Report No. R-40.2

PILOT PROJECT FOR FARMER-MANAGED IRRIGATED AGRICULTURE UNDER THE LEFT BANK OUT FALL DRAIN (LBOD), STAGE-I PROJECT, PAKISTAN

MAINTENANCE PLANS FOR IRRIGATION FACILITIES OF PILOT DISTRIBUTARIES IN SINDH, PAKISTAN

Volume Two
Heran Distributary, Sanghar District

by

Abdul Majeed Ansari
Niaz Hussain Sial
Abdul Jalil Ursani
Ghulam Shabir
M. Ghous Laghari
M. Naveed Khayal
Bakhshal Lashari
M. Akhtar Bhatti
Gaylord V. Skogerboe

December 1997
Hyderabad Office
PAKISTAN NATIONAL PROGRAM
INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGUTRES AND PHOTOGRAPHS

FOREWORD

The Water Users Federation (WUF) for each pilot distributary was established in mid-December, 1996. Three weeks later, a walk-thru survey was conducted along each distributary channel, where farmer leaders and IIMI staff walked together discussing the many maintenance and operational problems along the way. While walking, numerous farmers were encountered and discussions were held with them. There was a great deal of enthusiasm among the participants, even though it was Ramazan.

One year later, two days were spent with each WUF. The first day was spent conducting another walk-thru survey very similar to the survey conducted a year earlier. The second day was a large meeting to discuss the maintenance program, operational situation with particular emphasis on achieving equitable water distribution among the watercourses, and the combined management of the irrigation and drainage facilities.

The Heran Distributary WUF completed all of the deferred maintenance during 1997, which was an amazing accomplishment. One of the WUF office bearers has an unusual practical capability for correcting deficiencies that result in sediment deposition; in fact, he supervised the reconstruction of the distributary and minor channels at a total cost of Rs.175,000 (US $ 1.00 = Rs. 40). Desilting cost Rs.61,800 and improvements Rs.138,200 for a total cost of Rs.375,000, of which the WUF paid 56 percent.

Gaylord V. Skogerboe, Director
Pakistan National Program
International Irrigation Management Institute

ACKNOWLEDGEMENTS

The authors of this report express their profound thanks to the Project Leader, Mr. D. Tissa Bandaragoda, Senior Management Specialist, for his guidance and encouragement in undertaking most of the activities reported here. We also convey our gratitude to Dr. Yameen Memon, Team Leader and Sociologist, for his support in conducting these activities. Thanks are due to Mr. Abdul Hakeem Khan, Mr. Nisar Hussain Bukhari and Miss Rubina Siddiqui who helped in calibrating the outlet structures and measuring flows.

Special thanks are due to Mr. Ahsan Ali Kazi, Mr. Ayaz Anwar Solangi and Mr. Faisal Memon for assisting in several ways during the report preparation.

We are very grateful to Ms. Shahnaz Akhtar and Mr. Muhammad Akram Khan for their efforts in formatting and publishing this report.

1. INTRODUCTION

1.1 BACKGROUND

Many countries in the World have already constructed the most economical irrigation projects and the major focus of these countries in the future will be on improving irrigation management practices to increase crop production on existing irrigated lands. However, continuous deterioration of irrigation infrastructure (particularly supply channels) and inadequate operating procedures often preclude any significant improvement.

An important strategy for increasing the agricultural productivity of an existing irrigation system is, first of all, to evaluate the maintenance deficiencies on any particular irrigation system and then correct all maintenance deficiencies that interfere with the proper and efficient operation of that irrigation system (Skogerboe and Merkley, 1996). Secondly, improved operations practices should be developed that will provide reliable, predictable and equitable water deliveries to each outlet or tertiary unit. Finally, when operational practices have been improved, then technical assistance should be provided to the farmers so that they can improve their water management practices in order to increase productivity of available irrigation water leading to increased crop production and poverty alleviation.

A common problem encountered in many irrigation systems worldwide is the continual cycle of irrigation system construction, followed by deterioration of the system because of inadequate maintenance, then rehabilitation, followed again by deterioration. This recurring cycle of construction-deterioration-rehabilitation usually precludes the timely and equitable distribution of irrigation water supplies. However, timely maintenance and improved operational practices would provide equitable, reliable and predictable irrigation water supplies at different levels in the system, particularly at the tertiary level. Many problems regarding maintenance and operation which are effecting the system's performance can be resolved through active participation of water users / farmers' organizations.

1.2 MAINTENANCE AND OPERATION (M&O) OF AN IRRIGATION SYSTEM

The maintenance process has two major phases: one is the maintenance phase and the other is the operation phase. The M & O process has been developed to provide guidelines that will:

Identify problem which commonly prevent irrigation system operating efficiently;

Develop solutions that treat the causes of these problems, rather than just the symptoms, in order to sustain improved maintenance and operation; and

Provide field experience and insights for further improvement in the irrigation system.

The efficient maintenance and operation of an irrigation system is primarily based on its effective management and use of technical solutions. Generally, maintenance is the first

activity to be undertaken before embarking upon a program of improving operations. The proper maintenance of the water conveyance system, including irrigation flow control structures, can improve the irrigation conveyance efficiency, which leads to more equitable water distribution; however, additional efforts will be required to improve operations in order to provide more reliable water distribution, proper farm water management, and increased cropping intensity and crop yields.

To undertake efficient maintenance and operation, a comprehensive maintenance plan is required. A well conceived and organized maintenance plan can help in alleviating the operational and maintenance constraints regarding unreliable and inequitable irrigation water supplies.

1.3 MAINTENANCE SURVEY

The first important task is to gather sufficient valuable information about the irrigation system to be maintained. The information may cover the water supply situation, water distribution pattern, irrigation structures, channel reaches, channel physical conditions, existing maintenance strategies, involvement of beneficiaries, responsible agency role and possible constraints. This information will help in preparing the various maintenance plans.

The first step in this process is to compile existing information about the irrigation system. There should be some general maps of the project area as well as detailed design maps. Some reports may have been written regarding the project, either technical or economic evaluations, or both. There may be important information in the files that has never been placed in a report, such as short evaluations of either operation or maintenance problems. In addition, each project should have registers or a listing of the various structures in the system and the various channel reaches. These registers or listings should supply a history of changes including maintenance.

After acquiring sufficient knowledge about maintenance needs, all of the maintenance requirements are categorized in different maintenance programs. The first major field activity in the maintenance phase is to conduct an Operations Control Maintenance Survey (OCMS) of essential flow control structures that are required for improved operations of the irrigation system, which is used to identify Essential Structural Maintenance (ESM) needs.

The most important step in the maintenance phase is to conduct a detailed Diagnostic Walk-thru Maintenance Survey that lists all deferred maintenance needs along the distributary which is used to identify Priority Deferred Maintenance Needs (PDMN). The majority of maintenance problems are easily observed in the field during these walk-thrus. After conducting the survey of all the structures and channels, the major and minor problems can be identified. A detailed Essential Structural Maintenance Plan and a Deferred Maintenance Plan can be prepared for a comprehensive maintenance program according to time and budget available.

1.4 MAINTENANCE PLANS

1.4.1 Essential Structural Maintenance (ESM) Plan

Essential Structural Maintenance (ESM) is considered to be the minimum level of investment that should be made in order to improve water deliveries. It is the required maintenance for the essential flow control structures that will also allow these structures to be used for discharge measurements after repair and then discharge calibration.

An Essential Structural Maintenance Plan generally includes information on the following important key items:

1. Physical description of irrigation system.
2. Proposed flow measurement program for equitably distributing water supplies.
3. Proposed flow measurement program for evaluating channel losses.
4. Essential structural maintenance (ESM).
5. Cost of ESM.
6. ESM implementation plan.
7. Field notes and sketches.

1.4.2 Deferred Maintenance Plan

Deferred maintenance is the accumulation of maintenance needs being accrued under the normal or routine maintenance program; most likely because of a shortage of funds and other reasons. To prepare a Deferred Maintenance Plan, the following sections would be added to the above outline.

8. Inventory of required deferred maintenance.
9. Deferred maintenance costs.
10. Priority Deferred Maintenance Needs (PDMN) and costs.
11. Maintenance implementation plan.
12. Field notes and sketches.

1.4.3 Catch-up Maintenance

The purpose of catch-up maintenance is to take care of the accumulated deferred maintenance, which in most cases allows deterioration of the system. It is undertaken for taking care of the accumulated deferred maintenance needs in order to upgrade the hydraulic performance of the system.

1.4.4 Preventive Maintenance

Preventive maintenance is for taking care of the causes creating the maintenance needs when they are only a minor problem, rather than allowing such maintenance needs to go unattended until they become a major expensive problem. Preventive maintenance takes care of the causes creating deferred maintenance needs; its purpose is to avoid the need for

costly rehabilitation. Ideally, a normal maintenance program should be provided with sufficient resources that will allow a preventive maintenance program to be followed.

1.4.5 Normal or Routine Maintenance

Normal and Routine are synonymous terms referring to the usual maintenance activities that are conducted annually for an irrigation system. Normal maintenance activities are commonly done every year like "Khatti".

1.4.6 Emergency Maintenance

When unusual conditions occur that jeopardize the safety of the head works or the irrigation channels, then the required maintenance is termed emergency maintenance because of the urgent need to take immediate action.

1.5 MAINTENANCE PLAN OF HERAN DISTRIBUTARY

The preliminary Operations Control Maintenance Survey of the Heran Distributary, including Khadwari Minor and all of the outlet structures was conducted during the annual canal closure period of January 1996. After formation of the Water Users Associations (WUAs) and the Water Users Federation (WUF), a comprehensive Deferred Maintenance and ESM survey, along with the farmer leaders and members of WUF, was carried out during canal closure period of January 1997. Information was also collected regarding the effects of deferred maintenance in obtaining the desired flow conditions along the channels, as well as in flow control and regulation. The maintenance plan presented hereafter is the result of both maintenance surveys mentioned above.

The maintenance plan was prepared in consultation with the members of the Water Users Federation (WUF) in order to jointly identify specific problems and to propose technical solutions in the light of the experiences of the WUF members. Walk-thru surveys are done jointly by walking along the distributary channel for observing the problems of: vegetative growth; conditions of the channel bed, banks and berms; and functioning of the head regulator and all of the control structures along the distributary. Besides, efforts are made to explore the causes of these problems and to suggest the possible remedial measures along with estimating the costs of recommended measures.

2. PHYSICAL DESCRIPTION OF HERAN DISTRIBUTARY

The total cultureable command area (CCA) served by the Heran Distributary (including Khadwari Minor) is 15,387 acres. The total number of watercourses receiving water from the Heran Distributary is 31. The Heran Distributary is composed of a main distributary channel and a minor channel known as Khadwari Minor. Both are being described in this section.

A location map of the distributary is shown in Figure 2.1 and a layout plan of the Heran Distributary is shown as Figure 2.2.

2.1 THE MAIN DISTRIBUTARY

The Heran Distributary is taking off from the Nara Canal at RD 129. The length of the main distributary channel is 10.6 Km. The number of watercourses served from the main distributary channel is 24. They are all lined.

The head regulator consists of three gates (see Figure A-1). Two of them are closed and the middle one is functional. There is one cross regulator situated at RD 10. The main function of this cross regulator is to control the flow in to the Khadwari Minor. The cross regulator is dysfunctional. The distributary channel has a bend of about 65 degree at RD 19. The inspection path is in good condition.

2.2 THE MINOR

The Heran Distributary has a minor named as Khadwari Minor. The length of the minor is 5 Km. The Khadwari Minor has 7 watercourses, out of which 4 are lined.

The head regulator of Khadwari Minor is at RD 10 of the Heran Distributary main channel. The head regulator of the minor is functional. It is the only control point for increasing or decreasing discharge in the Khadwari Minor.

2.2 OUTLETS

There are a total of 31 outlets drawing water from the distributary. The types of outlets and their operating conditions are shown in Tables 2.1 and 2.2. The most common types are the Adjustable Proportional Module (APM) and open Flume (OF).

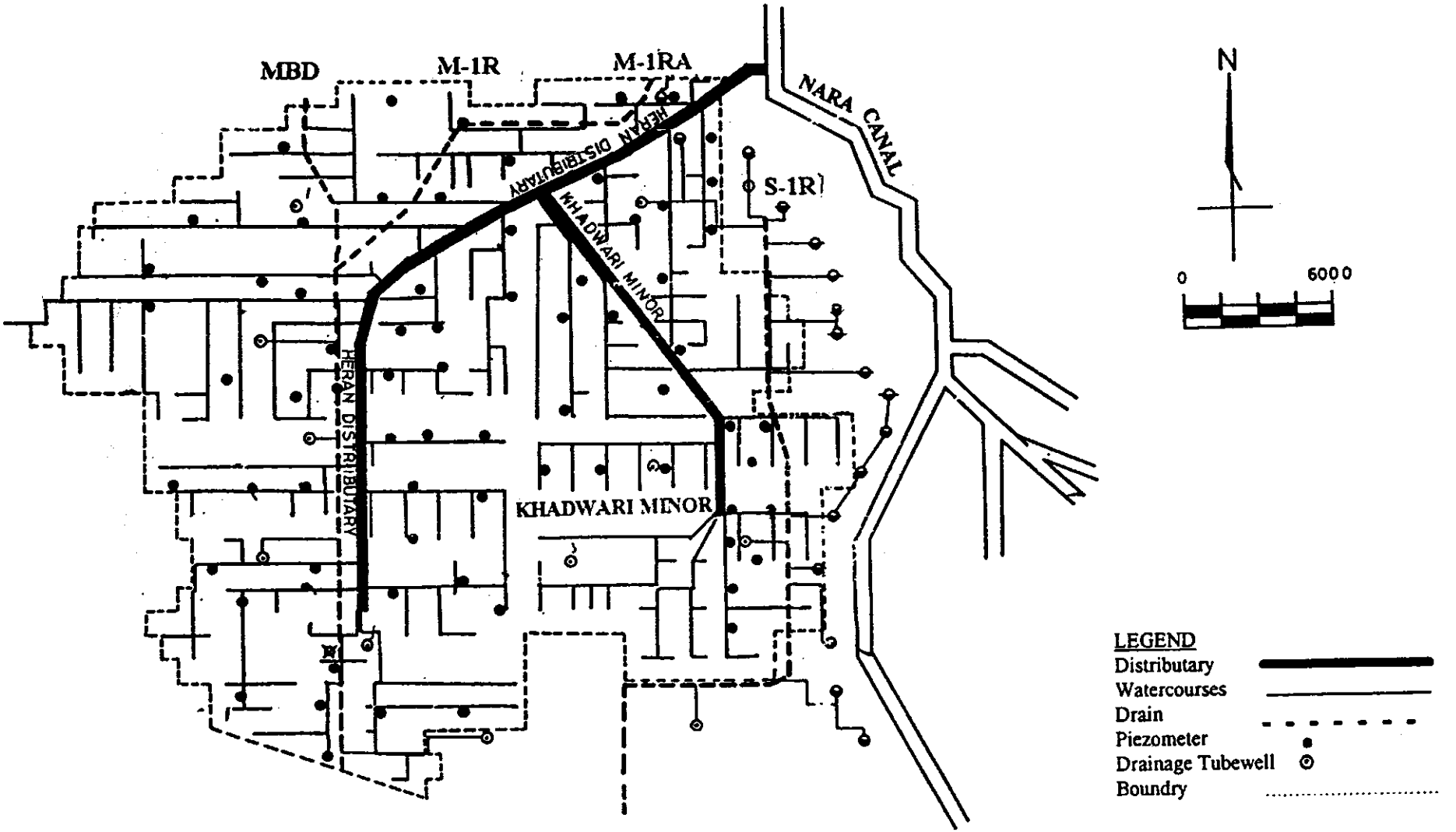


Figure 2.1. Location Map of the three pilot distributaries in Sindh Province.

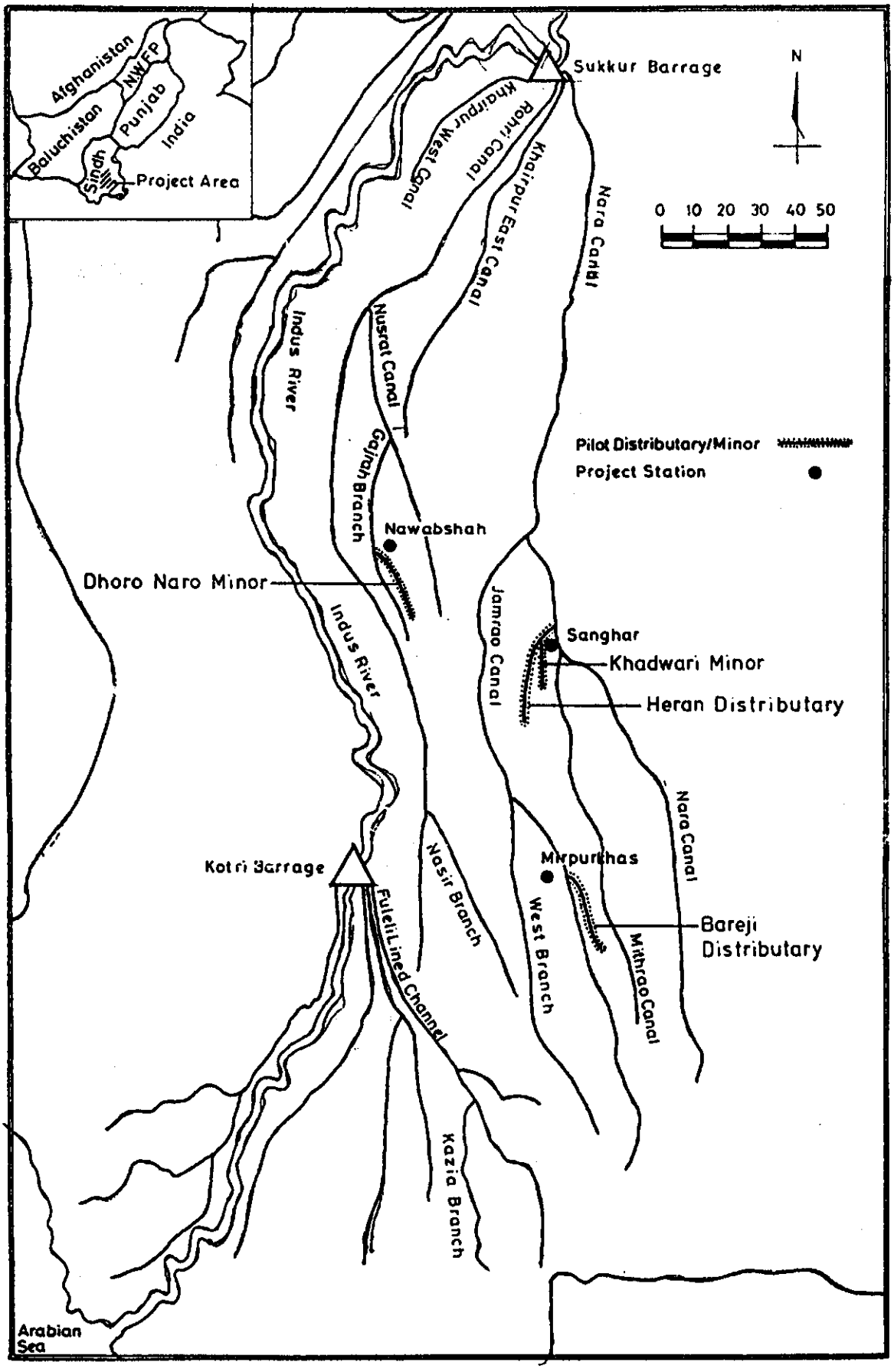


Figure 2.2. Layout Plan of the Heran Distributary Command Area.

Table 2.1 Types of outlets and their operating condition along the main channel of Heran Distributary.

No.	Outlet	TYPE	Flow condition
1.	1-L	APM	Submerged Orifice
2.	2-R	APM	Free Orifice.
3.	3-L	APM	Submerged Orifice
4.	4-R	APM	Submerged Orifice
5.	5-L	APM	Free Orifice.
6.	6-L	APM	Submerged Orifice
7.	7-L	APM	Free Orifice.
8.	9-AR	APM	Submerged Orifice
9.	8-L	APM	Free Orifice.
10.	9-R	APM	Free Orifice.
11.	10-R	APM	Submerged orifice
12&13	11+12-R	APM	Submerged Orifice
14.	13-R	APM	Free Orifice
15.	14-L	APM	Free Orifice
16.	8-AL	APM	Free Orifice
17.	15-L	APM	Free Orifice
18.	16-R	APM	Submerged Orifice
19.	17-AL	APM	Free Orifice
20.	16-AR	Open Flume	Submerged
21.	17-BL	APM	Free Orifice
22.	18-R	Open Flume	Submerged
23.	17-T	Open Flume	Submerged
24.	18-T	Open Flume	Free Flow

Table 2.2 Types of outlets and their operating condition along Khadwari Minor.

No.	Outlet	Type	Flow Condition
1.	1-Al	Open Flume	Free Flow.
2.	1-L	Open Flume	Free Flow.
3.	2-R	Open Flume	Submerged.
4.	3-L	open Flume	Free Flow.
5.	4-R	Open Flume	Submerged.
6.	5-T	Open Flume	Free Flow
7.	6-T	Open Flume	Submerged.

3. OPERATIONS CONTROL MAINTENANCE SURVEY

3.1 BACKGROUND

The required field work for undertaking the development of an Essential Structural Maintenance (ESM) Plan is the Operations Control Maintenance Survey. The field work consists of visiting each flow control structure and determining the maintenance needs so the structure can be used for flow measurement (Skogerboe and Merkley, 1996).

This activity is a crucial linkage between the Maintenance Phase and the Operations Phase. The field data collected during the Operations Control Maintenance Survey of essential flow control structures is used to identify different problems. The ESM is actually the summarized result of this field survey. From these results, the condition of structures will be understood.

3.2 IMPLEMENTATION OF SURVEY

The Operations Control Maintenance Survey of the Heran Distributary as well as the Khadwari Minor was undertaken jointly with the water users / farmers during the 1996-97.

Initially, the survey was done twice: once when the channels were operating and once during the canal closure. During operations, each structure was inspected for visible damage and leakage. During the canal closure, each structure was inspected for required maintenance.

3.3 RESULTS OF SURVEY

3.3.1 Regulators

Field notes alongwith the sketches were prepared during the survey. They are given in Annexure A. A brief summary of the results is given below.

The head regulator of the Heran Distributary is a rectangular-type gate structure was constructed during the British period. It has three main gates from which only the middle one is in good working condition. The other two, on the left and right sides, are not in working condition. The head regulator requires substantial maintenance to become fully operational.

The cross regulator of the Heran Distributary is to control flow into the Khadwari Minor. This regulator gate structure has been there since the early days in the 1930s. Due to a lack of proper maintenance, it is not in good working condition. The iron frame is broken. There are several holes in the gate from where water is leaking.

The head regulator for the Khadwari Minor is the only control point for increasing or decreasing discharge in the Khadwari Minor. This is rectangular-type gate structure with a

fixed iron frame. This regulator is operated almost on daily basis for Khadwari Minor. This is in good working condition.

3.3.2 Outlets

There are 31 outlets on the Heran Distributary and Khadwari Minor. They form an important part of the Heran Distributary irrigation system. The outlets were calibrated two to four times because of frequent changes resulting due to tampering of the outlets. The results are presented in the Annexure A. A brief summary is given below.

Most of the outlets are found tampered to draw more water. This implies that the problem has a social dimension. Therefore, WUAs and WUF need to be involved in rehabilitation / maintenance works to avoid future tampering.

4. FLOW MEASUREMENT PROGRAM

4.1 NEED

Flow measurement is an essential element for evaluating the performance of an irrigation system and water management practices. Particularly, it is required for quantifying the effects of various improvements in these practices. Also, the improvement of water management practices largely depends upon the ability to measure and regulate flow rates and volumes at key points in an irrigation system.

In order to distribute water equitably in an irrigation delivery system, knowledge of the variation in water supplies throughout the system is required. With the increasing emphasis upon improved irrigation water management practices, accounting for the movement of water through a system, including flow measurement, becomes even more important.

Every irrigation system has some irrigation structures to control, regulate and distribute irrigation supplies within the system. The role of these various structures in controlling flows in the system, and in equitably delivering water to the outlets serving the tertiary subsystems, needs to be clearly presented.

4.2 EQUITY AND FLOW MEASUREMENT

Flow measurements at the head regulator and each outlet provides information on the amount of water supplied to a particular area. The system providing equitable flow to tertiary units will provide the foundation for an equal distribution of water to farmers and promote their participation in operating and maintaining the tertiary system. Provision of a reliable water supply to the tertiary units should be a primary operational objective of a project. This objective was sometimes neglected in the past. The improvement of water management practices invariably hinges upon the ability to measure flow rates and volumes at key locations in an irrigation system.

4.3 FLOW MEASUREMENT AT HEAD REGULATORS

The head regulators of the Heran Distributary and the Khadwari Minor were calibrated. The head regulators are gated structures, which are rectangular in shape and have adjustable gates. The hydraulic flow conditions at the head regulators were observed on both the upstream and downstream side of the structure. When the upstream water level is higher than the top of the opening of these gated structures, they are functioning hydraulically as orifices. Tranquil water level locations were sought where there was a minimum of "bounce" in the water level; in other words, locations were preferred where the water surface is calm and smooth.

Before calibrating the structure, it was necessary to establish benchmarks at the upstream as well as downstream walls of the gate structure. The benchmarks were helpful in measuring upstream (u/s) and downstream (d/s) water levels. They were painted on the upstream and downstream walls of the gated structure, which were referenced to the crest level using a Dumpy Level. These observations were used to obtain the upstream depth and downstream depth of flow using vertical tape measurements from the benchmarks down to the water surface levels.

For a rectangular gate having a gate opening, G_0, and a gate width, W, the free-flow and submerged-flow discharge can be computed by using the appropriate equations, assuming that the dimensionless velocity head coefficient is unity. The velocity head coefficient approaches unity as the approach velocity to the orifice decreases to zero.

After establishing the white marks and their elevations with respect to the crest level, tape readings were taken regularly. These readings were used to determine the values of the upstream and downstream flow depths. Current metering was carried out at downstream of the head regulator to measure the actual flow and to determine C_d values for different gate openings. The C_d value was determined for future use in the following equations.

For free flow

$$Q_f = C_d G_o W \sqrt{2g(h_u - \frac{G_o}{2})} \qquad (4.1)$$

For submerged flow

$$Q_s = C_d G_o W \sqrt{2g(h_u - h_d)} \qquad (4.2)$$

Where C_d is the coefficient of discharge, G_0 is the vertical gate opening, W is the gate width, h_u is the upstream flow depth and h_d is the downstream flow depth. Values of h_u, h_d, G_0 and W were measured in the field and discharges were calculated using the above equations where the value of C_d had been calculatd by calibrating each structure using a current meter.

4.4 FLOW MEASUREMENTS OF OUTLETS (WATERCOURSES)

The physical condition of the outlets was observed to determine whether the outlet is functional or dysfunctional, its crest is tampered or in good condition, and the sides are damaged or in proper condition. The type of outlet was identified and the dimensions, such as width and height, were measured. The flow conditions were determined as to whether the flow is free flow or submerged flow. The discharge, using the Cutthroat Flume in unlined watercourses and a current meter in lined watercourses, was measured.

According to the flow condition and the type of outlet, the equations were used to determine the discharge coefficient, C_d. In the case of a tampered outlet, the K value which is equal to the cross-sectional area multiplied by C_d, was computed. By applying the appropriate equation for the determination of the discharge coefficient, the exponent was kept constant. To verify the accuracy of the discharge coefficient, a few readings were observed and the discharge coefficients were computed. Following the benchmarks, established earlier, the tape readings were recorded. The tape readings were subtracted from the benchmark elevations for obtaining the water depths above the outlet crest.

4.5 RESULTS OF FLOW MEASUREMENTS

A summary of flow measurements is given in Table 4.1.

Table 4.1 Performance summary of Irrigation Delivery System of the Heran Distributary, Sanghar.

Months 1997	Average Discharge at head regulator (cfs/1000 acres)	Temporal coefficient of variability at head regulator	Spatial coefficient of variability at outlets	Temporal coefficient of variability at outlets
April	4.85	0.12	0.47	0.24
May	6.31	0.09	0.48	0.21
June	6.61	0.11	0.46	0.18
July	7.04	0.10	0.48	0.20
August	6.44	0.10	0.39	0.20
Sept.	6.77	0.08	0.40	0.18

Average monthly values for discharge at the head regulator of the Heran Distributary from April to September 1997 show that the average monthly discharge received at the head of the Heran Distributary was much more as compared with its old design discharge, which would be expected. The discharges were also not very different from one month to the other except for the month of April, when the average discharge was significantly lower than the other months. The reason for the low supply in April could be related to a transition between the rabi and kharif seasons.

The average temporal coefficients of variability were found within an acceptable range i.e. being in the fair to good category according to Molden and Gates (1990) criteria. This means that the variations observed in the irrigation supplies at the head of the Heran Distributary were acceptable and the main system operations were found to be reliable. The data on spatial coefficient of variability show that the spatial coefficient of variability for the outlets ranged from 0.39 (39%) to 0.48 (48%) which implied that the water distribution along

the outlets was in the "poor" category according to Molden and Gates (1990). Temporal coefficients of variability at outlets varied from 0.18 (18%) to 0.24 (24%), which is comparatively small, thereby implying that each outlet was drawing proportionally the same amount whether the distributary had increased or decreased irrigation water supplies. The results presented above imply that the water distribution was not equitable and, therefore, equity may be rated as poor.

4.6 FLOW MEASUREMENTS FOR EVALUATION OF CHANNEL LOSSES

Seepage losses in the channel should be measured each irrigation season to determine the effects of channel water depths and water table depths on seepage rates. They vary with water surface elevation in the irrigation channel, which is also affected by sedimentation, vegetation and aquatic growth, but much more by biological life in the embankments. The channel losses can be evaluated for most of the reaches in the irrigation network using the inflow-outflow method. They are often expressed in cubic meters per day of water loss per square meter of wetted surface area, which can be converted to millimeters per day (mm/day). Similarly, the seepage rates can be expressed as cusecs (cfs) of seepage per million square feet (msf) wetted perimeter (cfs/msf).

Of particular importance is the rapid increase in seepage rate when the water surface elevation is raised above the normal operating level. This phenomena is primarily due to the large amount of biological life (rodents, snakes, worms, insects, etc.) that exists in an earthen embankment just above the saturated soil in the capillary fringe. The losses tend to increase with each season, sometimes resulting in failure of the embankment. This is highly important in the maintenance of earthen channels, as well as the losses that occur during the operation of the system. The results on the seepage rate measurements are presented below.

The distributary channel was divided into three reaches. The Khadwari Minor was treated as a single reach. The inflow and outflow discharge of each reach was measured by using a current meter. The upstream and downstream flow depths were obtained. Using the calibrated equations, the discharge for each outlet was computed. The seepage rate for each reach is given in Table 4.2.

Table 4.2 Seepage rate of the Heran Distributary, Sanghar.

Reach	Seepage Rate in cfs/msf
I	9.2
II	7.4
III	8.9

5. DIAGNOSTIC WALK-THRU MAINTENANCE SURVEY (DWMS)

5.1 PURPOSE

A diagnostic walk-thru maintenance survey is conducted to list in detail all deferred maintenance needs along the canal, branch canal, distributary and minor including the inlet structures to each tertiary sub-system. The main purposes for undertaking this survey in conjunction with farmers along the distributary and minor were:

(1) to realize more sensitivity about maintenance problems;
(2) to gain farmers views about maintenance problems; and
(3) to obtain historical and social aspects about specific irrigation system difficulties.

5.2 SURVEY

The survey was undertaken in January 1997 jointly with the Heran WUF for a detailed assessment of all the maintenance needs along the Heran Distributary and Khadwari Minor. The joint team walked along the distributary from the head regulator to the tail watercourses. All of the major and minor deferred maintenance needs of the distributary were comprehensively discussed with water users. Special attention was given to existing cross sections, condition of banks, vegetative growth, silt deposition, and animal crossing paths. Possible causes and effects of maintenance needs were identified. The sketches were drawn. All details of the survey, along with sketches are given in Annexure B.

The deferred maintenance needs were discussed with the farmers / water users. The water users came to the conclusion that ignoring the deferred maintenance needs could create major problems for the future. Therefore, these deficiencies should be handled quickly so that related problems like water distribution, breaches, etc. could be overcome. Similarly, for Essential Structural Maintenance, they were of the view that the outlets should be redesigned and a cast iron frame should be fixed for a small amount of money.

6. ESSENTIAL STRUCTURAL MAINTENANCE

6.1 ESSENTIAL STRUCTURAL MAINTENANCE

6.1.1 Head Regulator of Heran Distributary

Considerable importance is given to keeping the main head regulator structure in good working condition because it is the key location from where water flow is regulated into the channel. The head regulator for the Heran Distributary is located on Nara canal at RD 129. It is a rectangular-type gate structure. It was constructed during the British period. There is a serious problem in proper functioning (see Figure A-1). There are three gates. Two of them, located on the left and right sides, are not operational. Only the middle gate is operational.

After formation of the Heran Water Users Federation (WUF), the first decision taken by the WUF was to improve the head regulator. The WUF of the Heran Distributary pointed out in a FICC meeting that the main gate of the distributary had been out of order for a long time and they requested to the SDO, Irrigation Department, Bakhoro Sub-division, for repairs. The SDO informed them that the Irrigation Department had no funds and, therefore, he was unable to repair the gate in the near future. However, he allowed the Heran WUF to repair the gate, in case they were able to arrange for funds. The Heran WUF submitted an application to the Irrigation Department for necessary permission and started the work. For this purpose, a contribution of Rupees five hundred (500) from each watercourse was collected and the head regulator was rehabilitated. Total expenditures for maintenance were about Rupees six thousand (6,000). The Heran WUF financed the full cost of the repairs.

6.1.2 Cross Regulator of the Heran Distributary

The cross regulator of the Heran Distributary situated at RD 10 is a rectangular gate structure with an iron frame (see Figure A-2). The main function is increasing or decreasing water flow into the Khadwari Minor. This is an old structure and due to the lack of proper maintenance, it was not in good working condition. The iron frame was broken. There are two holes in the frame from where water was leaking. The Heran WUF is considering to repair this gate soon.

6.1.3 Head Regulator of the Khadwari Minor

The head regulator of the Khadwari Minor is located near RD 10. This regulator is operated almost on a daily basis for regulating flows to the Khadwari Minor. This gate is in good working condition (see Figure A-2).

6.1.4 Outlet Structures

The results of the field survey on the outlet structures are presented in Annexure A. The sketches are provided in Figures A-3 through A-14.

The results of the field survey indicates that a vast majority of the outlets from the Heran Distributary, as well as from the Khadwari Minor, are tampered simply to draw more water. The cost estimates are given in the following section.

6.2 COSTS OF ESSENTIAL STRUCTURAL MAINTENANCE

The ESM costs were estimated on the basis of field observations and through consultation with the water users / farmers. They are presented in Table 6.1. The total cost for the ESM works identified so far is estimated to be Rupees fifteen thousands four hundred and eighty (Rs. 15,480).

6.3 ESM IMPLEMENTATION PLAN

The ESM of the head regulator was undertaken by the Heran WUF in 1997. The ESM of the outlet structures will be undertaken after taking over of the M and O responsibility of the Heran Distributary by the Heran WUF, so that tampering could be avoided through reaching concensus among the water users. Also, it will form the basis for the equitable distribution of irrigation supplies among the water users / members.

Table 6.1 Summary of ESM costs of Heran Distributary.

Structure	Cement (Rs)	Bricks (Rs)	Sand (Rs)	Bajri (Rs)	Labor skilled (Rs)	Labor un-skilled (Rs)	Other (Rs)	Total Cost Rs.
Head Reg.					1200	600	3200	6,000
1-L	190	200	50		250	240	100	1,030
2-R	190	200	50		250	240	100	1,030
3-L	190	200	50		250	240	100	1,030
4-R	190	200	50		250	240	100	1,030
X-Reg					250	100	500	800
8-L	50	10		50	100			210
9-R	50	10		50	100			210
10-R	50	10		50	100			210
11+12R	50	10		50	100			210
14-L	50	10		50	100			210
16-R	190	200	50		250	240	100	1,030
17-AL	50	10		50	100			210
16-AR	50	10		50	100			210
18-R	190	200	50		250	240	100	1,030
17-BL	190	200	50	-	250	240	100	1,030
Total								15,480

7. DEFERRED MAINTENANCE PLAN

7.1 INVENTORY OF REQUIRED MAINTENANCE

A general description of a Deferred Maintenance Plan for the Heran Distributary is presented in order to understand the relationship between the field maintenance inventory and the proposed solutions contained in the form of maintenance needs, costs & manpower. From the diagnostic walk-thru survey of the Heran Distributary, different major and minor maintenance problems were observed. Most of the problems were inter-related. The inventory of those main problems observed as deferred maintenance problems is given below.

1 Sedimentation;
2 Vegetation;
3. Wider cross-sections;
4. Weak Banks;
5. Erosion; and
6. Lack of Inspection Path (IP).

Water Users Federation (WUF) for the Heran Distributary, Sanghar, was formed in December 1996. After the establishment of the WUF, a joint walk-thru survey was carried out from the head to the tail of the Heran Distributary. IIMI staff from Lahore, Hyderabad, Sanghar and members of WUF participated in the survey. During the survey, members of WUF with the assistance of IIMI staff identified key problems related to M and O of the distributary and suggested interventions for the rehabilation of the Heran Distributary. The key problems identified are:

- Rehabilitation / stabilization of the non-inspection path (left bank) from RD 23 to 27.
- Rehabilitation / stablization of inspection path (right bank) from RD 27 to 31.
- Stabilization of Non Inspection Path (NIP) from RD 8.6 to 10.1.
- Construction of culverts on watercourses and Khadwari Minor.

Detailed inventory of the required maintenance prepared jointly for the Heran Distributary and Khadwari Minor is given in Tables 7.1 and 7.2.

Table 7.1 Inventory of required maintenance of Heran Distributary.

No	RD	Inventory List
1	Head to 10	wide portion, sediment deposition, no berm, vegetation on the left bank.
2	From 10 to 11	silt deposited near road bridge, week non-inspection path.
3	From 11 to 19	vegetation on the left bank, silt deposition, no berm, wider and narrow sections
4	From 19 to 23	vegetation on the left bank
5	From 23 to 27	weak non-inspection path, dense vegetation, waterlogging in surrounding
6	From 27 to 31	no Inspection Path, dense vegetation on both sides, channel not accessible

The results for the Khadwari Minor are summarized in Table 7.2.

Table 7.2 Inventory of required maintenance of Khadwari Minor.

No	RD	Inventory List
1	Head to 4.9	wider section and dressing of Inspection Path
2	From 5 to 11	silt deposition and cuts on the banks
3	From 11 to 13	vegetation on the left bank, silt deposition, no berm, wider and narrow sections
4	From 13 to 16	vegetation on the left bank and IP weak

7.2 DEFERRED MAINTENANCE COST

7.2.1 WUF and IIMI

Some key activities were undertaken jointly by the Heran WUF and IIMI. The cost estimates were prepared on the basis of field observations and through consultation with the water users. The actual costs were even less than the original estimates. Tables 7.3 presents the actual costs of Deferred Maintenance works completed jointly during 1997. All costs are in Pak Rupees (Rupees 44 = 1 US $ approximately)

Table 7.3 Cost of Deferred Maintenance undertaken in 1997 on Heran Distributary, Sanghar.

S#	Type of Work	Project Fund(Rs.)	WUOs Contribution. (Rs)	Total Cost (Rs)
1	Rehabilation of Inspection Path from RD 27 to 31	22,080	22,550	44,630
2	Repair of Inspection Path(IP) Near Tail	2,400	1,250	3,650
3	Stablization of Non Inspection Path (NIP) from RD 23 to 27	44,400	40,200	84,600
4	Stablizaton of Non Inspection Path (NIP) from RD 8.6 to 10.1	22,690	19,290	41,980
	Total	91,570	83,290	174,860

7.2.2 Works Undertaken by Heran WUF

The Heran WUF undertook some activities exclusively through its own resources. The costs incurred are given in Tables 7.4 and 7.5 for the Heran Distributary and the Khadwari Minor, respectively.

Table 7.4 Desilting cost of Heran Distributary.

Date	Khati done form w\c to w\c	Labors used	Labor cost Rs100 \day	Tractor used/day	Fuel cost/day in liter	Fuel cost/day 10.5	Equipment rent\day	total cost of the day Rs
20.1.97	Head to 7-L	93	9,300	3	150	1,575	NA	10,875
21.1.97	7-L to 9-R	44	4,400	2	110	1,155	NA	5,555
22.1.97	9-R to 8-AL	58	5,800	3	135	1,418	900	8,117
23.1.97	8-AL to 15-L	54	5,400	2	95	9,97	NA	6,397
24.1.97	15-AL to 18-AT	108	10,800	1	50	525	NA	11,325
25.1.97	7-L to 10_R	25	2,500	3	95	2,500	NA	5,000
Total		382	38,200	14	635	8,170	900	47,270

Table 7.5 Desilting cost of Khadwari Minor

Date	Khati done form w\c to w\c	Labors used	Labor cost Rs100 \day	total cost of the day
29.1.97	Head to 1-AL	45	4,500	4,500
30.1.97	1-AL to 1-L	59	5,900	5,900
1.2.97	1-L to Tail	41	4,100	4,100
Total		145	14,500	14,500

7.2.3 Summary of Deferred Maintenance Costs

The summary of Deferred Maintenance Costs is given in Table 7.6.

Table 7.6 Summary of Deferred Maintenance Costs.

Work	Total Cost (Rs)	WUF and WUAs Contribution	Project Contribution
Tables 7.3, 7.4 and 7.5	236,630	145,060	91,570

7.3 IMPLEMENTATION OF DEFERRED MAINTENANCE

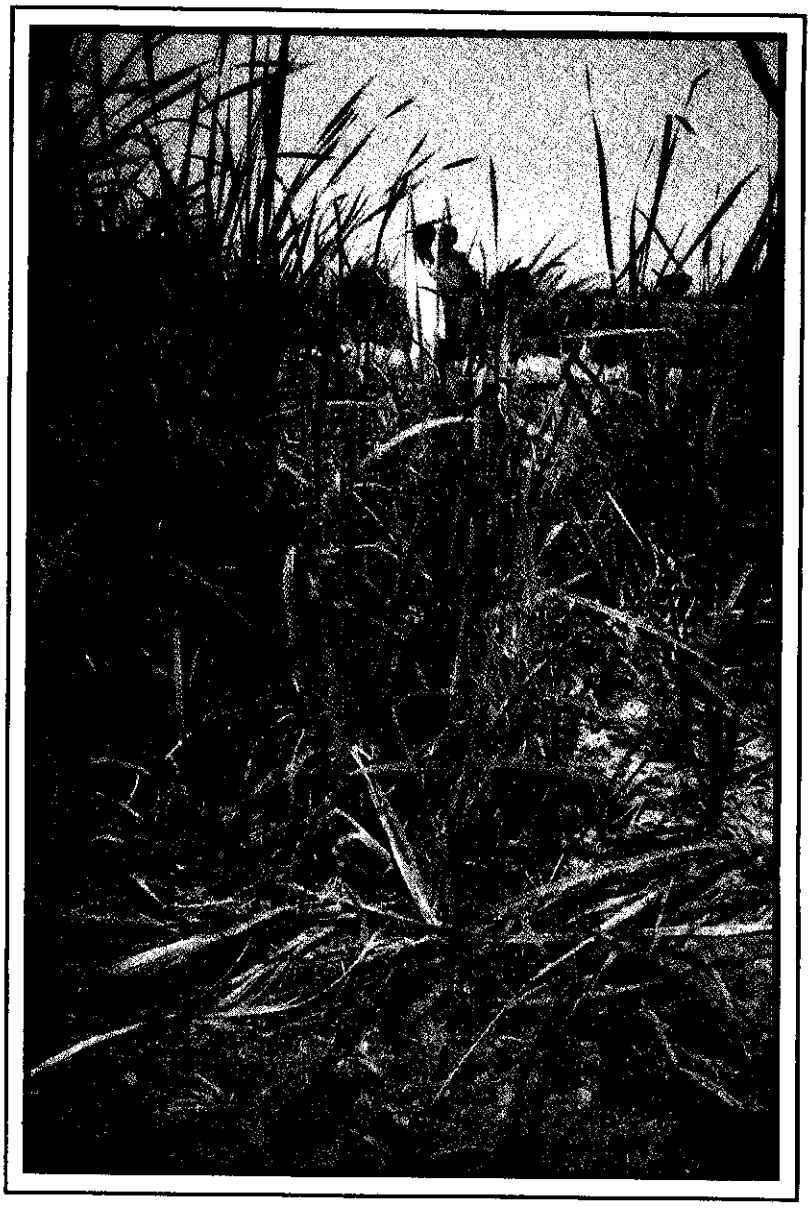
7.3.1 Rehabilitation of non-Inspection Path From RD 23 to 27

Due to continuous leakage of water from the Heran Distributary, the nearby area around this portion was always under water. Therefore no crop was being cultivated in the vicinity. Rather dense vegetation was always growing there (see Photographs A through C showing the nature and extent of the problem). The Heran WUF with the assistance from IIMI decided to rehabilitate this portion. The development scheme was prepared and presented in a meeting of the Heran WUF. The work was carried out in July- August of 1997 under the joint supervision of the members of the WUF and IIMI field staff (see photographs D, E and F showing the work under progress). The rehabilitation / stabilization of non-inspection path from RD 23 to 27 (about 4000 ft) has checked completely the leakage of water and has also stopped the occurrence of frequent breaches. About 30 acres of waterlogged and waste land has been reclaimed through this intervention. The area is being prepared for cultivation after a very long period (about 20 years). The land is being prepared for crops as given in Table 7.7 (also see photographs G, H, I and J showing the land already cultivated and being prepared for cultivation).

Table 7.7 Land being reclaimed on Heran Distributary.

Land Owner	Land being prepared (ac)	Land cultivated (ac)	W/C
Mr. Abdul Hameed	16 (are being prepared)	4 (wheat)	15-L
Mr. Mohd Hassan	5 (are being prepared)	-	15-L
Mr. Abdul Hameed	9 (are being prepared)	2 (wheat) 1 (Sugarcane) 6 (kharif 98)	17-AL

Photographs A, B, and C, are showing the condition of Non-Inspection Path from RD 23 to 27 before Rehabilitation.



Photograph A.

Photograph B.

Photograph C.

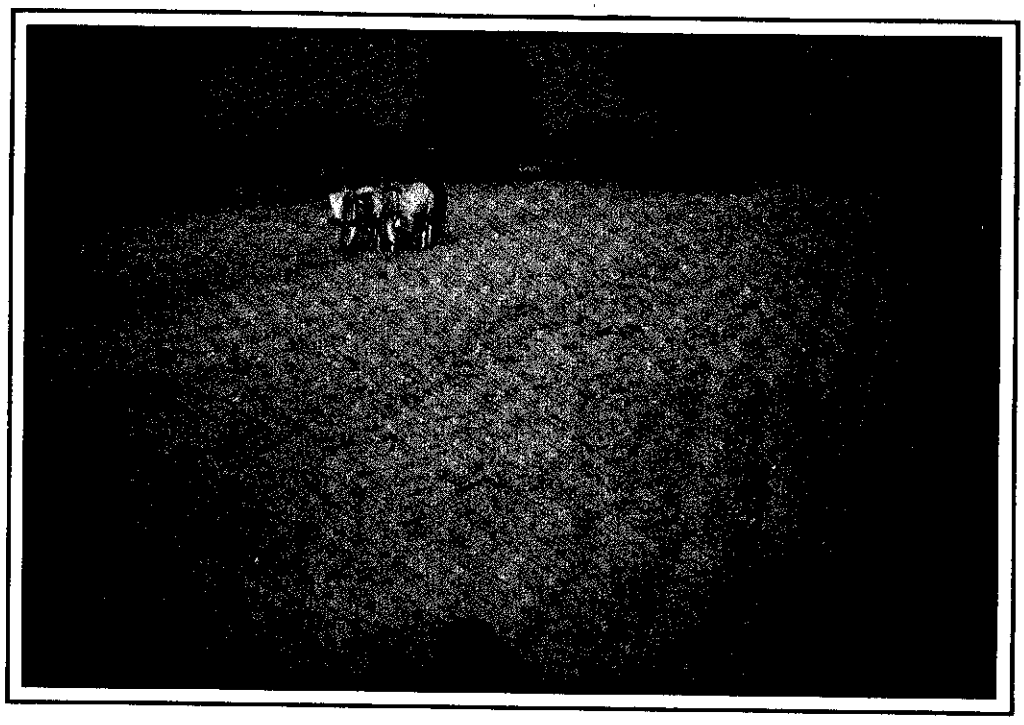
Photographs D, E and F showing the works in progress from RD 23-27.

Photograph D.

Photograph E.

Photograph F.

Photographs G, H, I, and J showing the area reclaimed.



Photograph G.

Photograph H.

Photograph I.

Photograph J.

7.3.2 Rehabilitation of Inspection Path From RD 27 to 31

This portion of the distributary was not accessible for inspection patrolling since long time. The bank elevation was too high compared to the FSL of the channel. Therefore, this portion of the distributary was very difficult to desilt manually (see Photographs K, L, M and N showing the past and present conditions).

In this portion, the extra soil was removed upto required bank elevation. The extra soil was used to widen the inspection path. Also, local building contractors in the Sanghar City who needs this silt filling purpose were contacted and were encouraged to take this extra soil free of payment. This also helped in removing the extra silt quickly.

At present, the water users are using this inspection path for the transport of their agriculture products. The visitors and patrolling team can drive over it. The water users now feel very comfortable for desilting this portion of the distributary.

Photograph K. Inspection path from RD 27 to 31 before rehabilitation.

Photograph L. Inspection path from RD 27 to 31 after rehabilitation.

Photograph M. Inspection path from RD 27 to 31 before rehabilitation.

Photograph N. Inspection path from RD 27 to 31 after rehabilitation.

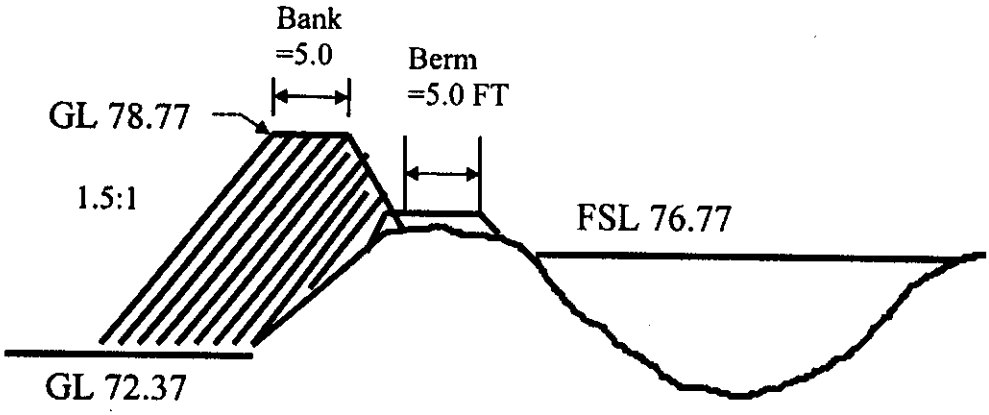
7.3.3 Stabilization of Bank from RD 8.6 to 10.1.

Along this portion of the distributary one village named chak No.1 is located. This portion is always being used for washing clothes and bathing animals. Therefore, the bank of the distributary channel in this portion was very weak. The stabilization of this portion of the bank has made the bank stronger. The villagers are now very happy because of safety against breaches.

7.4 SAMPLE CALCULATIONS

Sample calculations are given below.

7.4.1 Cost-Estimation for stabilizing the left bank from RD 8.6 to 10.1



Typical x-section at RD 9.3 of NIP

Calculation of Cross-sectional Area

Offsets (ft)	Existing Level (ft)	Proposed level (ft)	Depth (ft)	Mean Depth (ft)	Bottom Width (ft)	Area (ft^2)
0	72.37	72.37	-----	-----	-----	------
3.6	72.37	74.77	2.4	1.2	3.6	4.32
11.6	75.07	78.77	3.7	3.05	8	24.40
16.6	75.07	78.77	2.0	2.85	5	14.25
17.35	76.77	76.77	-----	1.0	0.75	0.75
					Total area =	43.72

Measurement Sheet

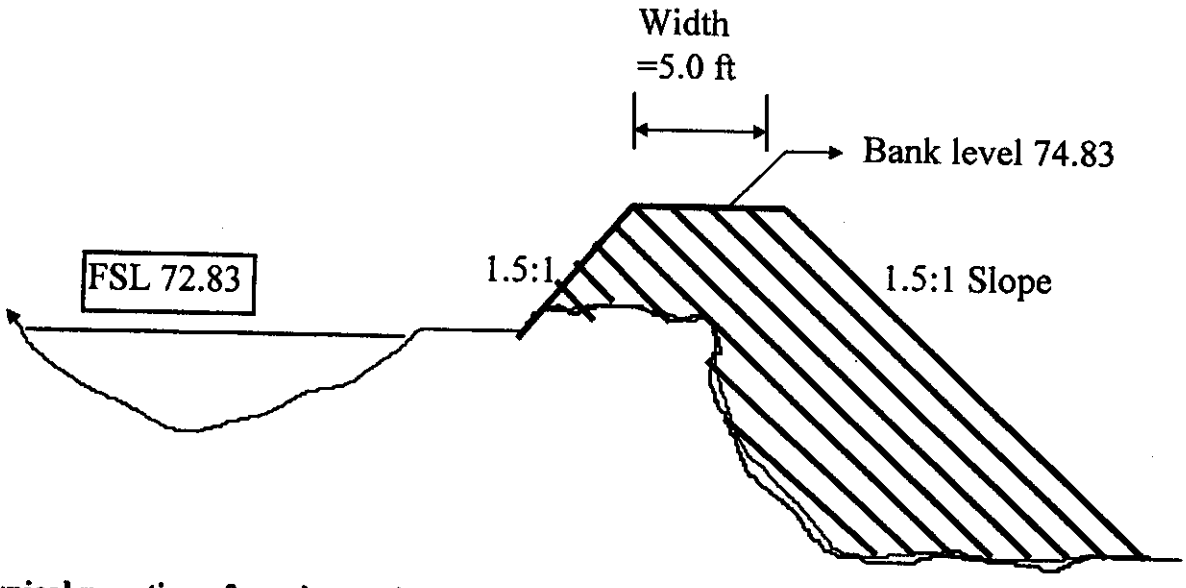
Item	Area (ft2)	Length (ft)	Quantity (cft)
1. Barrow pit excavation undressed upto 100 ft ordinary soil	43.72	1,500	65580
2. Dressed and leveling of earth work to designed section (complete ordinary soil)			65580

Abstract Sheet

Quantity (cu. ft.)	Item	Rate (Rs/1000 cft)	Total Amount Rs
65580	1. Barrow pit excavation undressed up to 100 ft ordinary soil.	550.50	36,105.33
65580	2. Dressing and leveling of rough work to designed section etc complete ordinary soil.	54.80	3,593.78
	Total:		39,699.00

7.4.2 Cost-Estimation for Rehabilitation of non Inspection Path from RD 23 to 27.

The Water Users Federation (WUF) identified the need for the maintenance of left side bank from RD 23 to 27 (about 4000 ft length). This portion was always creating problem of breach, seepage and slippage of water. Therefore, the nearby area could not be cultivated. Looking into the problem, the IIMI field staff prepared a cost-estimation for raising and strengthening the bank of Distributary from RD 23 to 27.



Typical x-section of non inspection path of Heran Distributary, Sanghar.

Calculation of Cross-sectional Area

Offsets (ft)	Existing Level (ft)	Proposed Level (ft)	Depth (ft)	Mean Depth (ft)	Bottom Width (ft)	Area (ft^2)
0	---	---	---	---	---	---
5.0	---	---	---	---	---	---
8	72.88	72.83	---	---	---	---
12.0	73.0	74.83	1.83	0.9	4.0	3.6
14.0	73.0	74.83	1.83	1.83	2.0	3.66
18.0	70.0	74.83	4.83	3.33	4.0	13.32
25.0	70.0	70.0	---	2.41	7.0	16.87
				TOTAL	AREA	37.45

The total cross-sectional area is about 37.45 sq:ft The condition of required 4000 ft length is not exactly the same but it is almost similar. Therefore, the total length is multiplied by the cross-sectional area to get volume of required earth for raising and stabilizing the bank.

Volume : 37.45 sq.ft x 4000 ft = 149,800 cft

Measurement Sheet

Item	Area (ft^2)	Length (ft)	Quantity (cft)
Barrow pit excavation undressed upto 100 ft ordinary soil	37.45	4,000	149,800
Dressing and leveling of earth work to designed section, (complete ordinary soil)			149,800

Abstract Sheet

Quantity (cft)	Item	Rate Rs (Rs/1000 cft)	Total Amount Rs
149,800	1. Barrow pit excavation undressed up to 100 ft ordinary Soil.	550.50	82,465
149,800	2. Dressing and leveling of rough work to designed section (complete ordinary soil)	54.80	8,209
		Total Cost Rs:	90,674

8. ACHIEVEMENTS

8.1 GENERAL

8.1.1 Federation Office

The Heran WUF established an office at Chak No 3. The room for office was provided by Secretary Union Council Khadwari. The Heran WUF repaired the office to make it functional through spending Rupees Four Thousand Eight hundred only (Rs 4800).

8.1.4 Bank Account

The Heran WUF opened an account with the United Bank Limited branch located at Chak No 3 and deposited the funds in the account collected so far.

8.1.5 Meetings

The WUAs and WUF have been organizing their meetings regularly. They discussed various field issues and decided on follow-up actions. They also reviewed the progress made in implementing the decisions taken at the previous meetings. The WUAs are keeping the minutes of the meetings and a record of their correspondence.

8.2 MAINTENANCE

8.2.1 Essential Structural Maintenance

The WUF of the Heran Distributary repaired the head regulator of the main channel by spending Rupees Six Thousand only (Rs: 6,000) from their own resources.

8.2.2 Deferred Maintenance

The WUF has spent Rupees 236,630 on the deferred maintenance. The project contribution was only rupees 91, 570.

8.3 IMPROVEMENTS

Water users / farmers generally transport their agriculture produce from farm to market using bullock carts and tractor trolleys. At the crossing point of the most of the watercourses there are no culverts. Therefore, considerable amount of water is being lost due to crossing of local transport above the watercourses having no culverts.

The Heran WUF took note of this situation and mobilized support within its members to construct culverts on such watercourses. After the construction of culverts at 12 important watercourse crossing points, the wastage water has been stopped and crossing above the watercourses has been effectively improved. The water users are now feeling quite satisfied.

This activity also encouraged many water users to contact the WUF for construction of culverts on their watercourses.

A bridge was also constructed near Jamali Village. The costs incurred and the financing arrangements are shown in Table 8.1

Table 8.1 Cost of Improvements on Heran Distributary, Sanghar.

S#	Type of Work	Project Fund(Rs.)	WUOs Contribution. (Rs)	Total Cost (Rs)
1	12 Culverts on different watercourses	59,981	54,380	114,361
2	Bridge Near Jamali village (Goth)	12,645	11,250	23,895
	Total	72,626	65,630	138,256

The WUF spent Rupees 138,256 on the improvements by constructing a bridge and 12 culverts. The project contribution was Rupees 72,626. An example of cost estimates is given in Table 8.2.

Table 8.2. Estimation for culvert on W/C no 6-T of Khadwari Minor.

Item	Quantity	Rate Rs	Amount Rs
Cement	8 bags	190	1,520
Bricks	2,000 Nos.	1,000	2,000
Iron bars			3,000
Crash	100 cft	1200	1,200
Bajri	100 cft	600	600
Labor (i) Skilled	2/day	250	500
(ii) Unskilled	3/day	100	300
Rent Tractor Trolley	3 Trip	400	1,200
Total			10,320

9. CONCLUSIONS AND RECOMMENDATIONS

The study has led to the following general conclusions and recommendations.

- Tampering of the outlets and lack of essential structural maintenance coupled with deferred maintenance resulted in the problem of inequity in water distribution from the main channel.

- The deferred maintenance needs for the Heran Distributary were great because of lack of routine maintenance over the last many years (about 10 years).

- The maintenance activities undertaken on the Heran Distributary by the Heran WUF is a clear indicator of the farmers' willingness and ability to participate in the maintenance activities. This also shows, once organized, they can be very effective in undertaking the maintenance activities in a very economical way.

- Maintenance activities require considerable technical and financial resources. Considering the present level of resource availability for M & O activities, it would be very difficult for a government agency to undertake maintenance activities on their own. Therefore, it is necessary that the water users, who are also the beneficiaries, may be involved in this process.

- A strong recommendation is that the farmers, through their WUF, may be provided necessary training, resources and powers (legal authority) to undertake these activities in the future. Without legal authority, they will be unable to achieve equitable water distribution.

REFERENCES

Molden, D. and Gates, T. K. 1990. Measures of Evaluation of Irrigation Water Delivery Systems. In Journal of Irrigation and Drainage Engineering, Volume 116, No. 6, ASCE, USA.

Skogerboe, G. V. and Merkley, G. P. 1996. Irrigation Maintenance and Operations Learning Process. USA.

ANNEXURES

ANNEXURE A

FIELD NOTES AND SKETCHES
ON
OPERATIONS CONTROL MAINTENANCE SURVEY
OF
HERAN DISTRIBUTARY

ANNEXURE A. Field Notes And Sketches on Operation Maintenance Survey of Heran Distributary

RD 91.4 **1. HEAD REGULATOR OF HERAN DISTRIBUTARY**

NARA CANAL

The head regulator for the Heran Distributary is located on Nara canal at RD 129. The gate is rectangular type and it was constructed during British time. The head regulator (Figure A-1) has three cast iron gates. The gates were not well maintained. Two of them (located on the left and right sides) are not operational. Only the middle one is operational. The culvert was constructed with bricks.

RD 10 **2. CROSS REGULATOR AT HERAN DISTRIBUTARY**

HERAN D.

Cross regulator is situated at RD 10. It is rectangular in shape (Figure A-2). It has an iron frame. The main function of this cross regulator is to control flow in the Khadwari minor. This regulator is there since early days. Due to lack of proper maintenance, it was not in good working condition. The iron frame is broken. There were several holes in the frame from where water was leaking.

RD 10 **3. HEAD REGULATOR OF THE KHADWARI MINOR**

HERAN D.

The head regulator for the Khadwari minor is located at RD 10 of the Heran Distributary. It was the only control point for increasing or decreasing discharge in the Khadwari Minor. This is rectangular type with fixed iron frame. This regulator is operated almost on daily basis for Khadwari minor. This gate was in good working condition (Figure A-2).

4. OUTLETS STRUCTURES (MOGHAS) FROM THE HERAN DISTRIBUTARY

OUTLET 1-L

Type It is an Adjustable Proportional Module (APM).

Condition Its crest is tampered. The wing walls are in good condition. There is considerable amount of silt deposition near the left wing wall. It was tampered for drawing more water during the current season. (see Figure A-3)

Remedy The outlet needs to be repaired for restoring its original condition.

OUTLET 2-R

Type It is an APM.

Condition Its crest is tampered. The roof block is also broken which allows water to spill over. The wing walls are in good condition. There is considerable amount of silt deposited on the right wing wall. It was tampered for drawing more water.

Remedy The outlet need to be repaired for restoring its original condition.

OUTLET 3-L

Type It is an APM.

Condition Its crest is tampered. The side walls of the orifice are also tampered to provide space for the passage of more water. There is considerable amount of silt deposition on the left wing wall. It has been tampered for the simple reason of drawing more water (see Figure A-4).

Remedy The outlet needs to be repaired for restoring its original condition. It is also necessary to remove the silt deposition on the right wing wall. (see Figure A-4)

OUTLET 5-L

Type It is an APM.

Condition The crest as well as walls of the orifice are tampered. (see Figure A-4). There is considerable silt deposition near the right wing wall of the outlet.

Remedy The outlet needs to be repaired and rehabilitated to its original design. It is necessary to remove the silt deposition on the right wing wall.

OUTLET 4-R

Type It is an APM.

Condition The crest as well as the walls of the orifice are tampered. Due to this water flows over the roof block.

Remedy The outlet needs to be repaired to restore its original condition.

OUTLETS 6-L & 7-L

Type Both are APMs.

Condition Their crests are tampered. The side walls of the orifices are severely tampered to provide free passage of more water. Apparently, tampering has been done for drawing more water.

Remedy Both of the outlets need to be rehabilitated to their original design.

OUTLET 8-AL

Type It is an APM.

Condition Its crest is tampered. The side walls of the orifice are also tampered to make more room for the passage of more water. There are no wing walls. Its roof block is very weak. There is considerable amount of silt deposition on the left side of the orifice. It has been tampered for the simple reason to draw more water.

Remedy The wing wall should be constructed so as to prevent the erosion of bank of distributary. The outlet also needs to be repaired to bring it back to its original condition.

OUTLET 8-L

Type It is an APM.

Condition Its crest is tampered. The side walls of the orifice are also tampered to make room for the passage of more water. The roof block and wing walls are in good condition. There is considerable amount of silt deposition on the left wing wall.

Remedy The outlet needs to be repaired to bring to its original condition.

OUTLET 9-AR

Type It is an APM.

Condition It is in good shape. The wing walls and roof block are in good condition. There is no silt deposition. It is drawing its due share of water.

Remedy There is no need of any intervention.

OUTLET 9-R

Type It is an APM.

Condition Its crest and side walls are tampered to make more room for the passage of more water. The roof block and wing walls are in good condition. It has been tampered for the simple reason of drawing more water see Figure A-5).

Remedy The outlet needs to be repaired.

OUTLET 10-R

Type It is an APM.

Condition Its crest is tampered. The roof block and wing walls are in good condition. It has been tampered to draw more water.

Remedy The outlet need to be repaired to restore its original condition.

OUTLET 11 & 12-R

Type It is an APM type.

Condition Its crest is tampered. The wing walls are in good condition. There is small amount of silt deposition on right wing wall. It has been tampered for the simple reason to draw more water.

Remedy The outlet need to be repaired to rehabilitate to its original condition.

OUTLET 13-R

Type It is an APM.

Condition Its crest is tampered. The wing wall and roof block are in good condition. There is considerable amount of silt deposition on both wing walls.

Remedy The outlet needs to be repaired to restore its original condition.

OUTLET 14-L

Type It is an APM.

Condition Its crest is tampered. The right wing wall is broken. It has been tampered to draw more water. (see Figure A-6).

Remedy The outlet and wing walls need to be repaired.

OUTLET 15-L

Type It is an APM.

Condition Its crest is tampered. The small portion of left wing wall is broken. There is considerable amount of silt deposition on both sides of the wing walls.

Remedy The outlet and the left wing wall need to be repaired. Silt deposition to be cleared.

OUTLET 16-R

Type It is an APM.

Condition Its crest is tampered. The wing walls are in good condition. There is considerable amount of silt deposition on left wing wall. It has been tampered to draw more water. (see Figure A-7).

Remedy There is need for the outlet to be repaired and silt to be removed.

OUTLET 17-AL

Type It is an APM.

Condition Its crest is tampered. Left wing wall is not present. Also, the left bank of the distributary channel is very week at this location. Water spilling over the bank of the channel at this place was observed occasionally. There is considerable amount of silt deposition on both sides of the outlet. Due to the silt deposition, water flows over the roof block sometimes. Farmers / water users have made small mud bund to stop spilling of water over the roof of the outlet. (see Figure A-8)

Remedy The left wing wall and roof block should be constructed. The outlet also needs to be repaired.

OUTLET 16-AR

Type It is an Open Flume.

Condition Its floor is tampered. The throat width is also tampered to provide space for free passage of more water. The wing walls are in good condition. There is considerable amount of silt deposition near the left wing wall. It has been tampered to draw more water.

Remedy The outlet needs to be repaired and silt deposition to be cleared.

OUTLET 17-BL

Type It is an APM.

Condition Its crest is tampered. The wing walls are in poor condition. The water flows over the left wing wall and roof block. There is considerable amount of silt deposition near the both wing walls. It has been tampered to draw more water.

Remedy The wing walls and outlet need to be repaired. Silt needs to be removed.

OUTLET 18-R

Type It is an Open Flume.

Condition Its floor is tampered. The throat width is also tampered to provide space for the free passage of more water. The wing walls are in good condition. There is considerable amount of silt deposition near left wing wall. It has been tampered to draw more water.

Remedy The outlet needs to be repaired and silt needs to be cleared.

OUTLETS 17-AT & 18-AT

Type They are Open Flumes.

Condition Their floors are tampered. Their throat widths and wing walls are in good condition. There is considerable amount of silt deposition near both wing walls. (see Figure A-9).

Remedy The outlets need to be repaired and silt to be removed.

OUTLETS FROM KHADWARI MINOR

OUTLET 1-AL

Type It is an Open Flume.

Condition The outlet structure is in good physical condition (not tampered). The floor, throat width and wing walls are in good condition. There is considerable amount of silt deposition near right wing wall. (see Figure A-10).

Remedy Silt is to be removed.

OUTLET 1-L

Type It is an Open Flume.

Condition Its floor is tampered to draw more water. There is considerable amount of silt deposition near the left wing wall. Due to the silt deposition, water spill over the left wing wall.

Remedy The outlet floor to be repaired and silt deposition to be cleared.

OUTLET 2-R

Type	It is an Open Flume.
Condition	The outlet floor is tampered. There is an huge amount of silt deposition near the left wing wall. The wing walls are in good condition. It was tampered to draw more water. (see Figure A-11).
Remedy	The outlet needs to be repaired and silt deposition to be cleared.

OUTLET 3-L

Type	It is an Open Flume.
Condition	The outlet floor is tampered. The throat width is also tampered to provide more space for the free passage of more water. Both wing walls are in bad condition. There is also huge amount of silt deposition near the both wing walls. (see Figure A-12).
Remedy	The outlet and both wing walls need to be repaired and silt deposition to be cleared.

OUTLET 4-R

Type	It is an Open Flume.
Condition	The outlet floor and throat is tampered to provide more space for the free passage of water. The wing walls are in good physical condition. There is no silt deposition near the wing walls. The tampering was done to draw more water. (see Figure A-13).
Remedy	The outlet floor and throat need to be rehabilitated.

OUTLETS 5-T

Type	It is an Open Flume.
Condition	The floor and throat is tampered to provide more space for the passage of more water. The wing walls are in good physical condition. There was no silt deposition near the wing walls. (see Figure A-13).
Remedy	The outlet need to be rehabilitated to restore its original design condition.

OUTLET 6-T

Type	It is an Open Flume.
Condition	There is no permanent structure to control the discharge. There are two simple rectangular block. Water can flow beneath and around these blocks. There are no wing walls. (see Figure A-14).
Remedy	The outlet needs to properly designed and constructed.

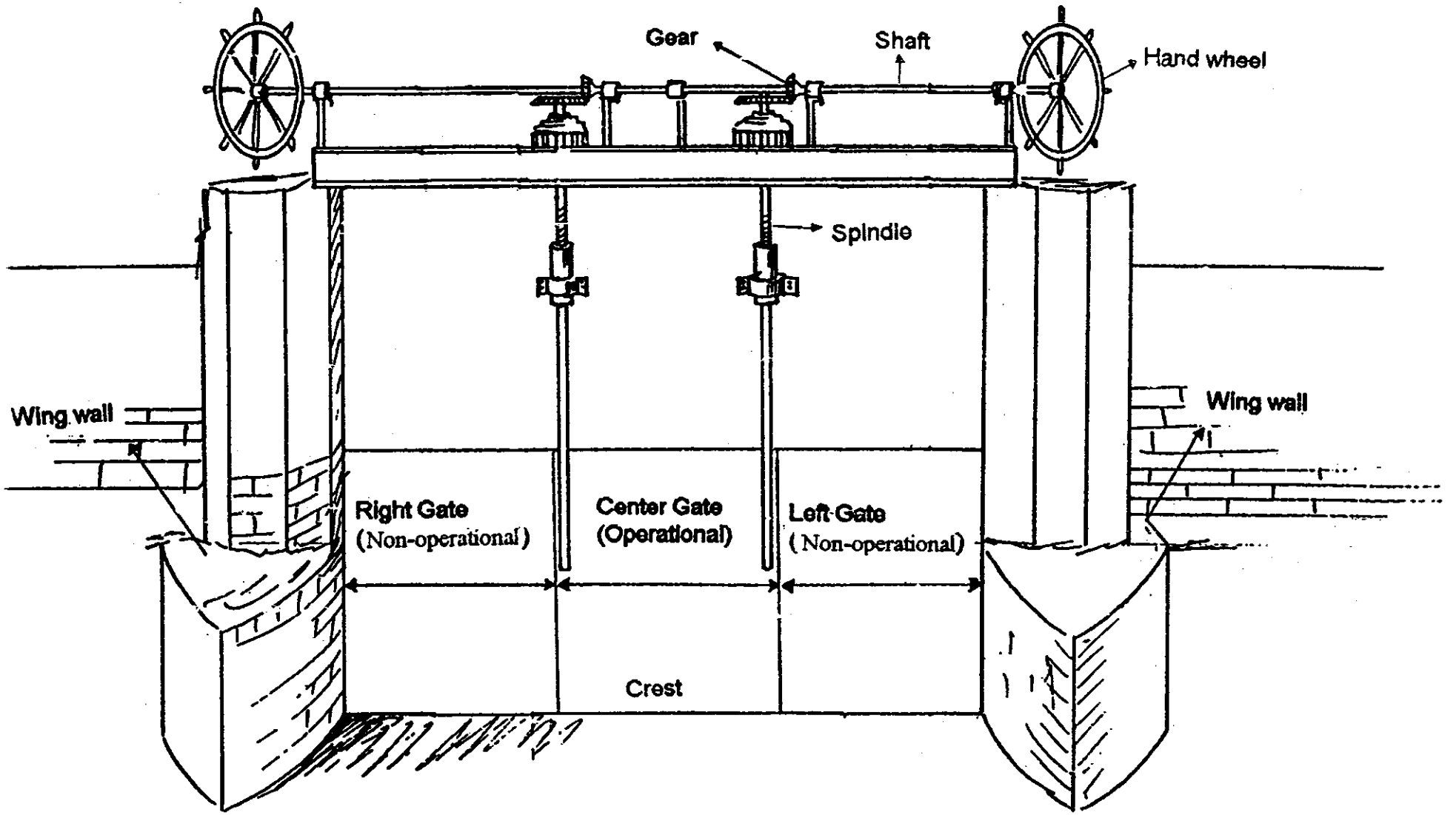


Figure A-1. Head Regulator of Heran Distributary.

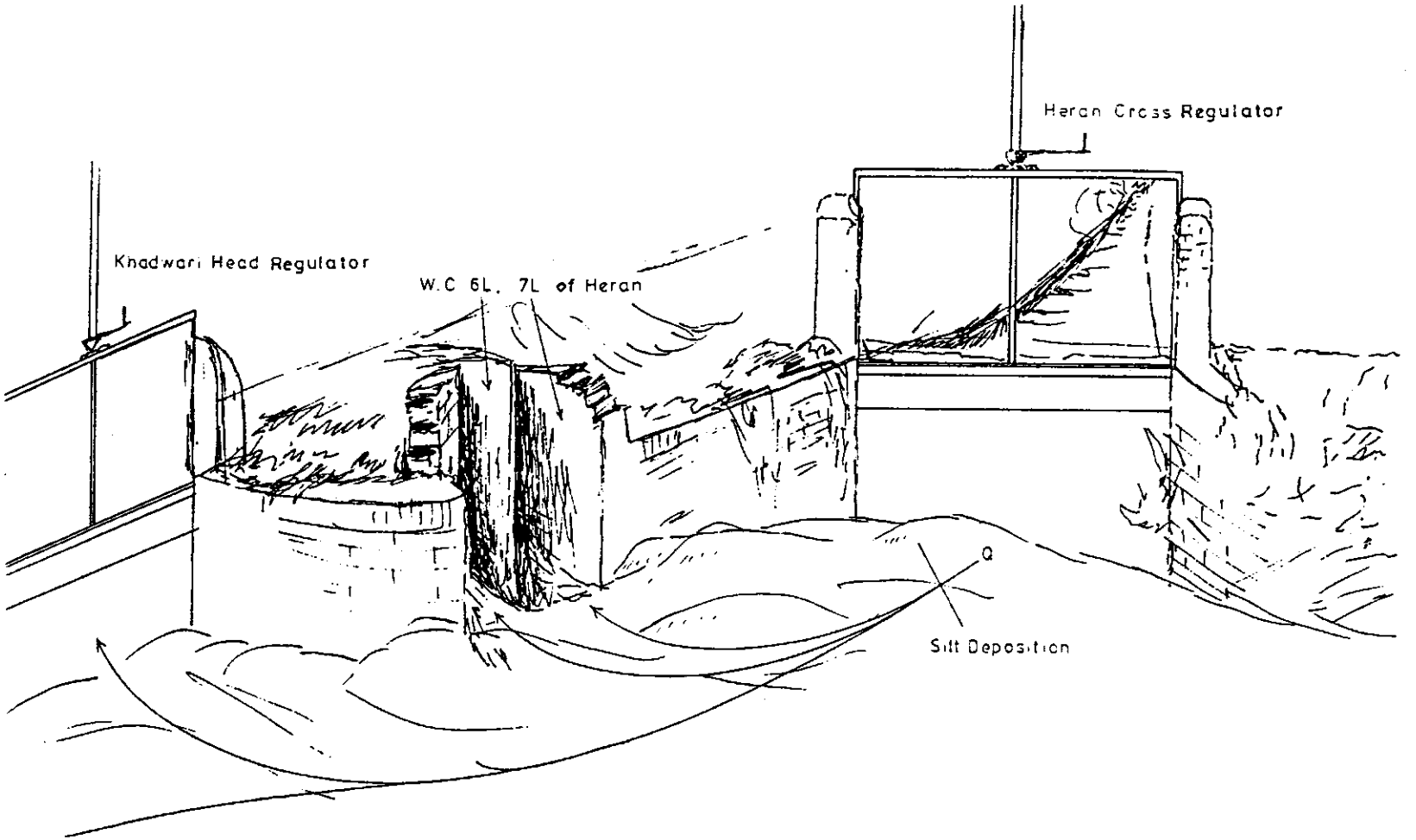


Figure A-2. Sketch of Heran Distributary at RD 10.0.

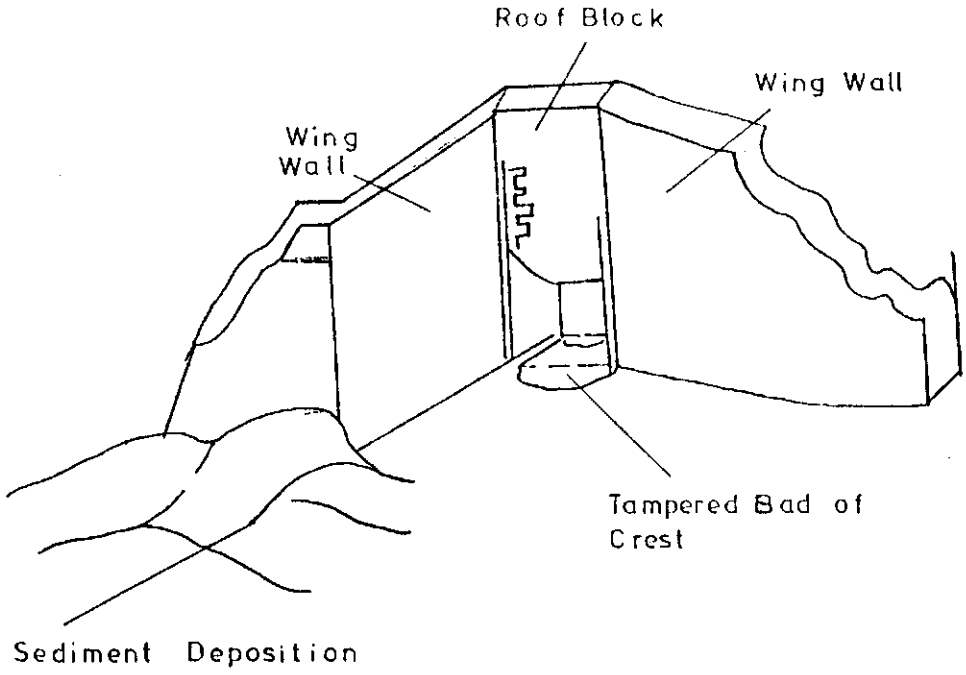


Figure A-3. Outlet 1-L Heran Distributary.

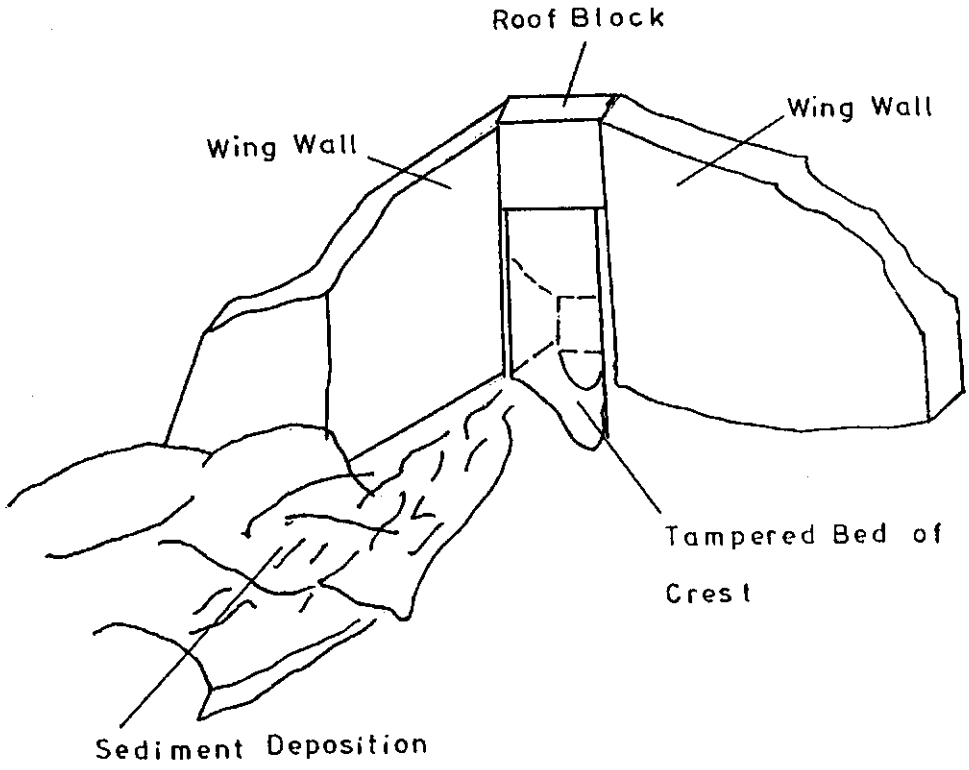


Figure A-4. Outlet 3-L & 5-L of Heran Distributary.

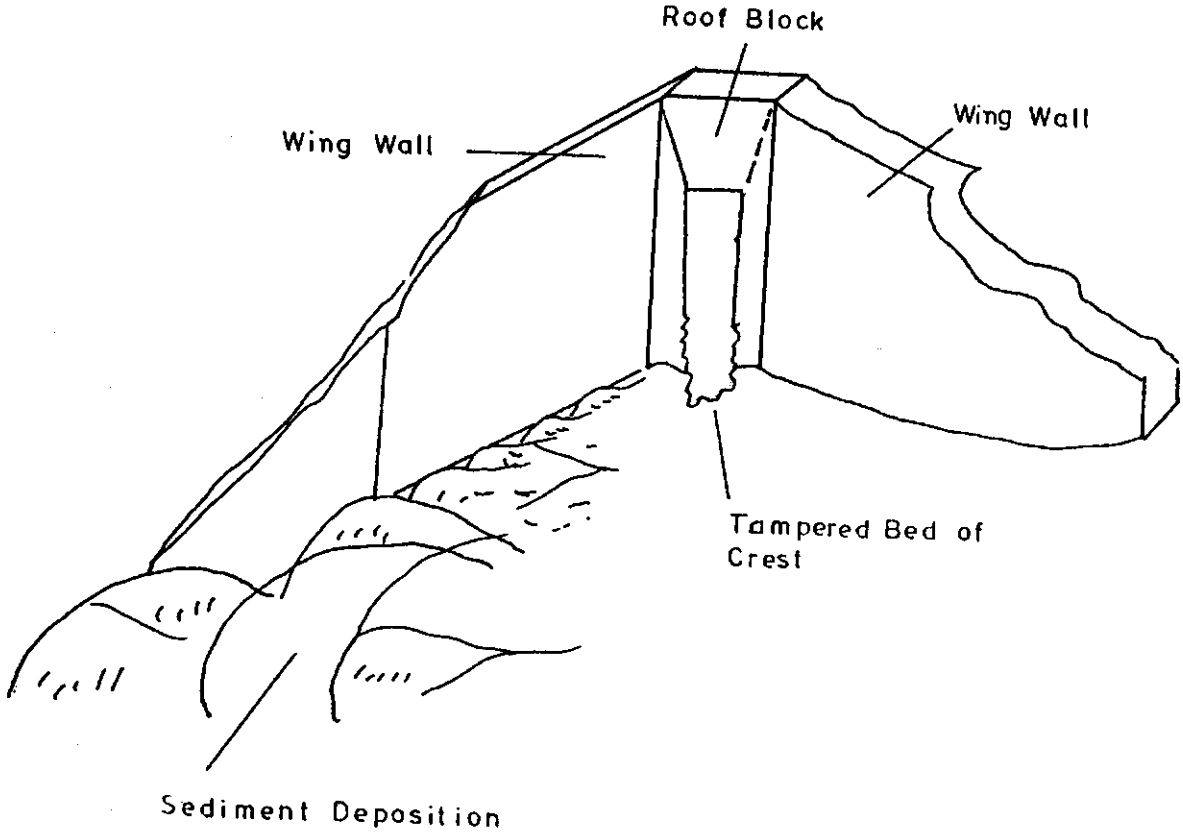


Figure A-5. Outlet 9-R of Heran Distributary.

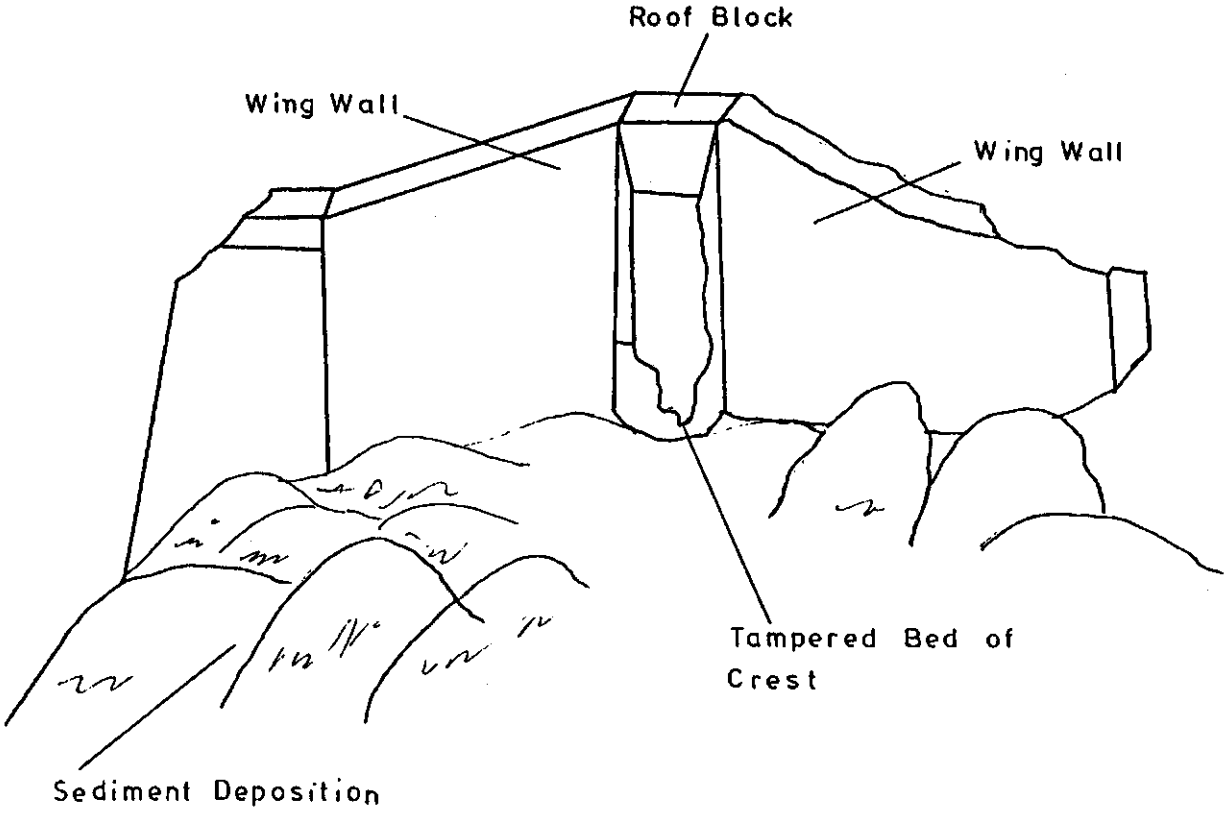


Figure A-6. Outlet 14-L of Heran Distributary.

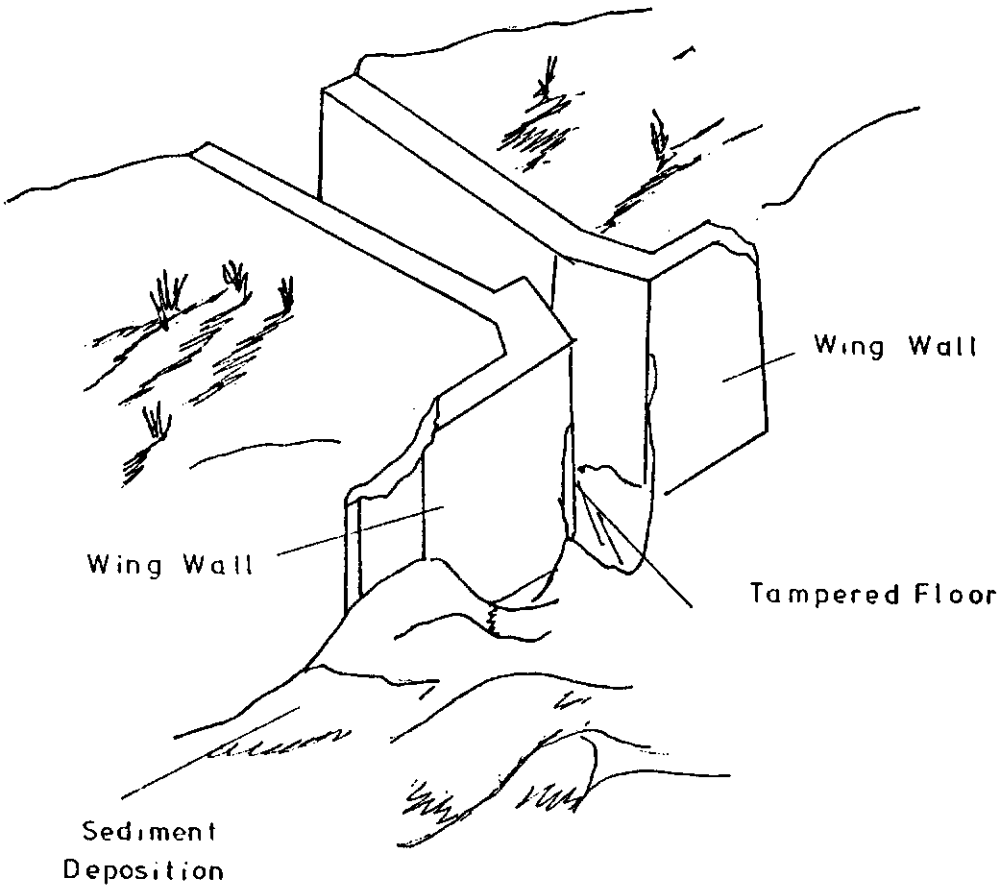


Figure A-7. Outlet 16-R of Heran Distributary.

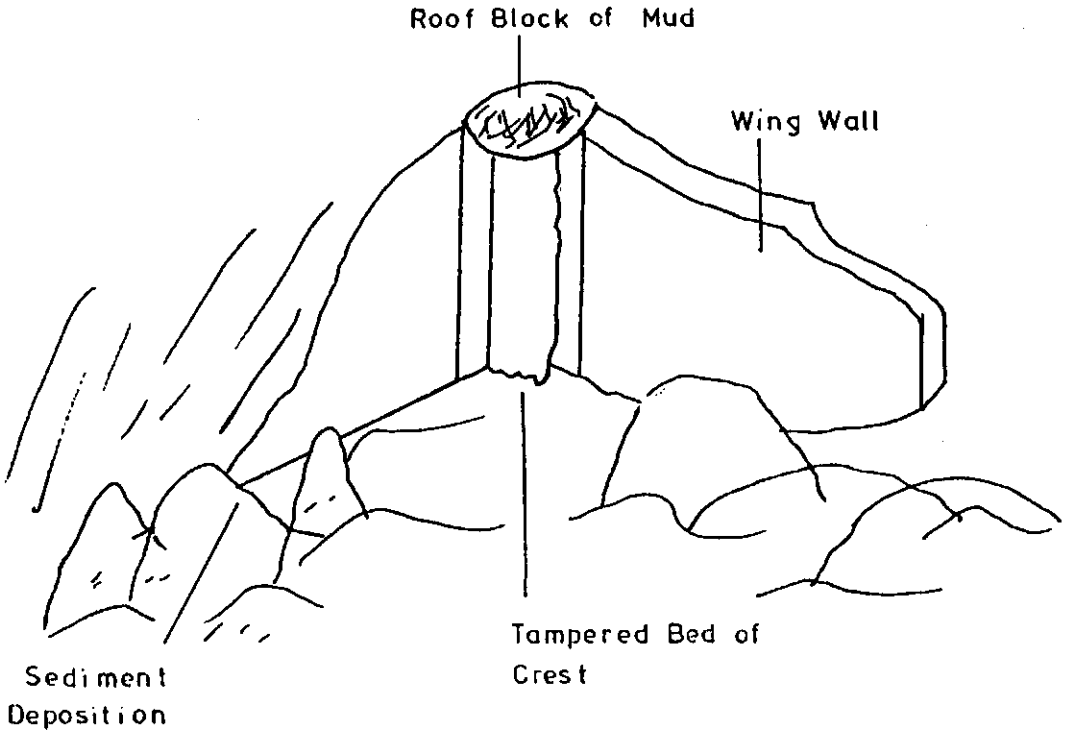


Figure A-8. Outlet 17-AL of Heran Distributary.

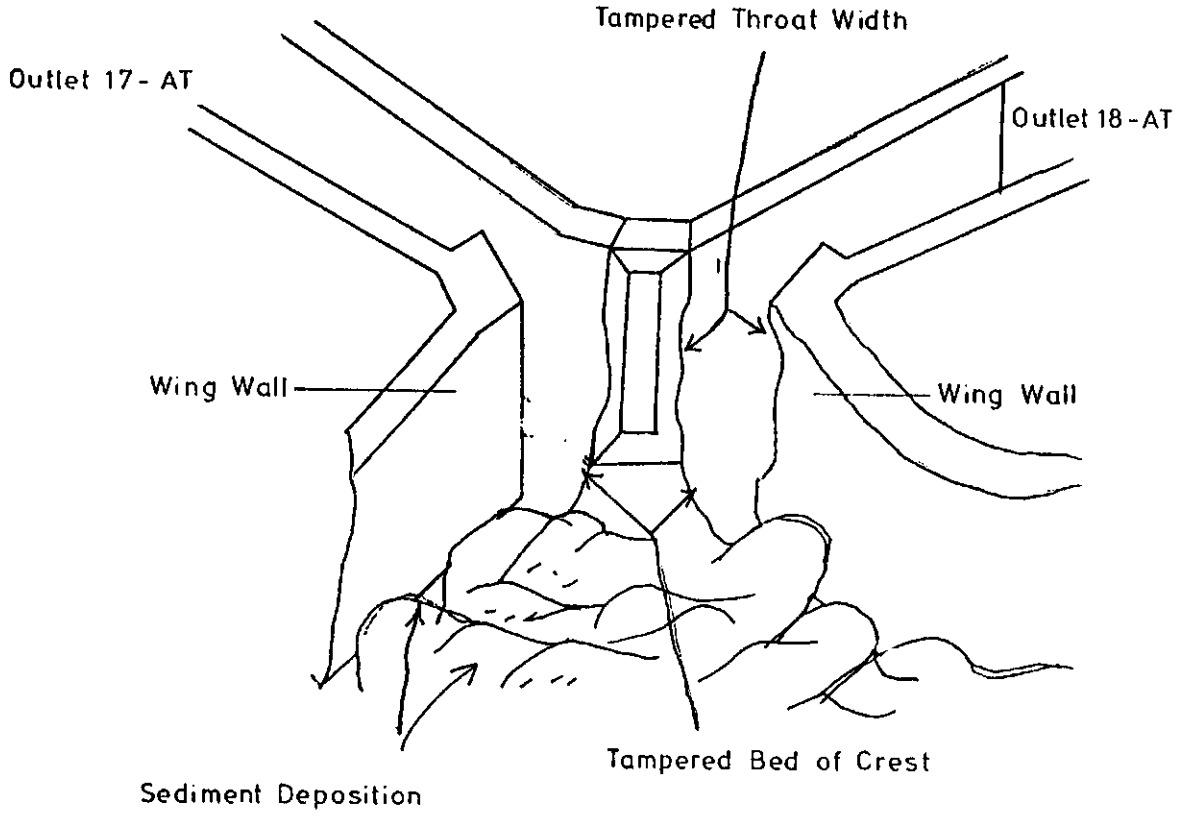


Figure A-9. Outlet 17-AT and 18-AT of Heran Distributary.

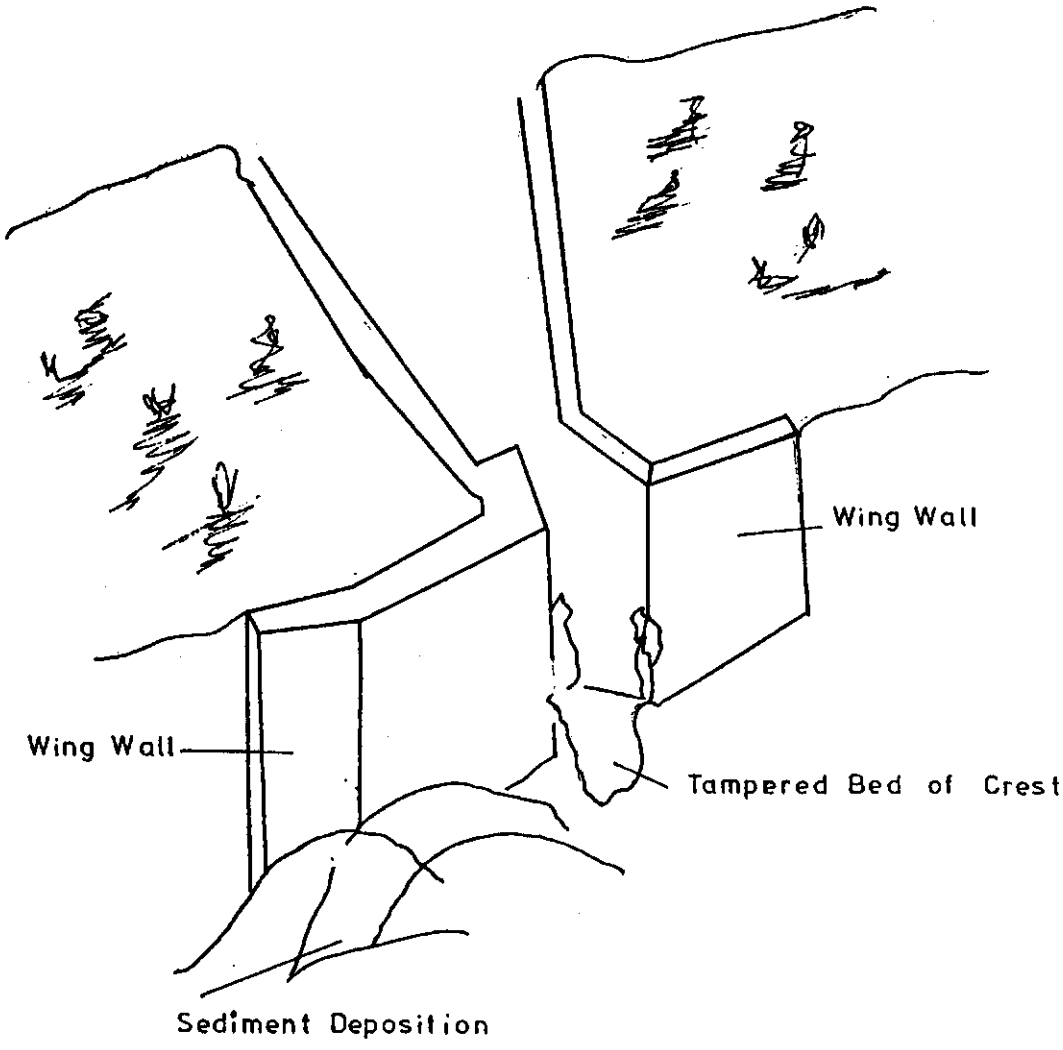


Figure A-10. Outlet 1-AL of Khadwari Minor.

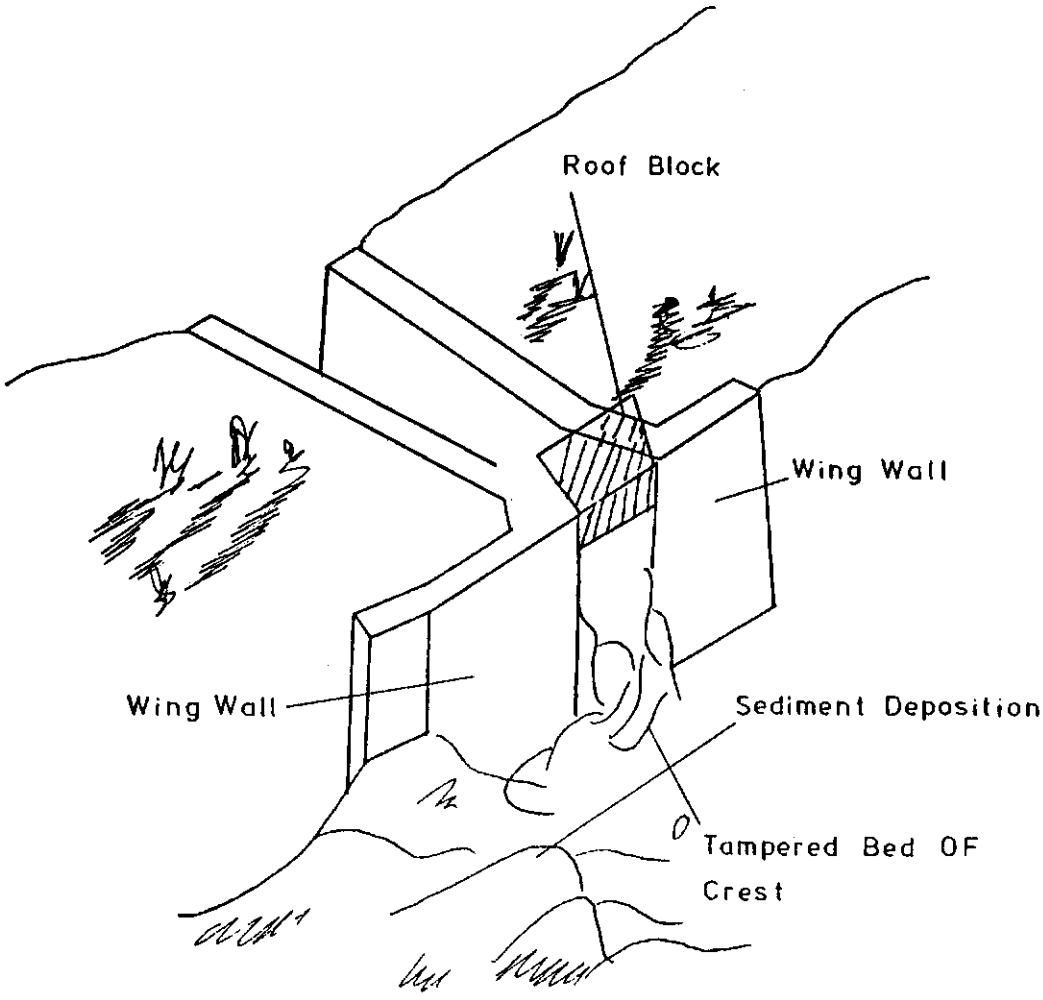


Figure A-11. Outlet 2-R of Khadwari Minor.

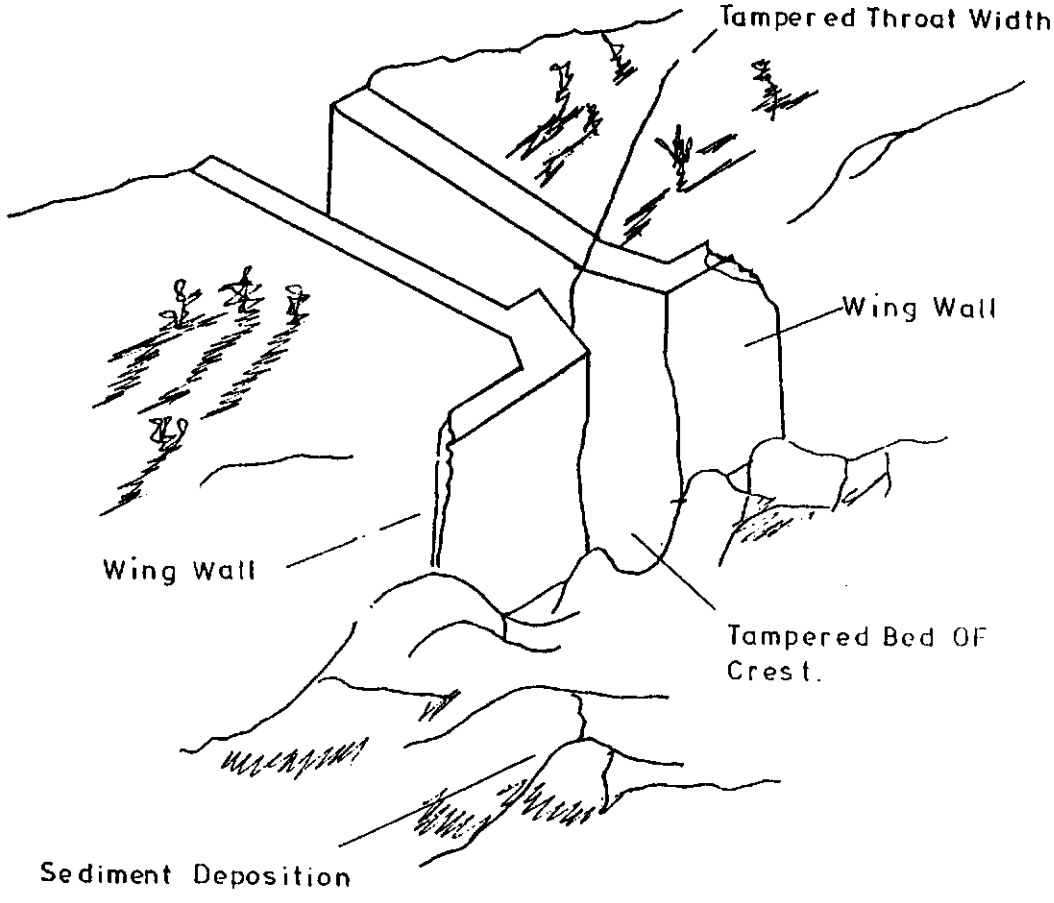


Figure A-12. Outlet 3-L of Khadwari Minor.

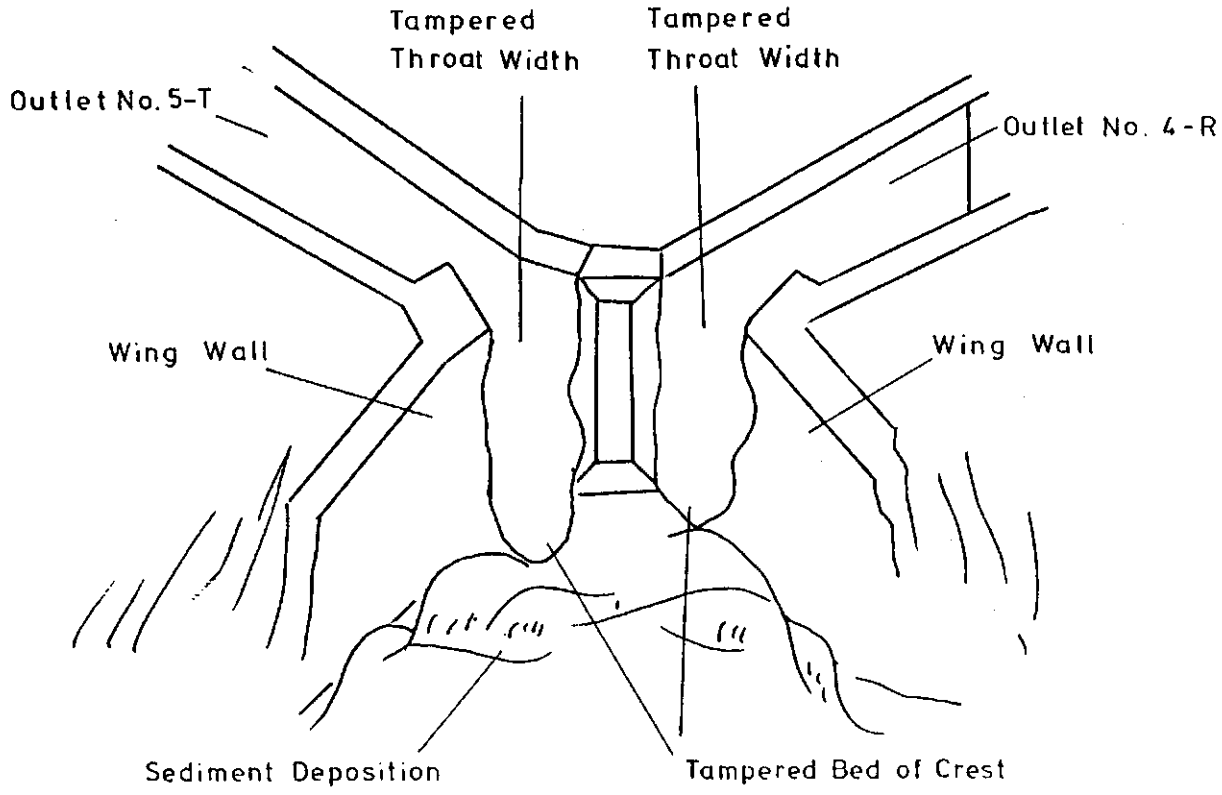


Figure A-13. Outlet 4-R and 5-T of Khadwari Minor.

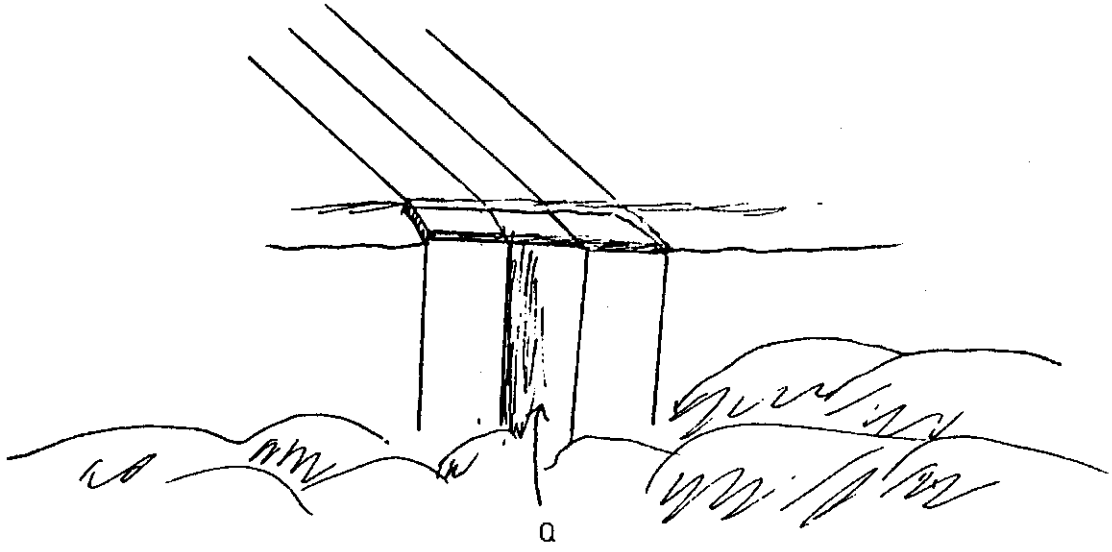


Figure A-14. Outlet 6-T of Khadwari Minor.

ANNEXURE B

FIELD NOTES AND SKETCHES
ON
DIAGNOSTIC WALK-THRU MAINTENANCE SURVEY
OF
HERAN DISTRIBUTARY

ANNEXURE B Field Notes and Sketches on Diagnostic Walk-Thru Maintenance Survey of Heran Distributary

Field notes and sketches resulting from the Diagnostic Walk-thru Maintenance Survey of the Heran Distributary are presented below. All the distances are given in RD (multiples of 1000 feet beginning with zero at the distributary head regulator).

From RD 0 to 1	**Condition**	Considerable vegetative growth is observed on the left bank of the distributary channel. Whereas, the right bank has almost no vegetation. The bed of the distributary channel is found according to its design. There is no silt deposition observed. The inspection path is in good condition. (see Figure B-1).
	Causes	Lack of removing vegetation.
	Solution	There is no immediate need of any major maintenance activity in this section except removal of the vegetative growth on the left bank.
1 to 9.29		**Condition** Considerable vegetative growth is observed on the left bank. Whereas, the right bank is almost clean. The bed of the distributary channel has some silt deposition. There are some cuts observed on the bank. The inspection path is in good condition. (see Figure B-2).
	Causes	Lack of routine maintenance.
	Solution	There is need of silt removal and cutting of the vegetation on the left bank. The cuts on the banks should also be filled.
9.29 to 10.1	**Condition**	There is considerable vegetation on the left bank of the channel. The channel section has become wider from RD 9.29 to RD 9.53. The banks have become weak. There is considerable amount of silt deposition at this place. (see Figure B-3). The inspection path is not in good condition.
	Causes	The main cause is frequent crossing / bathing of animals and people at this location.
	Remedy	The bed needs to be desilted. The inspection path needs to be repaired. The crossing / bathing of the animals and people should be prohibited through cooperation of WUF.
10.1 to 11.9	**Condition**	Both banks of the channel are almost clean. However, there are some cuts in the banks. The bed of the distributary is according to design. There is no silt deposition of silt. The inspection path is in good condition. (see Figure B-4).

	Causes	Lack of maintenance of Banks.
	Solution	There banks need to be redressed.
11.9 to 13.7	**Condition**	There is small vegetative growth on the left bank of the channel. The right bank is almost clean. The bed of the distributary channel is according to the old design. There is no major silt deposition. The inspection path is in good condition. (see Figure B-4).
	Remedy	There is no immediate need for the maintenance except removal of vegetation.
13.7 to 16	**Condition**	There was considerable vegetation on the left bank of the channel. The right bank is almost clean. The bed of the distributary channel is according to its design. There is no major silt deposition. This x-section of the distributary channel is little narrow due to the silt deposition near the banks. (see Figure B-4). The inspection path is in good condition.
	Causes	Due to lack of routine maintenance, the x-section has deformed.
	Remedy	The x-section of the channel needs to be rehabilitated.
16 to 16.7	**Condition**	The left bank has become weak mainly due to the soil erosion. Animal sitting in and around the distributary channel is found common in this section. The banks have no vegetation. There is considerable amount of silt deposition in the bed of the distributary. This section has also become wider due to sitting of animals (see Figure B-4). The inspection path is in good condition.
	Causes	The main cause of the problems observed in this section is animal sitting.
	Remedy	The left bank need to be strengthened. There is need to desilt the bed of the distributary to its original cross section. Animal sitting needs to be controlled through cooperation of farmers in this area.
16.7 to 17.35	**Condition**	The left bank is weak. There is small vegetation on the both banks of the distributary channel. There is considerable amount of silt deposition in the bed of the

		distributary. (see Figure B-4). The inspection path is in good condition.
	Causes	Lack of vegetation removal.
	Remedy	The left bank need to be strengthened. There is need to desilt the bed of the distributary. Vegetation needs to be removed.
17.35 to 18.77	**Condition**	There is considerable small vegetative growth on both sides of the channel. The left bank is in good condition. The right bank is also in good condition. The bed of the distributary is according to the design. There is no major silt deposition. (see Figure B-5).
	Causes	Lack of vegetation cleaning.
	Remedy	The vegetation need to be cleaned from both the banks.
220.0 to 26.5	**Condition**	The left bank is very weak in this section. Several breaches occurred in this section during the previous year. The frequent breaches made the soil hallow, and water creeps through it. There is considerable vegetation also. (see Figure B-6). The right bank is in good condition. The bed of the distributary is in good condition. There is not much deposition of silt. The inspection path is in good condition also.
	Causes	Due to lack of routine maintenance and frequent breaches, the left bank has become very weak.
	Remedy	There is need of redressing of the soil on the left bank to avoid frequent breaches and leakage of water. Vegetation also needs to be removed.
26.5 to 26.72	**Condition**	This section is almost clean from vegetative growth. But it is very weak. The free board is zero. There is considerable amount of silt deposition. Due to silt deposition water spills over the banks. (see Figure B-6).
	Causes	Due to lack of routine maintenance and huge silt deposition, the channel shape has been distorted.
	Remedy	There is need for rehabilitation of this section.

26.72 to tail	**Condition**	There is considerable vegetation on the left bank. During the cleaning of MBD drain, the waste material thrown on the right bank made the right bank very high. During the desilting of the distributary, the bank was not accessible to throw the material out. These is also dense and high vegetative growth. (see Figure 6). There is considerable amount of silt deposition in the bed of the channel. There is no inspection path. Along the drain there is a path but it is difficult to inspect the distributary due to height.
	Causes	Lack of proper maintenance activities.
	Remedy	There is immediate need of removing excess amount of soil on the right bank to form the inspection path. The bed also need to be desilted.

KHADWARI MINOR

0.0 to 5.0	**Condition**	The banks are clear from vegetation. The bed is according to the design. There is no silt deposition. (see Figure B-7). The inspection path is in poor condition.
	Causes	Lack of maintenance.
	Remedy	The inspection path needs to be repaired for the inspection of the minor.
5.0 to 7.0	**Condition**	There is considerable vegetation on the left bank. It is also weak and water spills over occasionally as there is no free board. The right bank is almost clean There is considerable amount of silt deposition. (see Figure B-8). The inspection in path is in good condition.
	Causes	Lack of maintenance.
	Remedy	The bed of the minor needs to be desilted to avoid the spilling of water. Also, cleaning and strengthening of the left bank is required.
7.0 to 9.0	**Condition**	The left bank is almost clean. But it is very thin and weak. Free board is zero. The right bank is also clean. But it is very thin and weak. Free board is zero. There is considerable amount of silt deposition in the bed. Due to silt deposition water spills over the banks. This section of the minor has become wider due to the crossing of the animals. (see Figure B-9). The inspection path was in poor condition.

	Causes	Lack of maintenance and animal crossing.
	Remedy	The bed of the minor needs immediately desilting to save the water. The banks need to be rehabilitate.
11.48 to 12.0	**Condition**	There is considerable vegetative growth on the left bank. The shape of the bank is irregular. There are cuts. The right bank is almost clean but it has some cuts also. The bed of the minor is in good condition. The path is in good condition.
	Remedy	The banks need to be redressed. The vegetation also needs to be removed from the left bank.
12 to 13	**Condition**	There is considerable vegetation on left side. The bank on the right side has soil erosion due to which a cavity has formed. There is considerable amount of silt deposition. Due to silt deposition water spills over the left bank. The inspection path is in good condition. However, some farmers draw water directly by cutting the inspection path.
	Causes	Lack of maintenance.
	Remedy	The bed needs to be desilted. The cavity and cuts in the inspection path need to be redressed. Vegetation needs to be removed.
13 to tail	**Condition**	There is considerable vegetation on the left bank. The right bank is almost clean. There is considerable amount of silt deposition. Due to silt deposition water spills over the right bank. The extreme tail portion of minor has become wider due to the sitting and crossing of the animals. (see Figure B-10). The inspection path is in good condition.
	Causes	Lack of maintenance and sitting of animals.
	Remedy	The bed needs to be desilted. The vegetation on left bank needs to be removed.

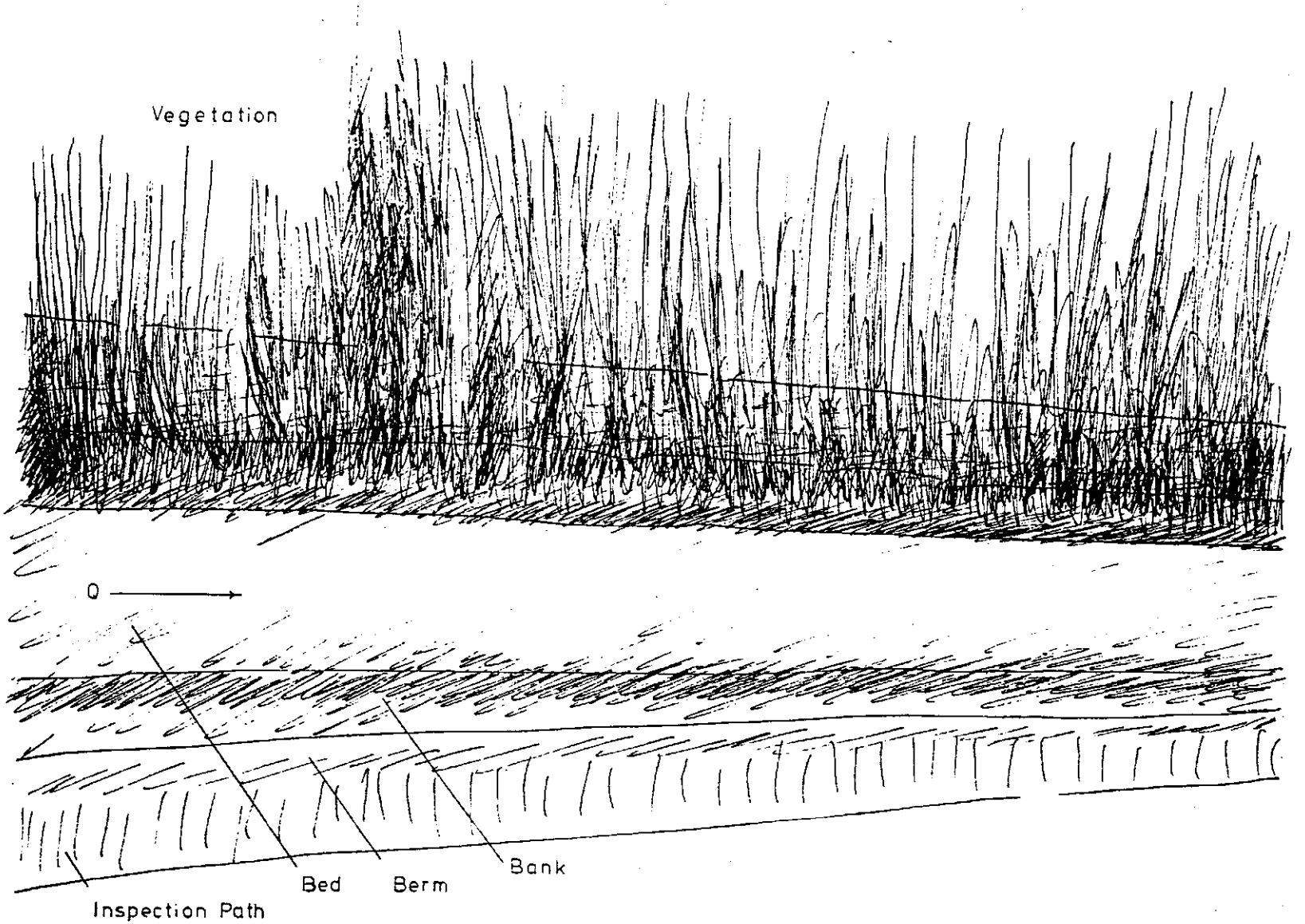


Figure B-1. Sketch of Heran Distributary from RDs 0.0 to 1.0.

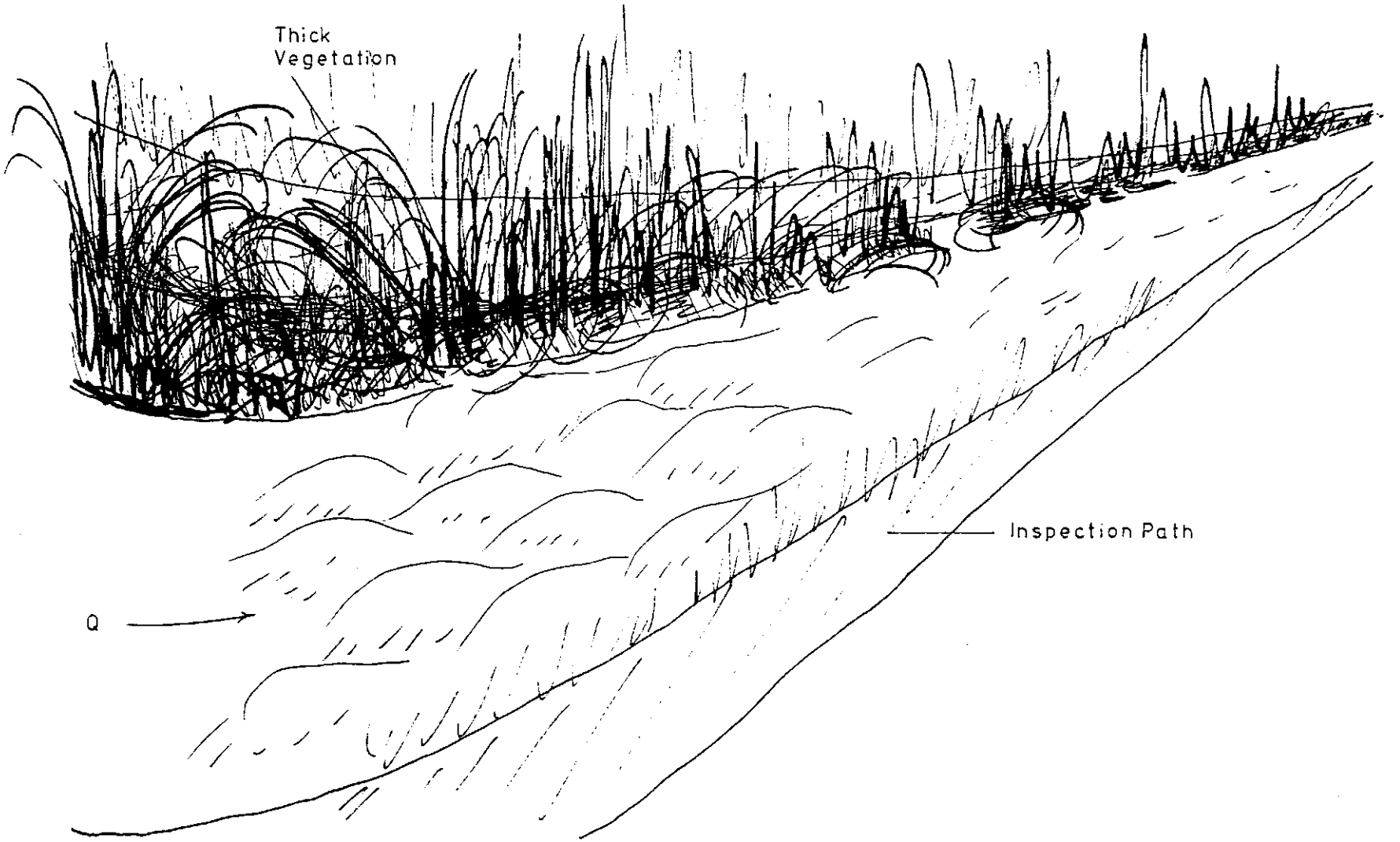


Figure B-2. Sketch of Heran Distributary from RDs 1.0 to 9.29.

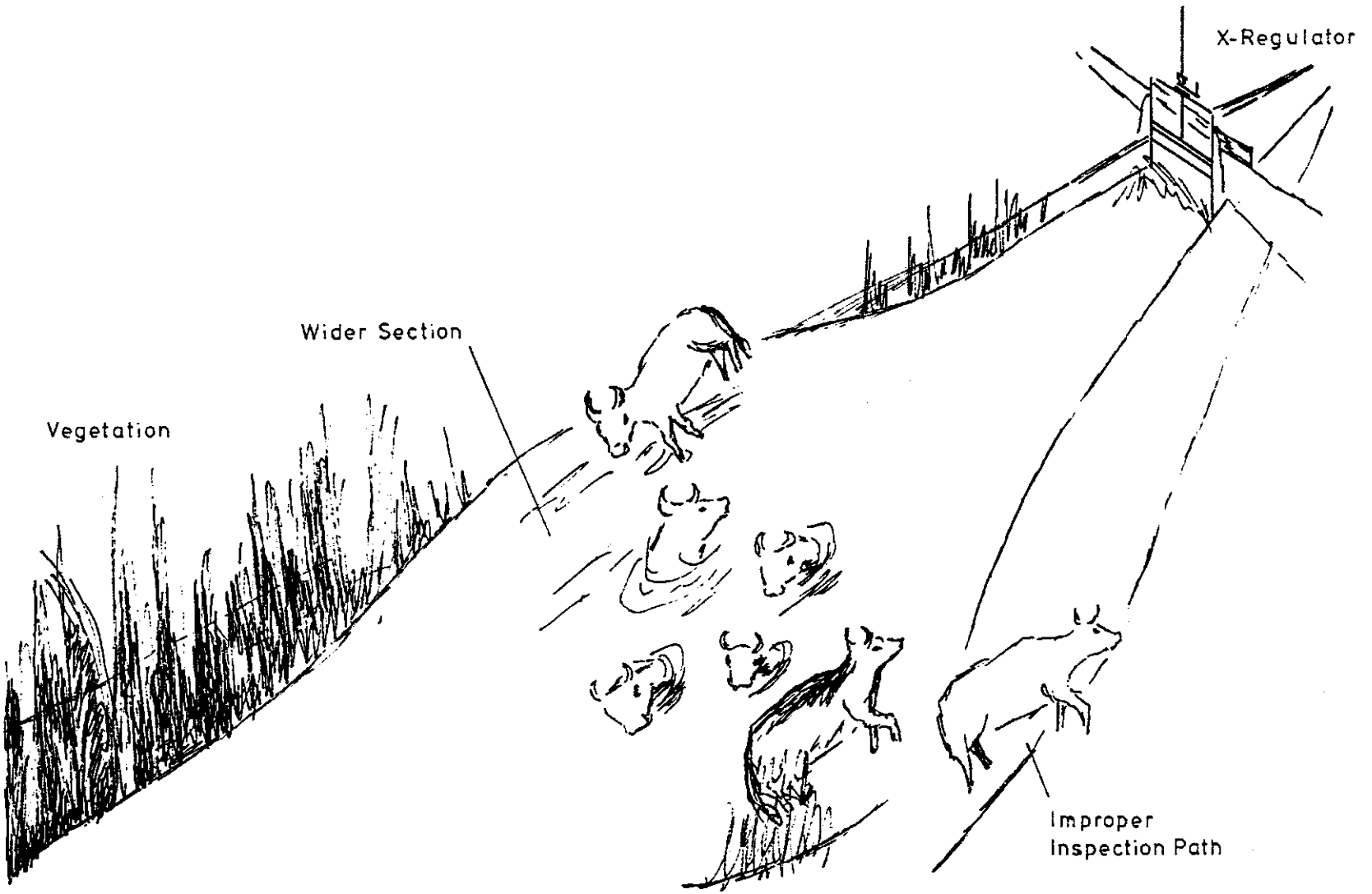


Figure B-3. Sketch of Heran Distributary from RDs 9.29 to 10.0.

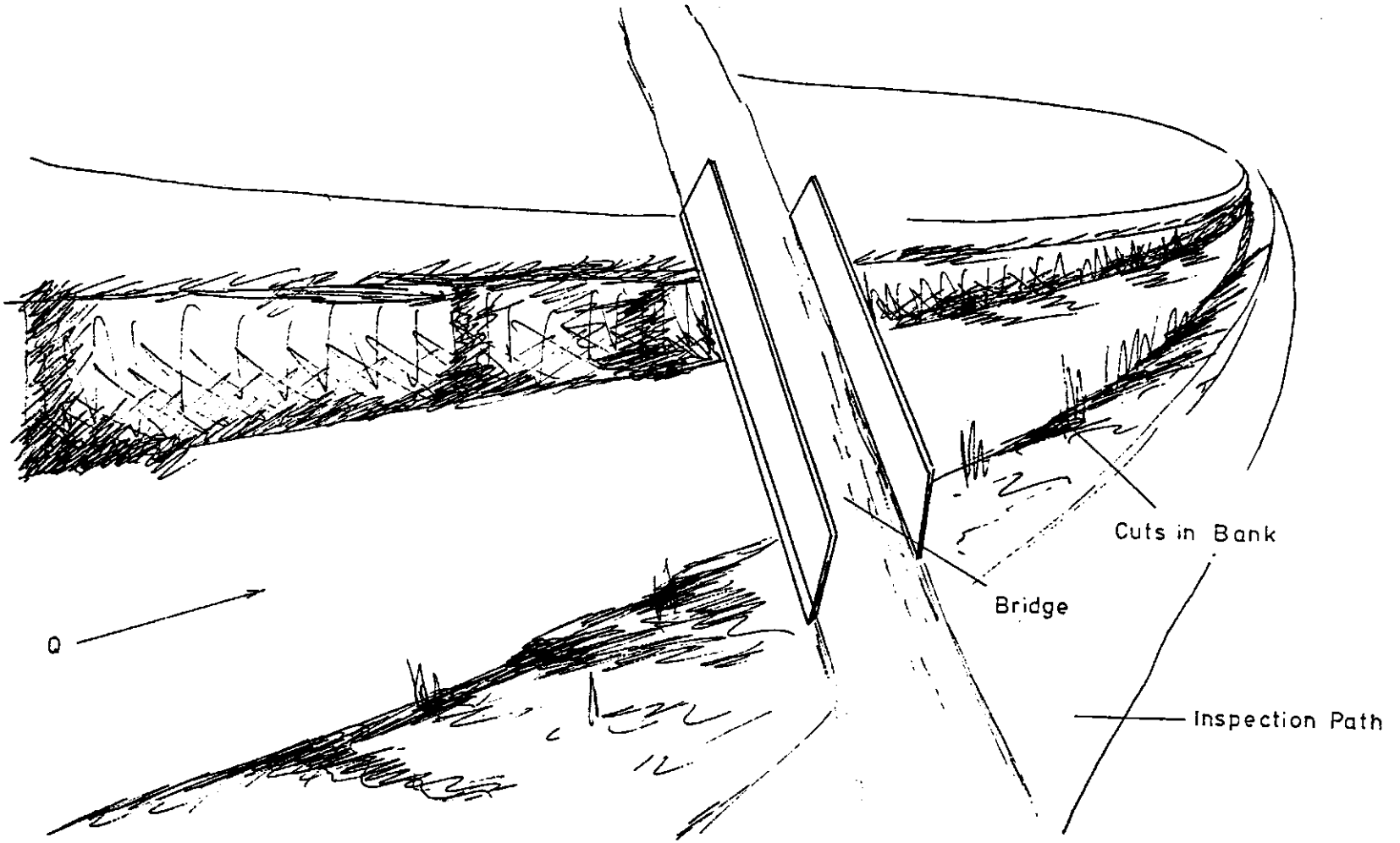


Figure B-4. Sketch of Heran Distributary from RDs 10.1 to 17.35.

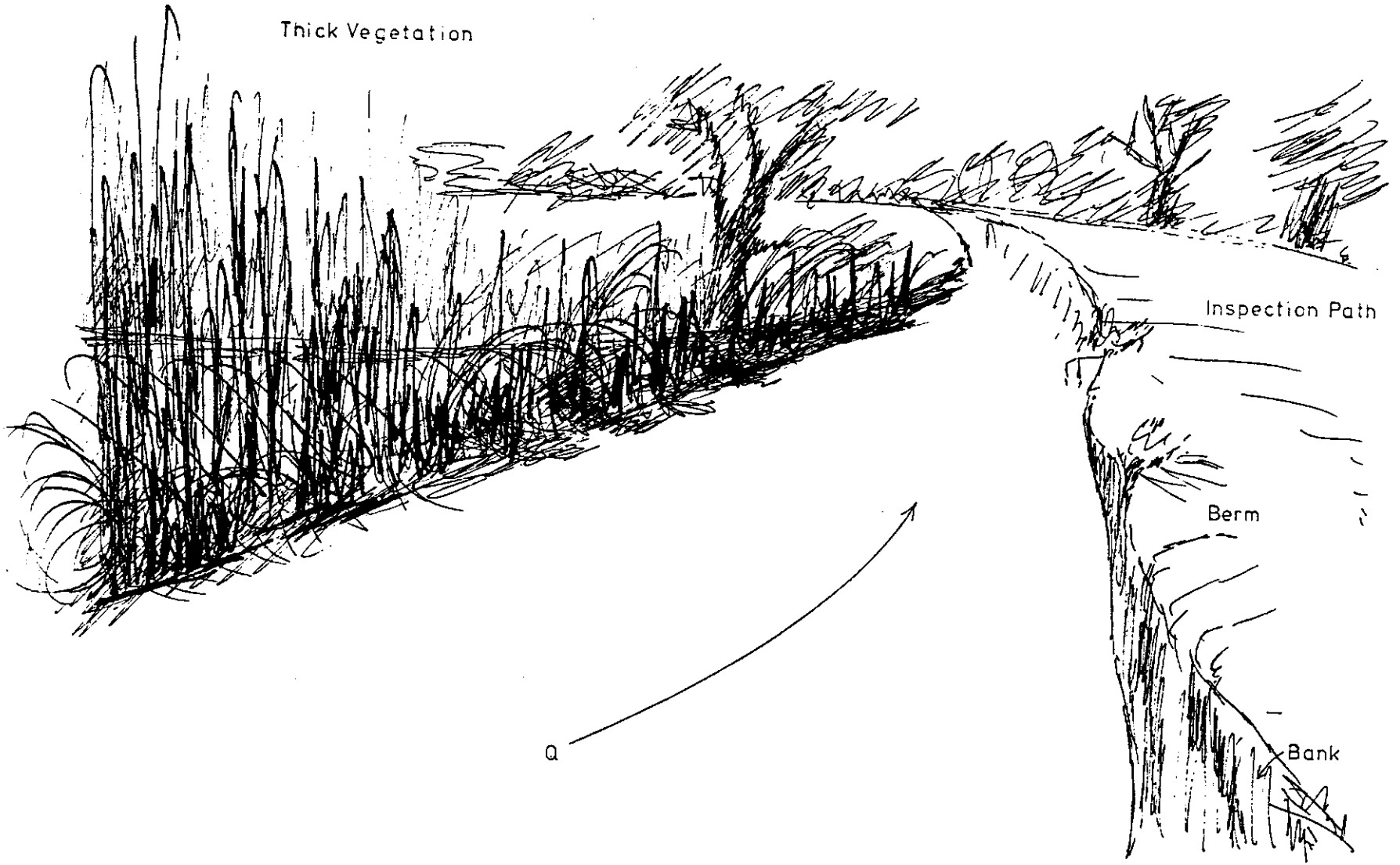


Figure B-5. Sketch of Heran Distributary from RDs 17.35 to 18.77.

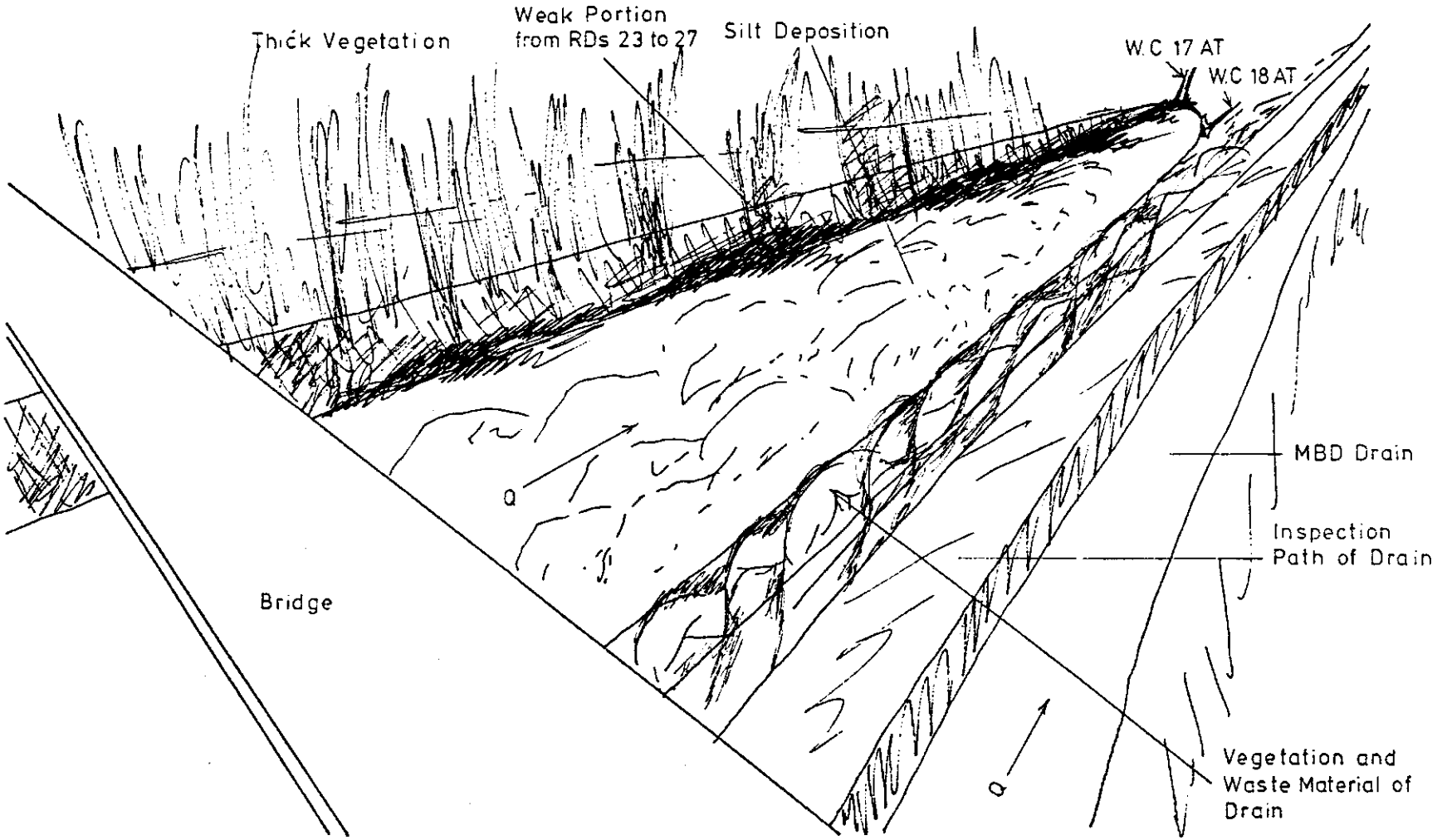


Figure B-6. Sketch of Heran Distributary from RDs 22.0 to Tail.

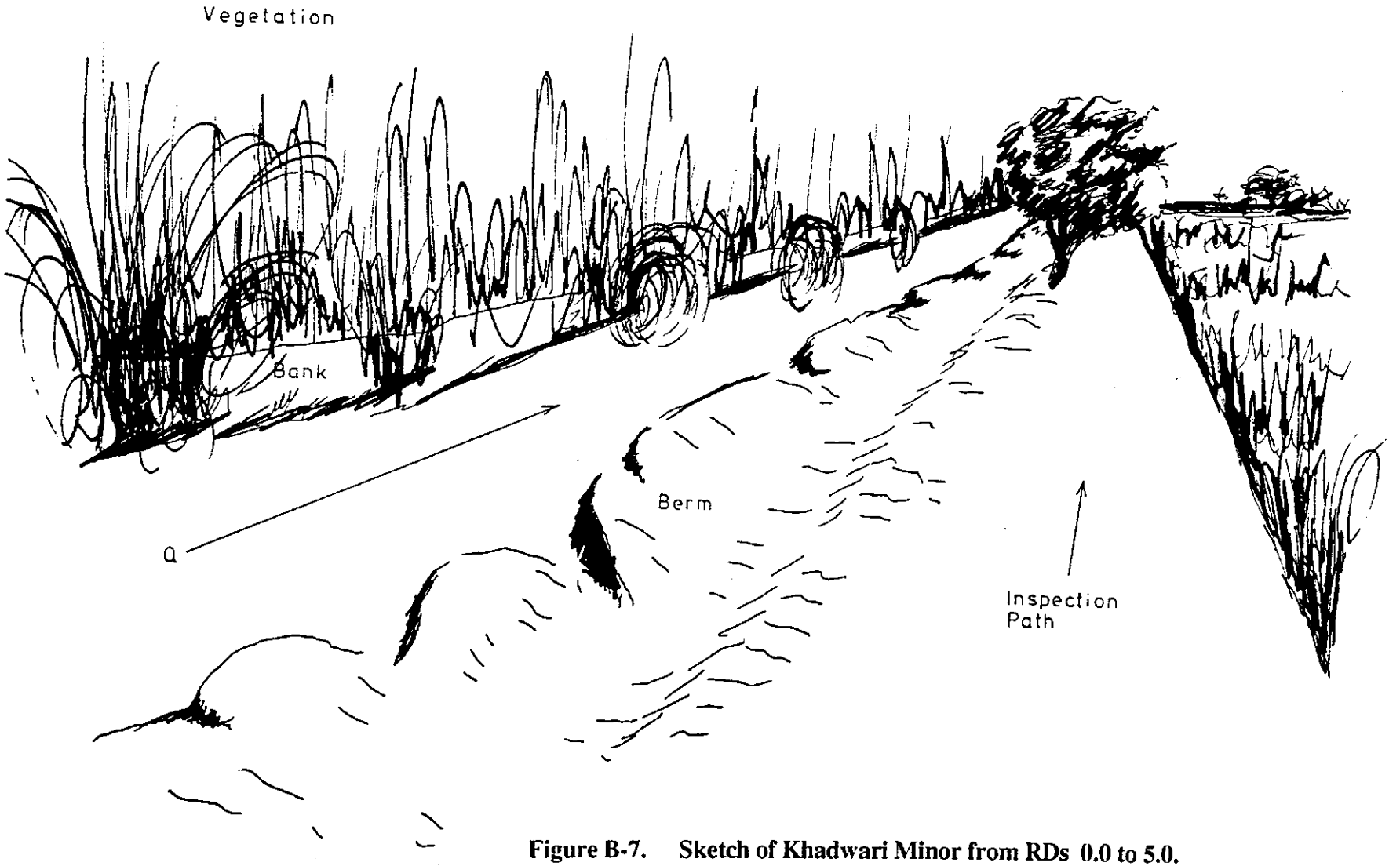


Figure B-7. Sketch of Khadwari Minor from RDs 0.0 to 5.0.

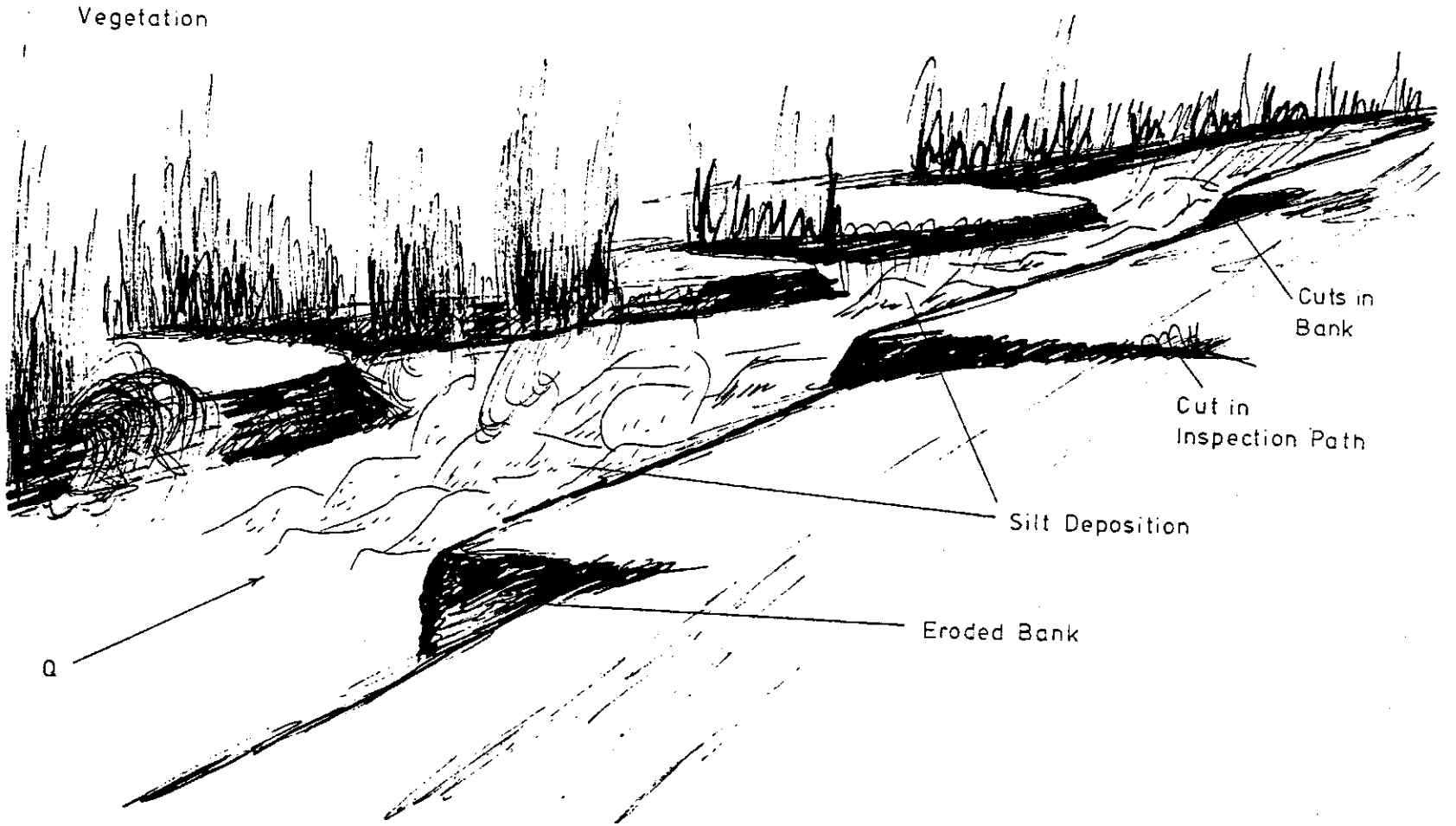


Figure B-8. Sketch of Khadwari Minor from RDs 5.0 to 7.0.

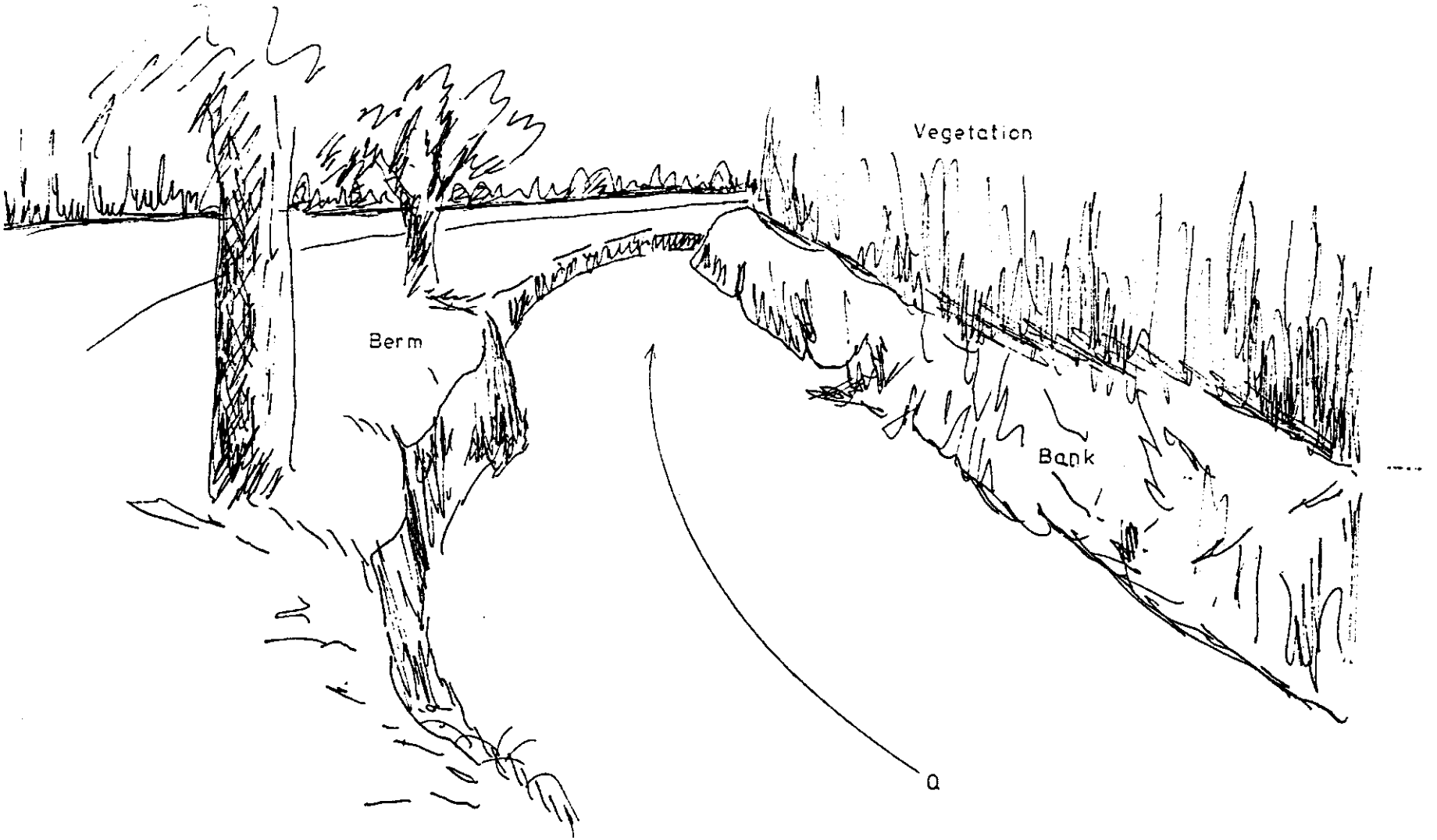


Figure B-9. Sketch of Khadwari Minor from RDs 7.0 to 9.0.

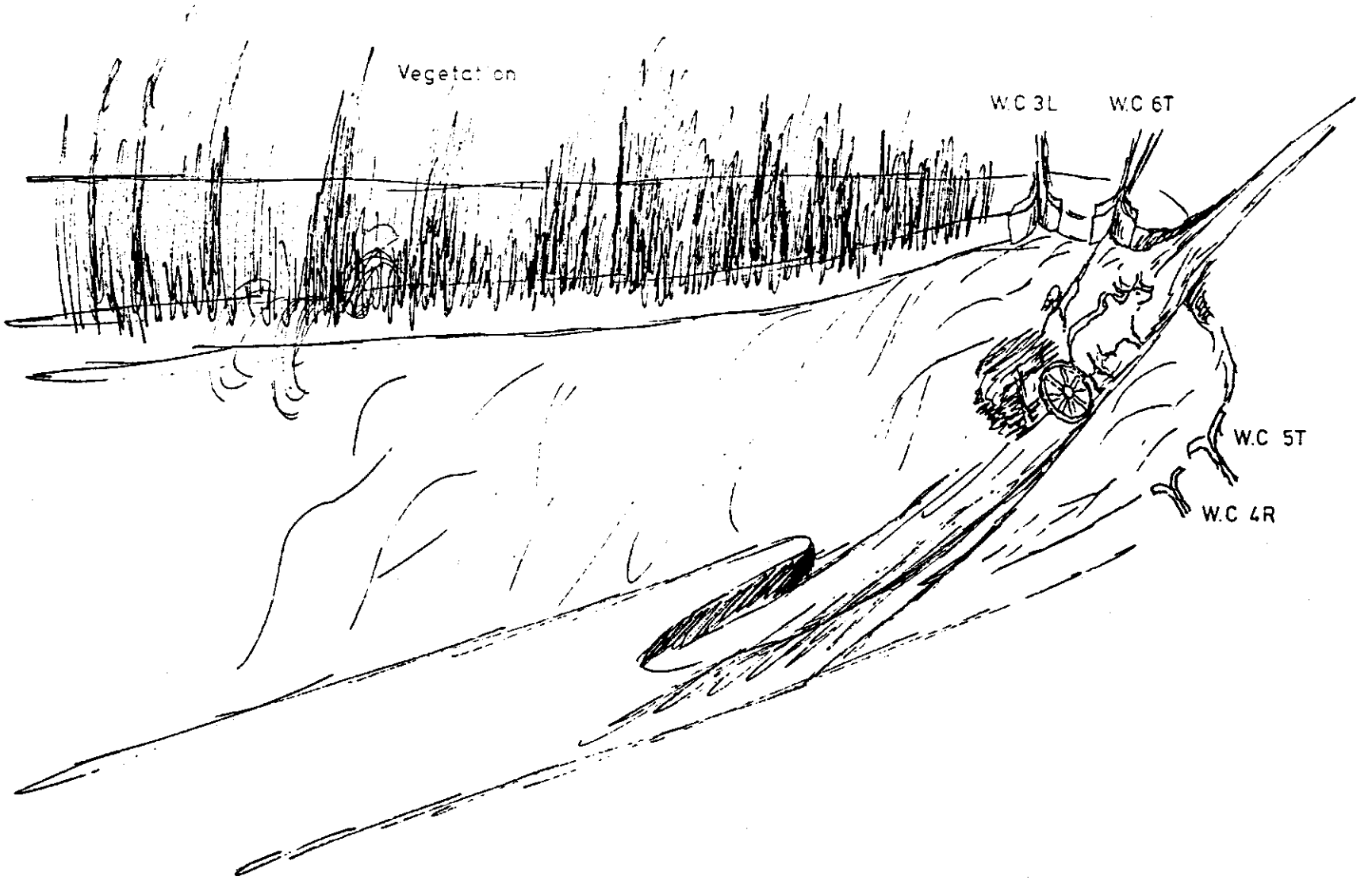


Figure B-10. Sketch of Khadwari Minor from RDs 13.0 to Tail Before Development.

IIMI-PAKISTAN PUBLICATIONS
RESEARCH REPORTS

Report No.	Title	Author	Year
R-1	**Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan** Volume I: Synthesis of Findings and Recommendations	Carlos Garces-R D.J. Bandaragoda Pierre Strosser	June 1994
	Volume II: Research Approach and Interpretation	Carlos Garces-R Ms. Zaigham Habib Pierre Strosser Tissa Bandaragoda Rana M. Afaq Saeed ur Rehman Abdul Hakim Khan	June 1994
	Volume III: Data Collection Procedures and Data Sets	Rana M. Afaq Pierre Strosser Saeed ur Rehman Abdul Hakim Khan Carlos Garces-R	June 1994
R-2	Salinity and Sodicity Research in Pakistan - Proceedings of a one-day Workshop	J.W. Kijne Marcel Kuper Muhammad Aslam	Mar 1995
R-3	Farmers' Perceptions on Salinity and Sodicity: A case study into farmers' knowledge of salinity and sodicity, and their strategies and practices to deal with salinity and sodicity in their farming systems	Neeltje Kielen	May 1996
R-4	Modelling the Effects of Irrigation Management on Soil Salinity and Crop Transpiration at the Field Level (M.Sc Thesis - published as Research Report)	S.M.P. Smets	June 1996
R-5	Water Distribution at the Secondary Level in the Chishtian Sub-division	M. Amin K. Tareen Khalid Mahmood Anwar Iqbal Mushtaq Khan Marcel Kuper	July 1996
R-6	Farmers Ability to Cope with Salinity and Sodicity: Farmers' perceptions, strategies and practices for dealing with salinity and sodicity in their farming systems	Neeltje Kielen	Aug 1996
R-7	Salinity and Sodicity Effects on Soils and Crops in the Chishtian Sub-Division: Documentation of a Restitution Process	Neeltje Kielen Muhammad Aslam Rafique Khan Marcel Kuper	Sept 1996
R-8	Tertiary Sub-System Management: (Workshop proceedings)	Khalid Riaz Robina Wahaj	Sept 1996
R-9	Mobilizing Social Organization Volunteers: An Initial Methodological Step Towards Establishing Effective Water Users Organization	Mehmoodul Hassan Zafar Iqbal Mirza D.J. Bandaragoda	Oct 1996
R-10	Canal Water Distribution at the Secondary Level in the Punjab, Pakistan (M.Sc Thesis published as Research Report)	Steven Visser	Oct 1996
R-11	Development of Sediment Transport Technology in Pakistan: An Annotated Bibliography	M. Hasnain Khan	Oct 1996

Report No.	Title	Author	Year
R-12	Modeling of Sediment Transport in Irrigation Canals of Pakistan: Examples of Application (M.Sc Thesis published as Research Report)	Gilles Belaud	Oct 1996
R-13	Methodologies for Design, Operation and Maintenance of Irrigation Canals subject to Sediment Problems: Application to Pakistan (M.Sc Thesis published as Research Report)	Alexandre Vabre	Oct 1996
R-14	Government Interventions in Social Organization for Water Resource Management: Experience of a Command Water Management Project in the Punjab, Pakistan	Waheed uz Zaman D.J.Bandaragoda	Oct 1996
R-15	Applying Rapid Appraisal of Agricultural Knowledge Systems (RAAKS) for Building Inter-Agency Collaboration	Derk Kuiper Mushtaq A. Khan Jos van Oostrum M. Rafique Khan Nathalie Roovers Mehmood ul Hassan	Nov 1996
R-16	Hydraulic Characteristics of Chishtian Sub-division, Fordwah Canal Division	Anwar Iqbal	Nov 1996
R-17	Hydraulic Characteristics of Irrigation Channels in the Malik Sub-Division, Sadiqia Division, Fordwah Eastern Sadiqia Irrigation and Drainage Project	Khalid Mahmood	Nov 1996
R-18	**Proceedings of National Conference on Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan**	M. Badruddin Gaylord V. Skogerboe M.S. Shafique (Editors for all volumes)	Nov 1996
R-18.1	Volume-I: Inauguration and Deliberations		
R-18.2	Volume-II: Papers on the Theme: Managing Canal Operations		
R-18.3	Volume-III: Papers on the Theme: Water Management Below the Mogha		
R-18.4	Volume-IV: Papers on the Theme: Environmental Management of Irrigated Lands		
R-18.5	Volume-V: Papers on the Theme: Institutional Development		
R-19	Detailed Soil Survey of Eight Sample Watercourse Command Areas in Chishtian and Hasilpur Tehsils	Soil Survey of Pakistan IIMI-Pakistan	Nov 1996
R-20	Unsteady Flow Simulation of the Designed Pehur High-Level Canal and Proposed Remodeling of Machai and Miara Branch Canals, North West Frontier Province, Pakistan	Zaigham Habib Kobkiat Pongput Gaylord V. Skogerboe	Dec 1996
R-21	**Salinity Management Alternatives for the Rechna Doab, Punjab, Pakistan**	Gauhar Rehman Waqar A. Jehangir Abdul Rehman Muhammad Aslam Gaylord V. Skogerboe	May 1997
R-21.1	Volume One: Principal Findings and Implications for Sustainable Irrigated Agriculture		
R-21.2	Volume Two: History of Irrigated Agriculture: A Select Appraisal	Gauhar Rehman Hassan Zia Munawwar Asghar Hussain	Jan 1997

Report No.	Title	Author	Year
R-21.3	Volume Three: Development of Procedural and Analytical Liniks	Gauhar Rehman Muhammad Aslam Waqar A. Jehangir Abdul Rehman Asghar Hussain Nazim Ali Hassan Zia Munawwar	Jan 1997
R-21.4	Volume Four: Field Data Collection and Processing	Gauhar Rehman Muhammad Aslam Waqar A. Jehangir Mobin Ud Din Ahmed Hassan Zia Munawwar Asghar Hussain Nazim Ali Faizan Ali Samia Ali	Jan 1997
R-21.5	Volume Five: Predicting Future Tubewell Salinity Discharges	Muhammad Aslam	Jan 1997
R-21.6	Volume Six: Resource Use and Productivity Potential in the Irrigated Agriculture	Waqar A. Jehangir Nazim Ali	Feb 1997
R-21.7	Volume Seven: Initiative for Upscaling: Irrigation Subdivision as the Building Block	Gauhar Rehman Asghar Hussain Hassan Zia Munawwar	Apr 1997
R-21.8	Volume Eight: Options for Sustainability: Sector-Level Allocations and Investments	Abdul Rehman Gauhar Rehman Hassan Zia Munawar	Apr 1997
R-22	Salinisation, Alkalinisation and Sodification on Irrigated Areas in Pakistan: Characterisation of the geochemical and physical processes and the impact of irrigation water on these processes by the use of a hydro-geochemical model (M.Sc Thesis published as Research Report)	Nicolas Condom	Mar 1997
R-23	Alternative Scenarios for Improved Operations at the Main Canal Level: A Study of Fordwah Branch, Chishtian Sub-Division Using A Mathematical Flow simulation Model(M.Sc Thesis published as Research Report)	Xavier Litrico	Mar 1997
R-24	Surface Irrigation Methods and Practices: Field Evaluation of the Irrigation Processes for Selected Basin Irrigation Systems during Rabi 1995-96 Season	Ineke Margot Kalwij	Mar 1997
R-25	Organizing Water Users for Distributary Management: Preliminary Results from a Pilot Study in the Hakra 4-R Distributary of the Eastern Sadiqia Canal System of Pakistan's Punjab Province	D.J. Bandaragoda Mehmood Ul Hassan Zafar Iqbal Mirza M. Asghar Cheema Waheed uz Zaman	Apr 1997
R-26	Moving Towards Participatory Irrigation Management	D.J. Bandaragoda Yameen Memon	May 1997
R-27	Fluctuations in Canal Water Supplies: A Case Study	Shahid Sarwar H.M. Nafees M.S. Shafique	June 1997
R-28	Hydraulic Characteristics of Pilot Distributaries in the Mirpurkhas, Sanghar and Nawabshah Districts, Sindh, Pakistan	Bakhshal Lashari Gaylord V. Skogerboe Rubina Siddiqui	June 1997

Report No.	Title	Author	Year
R-29	Integration of Agricultural Commodity Markets in the South Punjab, Pakistan	Zubair Tahir	July 1997
R-30	Impact of Irrigation, Salinity and Cultural Practices on Wheat Yields in Southeastern Punjab, Pakistan	Florence Pintus	Aug 1997
R-31	Relating Farmers' Practices to Cotton Yields in Southeastern Punjab, Pakistan	P.D.B.J. Meerbach	Aug 1997
R-32	An Evaluation of Outlet Calibration Methods: A contribution to the study on Collective Action for Water Management below the Outlet, Hakra 6-R Distributary	Arjen During	Aug 1997
R-33	Farmers' use of Basin, Furrow and Bed-and-Furrow Irrigation Systems and the possibilities for traditional farmers to adopt the Bed-and-Furrow Irrigation Method.	Nanda M. Berkhout Farhat Yasmeen Rakhshanda Maqsood Ineke M. Kalwij	Sep 1997
R-34	Financial Feasibility Analysis of Operation and Maintenance Costs for Water Users Federations on three distributaries in Province of Sindh, Pakistan.	Amin Sohani	Sep 1997
R-35	Assessing the Field Irrigation Performance and Alternative Management Options for Basin Surface Irrigation Systems through Hydrodynamic Modelling.	Ineke Margot Kalwij	Oct 1997
R-36	Socio-Economic Baseline Survey for Three Pilot Distributaries in Sindh Province, Pakistan.	Yameen Memon Mehmood Ul Hassan Don Jayatissa Bandaragoda	Nov 1997
R-37	Socio-Economic Basline Survey for a Pilot Project on Water Users Organizations in the Hakra 4-R Distributary Command Area, Punjab.	Muhammad Asghar Cheema Zafar Iqbal Mirza Mehmood Ul Hassan Don Jayatissa Bandaragoda	Dec 1997
R-38	Baseline Survey for Farmers Organizations of Shahpur and Mirwal Small Dams, Punjab, Pakistan.	Muhammad Asghar Cheema Don Jayatissa Bandaragoda	Dec 1997
R-39	**Monitoring and Evaluation of Irrigation and Drainage Facilities for Pilot Distributaries in Sindh Province, Pakistan**		
R-39.1	Volume One: Objectives, Stakeholders, Approaches and Methodology	M.S. Shafique B.K. Lashari M. Akhtar Bhatti Gaylord V. Skogerboe	Dec 1997
R-39.2	Volume Two: Bareji Distributary, Mirpurkhas District	B.K. Lashari Waryam Balouch Ghulam Mustafa Talpur Muhammad Nadeem Asghar Ali Memon Badrul Hassan Memon M. Akhtar Bhatti M.S. Shafique Gaylord V. Skogerboe	Dec 1997
R-39.3	Volume Three: Dhoro Naro Minor, Nawabshah District	B.K. Lashari Abdul Rehman Soomro Nizamuddin Bharchoond Muneer Ahmed Mangrio Parvez Ahmed Pirzado Fateh Mohammad Mari M. Akhtar Bhatti M.S. Shafique Gaylord V. Skogerboe	Dec 1997

Report No.	Title	Author	Year
R-39.4	Volume Four: Heran Distributary, Sanghar District	B.K. Lashari M. Naveed Khayal Niaz Hussain Sial Abdul Majeed Ansari Abdul Jalil Ursani Ghulam Shabir Soomoro M. Ghous Laghari M. Akhtar Bhatti M.S. Shafique Gaylord V. Skogerboe	Dec 1997
R-40	**Maintenane Plans for Irrigation Facilities of Pilot Distributaties in Sindh Province, Pakistan.**		
R-40.1	Volume One: Dhoro Naro Minor, Nawabshah District	Abdul Rehman Soomro Munir Ahmed Mangrio Nizamuddin Bharchoond Fateh Muhammad Mari Parvez Ahmed Pirzado Bakhshal Lashari M. Akhtar Bhatti Gaylord V. Skogerboe	Dec 1997
R-40.2	Volume Two: Heran Distributary, Sanghar District	Abdul Majeed Ansari Niaz Hussain Sial Abdul Jalil Ursani Ghulam Shabir M. Ghous Laghari M. Naveed Khayal Bakhshal Lashari M. Akhtar Bhatti Gaylord V. Skogerboe	Dec 1997
R-40.3	Volume Three: Bareji Distributary, Mirpurkhas District	Asghar Ali Memon Waryam Balouch Ghulam Mustafa Talpur Muhammad Nadeem Badrul Hassan Memon Bakhshal Lashari M. Akhtar Bhatti Gaylord V. Skogerboe	Dec 1997
R-41	**Preliminary Business Plans**	Pervaiz Ahmad Pirzada Mohsin Khatri Syed Daniyal Haider	Dec 1997
R-41.1	Volume One: Dhoro Naro Minor, Nawabshah District		
R-41.2	Volume Two: Bareji Distributary, Mirpurkhas District	Muhammad Nadeem Mohsin Khatri Syed Daniyal Haider	Dec 1997
R-41.3	Volume Three: Heran Distributary, Sanghar District	Niaz Hussain Sial Mohsin Khatri Syed Daniyal Haider	Dec 1997
R-42	Prospects of Farmer-Managed Irrigated Agriculture in the Sindh Province of Pakistan. LBOD Project Final Report	D.J. Bandaragoda Yameen Memon Gaylord V. Skogerboe	Dec 1997
R-43	Study Tour of Pakistani Pilot Project Farmer-Leaders to Nepal	Mehmood Ul Hassan Yameen Memon	Jan 1998
R-44	Self-Help Maintenance Activities by the Water Users Federation of Hakra 4-R Distributary	Waheed uz Zaman	Feb 1998

Report No.	Title	Author	Year
R-45	Semi-Detailed Soil Survey of Chishtian Irrigation Sub-Division	Soil Survey of Pakistan IIMI-Pakistan	Mar 1998
R-46	Tenancy and Water Management in South-Eastern Punjab, Pakistan	Annemiek Terpstra	Mar 1998
R-47	The Collaboration between the International Irrigation Management Institute and Cemagref in Pakistan: Proceeding of a one-day workshop	IIMI Cemagref	Apr 1998
R-48	Methodologies for Developing Downstream Gauge Ratings for Operating Canal Discharge Regulating Structures	Paul Willem Vehmeyer Raza ur Rehman Abbasi Mushtaq A. Khan Abdul Hakeem Khan Gaylord V. Skogerboe	Apr 1998
R-49	Community Irrigation Systems in the Province of Balochistan	Olaf Verheijen	Apr 1998
R-50	Modelling Soil Salinity and Sodicity Processes in an Unsaturated Zone using LEACHM: A Case Study from the Chishtian Irrigation Sub-Division	M. Aslam J.C. van Dam	Apr 1998
R-51	Water Measurement Training for Subsystem Management of Hakra 4-R Distributary by the Water Users Federation	Waheed-uz-Zaman Anwar Iqbal Abdul Hamid Gaylord V. Skogerboe	May 1998
R-52	Comparison of Different Tools to Assess the Water Distribution in Secondary Canals with Ungated Outlets	Mobin ud Din Ahmad E.G. van Waijjen Marcel Kuper Steven Visser	May 1998
R-53	Sediment Behavior of Sangro Distributary, Mirpurkhas Sub-division, Sindh	Gilles Belaud Abdul Hakeem Khan Ghulam Nabi	May 1998
R-54	Evaluation of the Integrated Approach Developed in the Context of the IIMI-CEMAGREF Collaboration in Pakistan	Patrice Garin Marcel Kuper Frederic Labbe Pierre Strosser	May 1998