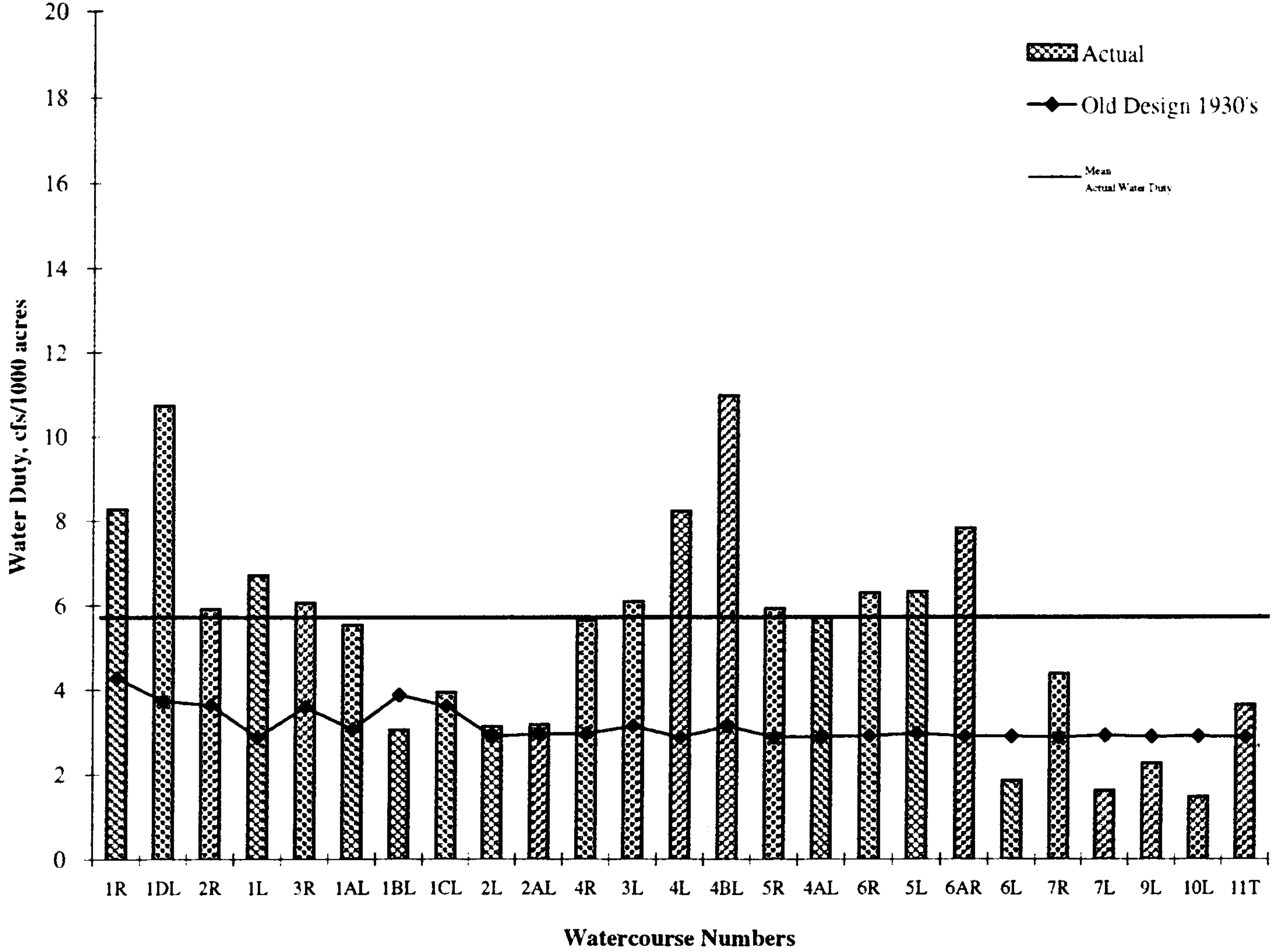

Figure 3.5 Normalized water discharge of Outlets from Dhoro Naro Minor for Juiy 1997.

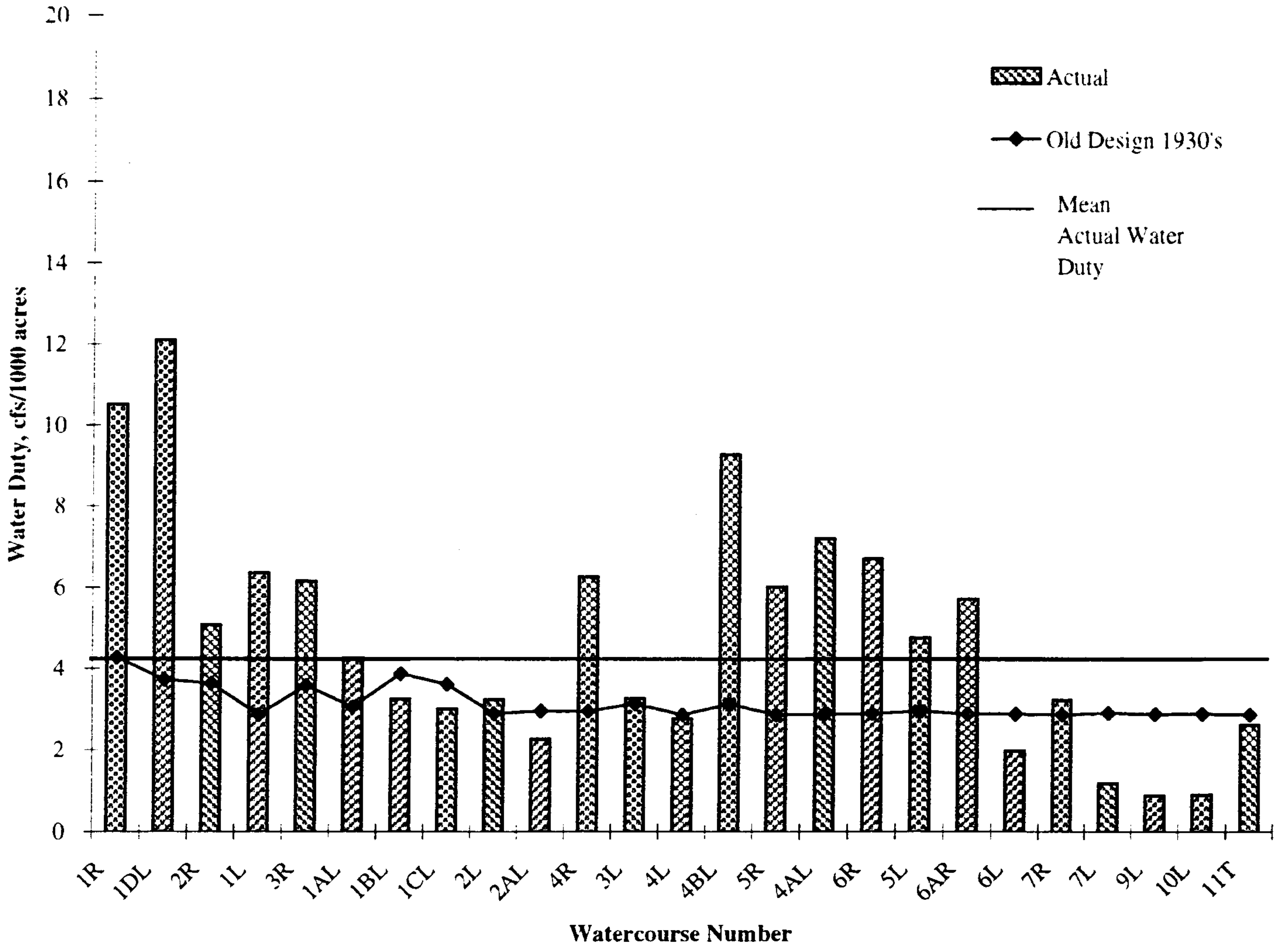

Figure 3.6 Normalized water discharge of Outlets from Dhoro Naro Minor for August 1997.

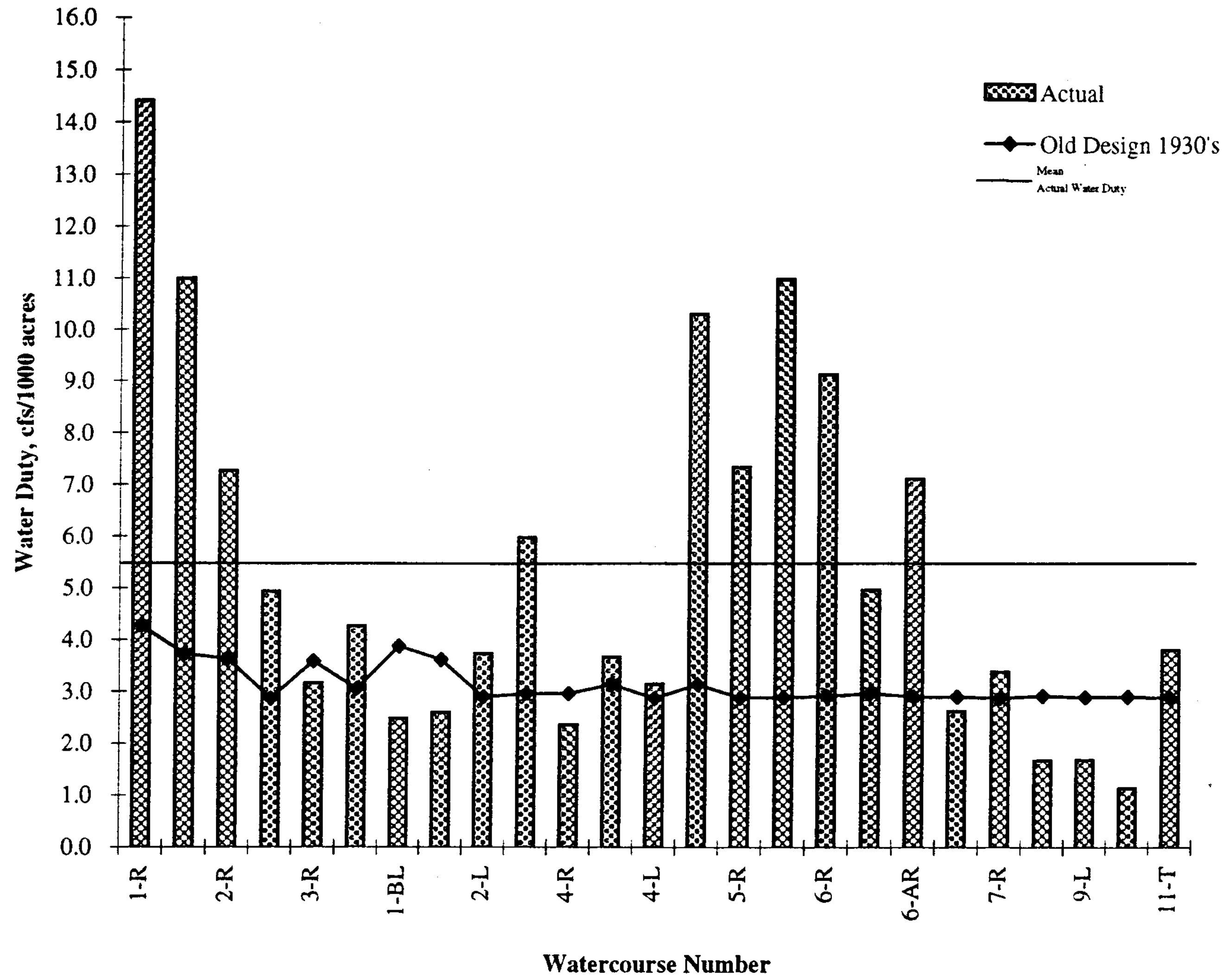

Figure 3.7 Normalized water discharge of Outlets from Dhoro Naro Minor for September 1997.

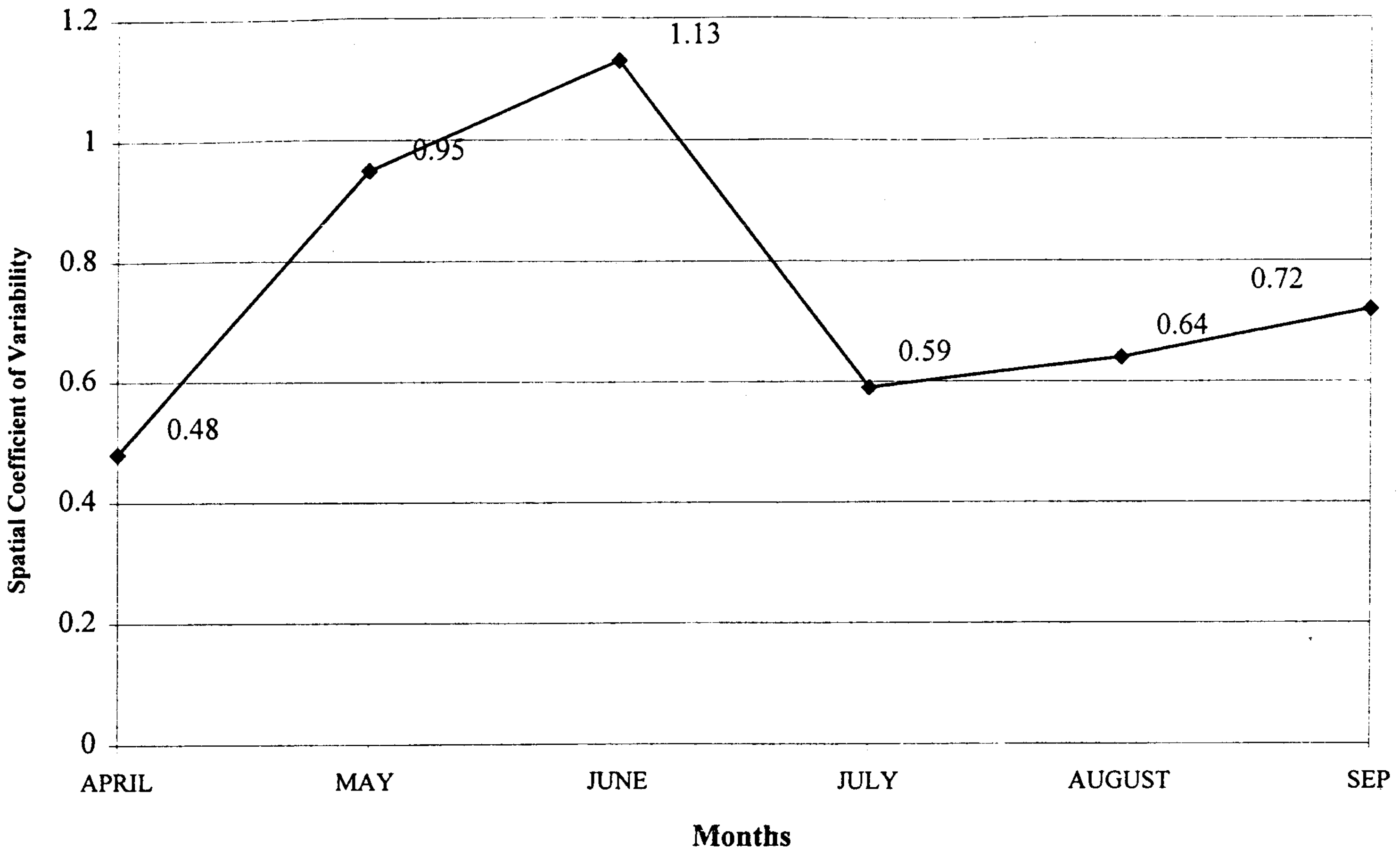

Figure 3.8 Spatial Coefficient of Variability among the outlets from Dhoro Naro Minor for Kharif 1997.

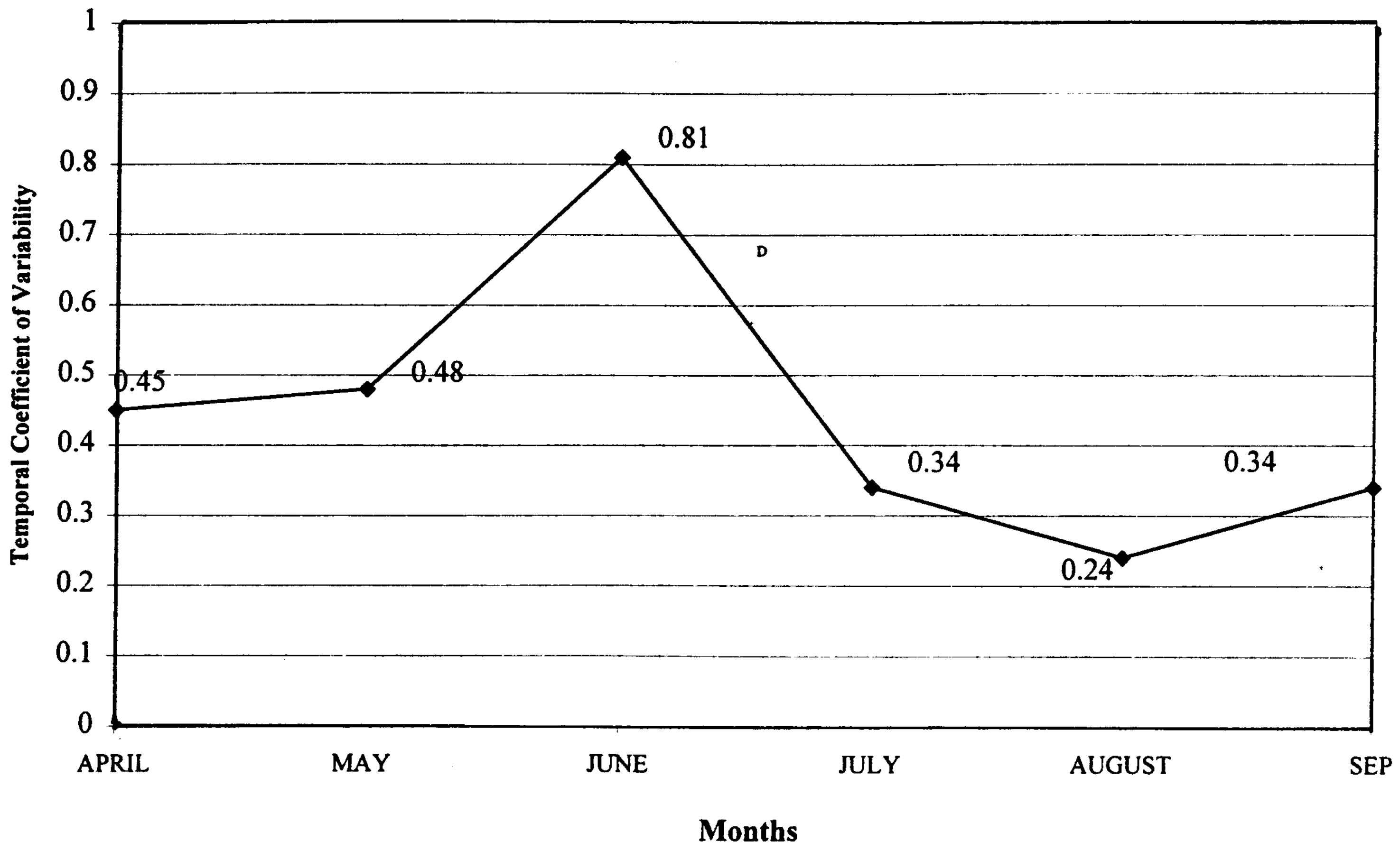

Figure 3.9 Temporal Coefficient of Variability at outlets from the Dhoro Naro Minor, Nawabshah for Kharif 1997.

3.1.1.3. Round-the-clock Measurements of Watercourse Supplies

Flow measurements at the head regulator and sample watercourses selected from the head, middle and tail portions of the distributary were undertaken continuously for 7 days to determine the variations in irrigation supplies. The resulting data are presented in Figures 3.10 through 3.16.

The irrigation supply to the head regulator was more or less uniform during the observation period except for very small variations. This is in line with findings presented ealier under temporal variation at the head regulator (Figure 3.2). Both data are leading to the conclusion that the irrigation supplies at the head regulator are quite satisfactory. This implies that the main system operations were during the Kharif 1997 season.

Two of the three sample outlets were also found to be uniform in cfs per 1000 acres. The results also indicate that the supplies remained more or less constant, or in the same range, during the measurement period except for the third outlet (9L) where significant fluctuations were recorded. A slight trend of increased irrigation supplies was observed during the night, which implied that its due share was being used somewhere during the day.

Coefficients of temporal variation for day and night discharge measurements were calculated for the head regulator as well as for all of the three sample watercourses. They are presented in Table 3.1.

Table 3.1. Coefficient of temporal variation (CV_t) for day and night discharge measurements of Dhoro Naro Minor, Nawabshah.

Date	1L Day	1L Night	4L Day	4L Night	9L Day	9L Night	HR Day	HR Night
8-9	0.06	0.02	0.02	0.23	0.05	0.11	0.01	0.00
9-10	0.04	0.00	0.08	0.22	0.06	0.06	0.01	0.00
10-11	0.04	0.01	0.08	0.24	0.12	0.07	0.05	0.01
11-12	0.03	0.02	0.07	0.28	0.17	0.10	0.01	0.01
12-13	0.03	0.04	0.08	0.30	0.09	0.30	0.03	0.02
13-14	0.04	0.03	0.08	0.34	0.35	0.12	0.03	0.01
14-15	0.05	0.01	0.06	0.46	0.17	0.07	0.04	0.00

Coefficients of temporal variation on an hourly basis were calculated for the head regulator, as well as for the three sample watercourses. They are presented in Table 3.2

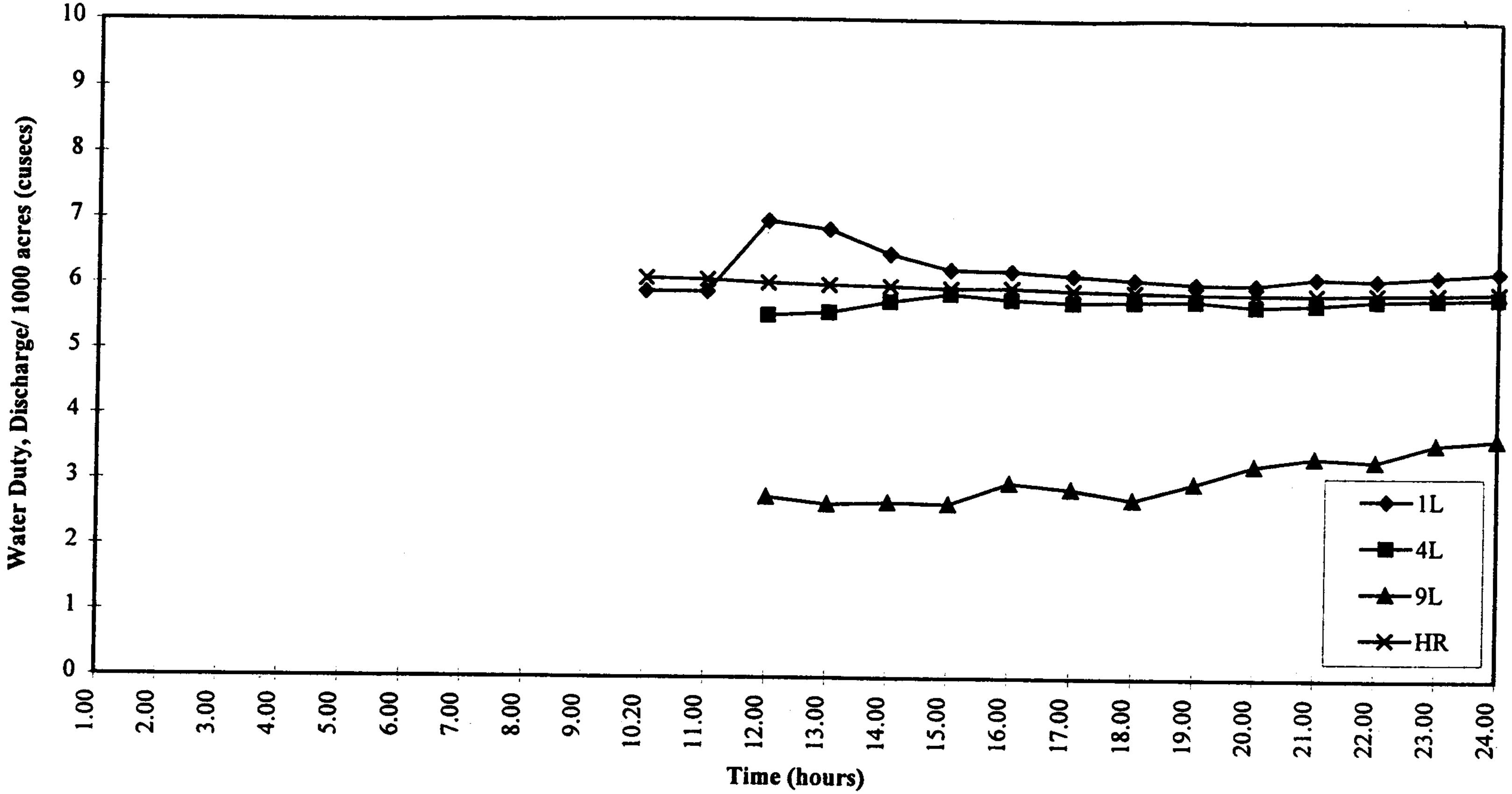

Figure 3.10 Discharge of Dhoro Naro Minor and some sample outlets (August 8/9, 1997).

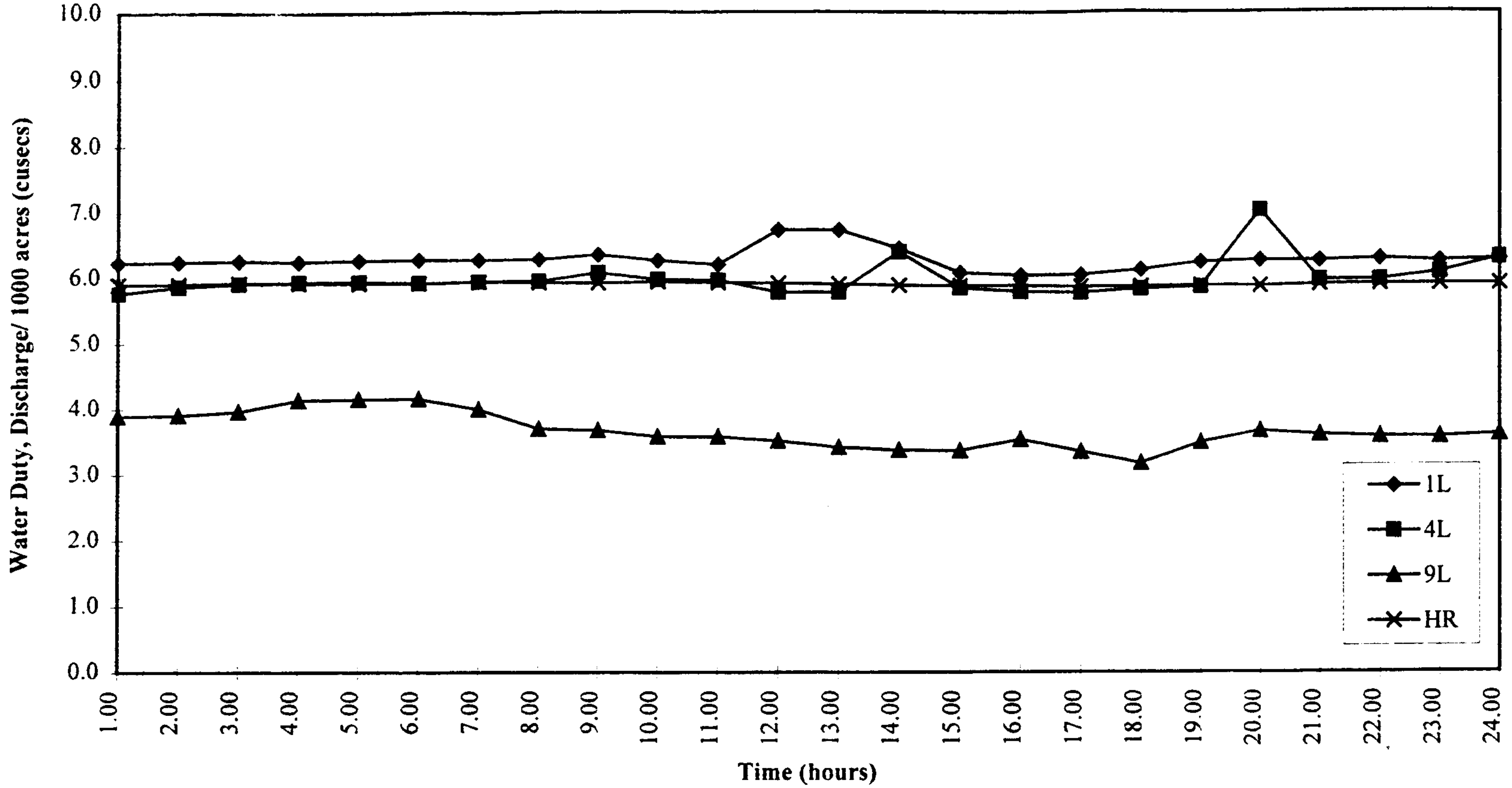

Figure 3.11 Discharge of Dhoro Naro Minor and some sample outlets (August 9/10, 1997).

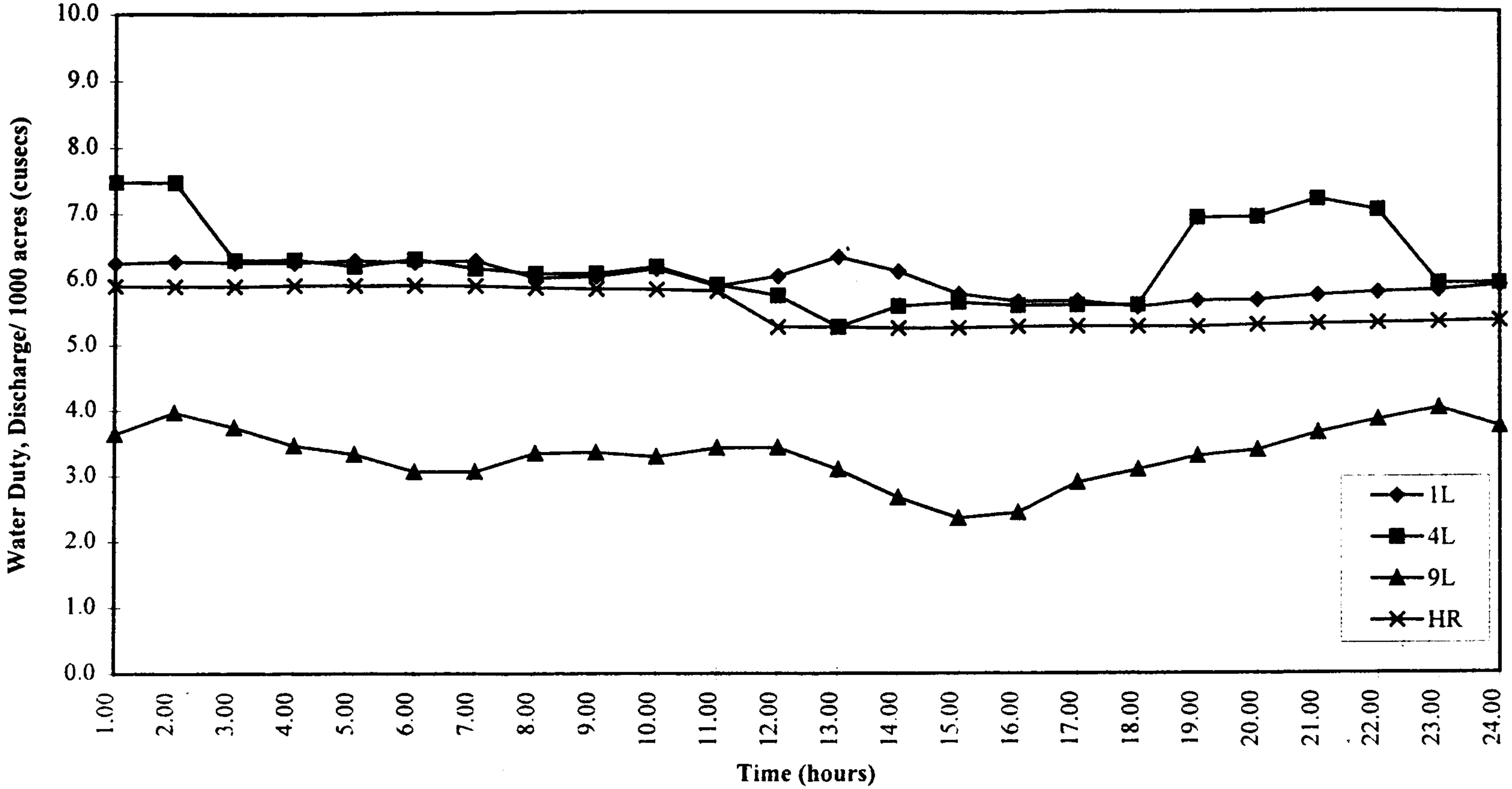

Figure 3.12 Discharge of Dhoro Naro Minor and some sample outlets (August 10/11, 1997).

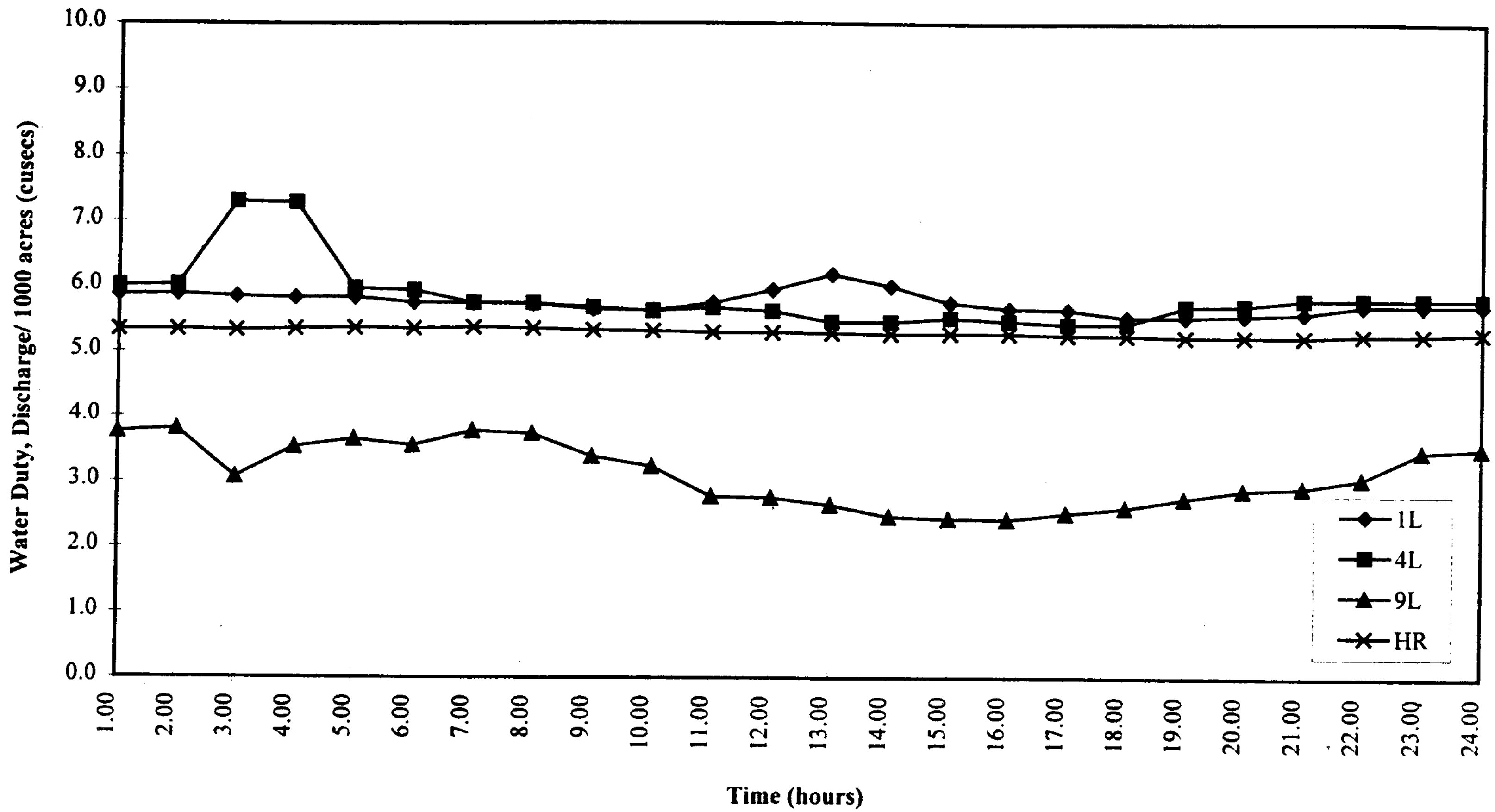

Figure 3.13 Discharge of Dhoro Naro Minor and some sample outlets (August 11/12, 1997).

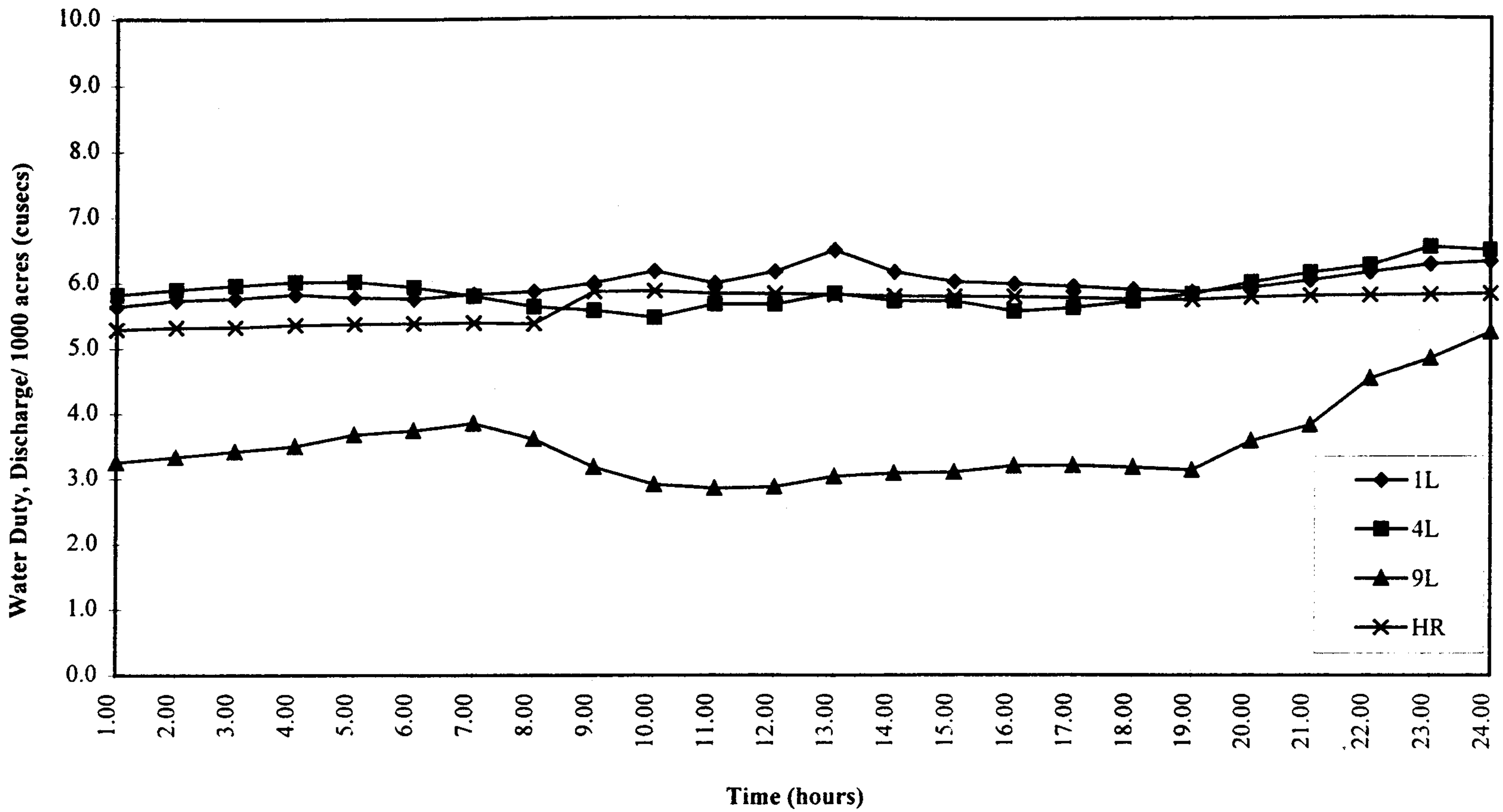

Figure 3.14 Discharge of Dhoro Naro Minor and some sample outlets (August 12/13, 1997).

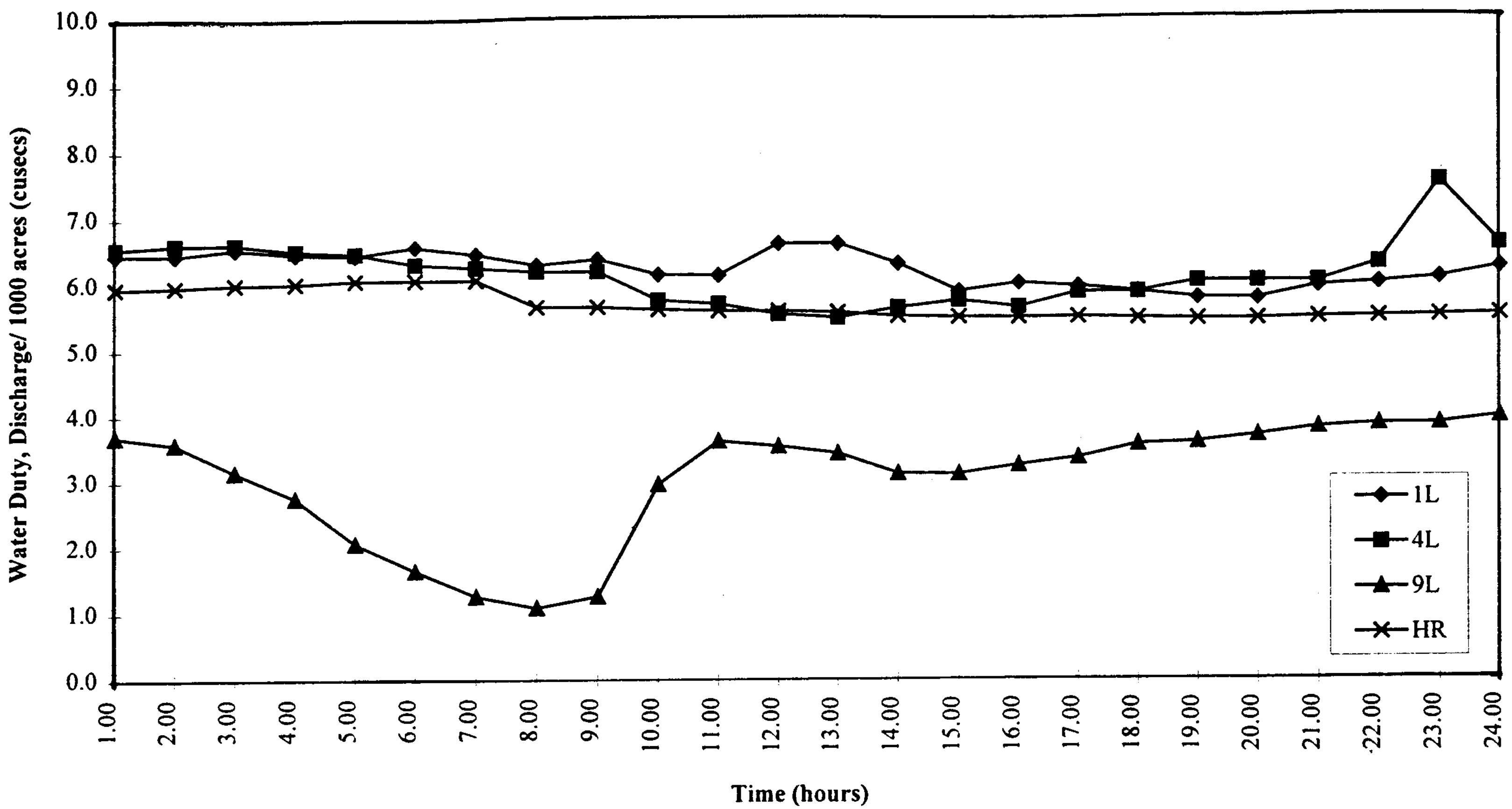

Figure 3.15 Discharge of Dhoro Naro Minor and some sample outlets (August 13/14, 1997).

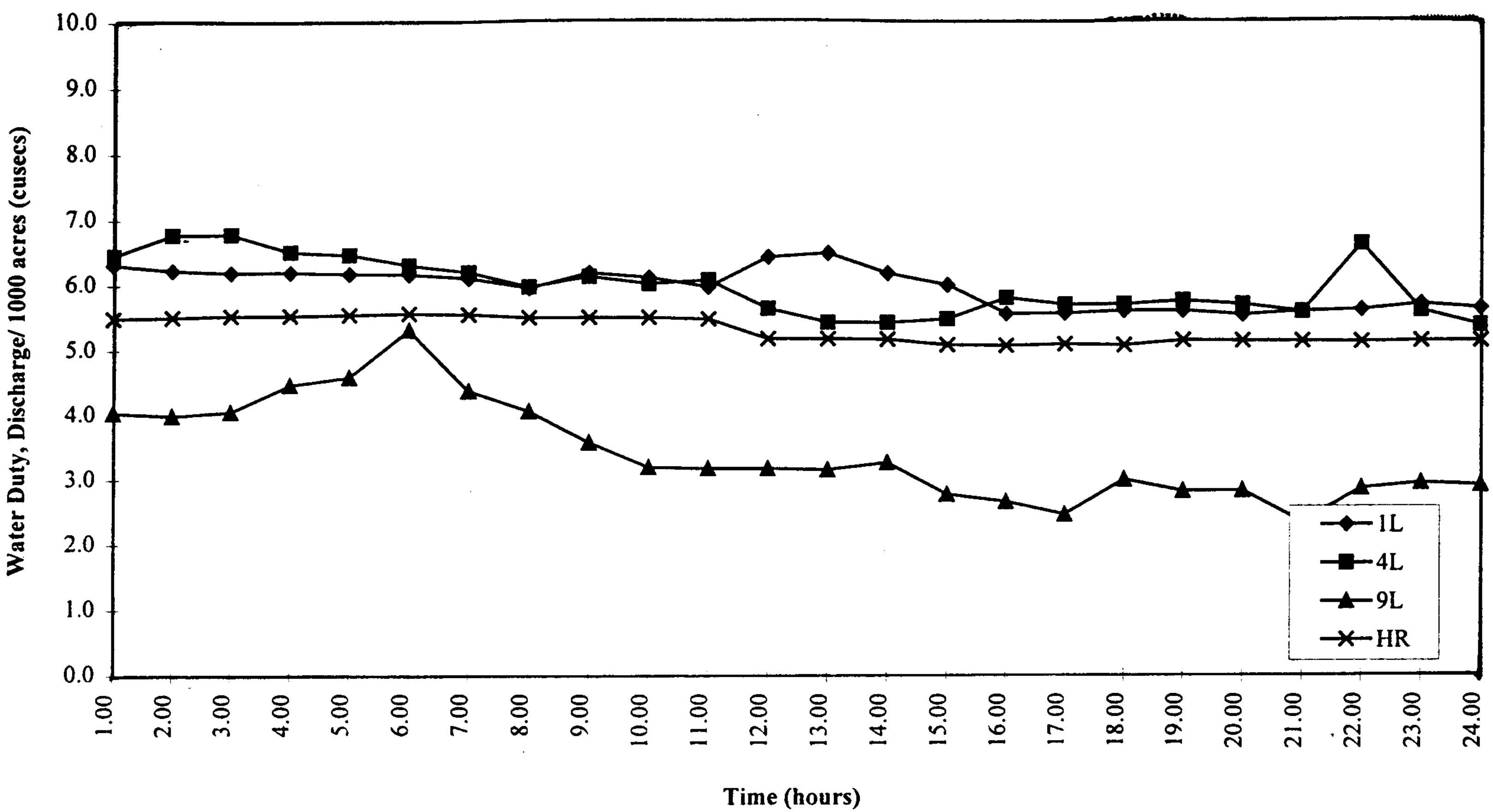

Figure 3.16 Discharge of Dhoro Naro Minor and some sample outlets (August 14/15, 1997).

Table 3.2. Coefficient of temporal variation (CV_t) for hourly basis Dhoro Naro Minor, Nawabshah.

Date	1L Day	4L Day	9L Day	HR Day
8-9	0.06	0.02	0.05	0.01
9-10	0.03	0.02	0.09	0.00
10-11	0.04	0.09	0.07	0.05
11-12	0.02	0.11	0.08	0.01
12-13	0.04	0.08	0.14	0.05
13-14	0.04	0.06	0.34	0.04
14-15	0.04	0.08	0.18	0.03
15-16	0.02	0.07	0.08	0.01

The temporal variation in flows during round-the-clock discharge measurements was found to be satisfactory.

3.1.2. Maintenance of Irrigation Delivery System

3.1.2.1. General Maintenance

The Doro Naro Minor was monitored periodically for evaluating its physical conditions and the maintenance practices. The monitoring is generally done by undertaking walk-thru surveys and conducting interviews with the farmers / water users. During these surveys, efforts were made to record vegetation growth, weak points of banks and berms, condition of the inspection path (berm used for traveling) and non-inspection path (berm on opposite side of the channel from the inspection path), and physical condition of the outlets.

The monitoring of maintenance activities revealed that two major maintenance activities were undertaken in 1997. The first one was "desilting" of the channel, which was done during the month of June 97. The second was a Catch-up Maintenance program implemented during the annual canal closure period. No other maintenance activity was undertaken subsequently. Most of the outlets of the minor were found tampered; therefore, because of tampering, they draw more water than their due share.

3.1.2.2. Physical Conditions

The physical condition of the channel has considerable bearing on the conveyance and distribution of water among the outlets. Presence of vegetation in the irrigation system is a major source for disturbing the uniform flow of water, which also leads to changes in flow conditions such as from free-flow to submerged-flow. The vegetative growth was classified as follow:

Class I : Clean (vegetation less than 1 foot high)
Class II : Very little (vegetation between 1-2 feet high)
Class III : Little (vegetation between 2-3 feet high)
Class IV : Moderate (vegetation between 3-5 feet high)
Class V : Thick (vegetation greater than 5 feet high)

The summary of the physical conditions recorded during the walk-thru survey, are presented in Table 3.3. The data on vegetative growth presented in Table 3.3 show that the minor has high vegetative growth on both sides of the channel in the head reach. This disturbs the smooth flow of water by decreasing the velocity and consequently, the sediment deposition take places. Because of this, the flow conditions at the head regulator changes to submerged flow. The vegetative growth was found to be high on the left side of the channel.

The banks were observed to be in good physical condition except from Rd 2 to Rd 5.7, where the right side bank was observed as being weak. However, the berms were missing altogether.

Table 3.3 Vegetative growth and weak-portion survey of the Dhoro Naro Minor, Nawabshah.

Distance "RD"	Vegetative growth			Weak portion (G=good, W=weak, NB=no berm)			
	Right	Bottom	Left	Bank		Berm	
				Left	Right	Left	Right
0.8 to 2.0	5	1	5	G	G	NB	NB
2.0 to 5.7	3	1	4	G	W	NB	NB
5.7 to 7.3	4	1	4	G	G	NB	NB
7.3 to 9.28	1	1	1	G	G	NB	NB
9.28 to 11.0	5	1	5	G	G	NB	NB
11.0 to 12.96	4	1	4	G	G	NB	NB
12.96 to 4.95	1	1	5	G	G	NB	NB
14.95 to 15.28	1	1	5	G	G	NB	NB
15.28 to 18.8	2	1	5	G	G	NB	NB
18.8 to 22.08	5	1	5	G	G	NB	NB
22.08 to 22.88	1	1	1	G	G	NB	NB
22.88 to 24.17	5	1	5	G	G	NB	NB
24.17 to 27.53	5	1	5	G	G	NB	NB
27.53 to 27.93	1	1	1	G	G	NB	NB
27.93 to 31.6	1	1	5	G	G	NB	NB
31.6 to 32.28	4	1	4	G	G	NB	NB

G = good, W = weak and NB = no berm

3.2. DRAINAGE DISPOSAL SYSTEM (DDS)

The Dhoro Naro Minor command area is equipped with a vertical drainage system (tubewells) to lower the water table and to maintain it at the required level for ensuring and sustaining agricultural production. There are eight saline / drainage tubewells in the command area. They discharge saline water into disposal channels, which are connected to Subdrain WN 1-AR and Gajrah Branch Drain. The subdrain WN 1-AR discharges its drainage effluent into Gajrah Branch Drain. The details of the drainage system are shown in Tables 2.2 and 2.3.

3.2.1. Operations of Drainage System

3.2.1.1. Saline / Drainage Tubewell Operations

Saline tubewells in the Doro Naro Minor command area were identified with their exact locations. Data on actual tubewell operations were collected monthly to evaluate their performance and to make a comparison with the design efficiency. They are supposed to be operating 16 hours daily. The operating hours of tubewells were estimated from the energy consumption through taking meter readings. These readings were divided by the actual days of the month to obtain the daily energy consumption and average operating hours in a day. A comparison was made between the design efficiency and actual efficiency. Energy consumption per hour is also determined.

The saline / drainage tubewells have been operational for quite some time. As the water table has gone to a depth of 7-8 feet, daily operations of 16 hours are no more essential. The benefits of these tubewells were discussed with the water users organizations.

Monthly operational efficiencies are presented in Table 3.4. The detailed data are presented in Annex B.

Table 3.4. Summary of operational efficiency of saline / drainage tubewells of Dhoro Naro Minor command area, Nawabshah.

Tubewell	Operational Efficiency (%)								
	Feb	Mar	Apr	May	June	July	Aug	Sep	Nov	Avg
Gaj-16	38	20	30.5	67.0	14.32	20.37	14.0	18.58	8.52	25.7
EN-134	----	---	7.0	2.0	3.5	34.43	30.19	0.837	7.86	14.82
EN-142	11.46	12.12	11.8	95.75	---	105.5	---	67.16	96.25	57.15
EN-143	48	39.56	6.43	7.62	60.63	80.0	9.37	73.87	70.0	44.0
EN-144	----	1.0	----	38.0	----	29.0	----	----	14.0	20.5
EN-154	----	----	34.63	36.86	41.5	57.0	20.81	29.38	61.6	40.25
EN-155	33.5	19.18	27.43	58.54	57.5	59.7	10.56	24.58	36.87	36.42

From the above results of operational efficiency of saline tubewells, it is obvious that the efficiency of each tubewell differs every month. Main reasons observed for fluctuations in operating are:

- Breakdown in electric power supplies;
- Mechanical faults in motor or pump;
- Disconnection between source and transformer;
- Lack of proper maintenance of disposal channels; and
- Absence of concerned operator.

The operational efficiency of the tubewell EN-142 is found better when compared to others, because its disposal channel is well maintained. The tubewell GAJ-16 has low efficiency mainly due to lack of maintenance of the disposal channel. The tubewell EN-134 has also very low operating efficiency due to its disposal channel, which was abandoned due to the construction of a road. The tubewell EN-144 has less operational efficiency due to absence of the operator coupled with lack of interest by farmers. The remaining tubewells have somewhat satisfactory efficiency.

In cases where the disposal channels were well maintained and farmers were taking an interest, the efficiencies were observed to be higher.

3.2.1.2. Watertable Depth

There were seventy piezometers installed in the Dhoro Naro Minor command area to monitor the watertable depth. The watertable depths were observed on a monthly basis. The average monthly water table depth is given below:

MONTH	April	May	June	July	August
WATER TABLE DEPTH	6.4	6.73	7.71	8.24	8.57

All of the piezometers were referenced to mean sea level. The average watertable depth for the piezometers is shown in Figure 3.17. As shown in Figure 3.17, the average watertable depth in the Doro Naro Minor command area is now between 8 to 9 feet. The operations of saline tubewells have been successful in lowering the average watertable depth from 6-7 to 8-9 feet during kharif season. The water table depth is increasing with time. This is a positive sign for the agricultural activities. The detailed piezometer data are presented in Annex C.

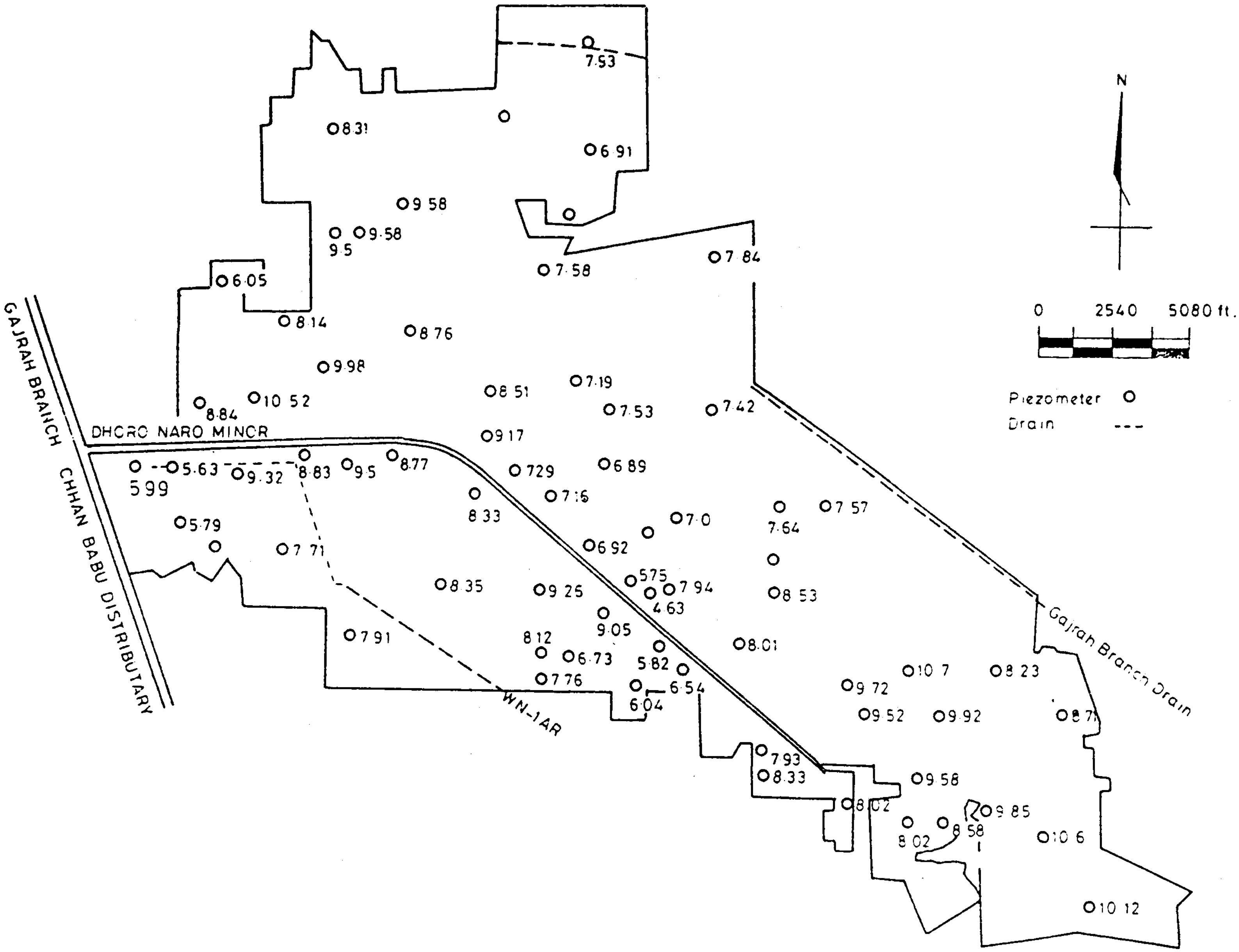

Figure 3.17. Piezometers Location and average water depth for Kharif 1997 in the command area of Dhono Naro Minor, Nawabshah.

3.2.1.3. Groundwater Quality

To monitor groundwater quality, water samples were collected from each piezometer on a monthly basis and the electrical conductivity was measured. Also, a detailed chemical analysis of these samples was done on a quarterly basis. The results are presented in Table 3.5.

The results of the water quality analysis indicate that for most of the water samples were in the range of marginal quality to hazardous. Therefore, it cannot be used directly for irrigation purposes. Even after mixing or treating, care has to be taken for its long term effects on the soils and crop production.

Table 3.5. Results of water quality analysis in the command area of the Doro Naro Minor.

WC No.	Head				Middle				Tail			
	EC,d S/m	PH	SAR	SSP	EC,d S/cm	PH	SAR	SSP	EC, dS/c m	PH	SAR	SS P
1L	1.24	7.4	4.00	55	2.20	7.0	6.58	58	2.90	?	10.11	68
1R	1.20	7.3	3.85	53	0.79	7.5	1.98	40	-	-	-	-
1AL	0.70	7.3	1.72	37	0.90	7.3	1.01	23	-	-	-	-
1BL	1.36	7.3	5.19	62	-	-	-	-	38.0	7.5	34.91	73
1DL	0.93	7.5	2.04	40	1.80	7.3	5.07	53	-	-	-	-
1CL	-	-	-	-	-	-	-	-	1.35	8.4	1.13	25
2L	0.66	7.2	1.16	29	4.43	8.2	36.87	89	2.50	?	7.03	57
2AL	0.72	7.6	1.05	25	1.38	8.3	3.93	53	1.04	8.1	8.46	74
2R	1.12	7.4	1.64	28	-	-	-	-	0.88	7.4	3.39	57
3L	0.95	7.8	1.55	36	-	-	-	-	1.19	7.5	4.16	53
3R	-	-	-	-	1.85	7.2	5.69	58	0.95	7.6	4.26	59
4L	-	-	-	-	0.86	7.5	2.47	43	1.55	7.2	5.56	65
4AL	0.71	7.4	1.20	30	1.05	7.0	2.25	38	2.11	7.0	4.97	50
4BL	-	-	-	-	0.75	7.3	1.57	33	1.99	?	4.19	46
4R	0.75	7.5	6.59	69	1.34	7.2	2.70	42	2.55	7.3	15.48	80
5L	0.75	8.2	1.50	32	2.16	7.5	11.00	76	31.3	7.2	14.71	48
5R	1.24	7.6	2.70	43	-	-	-	-	1.66	7.8	1.20	26
6L	0.70	7.4	1.81	37	4.75	7.9	13.27	69	1.11	7.8	1.97	34
6R	0.85	7.4	6.13	67	0.82	7.5	1.41	32	0.75	7.9	1.08	20
6AR	0.65	7.1	1.15	28	0.70	7.4	0.97	24	1.26	7.5	6.33	65
7L	0.66	7.3	1.31	32	5.88	7.6	51.64	94	0.75	8.0	1.79	38
7R	1.00	7.3	3.52	57	1.18	7.5	3.85	62	0.90	7.7	1.91	39
9L	0.80	7.5	5.27	65	1.10	7.5	2.52	42	2.58	7.0	9.29	67
10L	1.40	7.6	6.81	68	1.76	7.7	7.21	66	0.70	8.0	2.04	43
									3.25	8.4	14.18	77
11L	-	-	-	-	1.25	8.0	3.16	44	0.80	8.0	5.71	68

The monthly average water quality of piezometers presented in Table 3.6.

Table 3.6. Average water quality of piezometers of Dhoro Naro Minor command area.

Month	Minimum (ppm)	Maximum (ppm)	Average (ppm)
April	346	16832	1336
May	294	5005	923
June	250	5158	1037
July	224	7994	1123
August	243	23424	1721
September	262	1244	1816

Table 3.7. Groundwater quality of saline tubewells in the Dhoro Naro Minor command area.

Tube Well No.	Water Quality (ppm)
Gaj 16	3008
EN-134	15936
EN-142	11520
EN-143	11916
EN-144	17088
EN-154	15392
EN-155	13632
Average:	12641

Details of water quality data are presented in Annex D.

3.2.2. Maintenance of Surface Drains

The drainage system was found to be more or less in good physical condition because being constructed recently, except for some disposal channels which were badly maintained. Vegetative growth was also observed to be affecting water flow.

A vegetative growth survey of the drains of Dhoro Naro Minor command area was conducted during the Kharif 1997 season. The following criteria were used for that survey.

1	=	Very clean (no vegetation)
2	=	Very little vegetation (< 0.5 foot)
3	=	Little vegetation (0.5 to 1 foot)
4	=	Moderate vegetation (1 to 2 feet)
5	=	Thick vegetation (> 2 feet)

The results of the survey are presented in Tables 3.8 and 3.9.

Table 3.8 Physical conditions of Subdrain WN 1-AR of the Dhoro Naro Minor command area, Nawabshah.

Distance (km)	Vegetative growth	Remarks
0.0 - 0.6	3	In general, the condition of this drain was satisfactory. No significant effect on flow of water was observed due to vegetation.
0.6 - 0.7	2	
0.7 - 1.2	4	
1.2 - 1.6	2	
1.6 - 2.1	2	
2.1 - 2.4	1	
2.4 - 2.6	4	

Table 3.9 Physical conditions of Gajrah Branch Drain of the Dhoro Naro Minor command area, Nawabshah.

Distance (km)	Vegetative growth	Remarks
0.0 - 0.7	5	In this branch drain, many sections had vegetation as high as 15 to 20 feet.
0.7 - 1.0	3	
1.0 - 1.4	5	
1.4 - 1.6	4	
1.6 - 2.0	1	
2.0 - 2.8	1 and 4	
2.8 - 3.0	5	
3.0 - 3.7	1	
3.7 - 4.2	2 and 4	
4.2 - 4.7	2 and 5	
4.7 - 4.9	1	
4.9 - 6.1	5	
6.1 - 6.5	2 and 4	
6.5 - 6.9	2	
6.9 - 7.2	2 and 4	
7.2 - 7.5	1	
7.5 - 8.4	3	
8.4 - 9.0	2	
9.0 - 9.5	4 and 5	

4. CONCLUSIONS

From the results and discussions presented in Section 3, the following conclusions were reached.

- The actual irrigation water supplies at the head regulator of the Dhoro Naro Minor are more than the old designed. Their "reliability" at the head regulator is in an acceptable range except for one month, according to the criteria of Molden and Gates (1990). Therefore, the main system performance could be considered as almost satisfactory.

- Most of the outlets were found tampered. Irrigation water distribution among the outlets (equity) is found to be very poor according to the criteria of Molden and Gates (1990). Specially the outlets located in the tail reach are suffering badly. This situation needs to be improved through cooperation and concerted efforts to be made by the water users through their WUAs and WUF.

- Due to a lack of proper maintenance, uniform water distribution is greatly affected. Particularly, the presence of high vegetation on the banks of the minor reduces the velocity of flow and increases sediment deposition. Because of this silt deposition, the flow depth (head) increases and more water is drawn by the surrounding outlets. A similar situation occurs for surface drains.

- The watertable depth has been controlled successfully due to the operations of the drainage tubewells.

- The ground water quality is brackish as the water samples, collected from the piezometers and the drainage tubewells, were in the marginal range and hazardous range. Hence, this water cannot be used for irrigation purposes.

- The interference by influenced water users is also making the situation more complicated.

REFERENCE

Molden, David J. and Timoth K. Gates. 1990. Measures of Evaluation of Irrigation Water Delivery Systems. In: Journal of Irrigation and Drainage Engineering, Volume 1/6, No. 6, ASCE.

ANNEXES

ANNEX A

DISCHARGE MEASUREMENTS

Table A1. Discharge measurements in cusecs at head regulator for Kharif 1997 of Dhoro Naro Minor, Nawabshah.

May	June	July	Aug.	Sept.
48.800	66.370	63.569	40.215	47.011
53.320	48.179	63.231	39.960	72.169
53.600	65.266	80.891	50.227	63.250
60.800	51.020	52.673	73.841	60.340
60.070	43.658	64.011	59.890	64.858
61.910	37.024	63.856	. 63.677	65.123
53.330	48.179	73.120	62.246	50.032
			59.345	50.968
			62.788	50.851
				50.558
				66.160
				66.160

Table A2. Discharge measurements of watercourses in cusecs May 1997.

W/C #.	Discharge (cusecs)						
	1-5-97	3-5-97	15-5-97	21-5-97	24-5-97	26-5-97	29-5-97
1-R	2.691	3.220	4.050	4.540	2.994	3.120	2.690
1-DL	6.130	5.580	6.010	6.840	5.600	6.100	3.440
2-R	No Flow	2.650	2.936	3.090	2.601	2.510	2.317
1-L	3.200	2.500	3.187	3.200	3.520	3.320	2.599
3-R	2.231	3.310	3.400	3.308	2.518	2.590	2.090
1-AL	2.786	2.100	2.940	2.140	3.127	3.320	2.770
1-BL	3.310	3.880	2.800	3.960	3.800	2.810	2.508
1-CL	2.090	2.080	No Flow	1.950	3.700	2.630	No Flow
2-L	3.420	3.420	2.190	2.620	2.800	2.730	3.412
2-AL	2.590	2.590	2.470	2.310	2.500	2.450	2.711
4-R	3.082	3.055	3.140	3.520	3.000	3.480	3.125
3-L	1.850	2.100	2.150	3.825	2.230	2.300	2.093
4-L	No Flow	1.200	1.050	1.350	No Flow	1.700	No Flow
4-BL	3.210	3.600	2.050	4.100	4.120	4.280	3.705
5-R	1.317	1.490	1.250	1.770	1.580	1.310	1.119
4-AL	No Flow	2.320	No Flow	No Flow	No Flow	2.100	0.148
6-R	No Flow	1.500	1.150	No Flow	1.400	1.320	1.060
5-L	1.914	2.085	2.310	2.400	2.590	2.690	No Flow
6-AR	1.311	1.030	No Flow	1.420	1.590	No Flow	1.100
6-L	No Flow	0.520	0.953	0.975	0.588	0.670	0.311
7-R	No Flow	No Flow	1.230	1.400	1.660	1.110	No Flow
7-L	No Flow	No Flow	0.898	1.200	1.169	1.020	No Flow
9-L	No Flow	No Flow	1.120	1.250	1.200	1.140	No Flow
10-L	No Flow	No Flow	0.967	1.100	1.198	1.170	No Flow
11-T	No Flow	No Flow	1.103	0.890	1.250	1.200	No Flow

Table A3. Discharge measurements of watercourses in cusecs June 1997.

W/C #	Discharge (cusecs)				
	5-6-97	6-6-97	10-6-97	13-6-97	16-6-97
1-R	3.140	4.440	4.530	4.604	4.577
1-DL	5.800	8.183	7.749	6.914	5.102
2-R	2.770	1.043	1.030	0.850	0.850
1-L	3.580	3.213	2.736	2.707	2.811
3-R	2.380	2.121	2.270	1.847	1.843
1-AL	2.550	0.316	3.833	2.216	2.938
1-BL	2.980	3.405	3.987	2.513	2.086
1-CL	3.000	3.046	3.982	2.418	2.123
2-L	3.200	3.605	3.861	2.808	2.677
2-AL	2.050	3.275	2.874	0.208	2.522
4-R	4.350	3.287	3.393	2.653	2.152
3-L	2.790	2.119	4.589	3.493	2.783
4-L	4.140	3.594	3.575	3.128	2.779
4-BL	4.410	3.644	4.337	No Flow	No Flow
5-R	1.640	1.593	1.632	No Flow	No Flow
4-AL	0.463	0.134	0.164	No Flow	No Flow
6-R	1.640	0.840	1.133	No Flow	No Flow
5-L	3.600	1.926	4.088	No Flow	No Flow
6-AR	Closed	0.867	1.016	No Flow	No Flow
6-L	1.210	0.197	0.503	No Flow	No Flow
7-R	1.830	No Flow	No Flow	No Flow	No Flow
7-L	1.170	No Flow	No Flow	No Flow	No Flow
9-L	1.200	No Flow	No Flow	No Flow	No Flow
10-L	0.910	No Flow	No Flow	No Flow	No Flow
11-T	1.150	No Flow	No Flow	No Flow	No Flow

Table A4. Discharge measurements of watercourses in cusecs July 1997.

W/C #	Discharge (cusecs)					
	8-7-97	14-7-97	17-7-97	21-7-97	24-7-97	28-7-97
1-R	2.567	3.218	2.803	2.467	2.608	2.587
1-DL	3.347	3.883	4.133	3.294	3.783	3.320
2-R	2.609	2.529	2.653	2.438	2.625	2.609
1-L	4.297	4.241	3.971	2.910	3.862	3.418
3-R	1.934	2.651	2.915	2.251	2.534	2.471
1-AL	4.453	4.889	3.082	1.807	2.339	2.539
1-BL	2.456	2.133	3.632	2.503	2.787	2.288
1-CL	3.814	4.316	3.595	1.983	2.680	2.229
2-L	1.775	1.939	2.901	1.814	2.371	2.268
2-AL	5.491	6.127	3.266	2.181	2.645	2.505
4-R	2.314	2.485	3.684	2.348	2.832	2.763
3-L	3.755	4.112	3.222	2.199	2.745	4.412
4-L	3.158	3.280	3.212	2.274	2.859	2.558
4-BL	6.396	6.761	3.480	2.378	3.019	7.857
5-R	1.367	1.412	3.427	3.020	2.951	2.210
4-AL	0.041	0.065	1.398	0.423	0.830	0.087
6-R	1.106	0.405	2.229	1.240	1.726	1.459
5-L	1.683	1.495	5.594	3.595	5.259	6.316
6-AR	1.106	1.111	2.744	0.895	1.465	1.083
6-L	0.568	0.495	3.629	1.315	1.895	1.495
7-R	1.012	0.811	2.965	1.408	1.783	1.305
7-L	0.787	0.659	2.197	1.143	1.152	0.760
9-L	1.378	0.934	2.856	1.610	1.701	1.428
10-L	1.533	0.067	2.330	0.984	1.417	0.875
11-T	1.233	0.267	1.229	1.228	1.443	0.898

Table A5. Discharge measurements of watercourses in cusecs August 1997.

W/C #	Discharge (cusecs)							
	4-8-97	8-8-97	11-8-97	16-8-97	19-8-97	22-8-97	25-8-97	29-8-97
1-R	0.000	3.432	4.007	3.895	4.139	4.017	3.858	4.139
1-DL	3.576	3.819	4.152	3.975	4.189	4.331	4.208	4.446
2-R	2.035	2.131	2.259	2.191	2.208	2.252	2.327	2.337
1-L	3.051	3.375	3.934	3.691	3.505	3.593	3.673	3.869
3-R	2.209	2.373	2.682	2.565	2.468	2.540	2.560	2.633
1-AL	2.230	2.072	2.457	2.776	3.033	2.370	2.178	2.482
1-BL	2.098	2.133	4.481	2.699	2.699	2.935	2.828	2.588
1-CL	1.559	1.972	2.967	2.469	2.296	2.406	2.497	2.846
2-L	1.673	1.967	2.573	2.285	2.183	2.285	2.573	2.493
2-AL	2.188	2.439	2.905	2.705	2.685	2.712	2.746	2.877
4-R	2.358	2.664	3.364	3.046	3.069	3.107	3.444	3.284
3-L	1.518	1.645	2.036	1.815	1.914	1.864	1.914	1.965
4-L	0.802	0.805	1.113	0.944	0.989	1.027	1.073	1.025
4-BL	3.539	3.756	4.905	4.090	4.410	4.387	4.341	4.364
5-R	1.803	2.043	2.597	2.505	2.665	2.822	2.261	2.871
4-AL	0.244	0.335	1.084	0.504	0.608	0.704	0.636	0.684
6-R	0.912	1.146	1.887	1.356	1.622	1.563	1.550	1.594
5-L	2.082	2.615	3.777	2.765	3.202	3.193	3.264	3.279
6-AR	0.726	0.808	1.315	0.921	0.741	1.455	1.046	1.194
6-L	0.684	0.883	2.466	1.416	2.044	1.965	2.053	1.991
7-R	0.773	0.841	1.833	1.339	1.247	1.039	1.061	1.046
7-L	No Flow	0.576	1.288	0.612	0.920	0.946	1.312	0.875
9-L	No Flow	No Flow	1.389	0.696	0.697	0.697	0.803	0.972
10-L	No Flow	No Flow	1.558	0.654	0.984	0.944	0.914	0.943
11-T	No Flow	No Flow	1.362	0.830	1.080	0.957	0.905	0.916

Table A6. Discharge measurements of watercourses in cusecs September 1997.

W/C #	Discharge (cusec)							
	2.9.97	5.9.97	9.9.97	11.9.97	16.9.97	20.9.97	22.9.97	27.9.97
1-R	4.446	4.158	4.092	4.285	4.139	5.406	5.443	5.741
1-DL	4.513	4.736	4.446	4.727	4.303	2.283	2.283	2.375
2-R	3.526	3.432	3.442	Closed	3.335	2.820	2.749	2.880
1-L	2.857	Closed	2.682	2.851	2.464	2.860	2.611	3.163
3-R	1.224	1.207	1.186	1.247	1.067	1.421	1.358	1.589
1-AL	2.519	2.613	0.856	2.467	1.592	2.245	4.896	2.413
1-BL	3.849	3.682	0.818	1.301	1.661	2.187	1.390	2.291
1-CL	3.637	3.525	2.977	1.871	1.622	1.857	1.518	3.594
2-L	2.985	2.845	2.681	3.013	2.057	2.225	1.959	2.985
2-AL	3.230	3.108	3.137	3.158	2.478	2.611	2.393	3.122
4-R	3.746	3.261	4.535	Closed	2.400	1.661	1.505	2.239
3-L	2.322	2.263	2.526	Closed	1.668	1.791	1.615	2.214
4-L	1.233	1.194	1.161	1.322	0.893	0.989	0.847	1.199
4-BL	5.196	4.503	4.986	5.493	4.052	4.203	3.800	5.107
5-R	3.428	2.801	4.906	2.727	2.467	2.468	1.569	3.386
4-AL	1.306	0.699	1.170	1.671	0.473	0.431	0.294	1.235
6-R	2.466	2.247	1.947	1.947	1.683	1.690	1.391	2.386
5-L	3.944	3.533	1.976	3.678	2.783	2.794	2.483	3.837
6-AR	0.714	1.474	0.417	1.662	0.902	1.041	1.516	2.451
6-L	2.933	2.307	1.784	3.511	1.784	1.495	1.277	2.716
7-R	1.510	1.142	0.999	2.099	0.999	0.890	0.678	1.250
7-L	1.152	0.878	0.781	3.072	0.781	0.781	0.649	1.104
9-L	1.335	1.595	0.785	1.968	0.785	1.140	0.745	1.437
10-L	1.536	0.868	0.562	1.933	0.562	0.643	0.301	1.085
11-T	1.578	0.911	0.794	2.392	0.794	0.726	0.500	1.080

ANNEX B

TUBEWELL OPERATING HOURS

Table B1. Tubewell operating hours in April 1997.

Tubewell	GAJ 16		EN 134		EN 142		EN 143	
Date	27.3.97	30.4.97	27.3.97	30.4.97	27.3. 97	30.4.97	27.3.97	30.4.97
Meter reading	017262	018201	015130	015558	026223.5	026765	025560	025965
Hours running reading	2780.38	2946.35	0908.46	946.27	03091.13	03155.37	03342.50	3377.49
Net hours running	165.97		37.81		64.24		34.99	
Energy consm (kwh)	939		428		541.5		405	
Hours per day	4.88		1.112		1.88		1.029	
Design running hours	16		16		16		16	
Operational efficiency	30.5%		6.95%		11.80%		6.43%	
Energy consm. per day	27.61		12.58		15.92		11.91	
Energy consm per hour	5.65		11.32		8.47		11.57	

Table B1. (Complete).

Tubewell	EN 144		EN 154		EN 155	
Date	27.3.97	30.4.97	27.3.97	30.4.97	27.3. 97	30.4.97
Meter reading	011967	Not Obd	029685.5	031305	029932	031117
Hours running reading	1493.64	Not Obd	03456.20	03644.59	03605.75	03755.00
Net hours running	----		188.39		149.25	
Energy consm (kwh)	----		1619.5		1185	
Hours per day	----		5.54		4.38	
Design running hours	----		16		16	
Operational efficiency	----		34.63%		27.43%	
Energy consm per day	----		47.63		34.85	
Energy consm per hour	----		8.59		7.95	

Table B2. Tubewell operating hours in May 1997.

Tubewell	GAJ 16		EN 134		EN 142		EN 143	
Date	30.4.97	27.5.97	30.4.97	28.5.97	30.4. 97	27.5.97	30.4.97	27.5.97
Meter reading	018201	019831	015558	016262	026765	030079	025965	026629
Hours running reading	2946.35	3236.29	0946.27	1031.76	03155.37	03553.75	03377.49	3409.34
Net hours running	289.94		85.94		398.38		31.85	
Energy consm (kwh)	1630		704		3314		664	
Hours per day	10.73		3.182		15.32		1.22	
Design running hours	16		16		16		16	
Operational efficiency	67.0%		19.89%		95.75%		7.625%	
Energy consm per day	60.37		26.07		127.46		25.53	
Energy consm per hour	5.62		8.192		8.32		20.933	

Table B2. (Complete).

Tubewell	EN 144		EN 154		EN 155	
Date	27.3.97	31.5.97	30.4.97	27.5.97	30.4. 97	27.5.97
Meter reading	011967	14794	031305	037603	031117	033037
Hours running reading	1493.64	1876.02	03644.59	03797.93	03755.00	03998.53
Net hours running	382.38		153.34		243.53	
Energy consm (kwh)	2827		6298		1920	
Hours per day	6.069		5.897		9.36	
Design running hours	16		16		16	
Operational efficiency	37.93 %		36.86%		58.54%	
Energy consm per day	44.87		242.23		73.84	
energy consm per hour	7.39		41.07		7.88	

Table B3. Tubewell operating hours in June 1997.

Tubewell	GAJ 16		EN 134		EN 142		EN 143	
Date	27.5.97	26.6.97	28.5.97	27.6.97	27.5.97	26.6.97	27.5.97	27.6.97
Meter reading	019831	020226	016262	016406	030079	not obd*	026629	029639
Hours running reading	3236.29	3304.74	1031.76	1047.94	03553.75	Not obd*	03409.34	3700.09
Net hours running	68.45		16.18		---		290.75	
Energy consm (kwh)	395		144		---		3010	
Hours per day	2.29		0.56		---		9.70	
Design running hours	16		16		---		16	
Operational efficiency	14.32%		3.49%		---		60.63%	
Energy consm per day	13.17		4.96		---		100.34	
Energy consm per hour	5.75		8.92		---		10.34	

Table B3. (Complete).

Tubewell	EN 144		EN 154		EN 155	
Date	31.5.97	27.6.97	27.5.97	3.7.97	27.5.97	26.6.97
Meter reading	14794	Not obd	032903	034624	033037	035223
Hours running reading	1876.02	Not obd	03797.93	04037.53	03998.53	04274.75
Net hours running	----		239.6		276.22	
Energy consm (kwh)	----		1721		2186	
Hours per day	----		6.65		9.20	
Design running hours	----		16		16	
Operational efficiency	----		41.5%		57.5%	
Energy consm per day	----		47.8		72.87	
Energy consm per hour	----		7.18		7.92	

Table B4. Tubewell operating hours in July 1997.

Tubewell	GAJ 16		EN 134		EN 142		EN 143	
Datd	31.7.97	26.6.97	31.7.97	27.6.97	31.7.97	27.6.97	31.7.97	27.6.97
Meter reading	020868	020226	017924	016406	038990	030079	032953	029639
Hours running reading	3415.60	3304.74	1235.36	1047.94	04635.06	03553.75	04135.47	3700.09
Net hours running	110.86		187.42		1081.31		435.38	
Energy consm (kwh)	642		1518		8911		3314	
Hours per day	3.26		5.51		16.89		12.80	
Design running hours	16		16		16		16	
Operational efficiency	20.37%		34.43%		105.56%		80.0%	
Energy consm per day	18.88		44.64		139.23		97.47	
Energy consm per hour	5.79		8.10		8.24		7.614	

Table B4. (Complete).

Tubewell	EN 144		EN 154		EN 155	
Date	31.7.97	31.6.97	31.7.97	3.7.97	31.7.97	26.6.97
Meter reading	016934	14794	036759	034624	037802	035223
Hours running reading	2159.23	1876.02	04292.89	04037.53	04599.55	04274.75
Net hours running	283.21		255.36		324.80	
Energy consm (kwh)	2140		2135		2579	
Hours per day	4.64		9.12		9.55	
Design running hours	16		16		16	
Operational efficiency	29%		57%		59.7%	
Energy consm per day	35.08		76.25		75.85	
Energy consm per hour	7.56		8.36		7.94	

Table B5. Tubewell operating hours in August 1997.

Tubewell	GAJ 16		EN 134		EN 142		EN 143	
Date	31.7.97	27.8.97	31.7.97	27.8.97	31.7.97	27.8.97	31.7.97	27.8.97
Meter reading	020868	021215	017924	018957	038990	not obd.	032953	033272
Hours running reading	3415.60	3475.91	1235.36	1365.80	04635.06	. Not obd.	04135.47	4175.97
Net hours running	60.31		130.44		Not observed		40.5	
Energy consm (kwh)	347		1033		----		319	
Hours per day	2.233		4.831		----		1.5	
Design running hours	16		16		----		16	
Operational efficiency	14.0%		30.19%		----		9.37%	
Energy consm per day	12.85		38.25		----		11.81	
Energy consm per hour	5.75		7.917		----		7.87	

Table B5. (Complete).

Tubewell	EN 144		EN 154		EN 155	
Date	31.7.97	27.8.97	31.7.97	27.8.97	31.7.97	27.8.97
Meter reading	016934	Not Obd.	036759	037521	037802	038182
Hours running reading	2159.23	Not Obd.	04292.89	04382.87	04599.55	04645.41
Net hours running	----		89.98		45.86	
Energy consm (kwh)	----		762		380	
Hours per day	---		3.33		1.69	
Design running hours	----		16		16	
Operational efficiency	----		20.81%		10.56%	
Energy consm per day	----		28.22		14.07	
Energy consm per hour	----		8.475		8.32	

Table B6. **Tubewell operating hours in September1997.**

Tubewell	GAJ 16		EN 134		EN 142		EN 143	
date	29.9.97	27.8.97	29.9.97	27.8.97	29.9.97	31.7.97	29.9.97	27.8.97
Meter reading	021807	021215	019009	018957	044122	038990	036190	033272
Hours running reading	3573.98	3475.91	1370.25	1365.80	05269.12	04635.06	04566.02	4175.97
Net hours running	98.07		4.45		634.06		390.05	
Energy consm (kwh)	592		52		5132		2919	
Hours per day	2.971		0.134		10.74		11.819	
Design running hours	16		16		16		16	
Operational efficiency	18.56%		0.837%		67.16%		73.87%	
Energy consm per day	17.93		1.575		86.98		88.45	
Energy consm per hour	6.03		11.75		8.098		7.84	

Table B6. **(Complete).**

Tubewell	EN 144		EN 154		EN 155	
Date	31.7.97	27.8.97	29.9.97	27.8.97	29.9.97	27.8.97
Meter reading	016934	Not Obd.	038864	037521	039466.5	038182
Hours running reading	2159.23	Not Obd.	04538.0	04382.87	04775.23	04645.41
Net hours running	----		155.13		129.82	
Energy consm (kwh)	----		1343		1284.5	
Hours per day	----		4.70		3.93	
Design running hours	----		16		16	
Operational efficiency	----		29.38%		24.58%	
Energy consm per day	----		40.69		38.924	
Energy consm per hour	----		8.65		9.90	

ANNEX C

PIEZOMETER OBSERVATIONS

Table C1. Watertable depths in April 1997.

W/C #	Watertable Depth (ft)		
	Head	Middle	Tail
1-R	6.412	5.838	Closed
1-DL	9.3	5.66	N.A
2-R	9.31	NA	6.83
1-L	9.07	10.38	9.72
3-R	8.57	N.A	8.28
1-AL	9.71	10.26	Closed
1-BL	8.856	Stolen	7.261
1-CL	N.A	Closed	7.353
2-L	8.364	7.53	7.035
2-AL	7.806	7.954	5.772
4-R	9.518	7.963	8.659
3-L	7.904	Closed	7.275
4-L	N.A	4.821	4.716
4-BL	6.461	4.805	5.612
5-R	8.73	N.A	7.642
4-AL	5.576	5.074	1.968
6-R	9.667	6.858	7.442
5-L	5.838	5.871	7.799
6-AR	5.346	5.166	4.487
6-L	6.068	7.56	5.641
7-R	7.5	8.21	7.35
7-L	8.921	9.495	8.364
9-L	8.068	8.70	8.013
10-L	8.59	9.298	9.512 T1 8.895 T2
11-L	N.A	7.799	8.052

Where NA = Not available

Table C2. Watertable depths in May 1997.

W/C.#	Watertable Depth (ft) May 1997		
	Head	Middle	Tail
1-R	4.243	4.02	4.065
1-DL	7.306	N.A	4.61
2-R	Closed	N.A	Closed
1-L	7.757	9.083	7.057
3-R	7.117	7.113	N.A
1-AL	8.319	8.955	7.725
1-BL	8.23	Stolen	Closed
1-CL	N.A	Closed	5.624
2-L	7.166	6.21	6.27
2-AL	7.42	N.A	5.254
4-R	8.477	7.325	7.377
3-L	6.185	Closed	5.956
4-L	N.A	4.608	Broken
4-BL	Broken	4.215	4.902
5-R	7.612	N.A	6.90
4-AL	5.34	3.27	2.96
6-R	8.46	5.08	6.403
5-L	4.554	Closed	6.412
6-AR	4.467	5.465	4.525
6-L	6.27	8.05	5.99
7-R	6.153	7.586	7.07
7-L	8.08	9.885	7.53
9-L	8.375	9.085	7.46
10-L	8.484	8.93	T1=9.6T2=9.04
11-L	N.A	7.434	7.69

Where NA = Not available

Table C3. Watertable depths in June 1997.

W/C.#	Watertable Depth (ft) June 1997		
	Head	Middle	Tail
1-R	5.89	5.58	5.81
1-DL	8.33	N.A.	5.37
2-R	Closed	N.A.	6.33
1-L	8.70	9.75	7.47
3-R	8.28	Closed	8.23
1-AL	9.50	9.81	7.76
1-BL	8.83	Stolen	6.58
1-CL	8.05	Closed	6.50
2-L	8.05	6.89	6.95
2-AL	9.08	7.87	6.24
4-R	9.72	7.75	7.60
3-L	8.28	6.89	7.04
4-L	Closed	5.17	Broken
4-BL	Closed	5.42	6.04
5-R	9.09	N.A.	7.82
4-AL	7.06	4.84	6.11
6-R	8.88	6.72	7.51
5-L	Closed	Closed	7.31
6-AR	5.60	6.34	5.39
6-L	7.54	7.43	8.70
7-R	8.22	8.01	7.62
7-L	8.95	10.60	8.16
9-L	9.24	9.80	8.07
10-L	9.30	9.60	T1=9.8 T2=9.47
11-L	7.62	8.20	8.56

Table C4. Watertable depths in July 1997.

W/C.#	Watertable Depth (ft) July 1997		
	Head	Middle	Tail
1-R	7.26	6.47	6.51
1-DL	9.43	N.A.	6.43
2-R	Closed	N.A.	7.44
1-L	9.12	10.86	8.34
3-R	9.45	9.21	9.08
1-AL	10.35	Closed	8.49
1-BL	9.92	Stolen	7.56
1-CL	9.51	Closed	6.93
2-L	9.51	7.92	7.72
2-AL	9.31	8.32	6.97
4-R	10.43	9.10	8.42
3-L	8.23	7.05	7.82
4-L	Closed	4.94	Broken
4-BL	Closed	7.12	7.85
5-R	9.53	N.A.	8.14
4-AL	7.11	6.30	5.60
6-R	9.34	6.96	7.84
5-L	Closed	Closed	7.91
6-AR	6.08	6.78	7.86
6-L	8.46	9.10	7.57
7-R	8.45	8.42	8.02
7-L	9.43	10.69	8.38
9-L	9.61	9.98	8.36
10-L	9.63	9.72	T1=10.83 T2= 10.81
11-L	8.02	8.64	9.05

Table C5. Watertable depths in August 1997.

W/C.#	Watertable Depth (ft) August 1997		
	Head	Middle	Tail
1-R	6.44	6.25	6.26
1-DL	9.81	N.A.	7.04
2-R	Closed	N.A.	7.91
1-L	10.75	11.63	9.06
3-R	9.58	9.70	9.88
1-AL	11.15	Closed	9.00
1-BL	9.87	Stolen	8.71
1-CL	9.50	Closed	7.10
2-L	9.50	8.03	9.12
2-AL	10.0	8.90	7.83
4-R	10.2	8.37	7.74
3-L	8.73	8.08	7.92
4-L	Closed	5.96	Broken
4-BL	Closed	6.92	8.50
5-R	9.69	N.A.	8.33
4-AL	7.89	6.81	5.56
6-R	8.32	6.29	8.50
5-L	Closed	Closed	8.40
6-AR	6.53	6.88	5.91
6-L	8.37	9.18	7.87
7-R	8.22	8.32	8.29
7-L	9.47	10.70	8.31
9-L	9.69	9.94	8.44
10-L	9.80	10.02	T1=10.8 T2=10.2
11-L	8.29	8.84	9.25

Table C6. **Watertable depths in September 1997.**

W/C#	Watertable Depth (ft) September 1997		
	Head	Middle	Tail
1-R	5.84	5.37	6.17
1-DL	8.79	N.A.	6.51
2-R	8.44	N.A.	7.15
1-L	9.78	10.88	8.46
3-R	9.81	9.42	9.20
1-AL	10.0	10.47	8.09
1-BL	9.85	9.31	6.83
1-CL	9.59	9.49	7.08
2-L	9.59	8.16	7.77
2-AL	10.21	9.03	7.84
4-R	8.92	8.44	8.20
3-L	8.14	7.94	9.61
4-L	9.10	7.83	6.52
4-BL	9.10	5.40	6.86
5-R	9.45	N.A.	7.89
4-AL	7.99	8.13	5.33
6-R	9.20	7.06	7.72
5-L	7.58	7.48	7.96
6-AR	5.88	6.96	6.19
6-L	8.62	8.59	7.49
7-R	7.41	10.09	8.97
7-L	9.89	10.24	8.33
9-L	10.05	9.97	8.59
10-L	10.04	10.07	T1=11.08 T2=10.53
11-L	8.97	9.37	9.68

Note: The closed and broken piezometers were installed again in the month of September 1997.

ANNEX D

WATER QUALITY

Table D1. **Water quality for the watercourse commands of Dhoro Naro Minor in April 1997.**

W/C #	Water Quality (ppm)		
	Head	Middle	Tail
1-R	755.2	512	Closed
1-DL	633.6	1094.4	N.A
2-R	787.2	NA	544
1-L	825.6	1395.2	1984
3-R	1216	N.A	601.6
1-AL	486.4	416	Closed
1-BL	832	Stolen	16832
1-CL	N.A	Closed	524.8
2-L	364.8	2912	1843.2
2-AL	467.2	684.8	576
4-R	454.4	889.6	1606.4
3-L	403.2	Closed	710.4
4-L	N.A	480	806.4
4-BL	Broken	371.2	1139.2
5-R	838.4	N.A	345.6
4-AL	448	588.8	1280
6-R	614.4	345.6	454.4
5-L	518.4	1452.8	13056
6-AR	403.2	390.4	812.8
6-L	416	3084.8	787.2
7-R	742.4	646.4	556.8
7-L	377.6	3756.8	492.8
9-L	563.2	768	1568
10-L	934.4	1120	371.2 T2 2073.6
11-L	N.A	742,4	454.4

Table D2. Water quality for the watercourse commands of Dhoro Naro Minor in May 1997.

W/C #	Water Quality (ppm) May 1997		
	Head	Middle	Tail
1-R	69.2	467.2	716.8
1-DL	448	N.A.	1536
2-R	Closed	N.A.	Closed
1-L	640	1344	2112
3-R	960	N.A	448
1-AL	473.6	384.0	1926.4
1-BL	736.0	Stolen	Closed
1-CL	N.A	Closed	320
2-L	300.8	3558.4	2035.2
2-AL	518.4	N.A	499.2
4-R	396.8	928	1299.2
3-L	364.8	Closed	851.2
4-L	N.A	294.4	Broken
4-BL	Broken	332.8	1350.4
5-R	806.4	N.A	377.6
4-AL	403.2	1056	1612.8
6-R	736	307.2	396.8
5-L	N.A	Closed	5004.8
6-AR	377.6	486.4	838.4
6-L	531.2	3443.2	908.8
7-R	864	761.6	582.4
7-L	332.8	3616	486.4
9-L	716.8	684.8	1702.4
10-L	665.6	864	T1=531.2 T2=1792
11-L	582.4	672	435.2

Table D3. Water quality for the watercourse commands of Dhoro Naro Minor in June 1997.

W/C #	Water Quality (ppm) June 1997		
	Head	Middle	Tail
1-R	454.4	684.8	627.2
1-DL	608	N.A.	1228.8
2-R	Closed	N.A.	524.8
1-L	1145.6	1497.6	2112
3-R	1062.4	Closed	582.4
1-AL	467.2	1708.8	2496
1-BL	742.4	Stolen	N.A
1-CL	307.2	Closed	345.6
2-L	307.2	3808	2227.2
2-AL	505.6	627.2	294.4
4-R	371.2	1017.6	1337.6
3-L	377.6	N.A	1062.4
4-L	Closed	326.4	Broken
4-BL	Closed	249.6	1408
5-R	800	N.A.	313.6
4-AL	396.8	1056	1766.4
6-R	659.2	320	409.6
5-L	Closed	Closed	5158.4
6-AR	377.6	390.4	1190.4
6-L	512	3552	838.4
7-R	774.4	723.2	556.8
7-L	352	3603.2	537.6
9-L	691.2	710.4	1747.2
10-L	851.2	1491.2	T1=588.8 T2=1740.8
11-L	556.8	672	460.8

Table D4. Water quality for the watercourse commands of Dhoro Naro Minor in July 1997.

W/C #	Water Quality (ppm) July 1997		
	Head	Middle	Tail
1-R	697.6	454.4	652.8
1-DL	620.8	N.A.	1088
2-R	Closed	N.A.	505.6
1-L	889.6	1510.4	2892.8
3-R	1235.2	403.2	569.6
1-AL	486.4	Closed	2534.4
1-BL	953.6	Stolen	N.A.
1-CL	364.8	Closed	441.6
2-L	364.8	3340.8	2201.6
2-AL	556.8	825.6	435.2
4-R	352.0	972.8	1414.4
3-L	224.0	934.4	1120.0
4-L	Closed	339.2	Broken
4-BL	Closed	307.2	2803.2
5-R	787.2	N.A.	396.8
4-AL	403.2	1113.6	1740.8
6-R	614.4	326.4	403.2
5-L	Closed	Closed	5356.8
6-AR	448.0	428.8	1004.8
6-L	1062.4	2368.0	966.4
7-R	678.4	823.4	524.8
7-L	371.2	1600.0	627.2
9-L	678.4	550.4	2771.2
10-L	467.2	614.4	T1 = 7993.6 T2 = 1497.6
11-L	524.8	665.6	467.2

Table D5. **Water quality for the watercourse commands of Dhoro Naro Minor in November 1997.**

W/C #	Water Quality (ppm) November. 1997		
	Head	Middle	Tail
1-R	576.00	640.00	448.00
1-DL	448.00	N.A.	768.00
2-R	704.00	N.A.	384.00
1-L	640.00	1792.00	14333.00
3-R	1024.00	256.00	448.00
1-AL	960.00	1024.00	960.00
1-BL	576.00	384.00	22400.00
1-CL	192.00	1024.00	896.00
2-L	192.00	4736.00	15232.00
2-AL	256.00	1152.00	256.00
4-R	128.00	832.00	2304.00
3-L	512.00	128.00	1856.00
4-L	192.00	128.00	640.00
4-BL	192.00	N.A	2944.00
5-R	640.00	N.A.	256.00
4-AL	256.00	1088.00	1728.00
6-R	448.00	192.00	256.00
5-L	320.00	960.00	7040.00
6-AR	256.00	256.00	768.00
6-L	1344.00	2880.00	768.00
7-R	704.00	960.00	384.00
7-L	192.00	3264.00	448.00
9-L	576.00	448.00	2752.00
10-L	576.00	448.00	T1=10752 T2=1728
11-L	384.00	448.00	320.00

Where NA = Not available

Table D6. Water quality of saline tubewells in May and June 1997.

NAME OF TUBEWELL	WATER QUALITY (ppm) JUNE 1997	WATER QUALITY (ppm) MAY 1997
GAJ 16	CLOSED	3008
EN 134	15936	CLOSED
EN 142	11193.6	11520
EN 143	12102.4	11916.8
EN 144	16896	17280
EN 154	14912	15872
EN 155	13504	13760

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