GOVERNMENT OF N.W.F.P.
IRRIGATION DEPARTMENT

OPERATION AND MAINTENANCE MANUAL FOR CANAL SYSTEMS IN NWFP

Peshawar
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PART 1

CANAL MANAGEMENT

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FOREWORD

The Manual of Irrigation Practice was first published in 1943 to meet the requirements of the field officers of the Irrigation Department. Initially it was supposed to contain 38 chapters on a variety of topics related to Irrigation Engineer's routine work but ultimately only 23 chapters could be finalized. Due to its great utility for the Irrigation engineers the first edition was soon sold out and for a while it was difficult to get hold of a copy of the document. The 1943 Edition contained references to obsolete Acts and Orders and out dated statistical data but still the technical contents of the manual provided considerable guidance to the young Irrigation Engineers. Due to its great demand the manual was reprinted in 1963 with out any revisions.

The United States Agency for International Development (USAID) started The Irrigation System Management Project for improving the performance of the four Irrigation Departments in early 1980's. One of the aims of the project was to prepare a manual for the field engineers which would be in line with the technological advancements that have been made in the field of Irrigation Engineering over the last three decades. USAID entrusted this job to a US based consulting firm, PRC, which hired a number of expatriate and local experts for the preparation of the document. After more than three years of sustained effort a document was prepared to meet the needs of the four provincial Irrigation Departments (PIDs).

The NWFP Provincial Irrigation Department expressed reservations regarding this document. The Irrigation Engineers of NWFP felt that the document was prepared for the conditions generally prevalent in the Sind and Punjab provinces. These conditions do not necessarily reflect upon the conditions in the NWFP. Specifically the channel bed slopes in NWFP are steeper than the one's in the Sind and Punjab. Their comments generally stated that the document did not reflect the specific conditions with respect to the O&M contracts and procedures being practiced in NWFP.

In the second phase of the ISM Project the work on tailoring the document according to the needs of the respective PIDs was initiated by the DAI/HARZA/ACE consulting team. Mr.Rameez Malik (ex Chief Engineer, Punjab Irr. Deptt.) who was involved in the preparation of the manual in the first phase of the project was retained by the consultants and entrusted this job. The task was under taken in late 1989 upon the arrival of new Provincial Advisor, Mr.Gene F.White. The Provincial Irrigation Department nominated a committee of four experienced Executive Engineers to review the document prepared under ISM I and suggest changes and improvements for tailoring it to the needs of local Irrigation engineers. The committee comprised of Mr.A.B.Baloch, Mr.Abdul Qayum Khan, Mr.Raqib Khan and Mr.Amman Gul Khattak. All the members of the committee took keen interest in the assignment and very promptly came up with their comments and suggestions. To expedite the preparation of the document Mr.White's office entered the document in the computer. After a series of meetings involving the provincial coordinator Mr.Saleem Ullah Khan, the four XEN's, Mr.Malik and Mr.White the O&M manual for the NWFP was finally revised and tailored to the local requirements. In July of 1991 the contract of Mr.Malik with the consultants expired and he handed over the first draft of the revised document to Mr.White. Though technically sound, the document still needed considerable organization and improvement in format. Mr.White and his Design Engineer, Dr.Farhat Javed, went through the document a number of times to give it a meaningful shape and was almost retyped on the computer by Mr.Amjad Bashir. The final Draft of the manual was reviewed by Mr.Jim Ringenoldus (Chief of Party, HARZA consultants), Dr.Carlos Gandarillas (Prov. Advisor, ISM II Project, Balochistan), Mr.Majeed Choudry (Design engineer, ISM II Project, Balochistan), Mr.A.B.Baloch and Mr.Raqib Khan. The comments of these experts were incorporated in the document by Mr.White and after another round of editing by the DAI/HARZA/ACE team the document was finalized around the end of 1991.

This manual has been prepared to embrace all of the activities carried out by NWFP Irrigation Department's canal officers and is divided into four parts as follows:

Part 1............................Canal Management
Part 2............................Water Management
Part 3............................Canal Embankment
Part 4............................Canal Structures

CHAPTER 1

1.0 Scope of Part 1 - Canal Management.

Part 1 includes the following topics:

Chapter 1 Irrigation Systems in NWFP
Chapter 2 Operation of Canal Systems
Chapter 3 Maintenance of Canal Systems
Chapter 4 Administration for Canal Systems
A glossery of terms is located in Annex 1 at the end of the manual.

1.1 Irrigation System in NWFP

Irrigated agriculture was initiated in the NWFP centuries ago. In those early days, small discharges were diverted from the rivers and small streams to irrigate strips of land adjoining the banks of the sources of water. Later, bigger discharges were withdrawn in summer when the water levels in the rivers were higher. These channels were termed as inundation canals. Following is a brief history of the development of the irrigation system in the NWFP.

A. Ancient Canals

i. Jue Sheikh Canal

As indicated in recorded history, a first bold attempt was made by the construction of an inundation canal from the right bank of River Kabul during the reign of Moghal Emperor Aurangzeb towards the end of seventeenth century. This canal, named Jue Sheikh, was provided to irrigate areas around Peshawar. Later it was merged into the Kabul River Canal System.

ii. Pharpur Canal

It is located at the right bank of Indus river and was constructed in 1908 near the village of Bilot, which is about 50 miles upstream from D.I.Khan. It provided irrigation right up to areas around D.I.Khan. It has recently been absorbed in the Chashma Right Bank Canal Project. It now irrigates 104,000 acres.

iii. Civil Canals

There is a vast network of civil canals in the Districts of Abbottabad, Peshawar, Kohat, Bannu and D.I.Khan. These canals were dug by the farmers on a self-help basis. Diversion of water is achieved by boulders and brushwood spurs. Technical supervision and regulation of water supplies to these canals is done by the Irrigation Department. Their internal distribution, however, is carried out by the farmers according to Rewaj (customs) which has been in vogue for a long time. Disputes are settled by the Deputy

Vogue Popular acceptance or favour

Commissioner or his representative. The revenue is also collected by the civil administration.

B. Earlier Canals

i. Lower Swat Canal

The first work undertaken in the development of the present Irrigation System in the NWFP was the construction of Lower Swat Canal in 1895. It took off from Munda Headworks on Swat River. It took eight years to construct at a cost of one quarter of a million pounds sterling and irrigated 135,000 acres in Charsadda and Nowshera Tehsils of Peshawar District and major portion of Mardan District. This canal was constructed as a political work on experimental basis and had little hope of being remunerative. Its success, however, outran all expectations. It paid back over 10% of the capital cost during first 12 years of operation. It was largely colonized from the Mohmand Tribe. The head discharge of this canal is 830 cusecs and the aggregate length of all channels is about 177 miles.

ii. Upper Swat Canal

This canal was opened in 1914 after a construction period of six years. It takes off from the Amandara Headworks and is remarkable for the boldness of its design. After 4 miles of open channel, the canal passes through an approximately two-mile long tunnel called the Benton Tunnel. Its design head discharge was 2,200 cusecs but due to constraints imposed by the tunnel, the capacity of canal downstream from the tunnel has been reduced to 1,800 cusecs. The system irrigates 279,000 acres in Malakand Agency, Mardan District and part of Nowshera Tehsil of Peshawar District. Two hydroelectrical stations, with a generating capacity of 20 MW each, are located on this canal system at Jabban and Dargai.

ii. Kabul River Canal

This canal was built during 1883 with a capacity of 800 cusecs. This canal includes 350 cusecs of Jue Sheikh Canal and as such the Kabul River Canal carries 450 cusecs. The length of the main canal is 40 miles and of distributaries 76 miles. The C.C.A. is 48,700 acres.

C. Post Independence Development

i. Warsak Canal System

This system (completed in 1965) consists of the Warsak Gravity Canal, Warsak Left Bank Canal and Warsak Lift Canal.

(a) **Warsak Gravity Canal**

It has a full supply discharge of 311 cusecs and irrigates about 59,000 acres. The main canal is 45.2 miles while the length of its 7 minors is 12.4 miles.

(b) **Warsak Left Bank Canal**

It has a discharge of 45 cusecs and irrigates about 11,000 acres in Mohmand and Shabquadar areas. The total length of the canal is 18.4 miles.

(c) **Warsak Lift Canal**

Its supply channel receives water from the Warsak Gravity Canal. Two hundred cusecs are lifted through static head of 167 ft. by a battery of 5 pumps to irrigate about 43,000 acres. The length of main canal is 37.0 miles and the length of the four minors is 9.0 miles.

ii. **Marwat Canal**

It was built in the year 1971 on the right bank of Kurram River, some six miles from Bannu. It provided irrigation to areas around Bannu and was subsequently absorbed in Baran Dam Project. The inundation canals were inefficient when judged from modern standards. There were no regulators or escapes and during high floods most of the cultivated area was subjected to periodic flooding. The supply channels were heavily silted every year. Annually, the whole manpower of the villages would be used for silt clearance.

iii. **Pehur Main Canal**

This canal was constructed in 1957 under the "Grow More Food Campaign" as an inundation canal with a designed capacity of 250 cusecs and irrigates about 43,000 acres. During construction of Tarbela Dam, the offtake point of this canal was submerged in the reservoir. Therefore WAPDA installed a pumping station and an intake to pump 250 cusecs from Indus River. The pump house has a battery of 6 pumps each with a pumping capacity of 50 cusecs. One pump serves as a stand-by. This system has 76 miles of main, distributaries, and minor canals and is infested with algae growth. This problem reduces the carrying capacity of the canal.

iv. **Kurram Ghari Project**

This project was completed in FY 1963-64. It consists of a weir on Kurram River at a distance of 6 miles from Bannu. Its purpose is two fold. It feeds the off-channel reservoir on Baran River through a canal and provides irrigation supplies of 650 cusecs to the Katchkote Canal System.

v. Baran Dam/Marwat Canal System

Baran Reservoir is an off-channel storage facility on the Baran Nallah. This reservoir is fed from the Kurram River on which a weir has been constructed. A feeder channel transfers water from the Kurram River to the Baran Reservoir which has a gross storage of 98,000 A.F. and live storage of about 96,000 A.F. The normal life of this reservoir (commissioned in 1962) was expected to be 40 years. Due to siltation, however, the reservoir is losing its capacity. The present capacity, according to a 1988 survey, is 55,000 A.F. Consultants have been engaged to study this problem. They have made some recommendations for increasing the storage capacity of the reservoir. These recommendations are being reviewed. The Marwat Canal System, which is fed from the Kurram Garhi weir, is designed for 800 cusecs and commands an area of 170,000 acres. It is 43 miles long (including its twenty-five distributaries).

vi. Tanda Dam Project

This dam, which is 115 ft. high has gross storage capacity of 78,000 A.F. It was commissioned in A 1967-68. The live storage capacity of the dam is 64,000 A.F. It has a projected life of 50 years. It is also an off-channel storage facility which is fed from the Kohat Toi through a feeder canal. The canal system fed from this reservoir is 42 miles long, has a discharge capacity of 263 cusecs and irrigates 32,000 acres. The flood flows of Kohat Toi are not being utilized fully. M/S NESPAK have been engaged to study this issue and make their recommendations.

vii. Small Lift Irrigation schemes

The Irrigation Department is operating and maintaining twenty-three Small Lift Irrigation Schemes in the province. these are mainly concentrated in the Malakand Agency. An area of about 97,000 acres is irrigated by these schemes.

viii. Khan pur Dam Canal System

Khanpur Dam was completed in 1985 on the Haro River. The gross storage capacity of the reservoir is 106,000 A.F. The canal taking off on the right side with a capacity of 118 cusecs irrigates about 18000 acres in NWFP. Due to the passage of canal through rugged country, its maintenance is problematic. A proposal has been prepared for its remodelling and renovation.

ix. Chashma Right Bank Canal

A barrage on Indus River was constructed at Chashma in 1971 under the Indus Basin Project Plan. A regulator was constructed on the right side of the barrage for feeding Paharpur Canal and irrigating additional areas lying on the right bank of Indus River. A canal with a capacity of 5,000 cusecs is under construction. Part of this new canal has become operative and the Paharpur Canal System is being fed from it.

CHAPTER 2

OPERATIONS

2.0 PURPOSE OF THE CANAL SYSTEM

The purpose of an irrigation system is to deliver water of appropriate quality in a specified quantity, time, and place for optimizing agricultural production in a given area; therefore considerable emphasis must be placed on measurement and control of the water flowing through the system.

The day-to-day management of water requires that daily water use be known and compared against flow reserves and demands. This can only be accomplished by knowing with reasonable accuracy the amount of water being diverted and delivered throughout the system. A water balance is the bookkeeping process that utilizes water measurement data to determine where all the water has gone so that a balance of water delivered into the system can be carried out.

2.1 CURRENT SITUATION

All irrigation systems in NWFP are perennial and are characterized by fairly large water shortages during Rabi. The cropping intensities on some canals exceed designed intensities particularly in the head reaches. The intensities vary from 142 - 164 percent. Very little fresh ground water is available in the canal commands of the Kabul & Swat rivers. The existing canal or surface water system is essentially exhausted with respect to the provision of adequate supplies for everyone. Increasing the supply to one watercourse can only be done at the expense of taking it from another watercourse. The exception is the rare case where a canal is lined to save water and the water thus saved is used to augment supplies elsewhere; or when storage facilities develop a new source.

Although surplus water may be available during the flood season, canal capacity constraints will not allow additional flows. Canal capacities can only be increased through a major reconstruction program that will require the lining or widening of the canals. Widening a canal requires the removal of a part or all of an old embankment, construction of a new embankment, widening/replacement of all structures across the canal and construction of new outlets in the rebuilt embankments.

2.2 AREAS REQUIRING IMPROVEMENT

The major areas that require attention to improve maintenance are:

- Full funded O&M budgets to keep systems in as-built condition
- Modernized maintenance procedures and standards
- Improved O&M contracts
- Improvements in management, training, discipline, morale and support (the human side)
- Improved communications
- Mechanization
- Computerization

A brief description of the above items is given below:

A) **Maintenance Yardsticks and full funded budget for Canals.**

Yardsticks for all the Canals in NWFP have been developed on the basis of a realistic cost of labor and materials. Budget estimates should be prepared by using these Yardsticks. However ratification of these Yardsticks by the Finance Department is necessary so that budget prepared on this basis are accepted by F.D. This process will provide enough funds for the proper O&M of the canals. The Yardsticks will require revision every few years due to increase in cost of labor and materials.

B) **Modernized Maintenance Procedures and Standards.**

It is desirable that an O&M work plan be prepared well in advance of the coming financial year. Generally, this work plan should be prepared by 1st October, when the first list of excesses and surrenders is prepared, i.e., 9 months in advance of next financial year. Initially, the costing of the work plan should be done on the basis of Yardsticks and later, detailed estimates for various works should be based on field surveys when funds have been made available in July. In regard to the performance and maintenance standards for the canals, these have been established previously and should be followed. If these are followed, the canals can be maintained in good state of repair.

C) **Improved O&M Contracts.**

(i) For bigger O&M contracts, proper formats should be prepared for the following components of the contract:

(a) Invitation to Bid.
(b) Pre-qualification of Contractors, if necessary.
(c) Preparation of Tender Documents to include:

General and Special Conditions of Contract
Technical Specifications
Performance Bond

(ii) Administration of Contract.

The contract should be administered in the following steps:
(a) Bid Evaluation and Award of Contract
(b) Review of Schedule given by the Contractor after award of contract.
(c) Preparation of construction drawings by consultants or Department.

(d) Shop drawings to be prepared by the contractor.
(e) Inspection and monitoring of quality of materials and enforcement of specifications during execution of work.
(f) Issuance of variation orders for deletion or addition of work.
(g) Extension in time of the contract period if justified
(h) Completion of contract according to schedule or extended period.

D) **Improvement in Management, Training Discipline, Morale & Support.**

(i) Improvement in Management.

(a) With regard to PID personnel, maintenance should be discharged without outside influences.
(b) In order to discharge responsibilities more effectively, decentralization of powers is required. SDOs and XENs need to be vested with more administrative powers so that action for accountability can be taken quickly.
(c) Monitoring of execution of works should be effectively carried out by officers.
(d) Besides the O&M duties, the officers are burdened with a lot of extra work and assignments which detract their attention from the O&M tasks.This should be minimized. SDOs and XENs have to devote a good deal of their time for handling legal cases and dealing with contractor's disputes. A special officer trained in these works should be assigned at the Divisional level to relieve the SDO and XEN from dealing with such disputes.

(ii) Improvement in Training etc.

Training needs to be imparted to SDOs and the Sub-Engineers in the following areas:

(a) Use of latest survey equipment for hydraulic survey of channels in connection with preparation of L-Sections of channels and rehabilitation schemes for drains and canals.

(b) Measurement of discharges for main canals branches, distributaries and minors using current meters and velocity rods.

(c) Measurement of discharges for outlets by using existing designed data and for water courses using portable flumes and the null point method.

(d) Measurement of silt load carried by the channels.

(e) Measurement of discharges for tubewells.

(f) Measurement of dry bulk density of embankments.

(g) Determination of strength of concrete from cubes.

The above mentioned list is not all inclusive. There may be many more areas for training. Such areas should be specified and training of concerned persons arranged.

E) **Improved Telecommunications.**

The existing telecommunication for Irrigation Department was installed around 1914 to link Northern and Central Irrigation Circles. Later it was extended to Bannu and D.I Khan. It worked on Morse code Key System. This system besides being outdated remains out of order most of the time. A study was carried out by the ISM Consultants in June 1988 and their recommendation for improvement are contained in their report. Consideration should be given to these recommendations.

F) **Mechanization.**

It has been proposed that on an experimental basis suitable O&M machinery should be provided to two Sub Divisions in NWFP so that routine repairs are carried out by the Sub Division itself without any contractor. If this experiment is successful all the Sub Divisions would be provided with the machinery.

G) **Computerization.**

It has been proposed that the computer applications should be extended to the Circle and Division level. This will enhance accuracy and efficiency of their work.

2.3 WATER RESOURCE MANAGEMENT.

A. General

Under normal conditions the irrigation system's management should consider the various resources available in the area including water, land and people. As has been mentioned earlier, both land and people in Pakistan are far in excess of ability to provide irrigation water for every bit of land. The basic irrigated land availability for Pakistan is as follows:

Land Capability in Canal Irrigated Areas (M ac)

Class	Capability	NWFP	%
I	Very good	0.19	33
II	Good	0.19	45
III	Moderate	0.09	18
IV	Poor	0.01	4
Total		1.10	100

Source: Soil Survey of Pakistan.

B. Future Water Resource Development Opportunities

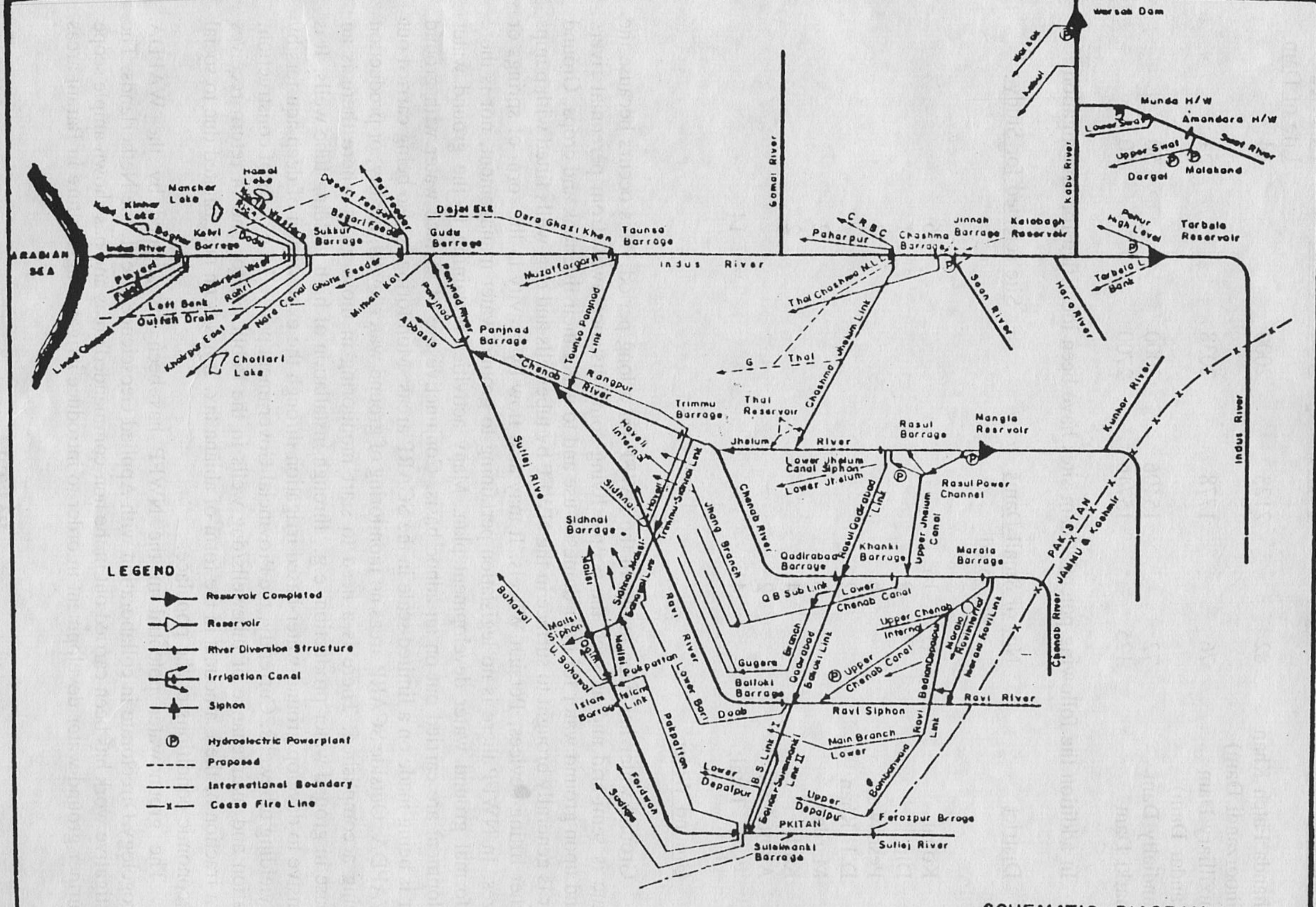
i. Surface Water Supplies

Essentially all of the surface water flow in NWFP has been allocated to the existing irrigation system. Only those wet season flood flows that are in excess of existing diversion requirements are available for development of new projects. The PID, out of necessity, tends to divert more water into the existing canal system than the sanctioned discharge. This can be a major cause of freeboard loss and canal berm erosion. The percent increase varies from canal to canal and the wet season flow availability at the various diversion points.

The availability of flood season water in NWFP is limited to a period of about two months or less in drier years. In addition, because of the spatial timing of the monsoon and rainfall, the high flow in the rivers does not occur at the same time each year. The high flow in the Indus River is controlled by Tarbela Reservoir which does not allow water in excess of the downstream irrigation requirements to be released until the reservoir has been filled. This further makes any pre-season prediction on availability of flood water more difficult.

Fig II-1 is schematic diagram of Irrigation System in Pakistan, including the NWFP. The construction of storage dams, large or small is the only means available to control and have a reliable supply of water. All dams need not be of large scale. Many small scale dams have and will continue to be built in NWFP to control and utilize the run off from the smaller watersheds. Sedimentation may be a major factor to consider at these dam sites as it can shorten the useful life of a reservoir. To develop small storage reservoirs for irrigated agriculture in NWFP, where perennial surface flows are not available, feasibility studies have been carried out for the following four dam sites.

FIGURE II-1



SCHEMATIC DIAGRAM
PAKISTAN IRRIGATION SYSTEMS

Name of Site	Height	Total Storage	Area Irrigated	Expected Life of Dam
1. Chanda Fateh Khan (Ghoorzandi Dam)	82	2123	2000	44
2. Auxilliary Dam (Kandar Dam)	76	1778	2038	54
3. Gandially Dam	72	15406	3000	50
4. Sharki Dam	125	15746	2700	50

In addition the following potential dam sites have been identified for investigation.

District	No. of Small Dams Proposed	Site selected for Study
Kohat	16	6
Dir	8	1
Peshawar	6	3
D.I. Khan	2	-
Mardan	3	2
Kark	4	2
Abottabad	2	-
Total:	41	14

ii. Ground Water

Ground water has been in use in the NWFP for a long period. This occurs because the climate is semi-arid and as such the people living some distance away from perennial rivers depend upon ground water for their domestic use and to water their livestock and crops. Ground water is generally brought to surface in the NWFP by tubewells and dug-wells fitted with pumps or other lifting devices, Persian Wheels. It may also flow by gravity in the form of springs or karezes. In NWFP there is no legislation pertaining to ground water management, nor is there any formal ground water development plan. Many activities pertaining to the ground water development are carried out on an adhoc basis. Conjunctive use of surface water with ground water is being made on a limited scale in the SCARP areas. Monitoring is also being carried out by WAPDA. Outside SCARP areas no monitoring of ground water levels, quality, or production is being accomplished. There is a need to start monitoring in those areas where there is an increase in ground water production, e.g., through installation of high yielding tube wells. It is expensive to develop ground-water-based irrigation through the exploitation of deep aquifers by high yielding tubewells. Currently, the Provincial Government pays all the costs of construction, operation and maintenance of tubewells/dug wells in the Public Sector and in return receives only a fraction of these amounts in the form of abiana tax. It has been necessitated due to social and economic conditions of the populace.

The groundwater potential in the NWFP has been investigated by the WAPDA Hydrogelogy Directorate in collaboration with Applied Geoscience, Delft, the Netherlands. The investigative work has been carried out in the non-commanded areas and has shown ample scope for further ground water development in order to introduce irrigated agriculture in Barani areas and for conjunctive use with surface water for increasing the agricultural production. In certain areas the amount of total dissolved salts (TDS) in water may render the groundwater unfit for agriculture. Table II-1 shows salinity tolerance of various crops. A rough estimate of total dissolved salts can be obtained by determining the capability of water to conduct an electric current. This property is called electric conductivity (E.C.). The electrical conductivity is reciprocal of resistance and is expressed as mho/per cm. The chemical composition of the dissolved salts determines the chemical quality of water and is often decisive in determining its usefulness. The major constituents are the cation calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), and the anions: bicarbonate (HCo_3) chloride(Cl) Sulphate (SO_4) and nitrate (NO_4). It is a common practice to classify water by such terms as "calcium bicarbonate" water or "sodium chloride" water. These classifications represent the predominant cation and anion.

Water should satisfy certain criteria to be classified as "Suitable" for a specific purpose such as drinking water, irrigation, use in industrial process, or cooling. Table II-2 gives the various levels of acceptability. For irrigation use, water quality criteria differs per crop. Moreover well drained sandy soils permit the use of poorer quality water than poorly drained clay soil because salt accumulations in root zone are more easily leached out. Table II-1 shows relative tolerance of crops to salt. If the calcium and magnesium ions on the clay and colloids of the soil are replaced by sodium, soil permeability decreases and the soil hardens. The extent of the risk of Sodium hazard is estimated by the Sodium Absorption Ratio (SAR) which is expressed by the formula:

$$SAR=\frac{Na}{\sqrt{(Ca+Mg)_{/2}}}$$

Table II-3 gives the summary of E.C. value, water type and SAR value of the ground water in the alluvial plains of N.W.F.P.

iii. Drainage Water

There are extensive areas in NWFP where the irrigated areas have become waterlogged due to restricted drainage. Many of these areas are also saline. The government is beginning to pay more attention to water logged areas. A number of drainage projects have been initiated and many more will be implemented in the future.

Little is known about the water quality of the drainage waters. Where the salt content is not too high this water can be mixed with fresh water sources and used for irrigation. Areas receiving the blended irrigation water must in themselves have a subsurface drainage network so that the excess salts can be leached out of the root zone to maintain the proper salt balance in the soils.

For the reuse of drainage water for irrigation purposes, analysis of water for its quality should be done. The following factors effect the suitability of drain water for irrigation;

TABLE-II-1

CROP TOLERANCE TO SALT AND YIELD DECREMENT TO BE EXPECTED FOR CERTAIN CROPS DUE TO SALINITY OF IRRIGATION WATER IN N.W.F.P.

CROP	0% /ECw*	10% /ECw	25% / ECw	50% / ECw
Barley**	5.3	6.7	8.7	12.0
Cotton	5.1	6.4	8.4	12.0
Wheat**/**	4.0	4.9	6.4	8.7
Soybean	3.3	3.7	4.2	5.0
Sorghum	2.7	3.4	4.8	7.2
Groundnut	2.1	2.4	2.7	3.3
Rice (Paddy)	2.0	2.6	3.4	4.8
Maize	1.1	1.7	2.5	3.9
Broad bean	1.1	1.8	2.0	4.5
Cowpea	0.9	1.3	2.1	3.2
Beans	0.7	1.0	1.5	2.4
Date palm	2.7	4.5	7.3	12.0
Pomegranate	1.8	2.6	3.7	5.6
Orange	1.1	1.6	2.2	3.2
Lemon	1.1	1.6	2.2	3.2
Apple	1.0	1.6	2.2	3.2
Walnut	1.1	1.6	2.2	3.2
Peach	1.1	1.4	1.9	2.7
Apricot	1.1	1.3	1.8	2.5
Almond	1.0	1.4	1.9	2.7
Plum	1.0	1.4	1.9	2.8
Tomato	1.7	2.3	3.4	5.0
Cucumber	1.7	2.2	2.9	4.2
Melon	1.5	2.4	3.8	6.1
Spinach	1.3	2.2	3.5	5.7
Cabbage	1.2	1.9	2.9	4.5
Potato	1.1	1.7	2.5	3.9
Pepper	1.0	1.5	2.2	3.4
Onion	0.8	1.2	1.8	2.9
Carrot	0.7	1.1	1.9	3.1
Beans	0.7	1.0	1.5	2.4
Crested Wheat Grass	2.3	4.0	6.5	11.0
Sudan grass	1.9	3.4	5.7	9.6
Trefoil, big	1.5	1.9	2.4	3.3
Alfalfa	1.3	2.2	3.6	5.9
Maize (forage)	1.2	2.1	3.5	5.7
Clover, beseem	1.0	2.1	3.9	6.8
Orchard grass	1.0	2.1	3.7	6.4
Clover	1.0	1.6	2.4	3.8

* ECw means electrical conductivity of the irrigation water in millisiemen per cm at 25^0 C (mS/cm). This assumes about a 15-20% leaching fraction and an average salinity of soil water taken up by crop about three times that of the irrigation water applied (ECsw = 3ECw) and about two times that of the soil saturation extract (ECsw =2ECe).

** Barley and wheat are less tolerant during germination and seedling stage. ECe should not exceed 4 5 mS/cm.

*** Tolerance data may not apply to semi-dwarf varieties of wheat.

TABLE II–2

VARIOUS LEVELS OF ACCEPTABILITY OF SALINE WATER

	Drinking	General Household Use		Irrigation		Food Processing	Boiler Water	
		Good	poor	good	poor		High Pressure	Low Pressure
Antimony	0.05	...	...	...	...	0.05	...	...
Arsenic	0.05	...	...	...	...	0.05	...	...
Barium	1.0	...	...	...	...	1.00	...	...
Bicarbonate	500	150	500	200	500	300	5	50
Boron	20	...	...	0.3	3.0	...	...	...
Cadmium	0.01	...	...	...	...	0.1	...	...
Calcium	200	40	100	...	...	80	1	40
Chloride	250	...	...	100	300	300	...	...
Chromium	0.05	...	...	...	...	0.05	...	...
Copper	1.0	0.5	3.0	...	...	3.0	...	...
Cyanide	0.2	...	...	...	...	0.2	...	...
Fluoride	1.5	...	...	...	...	1.5	...	...
Hydrogen Sulfide	1.0	0.05	2.0	...	...	0.5	0	5
Iron	1.0	0.02	0.5	...	...	0.2	...	...
Lead	0.05	...	...	...	...	0.05	...	...
Magnesium	125	20	100	...	...	40	1	20
Manganses	0.05	0.05	0.3	...	...	0.1	...	...
Nitrate	20	...	...	...	...	20	...	...
Phenol	0.001	...	...	...	...	0.001	...	...
Selenium	0.01	...	...	...	...	0.01	...	...
Silica	...	10	50	...	...	50	1	30
Silver	0.05	...	...	...	...	0.05	...	...
Sodium	200	100	300	50	300	300	...	50
Sulfate	250	100	300	200	500	...	...	...
Synthetic Detergents	0.5	0.2	1.0	...	...	0.5	0	0
Total Solids	1500	300	2000	500	3000	1000	100	2000
Zinc	5	...	...	...	...	...	...	....

TABLE II-3

EC VALUE OF WATER AND SAR VALUE OF THE GROUND WATER IN THE ALLUVIAL PLAINS OF NWFP

Area	EC in mS/cm (mho per cm)	Water type	SAR value
Ground water quality good; EC less than 1.0 mS/Cm:			
Dir and Swat Districts			
Talash and Adinzai	0.3 - 0.6	Ca / HCO_3	SAR < 1
Jandool area	(No data; quality probably good)		
Nikpikhel	0.6	Ca - Mg / HCO_3	SAR 0.2
Daggar valley	0.3 - 0.5	Ca - Mg / HCO_3	SAR < 2
Chamla valley	0.2 - 0.7	Ca - Mg / HCO_3	
Chingalai basin	(quality probably as in the Chamla valley)		
Totali area	(No data; quality probably good)		
Indus left bank			
Haripur area	0.3 - 1.0	Ca / HCO_3	SAR > 1
Pakhli plain	0.2 - 1.1	Ca / HCO_3	SAR < 2
Ghazi area	0.2 - 0.9	Ca / HCO_3	SAR 0.3 - 2.3
Mardan and Peshawar Districts			
Peshawar Vale tubewells:			
SW of Kabul r.	< 1.0	Ca - Mg / HCO_3	
N of Kabul r.	< 1.0	Na / HCO_3 - C1	
Peshawar Vale shallow wells:			
SW of Kabul R.av.	1.35	Ca - Na / HCO_3	
Mardan District av.	1.30	Ca - Na / HCO_3	
Nizampu			
tubewells	0.5 - 1.1	Ca / HCO_3	SAR 0.8 - 2.2
Gadoon	0.5 - 0.8		
" exc.	0.6 - 4.6	high K / high SO_4 - high C1	
Kohat and Karak Districtcs			
Kohat plain			
tubewells	0.4 - 1.1	Ca / HCO_3	SAR 0.1 -1.
Hangu valley			
tubewells	< 1.0	Ca / HCO_3	SAR 1.8 - 2.2
Shallow w.	0.4 - 1.0(2.0)		
Doaba valley			
tubewells	< 1.0	Ca / HCO_3	SAR 0.1 - 1.1
shallow wells	1.2	Ca - (Na) / HCO_3	SAR 1.0 - 5.7
Western Karak valley			
Southern side	0.7 - 1.0	mixed / HCO_3	SAR 0.3 - 4.0
Eastern Karak v.	0.7 - 1.0	mixed / HCO_3	
Bannu basin			
Area between the Kashu Algad and Kurram river	0.5 - 1.8	Ca/HCO_3 (EC <1.0) Na / C1 (EC >1.0)	SAR 0.6 - 1.6
confined aquifer of the Marwat plain	0.9	Na / HCO_3 - So_4	SAR 4 -7
Dera Ismail Khan			
Western fans	< 2.0	Ca-Mg / HCO_3	
Northern fans	< 2.0	Na / HCO_3	
Indus flood plains	< 0.3	Ca or ^Na / HCO_3	
FATA (except Parachinar)	(No data; quality probably good)		
Parachinar	0.4 - 0.5 (1.5)	variable	SAR 0.1 - 2.4

1. Chemical composition of water
2. Crops to be irrigated
3. Soil to be irrigated
4. Climate

Chemical composition should be given in electrical conductivity or in PPM. Table II-1 shows crop tolerance to salinity for major crops. The table also gives electrical conductivity of water. The percentages given in the table show reduction in yield with increase of electrical conductivity both of soil and water.

C. Characteristics of a Well Managed Canal System

The main characteristics of a well operated canal system can be enumerated in their order of importance:

* Reliability (arrival of water according to schedule)
* Equitable distribution
* Efficient supply (minimization of canal losses)
* Accountability, discipline and enforcement
* Maintain canal standards (adequate budget and professional staff)
* Minimum involvement of administration with water distribution.

A well operated irrigation system should aim at the achievement of most, if not all, of these characteristics within the constraints imposed on the system by Government policies, topography and the physical facilities provided during initial construction. Improvements/betterment are made to alleviate or eliminate physical constraints but not allocation constraints.

2.4 SOME DEFINITIONS.

A. Water Allowance.

The outcome of all considerations like water duty, intensity, proposed crop ratios, and water availability is the fixing of the water allowance which is defined as the number of cusecs of outlet capacity, authorized per thousand acres of culturable irrigable area. Water allowance defines the size of each outlet and also forms the basis for the design of distribution channel.

In NWFP water allowance for various irrigation systems (in 1989) is presented below:

1.	Upper Swat Canal	6.42 Cusecs/1000 Acres
2.	Lower Swat Canal	7.13 Cusecs/1000 Acres
3.	Pehur Main canal	5.00 Cusecs/1000 Acres
4.	Warsak Gravity	5.30 Cusecs/1000 Acres
5.	Pahar Pur	4.20 Cusecs/1000 Acres

B. **Kharif Full Supply Factor (FSF)**

Kharif full supply factor is the area irrigated during the Kharif season divided by the authorized full supply discharge of the channel.

C. **Intensity of Irrigation**

It is the percentage of the culturable command area, C.C.A., irrigated during the year or Kharif or Rabi Seasons.

From the above mentioned items, the water allowance for thousand acres can be worked out as shown below.

Let the Kharif full supply factor be 55 acres per cusec and Kharif intensity 30%. Then water allowance for 1000 acres = 1000/55 X 0.3 = 5.45 cusecs. A C.C.A of 467 acres will have outlet capacities of 467/55 x 0.30 = 2.55 cusecs. Kharif full supply factors and Kharif Intensities in NWFP for various canals in 1989, are as below:

Name of Canal	Kharif Full Supply Factor	Kharif/Rabi Intensity
Upper Swat	119.87	76.98 / 52.67
Lower Swat	119.93	85.55 / 62.47
Kabul River	64.59	61.03 / 48.57
Tanda Dam	45.74	37.97 / 45.96
Baran Dam	45.57	20.71 / 8.43
Chashma Right Bank	27.28	19.57 / 45.42

D. **Delta.**

It is the total depth of water required by a crop during the entire period that the crop is in the field until its maturity. The delta of various crops in the NWFP is given in Table II-4.

Relation between FSF (duty and delta)

If F = Full supply factor
Dw = Total depth of water supplied in feet
B = Base period of kharif or rabi

If we take F acres of a field then water supply to the field corresponding to water depth D would be equal to FxD acre feet which is = DWxFx43,560 cft. Also for the same field F acres, one cusec of water is required to flow during the entire based period B. This is = 1xBx24x60x60 cft. These two quantities mentioned above are equal, therefore the following equation can be written:

$$DW \times D \times 43{,}560 = 1 \times B \times 24 \times 60 \times 60$$
$$DW = 1.985 \times B/D.$$

E. Crop Consumptive Use.

i. General

Each crop has a definite growth period from germination to maturity. During this period it consumes a certain amount of water, a part of which is utilized in building the plant material and the rest is either lost by evaporation from the soil surface and/or by transpiration through the plant leaves. The total amount of water consumed by a crop from germination to maturity is known as the consumptive use water requirement of that crop. Consumptive use is effected by many factors some of which are natural and other are man controlled. Important natural factors are precipitation, solar radiation, temperature, humidity, wind movement, period of growing season and the nature of soil/topography. The man controlled factors are water supply, its quantity and quality, date of plantation, crop variety, fertility level of soil, plant spacing, water management, and cultivation. All factors mentioned above have considerable effect on plant growth and its consumptive use which may vary from farm to farm, season to season and day to day. The amount water requirement of the plant increases with its growth. It reaches a peak during some part of growth period and then declines until the plant is harvested. An optimum production of a specific crop at a certain location requires a definite amount of water.

ii. Blaney-Criddle Method for Consumptive Use of Water

It has been found that Blaney-Criddle Method gives the best results for arid and semi-arid regions in Pakistan. This method has been used to determine the water requirements of various crops grown in various parts of Pakistan. This method is explained below:

Blaney-Criddle developed an empirical formula for the consumptive use of water in terms of temperature and day light hours. The formula is :

$$U = KF$$

Where U = seasonal consumptive use in inches for the total crop period from sowing to maturing.

K = empirical crop use coefficient for the growing period.

F = sum of monthly consumptive use factor for the given period

Let:

t = mean monthly temperature in degrees Fahrenheit

p = monthly percentage of day time hours of the year

Then:

U = sesonal consumptive use in inches

F = monthly consumptive use factor = txp/100

Blaney-Criddle established that, disregarding many unmeasured factors, consumptive use varies with temperature and day time hours. Multiplying mean monthly temperature (t) with possible monthly percentage of day time hours of the year (p), monthly consumptive use factor (f) is obtained. The sum of these monthly factors (f) gives the seasonal crop factor (F) for any site and specific crop. Consumptive use coefficient (K) has to be experimentally determined for a crop grown at a particular site. It can be determined month wise as well as for the whole period. The product of K & F gives the consumptive use of the crop.

iii. Example of Working Out Crop Consumptive Use

This is explained by an example. Suppose the consumptive use of cotton is to be determined. The cotton crop is sown in May and remains in the field up to November. The monthly factor (k) and the seasonal value (K) as determined for cotton are shown below:

Seasonal value (K)	Monthly values (k)						
	May	June	July	Aug	Sep	Oct	Nov
.78	.22	.25	.74	.80	1.24	.86	.55

Suppose consumptive use is to be determined for month of July. From the above table the factor for July is 0.74. Average mean monthly temperature for July in degrees fahrenheit is 94.3F (Tables are available for temperatures for various areas) and the percentage total day time hours (p) is 9.68 (Tables are also available for day time hours for various locations). The factor (f) for July for cotton would be equal to 94.3x9.68/100= 9.132. The consumptive use for cotton for the month of July would be 9.132x.74= 6.75 inches.

Similarly the seasonal factor (F) for cotton is .78 (as shown in the table above) for the period 15th May to 15th November. The consumptive use for this period is worked out as below :

Month	Temperature (mean)	% total day light hours.	Consumptive use factor (f)
1.	2.*	3.*	4.=2x3
May	91.75	9.545	4.378 (50%)
June	97.1	10.490	9.216
July	94.3	9.68	9.132
Aug	92.4	9.228	8.530
Sep	89.5	8.336	7.456
Oct	81.6	7.982	6.514
Nov	70.6	7.184	2.034 (50%)
		Total F =	47.260

Consumptive use for the season= 47.260 x .78 = 36.86 inches.

* Figures have been taken from Tables which are available.

2.5 METHODS OF IRRIGATION

Generally the following methods of irrigation are practiced:

- Basin irrigation
- Furrow irrigation
- Furrow cum basin irrigation
- Sprinkler irrigation
- Drip or trickle irrigation

These methods are briefly discussed below:

(A) Basin Irrigation

This method is most widely used in Pakistan. This method consists of rapid application of water through a water course to a level area which is completely enclosed by small dikes provided to retain water at a relatively uniform depth over the enclosed area. If the field is not level, the depth of water will be more on deeper points and less at higher points. In the beginning of crop growth; when plants are smaller, less water is required. Later when plants have grown bigger, greater depth is needed. The total depth of water given to a crop from start till maturity is called the delta of that crop. It varies from crop to crop and depends on soil and climatic condition.

(B) **Furrow Irrigation.**

In this method long furrows (sometimes 500 ft. long) are made in the field at right angles to the water course. A ridge separates the furrows from the water course and the furrows do not communicate with each other. Water to the furrow is supplied by small pieces of PVC flexible pipe (usually 1 to 1.25" in dia) through a syphon action. The farmer dips one end of pipe in the water course and sucks water from the other end with his mouth. When the pipe is full of water, he places that end in the furrow. In this way water starts flowing into the furrow which is sloping towards the lower end. When the water reaches the tail end of the furrow, the pieces of pipe are removed. Several pipes work simultaneously so that the inflow into the water course is equal to the outflow from the pipes into the furrows. This method is particularly useful for vegetables. The application of this method results in considerable water savings.

(C) **Furrow-cum-Basin Irrigation.**

In this method initially furrows are made as described above. The first three or four watering are done as usual when the plants are small and their water requirements are smaller. Later the furrows are made to communicate and the fields are flooded as basin irrigation. This method is suited for large sized crops such as maize, jwar and bajra.

(D) **Sprinkler Irrigation.**

In this method the water is sprayed into the air by pumps and allowed to fall on the land like rain. There are three types of sprinkler systems in use: (a) rotating sprinkler head (b) fixed jets end and (c) perforated pipes. Rotating sprinkler systems are more widely used. Portable or mobile systems are preferred as these can be moved from field to field. The rotating sprinkler head applies water to a given area for certain period. When sufficient irrigation has been done, the rotating head is moved to the next area. The efficiency of this method is above 75%. Sprinkler irrigation is adversely affected by intensive heat and high winds. It is better suited for colder climates and springs/tubewell water which is devoid of sediments.

(E) **Drip or Trickle Irrigation.**

This method is suited for fixed root plants like orchards, grape vines or gardens and requires sediment free water. The spring or tubewell water is passed through a sedimentation tank to remove any traces of fine silt. It is then pumped to an elevated reservoir from where water flows to the plants through flexible PVC pipes. Close to the root zone of each plant, an emitter is inserted. From this emitter water trickles drop by drop close to the roots of the plants. The rate of falling drops can be adjusted. This method results in water savings and is very suitable for areas where water is a scarce commodity. Additionally, this method is very suitable for areas where land is undulating and land levelling is not feasible.

2.6 GENERAL OPERATING PROCEDURES FOR SOME CANALS IN NWFP.

Operating procedures for the following canal systems are enclosed as Exhibits II-1.1 to II-1.6.

A)	Tanda Dam	(enclosed as Exib. II-1.1)
B)	Upper Swat Canal	(enclosed as Exib. II-1.2)
C)	Lower Swat Canal	(enclosed as Exib. II-1.3)
D)	Chashma Right Bank Canal	(enclosed as Exib. II-1.4)
E)	Baran Dam	(enclosed as Exib. II-1.5)
F)	Kabul River Canal	(enclosed as Exib. II-1.6)

2.7 DELIVERY MODES.

Operation deals with the delivery of water to the watercourses and not directly to the farmers. There are many operating strategies or delivery modes that are used in irrigation systems. These include:

* Continuous flow
* Proportional flow
* Rotational deliveries
* Demand deliveries

All of these strategies can be used at one time or another in the seasonal operation of an irrigation system or sub-system. No one strategy works all the time and they all require continual changes or adjustments. The operation of a run-of-river system wherein the river flows are in a continuous state of change, increasing or decreasing, is a difficult and challenging undertaking. The time that a river will maintain a constant flow is always short unless supplemental flows are available from a reservoir. The operating modes or strategies, as defined in terms of the canal systems in the NWFP, are as follows:

(A) Continuous Flow - When there is enough water in the river, all the canals run continuously up to their designed discharges. This is generally possible during the summer months.

(B) Proportional Flow - When the flow in the river is not enough to run the main canal to its authorized full supply demand, all the canals are supplied water by proportional discharges but not less than 75% of the authorized discharge so that all canals share shortage equally.

(C) Rotational Delivery - This method is used during periods of low flow. The available water is delivered to one or more distributary canals for a certain period of time (preferably multiple of seven days). Thus a canal runs with full supply discharge for some time and is closed for the rest of the time.

(D) **Demand Deliveries** - This refers to the SDO's or WUA's right to request additional amounts of water or to ask for a reduction in delivery to a distributary canal. The request for additional water is honored provided water is available and the canal is capable of carrying additional discharge.

2.8 INSTRUCTIONS FOR THE GUIDANCE OF NWFP CANAL OFFICERS IN THE PREPARATION AND MODIFICATION OF WARABANDIS.

These instructions are intended for the guidance of the canal officers for fixing turns and duration of watering by the farmers in NWFP. Irrigation Officers generally interfere as little as possible in the internal distribution of water on water-courses. When disputes arise, they endeavor to persuade the parties to settle the matter by mutual agreement, or if a panchàyat has been instituted in the concerned village, refer the matter to that body. The following general instructions are intended for the guidance of officers in cases where official interference cannot be avoided.

A. Procedure.

Canal Officers have no power to interfere in the internal distribution of water on a water-course except under Section 68 of the Canal and Drainage Act of NWFP. This section gives power to Divisional Canal Officers only, and not to officers of higher or lower rank.

- The Divisional Canal Officer may only take up a warabandis case on receipt of a written petition, bearing a court fee stamp of one Rupee from one or more of the share-holders, stating that a dispute has arisen regarding his rights in respect of the use of the water, and detailing the matter in dispute.

- Once in receipt of such a petition, the Divisional Canal Officer must take up the case. His enquiry must be confined to the matter detailed in the petition, and the preparation of a complete new Warabandi can only be undertaken when the petition is so worded as to justify this. In order to avoid useless work, it is advisable that the petition be carefully studied before the case is taken up. If the petition is not suitable it should be filed and the petitioner informed accordingly.

- The wording of Section 68 should not be taken to mean that the whole enquiry will be carried out by the Divisional Canal Officer in person. The preliminary enquiry and preparation of the warabandi or modification thereof will be carried out by the Zilladar under the supervision of the Deputy Collector. This, however, should not result in petitions being dealt with tardily. Cases of preparation and modification of warabandi should be dealt with by all concerned as expeditiously as possible. Strong disciplinary action should be taken against those found guilty of delaying the disposal of warabandi cases.

B. The Ownership Column in Warabandi Cases.

The "ownership" column in warabandi cases must be verified by the Civil Patwaris (who have orders to do this as promptly as possible) before the Divisional Canal Officer hears the case. Before passing orders on the proposed warabandi or the proposed modifications, the Divisional Canal Officer must hold an enquiry as laid down in Section 68 of the Act. A notice must be issued to all the shareholders of the water course by the Divisional Canal Officer fixing the date of the enquiry (for which 14 days clear notice should be given), and stating the subject, time and place of the enquiry in accordance with the procedure laid down in rules 79-A to 79-I of the Act.

C. Case Hearing.

At the enquiry the Divisional Canal Officer should explain the proposed warabandi to the share-holders present, and should then hear and record any objections raised thereto. The enquiry should then close.

- The Divisional Canal Officer's decision in the case should subsequently be issued in the form of an order under Section 6 of the Canal Act. The order should be in the form of a judgement. It should record the alteration desired in the petition and include an indication of the objections that have been accepted or overruled, giving reason in each case. A copy of the warabandi as modified should accompany the order.

- The order should be announced to the share-holders by the Zilladar personally and a copy handed over to the Lambardar. Any other copies required by share-holders should be supplied on payment of the usual copying fee.

D. Change of Order.

An order of the Divisional Canal Officer under section 68 can only be set aside by a decree of the Civil Court. It can, however, be altered by the DCO or his successor in the event of a different dispute arising and a written petition to this effect being received, upon which a fresh enquiry will be instituted under section 68, Canal Act.

E. Method of Framing a Warabandi.

Warabandi should be framed in accordance with the following principles. When alterations are proposed, the principle to be followed should be the conditions desired by the majority of the share-holders, subject to protection of the interests of the minority.

F. Period of Rotation.

The period of rotation of a warabandi may be fixed as;

(i) An integral number of days

The numbers most usually used are seven and ten.
The former has the advantage, that, when operation is continuous, a share-holder's turn always occurs at the same time on the same day of the week. The rotation length should conform with district practices. They must be suitable for use with the rotational periods of the canal concerned.

Example: The Divisional Canal Officer may frame two Warabandis, A & C, one offsets the other by 12 hours so that one Warabandi is operative in one year while in the following year the dated Warabandi is offset by 12 hours. The Divisional Canal Officer can order a change to take place from 1st Monday of April or October of each year.

(ii) An odd number of half days:

A disadvantage of the integral number of days is that in continuous operation it affords no relief from turns occurring at night. This is avoided by this method.

(iii) From the size of the chaks:

In this case, the turns are calculated from a fixed time allowance per unit of area, usually 12 hours per square. This system has the disadvantage that, in the case of very large or small chaks, the water received during a turn may be more or less than is suitable for single watering.

G. Operations.

Operation may be either:-

(i) Continuous, i.e., the turns are considered to be operative whether water is present or not. In this case the turns occur at regular intervals.

(ii) Non-continuous, i.e., operative only when water is available.

The latter system is preferable if the share-holders are sufficiently united to operate it amicably. Where disputes are likely to occur, responsibility is more easily fixed under the former system.

H. Order of turns.

The turn orders should be laid down in accordance with one of the following systems:-

(i) Down the water-course, i.e., in order of distance of the offtake from the outlet. In this case, the order proceeds down the main water-course to the head of the first branch; then down the branch before continuing down the main water-course. The situation is similar with regard to the sub-branches.

(ii) Round the water-course, i.e., down one bank and up the other, branch being treated as in (a) above. This latter system has the advantage that it distributes lead (distance between two outlets) and nikal (the amount of supply left in the W/C in between the outlet in use and the outlet to be used next) more evenly, but the former system is generally preferable as holdings usually lie on both sides of a water-course. Where two or more holdings are served by off-takes close together, and lead or nikal is of importance, the order of turns should alternate between the holdings.

I. Length of turns.

The length of turns should be strictly proportional to the area of the units. Variation should not be permitted on account of variations in soil and should only be allowed on account of the level of the land in exceptional circumstances.

J. Plan of chak

The sanctioned warabandi should be accompanied by a copy of the shajra which indicates the water-courses, the established off-takes, the nakkas and the boundaries of the units.

K. Form of warabandi

The warabandi should be arranged in tabular form showing the following columns:-

(i) Order of turn.
(ii) Field number comprised in unit.
(iii) Name of share-holder.
(iv) Areas of units.
(v) Length of turn in strict proportion to area.
(vi) Any additions or deductions.
(vii) Length of turn allotted.
(viii) Remarks: in this column "any additions or deductions" as per column 6 and any orders for "nikal" will be made, and every such entry will be signed and dated by the Divisional Canal Officer.

The method of operation laid down should be noted on the form. When the period is seven days and operation is continuous, the day and time of commencement of turn may be substituted for 7.

2.9 MONITORING.

Monitoring is the constant observation of what is occurring or happening in the system. This is carried out in several ways; daily observations by canal officers and operating personnel, inspections conducted by various levels of command personnel and by keeping detailed records of discharges, water surface elevations and area irrigated. Following are important items of monitoring.

- **Inspection by Officers**.

Inspection of canals by officers is an important aspect of monitoring the system. Inspections reveal what has been accomplished and what is wanted. The inspection reports are the basis for making evaluations and work programs. Inspection trips also indicate what is happening and what corrective action is required to rectify any malpractice.

- **Daily Gauges and Discharges of Channels**

The SDOs and the XENs daily get telegraphically gauges and discharges at the heads of channels under their charge. This indicates whether the channels are being run according to their authorized discharges. They also receive the tail gauge readings of all distributaries and minors. These gauge readings show the quantity of water reaching the channel tail. Generally the tail clusters are designed for one foot of head of water over their crests. Thus if the tail gauge is less then 1.0, the water reaching the tail of the channel is not according to designed discharge.

- **H. Register**

The Sub-Engineer is required to monthly observe the actual depth of water above the crest called (H) of every outlet under his charge. These observations are recorded in a special register (called H Register). Also the working head of each outlet is observed. This register is submitted every month to the SDO who after due scrutiny makes entries in his own H-register. The SDO sends his register to the XEN for examination and completing the H-register maintained in the Division. The instructions for maintenance of the H-register along with the format are given in Exhibit II-2.

- **Irrigation Register**

Every SDO is required to maintain an irrigation register by the outlet as well as by the village (Exhibit II-3). The patwari sends the information about irrigation to the SDO at the end of each crop season i.e. Kharif and Rabi. These figures are also communicated to the XEN. Comparison of these figures with the previous year will show improvement or deterioration of irrigation on any particular outlet or channel. Causes for deterioration can be investigated and remedial measures can be taken by the XEN.

- **Outlet Register**

The Outlet Register gives the sanctioned discharge. Discharge of each outlet is based on the full supply factor intensity of irrigation and CCA. It also monitors all sanctioned alterations. Instruction for maintenance along with the format are shown in Exhibit II-4.

- **Operation of a Channel**

To complement the operating water surface profile, the Register of Sanctioned and Regulated Flows has been prepared as shown in Table II-4. This table shows the discharges at the various points in the channel. This information indicates the equitable distribution of water through the outlet for Ormar Minor.

A. OPERATION OF CONTROL STRUCTURE.

XEN has the responsibility for the operation of regulation control structures. He exercises this responsibility through the SDO, Sub-Engineer and Signalers. The XEN receives daily gauges and discharge records for all channels under his charge. If he wants to make any changes in the discharge of any channel, he issues a canal wire to the concerned SDO and Sub-Engineer. The latter instructs the gauge reader in-charge of channel through the Signaler or Telephone Operator for compliance of the XENs instructions.

Full time attendance of the gauge reader is required at all control points where two or more distributaries takeoff. One or two Beldars assist the gauge reader in the performance of his duties. There is a signalling station or a telephone office close to the regulation point. The secondary regulation control points where there are offtakes from distributaries, do not have full time regulation staff. The offtaking channels operate in proportion to the changes in water levels upstream of the regulators. Such regulators are called "proportionate regulators."

B. MAINTENANCE OF GAUGE REGISTER.

For each regulator where a gauge reader is posted, a gauge register must be maintained. Daily morning and evening (timings should be given by officers) gauge and discharges should be noted for the parent channel (both u/s and d/s) and the offtaking channels. A file containing instructions issued by the XEN, SDO and Sub-Engineer is maintained. Time of receipt of instructions should be noted in the register. All officials who inspect the canal and regulators should sign the gauge register. Problems with the gate hoists and other equipment should be noted in the register and brought to the notice of the inspecting officers. The dates for greasing of hoists and gears should be noted in the gauge register.

C. FLOW LIMITS.

The following flow limits for canals should be observed :

1. The maximum inflow should not exceed 1.2 times the designed discharge.

TABLE II-4

REGULATED FLOWS IN DIFFERENT REACHES OF ORMAR MINOR OF WARSAK GRAVITY CANAL

S. No	Side	R.D.	GCA Acres	CCA	Size	Designed Discharge	Loss	Total discharge
1	L	2640	371	371	6"	1.37	0.4	15.72
2	R	3520	294	286	6"	1.06	0.3	14.05
3	L	8425	233	233	6"	0.81	0.30	12.69
4	R	8560	301	276	6"	1.13	0.25	11.48
5	L	10200	121	115	6"	0.43	0.2	10.10
6	L	11700	312	312	9"	1.16	0.2	9.47
7	L	13260	95	95	4"	0.35	0.15	8.11
8	R	14100	378	346	7"	1.28	0.15	7.61
9	L	14200	166	162	6"	0.6	0.1	6.18
10	R	15750	100	95	4"	0.35	0.10	5.46
11	R	17000	98	95	3"	0.25	0.10	5.03
12	L	17880	98	95	4"	0.35	0.05	4.68
13	R	18290	415	390	7"	1.44	0.05	4.29
14	L	20000	186	184	5"	0.68	0.02	2.79
15	R	21200	425	411	6"	1.52	0.00	2.08
16	L	21200	182	153	3"			

GCA. Gross Consumable Area
CCA. Cultural Command Area

2. Under no circumstances, the designed free board should be encroached more than 50%. If the limit of running of a canal at 1.2 times the designed discharge reduces the free board to less than 50%, the flow limit should be reduced.

D. CANAL FILLING AND DRAW DOWN.

Except for emergency conditions, the discharge in a canal should never be changed rapidly. A rapid rise or fall in the water level of canal is the major cause of berm or banks caving of main canals and branches. On the basis of experience, rates of rise or fall for different canals are about 10% increase or decrease in discharge in three hours. Sometimes flows are adjusted every six hours with the change limited to 20% of the total change in flow.

E. USE OF KARRIES AND NEEDLES FOR REGULATION.

Karries:

Horizontal wooden logs usually 5-6 inches square sections. These are inserted in slots located in the piers. Their length is generally limited to 10 ft. They are fitted with steel bars at their ends so that these can be lowered or raised under water with special forks having wooden handles.

Needles:

Vertical wooden logs which are placed side by side across the width of regulators. The crest of the regulator is raised so that the lower end of needle rests against it and the pressure of water holds them in position. The purpose of karries or needles,(stop-logs), is to raise the u/s water level so that the discharge into the offtaking channels can be increased or decreased. Karries do not allow small changes in water level such as 6 inches or less. Another disadvantage of Karries is that they cause sedimentation u/s and offtaking channels do not carry proportionate quantity of silt particularly if the angle of incidence of offtaking channel is larger. If water is proposed to be lowered with karries, then the karries in the central bay should be pulled out. This allows higher velocity water to remain in the center and thus eddies formed in the tail water pool remain away from the banks. However, if it is proposed that the water level be raised, karries should be placed in the abutments. There is leakage of water between the karries. This can be controlled by placement of mud or dry cow dung in the leaks.

Needles are used in combination with bridges. The bridge deck provides an easy work surface to work from. Needles should be placed in the canal starting at both banks and working towards the center. This keeps the flow pattern more uniform in the tail water area. An advantage of the needles is that they allow an infinite number of adjustments of the water level. A disadvantage with the use of needles is that they collect floating trash in the bays. This has to be removed with a cleaning form, very often, daily. The use of karries and needles is relatively an easy and cheap way of regulation. Establishment of a stage-discharge relation, however, is a problem with the use of these devices.

F. PERFORMANCE STANDARDS FOR CANAL OPERATIONS.

Performance standards have been established to provide the SDOs, SBEs, gauge readers, etc., with definitive standards by which the canals must be operated. The performance standards are presented in Exhibit II-5. These standards were prepared originally for rehabilitated canals but should be applied to all canals. The only standard that will be difficult to establish on non-rehabilitated canals would be the Standard which concerns freeboard encroachments. Since majority of canals are operated with normal discharge in excess of the design discharge for at least a part of the year with almost no freeboard, a different criteria must be used. The XEN should revise Standards to fit his individual system until the freeboard can be re-established. Without such a standard, minor mistakes in operation can easily cause a breach. The most appropriate method would be to limit upstream water surface elevations at water control points.

G. EMERGENCY CONDITIONS.

The XEN must establish written instructions covering all personnel in the division, their responsibilities and the actions that should to be taken in emergency situations. It should include who is to be notified and in what order; what physical steps individuals should take; for example, gates to be opened or shut or how to be controlled; how to communicate to higher authorities including where to reach a signaler or telephone; how to warn local population of breach and water dangers; mobilization of work gang(s), equipment, materials etc, in order to effect rapid repair and other items required to end the emergencies and provide for the health and safety of the people. Exhibit II-6 is an example of Emergency Instructions for a branch canal system (Lower Swat Canal in NWFP). Similar instructions can be issued by the XEN for necessary steps to be taken by SDO and the Sub-Engineer in case of a canal breach.

H. FACILITIES.

i. Communications.

About seventy years ago (around 1914) a Telegraph network was installed for the NWFP Irrigation Department communication between its canal stations and officers. It linked the canal stations of Northern Irrigation Circle and Central Irrigation Circle. This system consisted of a land line, ground return type, on which messages could be exchanged by Morse-key telegraph by the very old method of key and sounder. It comprised a single G.I Wire insulated with common porcelain, telephone pin insulators and hung on 20 feet poles at intervals of 500 feet. At each canal station grounding of telegraph/telephone lines was provided with a ground wire dug below ground level. The hole in the ground was filled with brine solution.

Each of these stations was equipped with equipment consisting of a single current Morse-key and sounder in a single Box connected to a line DC power supply and earth. The Morse key was used to transmit messages in Morse Code and the sounder which clicks out incoming messages i.e. it gave an audible indication of Morse Dots and dashes. This arrangement (known as simplex sounder circuit) provides facilities for station "A" to communicate with station "B" or vice versa but not simultaneously. Some stations which had more than one incoming and outgoing line, called junction stations, (e.g. Charsadda, Mardan, Hamzakot, Gohati, Dargai) contained two or more sounder circuits. When any station had to establish communication with another, the signaller (or Tar Babu as he was called in the Irrigation Department) at the calling station operated his key and transmitted the message. All stations got the signals by the clicking of their sounders. The called station were distinguished by a letter code (for example SWI for Swabi). The called station Signaller responded and took down the message.

The major function of the canal telegraph was to transmit gauges, operational and administrative messages between various offices of the Irrigation Department including Chief Engineers offices at Peshawar, Superintending Engineers office at Peshawar and Mardan. Other stations were located at Charsadda, Noshehra, Hathian, Khaki, Harichand, Narai, Ziam, Abazai, Dargai, Topi Jaggannath, Lahore Jalbai, Tour, Shahbaz Garhi and Zaida.

This system is now decidedly infested with innumerable problems and inadequacies which can not be overcome under the prevailing circumstances. It is, therefore, pertinent to devise a new system which should not suffer from these shortcomings. This is only possible by using radio as the transmission medium. Such a system is needed for Southern Circle. The ISM I Consultants looked into this problem and they submitted a report in June 1988. Their recommendations are presented below:

Recommendations

The present telecommunication system of the NWFP Irrigation Department is inadequate, worn out and unreliable. It needs to be replaced by a more effective one. For this it is recommended that

1. Optimum use of the existing telephone system should be made. All those controlling stations which are covered by national telephone network should have a telephone facility. Efforts should be made to connect main operational centers through micro wave network.

2. Initially, radio-communication equipment should be provided to supplement the existing telegraph equipment. The objective should be to gradually phase out the telegraph system.

3. As a first step, radio communication should be adopted for the north-east canal system. If this is successful, it should be extended to the southern canal system.

4. Field stations do not need point to point wireless linkages and these should have communication connection only with controlling offices.

5. Long distance communication should be by telephone. Most of the main operational stations are already connected through a micro wave system and there appears to be no urgent need of setting up a separate radio communication network for the Irrigation Department.

6. If required, equipment for long haul traffic may be installed in the main operational centers but this should be after the initial experimentation at the field level.

7. A senior officer, of at least XEN status, should be designated to look after the entire telecommunication system of the department.

8. Signalers who have been operating telegraph stations should be provided training to operate the new equipment. Training arrangements could be made with the Training School of the Telegraph & Telephone Department.

9. The Wireless-Set mechanics should be employed and each of them be stationed at the concerned Sub-Divisional Office. These mechanics would provide technical services for the equipment within the specified area.

10. It is estimated that the proposed improvement would cost 5.6 million rupees. About 1.1 million rupees would be needed to improve telephone facility and 4.5 million rupees to adopt a Wireless system.

ii. <u>Transportation</u>

Irrigation systems operated as continuous flow systems do not have high transportation requirements provided a communications network exists. The operation does not require much day-to-day change in the flows. Consequently the changes made to various distributaries and minors can be effected by telegraph. Only during emergencies or perhaps heavy rainfall periods would transportation needs increase. Transportation is more critical for maintenance and enforcement. Currently, most XENs have access to a vehicle for official transportation needs. Some of the SDO's are also provided with official transport. The remaining ones have mostly made private arrangements. Sub Engineers have access to motorcycles for the most part which makes them mobile. This allows these individuals to travel to their superiors office as well as having the ability to inspect their areas of responsibility. Transport at this level is extremely important for enforcement of regulations as it allows the canal officers to move rapidly about their areas. Making the SBE mobile will improve the degree of equitability the system can provide. The Sub Engineers are responsible for monitoring the canal water surface levels at each outlet and water control point. He makes a larger number of field visits and takes measurements. If the water surface at the control points is where it should be, the outlets will receive their proportional share and this would result in equitable distribution of water.

OPERATION OF TANDA DAM

EXHIBIT-II-1.1

Operation of tanda Dam Project is simpler than Kurram Garhi Irrigation Scheme. In an earlier chapter the main parameters of the project have been given and an operation schedule could be framed in the light of what has been said. The important point in the operation of the scheme is

- to ensure maximum diversion
- a proportioning of Rabi and Kharif releases
- a thorough knowledge of demand at any given time by field studies.

These three factors should ensure the maximum use of available resources not only by conservation but also through judicious release.

A) **Operation of Barrage**

The following sequence of operation is recommended:

i. The extreme two left bays of the barrage be kept fully open.

ii. All the other bays of the barrage are kept closed.

iii. The lower gate of canal head regulator be kept in a position to provide the maximum sill height, i.e. in its upper most position.

iv. The upper gate of the canal head regulator be kept at the pond level.

As the flood arrives the extreme left bays will be closed to an extent that the pond level is achieved. Should the pond level start rising above the prescribed level of 1839.92, the lower gates of canal head regulator should be lowered. If the pond level should rise even after the lower gate has been fully lowered it indicates a flood higher than 3000 cusecs and accordingly manipulation of under sluice and other gates be done to discharge the excess flood. The idea behind keeping the extreme left gates open and the upstream spur which is existing, is to reduce the bed load entry. The spur deflects the flow to the left and the closure of the left gates deflects the flow to the right making it flow somewhat parallel to barrage. The model tests indicate that the bed load entry is considerably reduced by this method. Needless to say that when the flood exceeds 3000 cusecs and the intake tower located upstream there is excessive still deposition. This intake tower containing grooves for putting stop logs and also houses the bulk head gate. At the downstream end of the conduit is a radial gate with hoisting arrangement for its raising and lowering. Releases from the reservoir are to be done strictly in the following sequence:-

i. The upstream bulkhead gate would be used only in case of emergencies or for the purpose of inspection of the tunnel; otherwise it shall be <u>always in full open position.</u>

ii. Regulation of discharge would be done by operation of the downstream radial gate. <u>This would also include complete closure of the tunnel at a very slow spend.</u>

iii. When the tunnel is empty special precautions would be taken to fill the tunnel with water <u>at a very slow rate.</u>

The sequence of operation would be:-

a) The tunnel is empty and both upstream and downstream gates are in the closed position.

b) With a very small opening of the upstream gate, allow about one cusec flow into the tunnel.

c) Wait for sufficient period till the tunnel is full of water.

d) Open the upstream gate fully.

e) Open the downstream gate slowly for the required discharge.

iv. The downstream radial gate should always be operated at a very slow speed. From water hammer considerations, the minimum time should not be less than two minutes for decreasing the discharge from 260 cusecs to zero or vice versa; but the actual increase or decrease in the discharge should be much slower involving considerable time to avoid any damage to the canal system and shall be in accordance with the irrigation practices.

B) <u>**Dam**</u>

An exhaustive Note regrading the observations to be made on the dam has been supplied. Needless to say that after every storm, the upstream rip rap should be thoroughly examined for any settlement or dislodging of rip rap. Close watch must be kept for any springs that might occur in the vicinity of the reservoir.

All the gates are manually operated and enough fexability has been built at barrage site to cater for the needs of regulation staff. As water is very precious, the diversion of the maximum quantity available is a factor not to be ignored. Actual experience will show the best mode of operation conductive to the maximum diversion.

C) **Canals Operation**

When the scope of irrigation was revised from 15000 to 32,000 acres it was natural for the cropping intensity to get reduced. The original scheme had conceived a cropping intensity of 175%. The revised intensity is estimated at 150%. However, it is likely that 150% may not be possible except in wet years. In an average year it might be of the order of 140 to 145%. The new design is based on Kharif-Rabi ratio of 60:90. The water requirements as worked out according to this intensity and the given cropping pattern. It may be remembered that this intensity assumes the full utilization of the water from Kohat springs in the canal system. Also it may be noted that for a given quantity of water and area, the intensity of cropping is a function of the cropping pattern alone. If the deviations from the assumed cropping pattern are abnormal, the same fact will be reflected in the intensity also. This table gives the kharif and rabi releases required for a 1000 acre. Purposes of release operations, keeping in view the water available at a given instant. We have already stressed the desirability of keeping the kharif ratio low. This fact may kindly be kept in mind.

D) **Releases from the Reservoir**

The arrangements for releasing water from the reservoir into the canal system is located in the right abutment of Tanda Dam. This arrangement consists of a circular conduit.

Exhibit-II-1.2 & II-1.3

OPERATION OF UPPER AND LOWER SWAT CANAL SYSTEMS IN N.W.F.P.

A. THE SYSTEMS

The L.S.C system was completed and put into operation during the year 1885. The canal has been designed for a discharge capacity of 830 cfs to irrigate an area of 1,34,586 acres in Mardan and Charsadda Districts. The aggregate length of the system is 176.50 miles with a main canal 22.38 miles in length. The canal receives its supplies from Swat River with its head works at Munda. It extends irrigation facilities to vast areas in Charsadda and Mardan Districts.

The U.S.C. system was put in to operation in 1914 and provides irrigation facilities to an area of 2,76,100 acres in Malakand Agency and Mardan, Swabi, Charsadda and Peshawar Districts. Two hydro-electric power plants, each with a capacity of 20 MW, are also in operation on U.S.C at Jabban and Dargai. The main U.S.C bifurcates at Dargai, into two branch canals, i.e Machai and Abazai, with a discharge capacity of 1348 cfs and 395 cfs respectively. Due to constraints imposed by the Benton tunnel, the actual discharge capacity has not exceeded 1800 cfs since the inception of the system. For the purpose of maintenance & operation, the organizational structure comprises two irrigation divisions at Malakand and Swabi, each under the charge of an Executive Engineer. Malakand Irrigation Division is responsible for maintenance of the main canal, Amandara H/Works and other training works on the Swat River and Abazai/Machai branches upto RD 101000. The rest of the system, i.e, Machai Branch with all off taking Distys D/S of RD 101000 is under the maintenance responsibilities of Swabi Irrigation Division. Malakand Irrigation Division is further sub-divided into two Sub-Divisions, i.e, Dargai and Malakand, whereas Swabi Division comprises 4 Sub-Divisions, i.e, Shahbaz Garhi, Gohati, Maira, and Pehur. The latter, i.e., Pehur Sub-Division is looking after another independent system called, the Pehur Canal, drawing water from Indus River at Turbela by means of electric pumps.

B. LOWER SWAT CANAL

For the purpose of operation and maintenance, the organizational structure comprises one Irrigation Division, headed by an XEN, with two Sub Divisions at Mardan, and Charsadda; each under the charge of an Assistant Engineer, usually designated as a Sub- Divisional Officer. Mardan Sub Division has been further subdivided amongst 3 Sub Engineers. Similarly Charsadda Sub Division, for purpose of L.S.C., comprises two sections, i.e., Abazai and Utmanzai, whereas a 3rd section is operating to maintain an independent lift scheme, i.e, Khashghi. In addition to engineering staff for maintenance, the division is divided into five revenue sections, each under the charge of a Zilladar. Each section has about 5 to 8 patwaries, depending upon the extent of commanded area. All the revenue staff, including Patwaries and Zilladars, work under the instructions of Deputy Collector. He is responsible to Divisional Officer, i.e, XEN on Divisional level. The revenue staff is primarily charged with the responsibilities of preparing a record of the Irrigation carried out and the assessment of water charges to be levied on the irrigated area. The revenue staff also prepares a warabandi (or a schedule for watering to be strictly observed by the Shareholders) for an outlet which is the basic record indicating water allocation to all land owners.

The present system of scheduling water deliveries to farms is based on 24 hours of canal operation, i.e., continuous supply in all the channels unless a change is desired due to climatic requirements or due to damages to canal banks, structures etc, in monsoon. According to the fixed warabandi system, both on the L.S.C. and the U.S.C. systems, a land owner is entitled to receive his share of water through a warabandi slip issued to him by the Zilladar. The quantity of water allocated to him in the warabandi remains unchanged unless he himself transfers his land wholly or partly or an additional area is accommodated in the outlet chak which would naturally affect every share holder. The fixed warabandi system requires the Irrigation Department to operate the canals 24 hours continuously irrespective of the nature of crops grown under a particular outlet, i.e., the discharge authorized to an outlet will continue to be delivered round the clock irrespective of the nature of crop grown by farmers. This system has one main disadvantage, i.e., continuous fixed supply has to be arranged regardless of the area and as such the maintenance staff cannot divert supplies to any other area, with high water demand for the crop grown. At the same time the farmer has to adjust the cropping pattern with his given turn of water. During the past one hundred years of canal operation the cropping pattern has developed to a stage where no further change is possible unless the deliveries are improved as envisaged under Mardan Scarp. The concept of water deliveries under Mardan Scarp would drastically change, i.e., irrigation water will be delivered on proper demand placed by the land owners and the supplies in canals (which previously used to run continuously) would now be arranged to meet the actual crop water requirements. The question arises whether a farmer, who had to follow a restricted cropping pattern with limited allocated turn of water in warabandi, will now follow the planned cropping pattern if the option for increasing/decreasing the discharge in canals wholly rests with him and that he would grow more water consuming crops within the prescribed limits.

The availability of water in Swat River at Munda Head Works is adequate year round to meet the present requirements with the existing canal capacities. After remodelling of the L.S.C. system under Mardan Scarp, the water availability in the river will fall short of the canal capacity during the months of November, December and January. Due to reduced demand for irrigation during the winter months, however, the crops will not suffer.

Under the existing system of water deliveries to water courses, the gauge reader (the official who keeps record of the daily discharges/gauges etc) maintains a daily record of gauges fixed at head and tail of each canal disty & Minor. Water courses (which are outside the maintenance responsibility of Irrigation Department) do not have gauges installed. The outlets, drawing water from a canal or a disty, function as proportionate modules, i.e., the discharge drawn is dependent upon the W.S.L. in the parent channel but is not influenced by W.S.L. in the w/course. The gauge reader on receipt of instruction from Sub Engineer incharge, reduces/raises, supply in a particular disty by referring to a discharge table wherein gauge vs discharge are listed a decimal of ft. called HISSAS by the field staff. The discharge is increased gradually so as to attain the maximum gauge (F.S.G.) to deliver the full supply discharge. With full supply discharge at head, all the outlets on the channel should draw their full authorized share of water. The gauge reader operates the head regulator gate issuing instructions to the regulation staff responsible for operation of head regulators. Such instructions are usually in the form of a canal wire (canal telegraph issued from main office) clearly indicating the change in supply position by HISSAS. The regulations staff quickly responds to the fresh demands and manipulate the gate position to maintain the required W.S.L. in canal. A gauge reader incharge of few distys/minors or canals receivers regulation instructions from his section officer, i.e., Sub Engineer, through a canal wire which is properly kept on record. The Sub Divisional Officer is the principal officer responsible for regulation of canals and directs the sub ordinate staff to operate the system accordingly and collects information about water demand in two ways.

1. Through his revenue staff, i.e. Deputy Collector and Zilladars, who usually keep in touch with irrigators and keep themselves informed about their problems related to irrigation, warabandi, water rates, disputes, assessments and cropped area.

2. The Zamindars (land owners) who visit the sub divisional head quarters as a delegation and place their demands for irrigation water.

Since the revenue staff members reside at their place of duty (usually the canal rest house) they are well informed about the crop water demand or rainfall in the area. normally they place indent for increase/decrease of the canal head gauges in their respective areas. Such demand for water is intimated to Sub Divisional Officer through a canal telegraph. He works out the net demand at head of the main canal or the Disty. The L.S.C. system is divided into two Sub Divisions, Mardan & Charsadda for maintenance purposes. It is controlled at the head and at RD. 84000 where the supplies off take to Mardan Sub Division. Mardan Sub Division is responsible for Disty 7,8,9 with their branches. The system is metered daily. The S.D.O., Mardan Sub Division, after collecting information from his revenue staff or land owners, works out his net demand and reports the gauge required at RD 84000 (main canal) to S.D.O.

Charsadda who is incharge of the main canal head regulator. He regulates the canal supplies at head, taking into account, demand for his Sub Division, i.e., channels 1 to 6. Reduction in supplies are made in the case of wide spread rains with the mutual consent of both the S.D.O's. The XEN is the overall incharge of the Division. He is responsible for the smooth running of canals and occasionally checks the head gauges of a disty, main canal or deliveries to tail areas. He is also informed by representatives of irrigators about any shortage of water in tail areas, in which case he issues instructions to the regulators of canals. More attention is required in the case of a sudden cloud burst. Sheet flow may enter the canals and cause damage to banks and structures. If the communication lines are functioning, the SDO incharge immediately contacts his Sub Engineer and issues directions to reduce supplies by escapee at required locations. In case of disruption in the communication lines, the field regulation staff, on the basis of their past experience, judgement & skill, reduces the canal supplies immediately and restores it in fair weather conditions.

The smooth operation & functioning of canals is largely dependent upon extensive touring of field engineers, i.e., XEN, SDO and Sub Engineer. They may spot any serious problems with canal operation when they inspect weak banks, faulty structures & worn out gates which are likely to get stuck during operation. With this objective, in British period, canal rest houses were constructed at appropriate locations to facilitate frequent inspections of canals. A canal officer, as a part of his duty, was required to stay at a rest house for a few days in a month. With the passage of time conveyance facilities have improved and the patrol roads along canals (either metalled or shingled) enable the officers to make detailed inspection in a short time. Thus, more time can be spared for other duties such as planning canal improvement works or required maintenance programs.

C. UPPER SWAT CANAL

In the command area of the Upper Swat Canal, the deliveries to various canals, disty, branches or minors are arranged by the field staff in a manner as described above for L.S.C. The U.S.C. which offtake in the upper reaches of the Swat river (at Amandara) experiences more shortages as compared to L.S.C. thus necessitating careful regulations so that the shortage of water is proportionately shared by each Disty and minor under the system. The shortage period (when the availability of water in Swat River at Amandara falls short of requirements) lasts for about five months, usually from mid October to mid March, depending upon the weather conditions. During the summer the canal can be operated at full capacity and deliveries to all distys and minors arranged to meet the optimum requirements. The availability of water in Swat River starts declining in September and by the first or 2nd week of October it becomes difficult to meet the full crop water requirements.

To overcome the aforementioned problem, the Irrigation Department (since the inception of U.S.C.) has introduced a system of "Rotational Deliveries" for each irrigation division, i.e., Swabi and Malakand. This system envisages supply of water to the command areas in an irrigation division, to meet full requirements for a predetermined period, usually 10 days. To accomplish this, the XEN Malakand during the month of August every year, works out a water distribution plan on a 10-day basis called a "Program of Rotational" for turns between Swabi and Malakand Irrigation Divisions, giving a schedule for water deliveries to channels of

Malakand and Swabi. According to this schedule (which is given wide publicity as well as circulated amongst the concerned officers) channels in Malakand division are so regulated to permit full water deliveries to C.C.A. under Swabi division for a period of 10 days. During the next 10-day period the channels in Malakand Division receive their full discharge allowing only the balance of available supplies to pass lower down to the Swabi area. As experienced during the past 70 years of canal operation, this system has worked satisfactorily and there appears to be no alternative until some arrangements for water storage are made in upper reaches of the Swat River.

The entire regulation of water deliveries in the U.S.C. is controlled through a network of canal telegraph lines connecting all rest houses (usually sub engineer head office). For the U.S.C., each sub engineer places an indent for supply of water to channels in his area to his SDO, who consolidates such indents and sends a list of required gauges for all distys to the SDO incharge for regulation duty. The SDO, Dargai Sub Division, regulates the supply in the U.S.C. at Dargai according to the indents placed by the XEN Swabi for Machai Branch at RD 95,000 and Sub Engineer Dargai, Katlang and Harichad section for their respective channels. Dargai bifurcation is the controlling structure for water distribution with arrangements for escapages. The supply to a channel can be instantly reduced by escapes without any change in the supply position from the canal head at Amandara. Deliveries to the Swabi Division (U.S.C. system D/S of RD 95,000) are controlled and metered at RD 95,000. An escapeway has recently been constructed making it possible to reduce supply in case of any emergency by an escape to Katlang Nullah. A regular and daily record of the gauge at RD 95,000, Machai Branch, is being maintained as occasionally disputes arise between the two divisions about releases of water during periods of keen demand. Experience has shown that in very hot period, when evapotranspiration losses and other field losses in conveyance are at maximum, full discharge in the system can not meet the requirements and this results in shortages for tail irrigators of certain channels. In such a situations the Sub Engineer incharge of head sections on Machai branch usually resorts to excessive withdrawals to feed tails of affected distributaries but this causes shortage of water lower down on Machai branch, i.e., the system in Swabi Division does not get adequate supply to feed tails. To overcome such a problem, which usually persists for a couple of weeks in Summer, the Superintending Engineer has to intervene to maintain a balance and to follow a VIA media by issuing instructions to both the Executive Engineers to maintain a decided level of gauges, sharing the net shortage proportionately. Like the L.S.C., the U.S.C. is also operating on the basis of continuous supply to all farmers regardless of the nature of crops. However, the fixed warabandi has always been a constraint, restraining the land holders to keep the cropping pattern within certain limits so as to permit proper irrigation. Thus, growing high water consuming crops such as sugar cane is practiced on a limited area keeping due provision for other crops.

The operation of U.S.C. is also influenced by two power plants, i.e., Dargai and Jabban, each with a generating capacity of 20 MW. In consultation with Resident Engineer, WAPDA, Dargai, the XEN, Malakand, has to arrange deliveries to U.S.C. at Amandara, to meet requirements for power generation. Supplies in excess of irrigation requirements in such cases are usually escaped at Dargai, allowing releases to Machai at Abazai according to indents placed by the respective field staff.

In summary, regulation of all irrigation channels under the L.S.C. or U.S.C. systems, is arranged taking into account the safety of canals and further to ensure that no excessive supply is released in any system which may cause damage to banks or structures. Past history of the two systems reveals that there been no damage due to the system of supplies being followed by the maintenance staff of Irrigation Department.

Exhibit II-1.4

CHASHMA RIGHT BANK CANAL

A. MAINTENANCE

1) General

The works shall be maintained in good order and condition in conformity with the instructions, drawings and specifications in force or that may be approved from time to time. The works either in maintenance and repairs or new works shall be carried out in due compliance of the departmental financial and technical discipline.

2) Barrage and regulators

a) Soundings:

Soundings on the floors and aprons shall invariably be taken under the supervision of Sub Engineer Discharge and Sub Divisional Engineer Headworks with a sounding rod having a metallic shoe at the probing end and graduate to 1/10th of a feet. Soundings shall be observed in accordance with the soundings plan that may be approved from time to time.

b) Barrage, Regulator floors and Aprons

Possibly after every major flood or as and when directed by the Executive Engineer Barrage and at least once during the month of September/October each year, soundings shall be taken to probe the conditions of the impermeable floors, the flexible block aprons and the loose stone apron.

c) Paharpur Feeder Canal Head Regulator

Soundings of the downstream aprons of the Paharpur Feeder Canal Head Regulator shall be taken at least once midway through each flow season and correctly determined by levelling after each flow season.

B. PAHARPUR CANAL RAISING AND LOWERING SCHEDULE

1) Opening and Raising Schedule after Stanching

The stable berms are most likely to form during the maintenance period. After this the canal be opened and raised at a faster rater to bring it to full supply level.

The following schedule will be followed based on requirements of supplies indented by Executive Engineer, Paharpur Canal Division D.I.Khan:-

a) Raise 0 to 1000 cusecs in 8 hours.
b) Raise 1000 to 2000 cusecs in 8 hours.
c) Raise 2000 to 3000 cusecs in 8 hours.
d) Raise 3000 to 4000 cusecs in 8 hours.
e) Raise 4000 to 5000 cusecs in 8 hours.

2) Closing and Lowering Schedule

Normally the operation of Head and Control Regulator gages shall be the function of down demands. However, the total closure of gates of head regulator/control regulator is required under certain circumstances. The conditions can be classified into two categories i.e. Normal Closure and Emergency Closure. The conditions for the two classifications are given below:-

3) Normal Closure

a) Annual Closure for routine maintenance.
b) Closure due to lack of Irrigation demand.
c) Closure due to inflow of sediment concentration of 500 P.P.M. This condition is expected to arise when the discharge in river Indus at Chashma is about 3,00,000 cusecs.

As a guide the following schedule is prescribed for normal closure conditions in 48 hours:

i) Lower from 5000 cusecs to 2000 cusecs in 12 hrs.
ii) Lower from 2000 cusecs to 1500 cusecs in 12 hrs.
iii) Lower from 1500 cusecs to 1000 cusecs in 12 hrs.
iv) Lower from 1000 cusecs to 0 cusecs in 12 hrs.

4) Emergency Closure

It is not feasible to determine closure period of gates of head regulator in emergency. Each emergency will be treated individually as it occurs. Emergency closure can however be affected in four hours. The gates of control regulator are required to be operated to avoid damage to banks due to sloughing.

EXHIBIT-II-1.5

KURRAM GARHI HEAD WORKS CUM BARAN DAM.

The project is located in Bannu District of D.I.Khan Division NWFP. It is a part of existing Kurram Garhi Project of which Baran Dam has a major significance. In 1949 the Department proposed to utilize the flood water of Kurram River for feeding the Civil Canals in Bannu District by constructing a weir across Kurram River and link channel for feeding the Civil Canals. Kurram Garhi cum Baran Dam project was put into operation in the year 1962. In order to have a tangible scheme, the original proposal was revised by adding the following:

1. Construction of Marwat Canal System.
2. Two hydro electric power plants on Katchkot feeder channel with generation capacity of 2 MW each, constructed at RD:1500 & 14100 of Katchkot feeder channel.
3. An earthen dam on Baran Nullah.

The upper main canal off takes from Kurram Weir and is fed through a Head Regulator and a tunnel 450 feet long and 18 feet diameter. At RD 6350 the canal bifurcates into two canals, one delivering the surplus flood water to Baran Reservoir and the other feeding the Marwat Canal. The Marwat Canal is 43 miles long and designed for 800 cusecs discharge. Four distributries also offtake from this canal. The entire system caters for the irrigation of 170,544 acres. The capacity of Baran Dam Reservoir is 98125 acre feet. Unfortunately the inflow from Baran Nullah and Kurram River has remained much less than what was assessed. As a result the highest conservation level could only be achieved twice since the construction of the dam. Now the reservoir bed has silted upto R.L.1420. This has reduced the storage capacity by 40%. The rate of sedimentation of 1750 acre feet per year is much more than the estimated figure of 1290 acre feet. Due to siltation of Baran Dam the irrigation requirements of the area are not being adequately met and the lands under Marwat Canal system are suffering from acute shortage of irrigation water.

In view of the above constraints, it has become necessary to increase the capacity of Dam by increasing its conservation level from R.L.1430 to R.L.1437, so that additional water could be stored. A feasibility study for increasing the capacity of Baran Dam under a phase I and II program was awarded to M/S NDC - EMC, a joint venture. They completed a study under phase-I and now the study under phase-II is near completion. It is hoped that with the completion of the study, the capacity of the reservoir could be increased and the problems of irrigators would be solved.

For the purpose of operation and maintenance the organizational structure is comprised of two irrigation divisions, i.e., Marwat Canal Division and Bannu Canal Division Bannu. Each is under the charge of an Executive Engineer. The Marwat Canal Division has 3 Sub Divisions, i.e.;

1: Head Works Sub Division.
2: Jani Khel Sub Division.
3: Tajori Sub Division.

However the regulation of Kurram Garhi Head Works, Upper Main Canal, Lower Main Canal, Katchkot Irrigation channel, Baran Feeder Channel and Flood Channel is the responsibility of XEN Marwat Canal Division who is assisted by a Sub Divisional Officer (Head Works Sub Division) and two Sub Engineers, i.e., Sub Engineer Head Works and Sub Engineer, Baran Dam.

It is the first and foremost duty of Marwat Canal Division to fulfill the supply demand of Bannu Canal Division according to its due share through Katchkot Channel. The surplus water, if any, is given to the reservoir through Baran Feeder Channel, which is then released in the Marwat Canal according to the requirements of the land owners. During the monsoon season releases in Marwat Canal are ensured directly from Kurram River through Right Bank Canal/Marwat Canal. Marwat Canal is a non perennial irrigation canal. The irrigation area under the command of this system often suffers due to inadequate storage in the Baran Dam Reservoir.

The Sub-Divisional Officer (Head Works) is responsible for regulation of canals and directs the staff to operate the system. A gauge reader incharge of a few Disty/Minors or Canals receives regulation instructions from his Sub-Engineer, which is properly kept on office record. The Sub Divisional Officers collect the water demand through revenue staff or the Zamindars (land owners) who often visit the office/headquarter and place their demands for irrigation water. More attention is required in the case of unprecedented rainfall/sheet flow which may enter the canals and cause damage to the structures/banks. If the telephonic system is functioning the SDO incharge immediately contacts his sub engineer and issues directions to reduce supply by escapes at required locations. Some times the communication system is totally disrupted due to bad weather and in such cases the field regulation staff, according to their experience and judgement, reduces the canal supplies and then restores the canals when the weather is fair.

The revenue staff is responsible for preparing a record of irrigation supply and the assessment of water charges to be levied on the irrigated area. The revenue staff prepares the Warabandi for an outlet which is the basic record for water distribution to all land owners. According to the fixed Warabandi, a slip is issued to the Zamindar through Zilladar of the concerned Division/Sub Division. It is also the duty of revenue staff to stop un-authorized irrigation by the framers and pursue legal action against the culprits. The irrigators often put illegal bunds to irrigate their lands which is strictly prohibited under the law. The revenue staff, along with the concerned Sub Engineer & police, arrange night patrolling along the canals in order to discourage the irrigators from putting un-authorized bunds in the Canal and ensure the due share to the tail irrigators.

EXHIBIT-II-1.6

OPERATION AND MAINTENANCE OF KABUL RIVER CANAL SYSTEM

The Kabul River Canal System is situated in Peshawar and Nowshera District. Its command area is bounded by Joe Sheikh Canal/Sheikh Katha Canal in the North, by Hazar Khani Branch in the southeast and by Kabul river canal in the south. The head regulator for the canal system is located about 1 mile downstream of Warsak Dam on the right bank of Kabul River. The Kabul River Canal System command area extends over a gross area of 56,400 acres. It covers 7.6 percent area of the two Districts Peshawar and Nowshera, 5.7 percent that of Peshawar District and 0.8 percent that of the Peshawar Division. There are 69 villages/settlements and one urban area namely Pabbi Town Committee situated within the Project Area. A part of Peshawar City/Cantt, and the District Headquarters also lies in it. Kabul River flows through the center of Peshawar District in a south easterly direction for about 40 miles. Kabul River Main Canal has a discharge of 800 cusecs and it off-takes from the Kabul River downstream of Warsak Dam. At RD 1+500, it bifurcates into Kabul River Canal(discharge of 450 cusecs) and Joe Sheikh Canal (discharge 350 cusecs).

The Kabul River Canal(K.R.C) system was completed and put into operation during the year 1902. The canal has been designed for a discharge capacity of 450 cusecs to irrigate an area of 56400 acres. The length of the main Kabul River Canal is 37.9 miles and the length of its branches and minors is about 46 miles. Hazarkhani Branch takes off from KRC at RD 72000 with design discharge of 111 cusecs. Similarly Kurvi Br(Q=45 cusecs), Wazir Garhi Minor(Q=17 cusecs) and Pabbi Br(Q=10 cusecs) take off at RD 133000,150000 ,167000 respectively.

For the purpose of operation and maintenance, the organizational structure comprises one Irrigation Sub Division, headed by an SDO who works under XEN,Peshawar Canal Division. There are two sub engineers responsible for operation and maintenance of Kabul River canal System. In addition to engineering staff for maintenance, the division is divided into two revenue sections, each under the charge of a Zilladar. Each section has about 5 to 8 patwaries, depending upon the extent of commanded area. All the revenue staff, including Patwaries and Zilladars, work under the instructions of Deputy Collector who is responsible for the whole Division. The revenue staff is primarily charged with the responsibilities of preparing a record of the Irrigation carried out and the assessment of water charges to be levied on the irrigated area. The revenue staff also prepares a warabandi (or a schedule for watering to be strictly observed by the Shareholders) for an outlet which is the basic record indicating water allocation to all land owners.

The present system of scheduling water deliveries to farms is based on 24 hours of canal operation, i.e., continuous supply in all the channels unless a change is desired due to climatic requirements or due to damages to canal banks, structures etc, in monsoon. According to the fixed warabandi system a land owner is entitled to receive his share of water through a warabandi slip issued to him by the Zilladar. The quantity of water allocated to him in the warabandi remains unchanged unless he himself transfers his land wholly or partly or an additional area is accommodated in the outlet chak which would naturally affect every share holder. The fixed warabandi system requires the Irrigation Department to operate the canals 24 hours continuously irrespective of the nature of crops grown under a particular outlet, i.e., the discharge authorized to an outlet will continue to be delivered round the clock irrespective of the nature of crop grown by farmers. This system has one main disadvantage, i.e., continuous fixed supply has to be arranged regardless of the area and as such the maintenance staff cannot divert supplies to any other area, with high water demand for the crop grown. At the same time the farmer has to adjust the cropping pattern with his given turn of water. Under the existing system of water deliveries to water courses, the gauge reader (the official who keeps record of the daily discharges/gauges etc) maintains a daily record of gauges fixed at head and tail of each canal disty & Minor. Water courses (which are outside the maintenance responsibility of Irrigation Department) do not have gauges installed. The outlets, drawing water from a canal or a disty, function as proportionate modules, i.e., the discharge drawn is dependent upon the W.S.L. in the parent channel but is not influenced by W.S.L. in the w/course. The gauge reader on receipt of instruction from Sub Engineer in charge, reduces/raises, supply in a particular disty by referring to a discharge table wherein gauge as discharge are listed decimal of ft. called HISSAS by the field staff. The discharge is increased gradually so as to attain the maximum gauge (F.S.G.) to deliver the full supply discharge. With full supply discharge at head, all the outlets on the channel should draw their full authorized share of water. The gauge reader operates the head regulator gate issuing instructions to the regulation staff responsible for operation of head regulators. Such instructions are usually in the form of a canal wire (canal telegraph issued from main office) clearly indicating the change in supply position by HISSAS. The regulations staff quickly responds to the fresh demands and manipulate the gate position to maintain the required W.S.L. in the canal. A gauge reader in charge of few distys/minors or canals receivers regulation instructions from his section officer, i.e., Sub Engineer, through a canal wire which is properly kept on record. The Sub Divisional Officer is the principal officer responsible for regulation of canals and directs the sub ordinate staff to operate the system accordingly and collects information about water demand in two ways.

1. Through his revenue staff, i.e. Deputy Collector and Zilladars, who usually keep in touch with irrigators and keep themselves informed about their problems related to irrigation, warabandi, water rates, disputes, assessments and cropped area.

2. The Zamindars (land owners) who visit the sub divisional head quarters as a delegation and place their demands for irrigation water.

Since the revenue staff members reside at their place of duty (usually the canal rest house) they are well informed about the crop water demand or rainfall in the area. normally they place indent for increase/decrease of the canal head gauges in their respective areas. Such demand for water is intimated to the Sub Divisional Officer through a canal telegraph. He works out the net demand at head of the main canal or the Disty. The XEN is the overall in charge of the Division. He is responsible for the smooth running of canals and occasionally checks the head gauges of a disty, main canal or deliveries to tail areas. He is also informed by representatives of irrigators about any shortage of water in tail areas, in which case he issues instructions to the regulators of canals. More attention is required in the case of a sudden cloud burst. Sheet flow may enter the canals and cause damage to banks and structures. If the communication lines are functioning, the SDO in charge immediately contacts his Sub Engineer and issues directions to reduce supplies by escapee at required locations. In case of disruption in the communication lines, the field regulation staff, on the basis of their past experience, judgement & skill, reduces the canal supplies immediately and restores it in fair weather conditions.

The smooth operation & functioning of canals is largely dependent upon extensive touring of field engineers, i.e., XEN, SDO and Sub Engineer. They may spot any serious problems with canal operation when they inspect weak banks, faulty structures & worn out gates which are likely to get stuck during operation. The patrol roads along canals (either metalled or shingled) enable the officers to make detailed inspection in a short time. Thus, more time can be spared for other duties such as planning canal improvement works or required maintenance programs. In brief, the operation of KRC involves proper regulation of gates according to demand, timely repair of damaged embankments, removal of vegetative growth and maintenance of petrol roads. Some of the maintenance works can only be done during the canal closure period. These works include silt clearance, lining or pitching, minor repairs to submerged structures and greasing of head regulator gates.

Exhibit II-2

INSTRUCTIONS FOR THE UPKEEP OF H REGISTER

1. This register shall be maintained for running canals in every Sub Engineer Section, Sub-Divisional and Divisional Office. The register is bound in two sizes, one of 10 pages (double) for Sub Engineer and the other of 20 pages for use in the Sub-Divisional and Divisional Office. In the Divisional Office, a separate register is maintained for each Sub-Division. Form for the H Register is presented as table on the following page.

2. The name of the channel should be entered in red in the middle of the page and below it. Columns 1 to 3 should be written in black and columns 4 and 5 in red. Control points, meter flume, etc. should be noted in red, at the R.Ds, where they exist, and not at the end of the entries for the channel concerned. The entries should be continuous and a separate page need not be allowed for each channel.

3. A new register should be opened for every year.

4. Every Sub Engineer must inspect all outlets in his section at least once a month when the channel is running with full supply at the head. He should measure the value of H and the working head of each outlet and control point and not whether the outlet or control point is working modularly or non-modularly. If the head regulator of the minor or distributary is not a flume, the head gauge should be noted. Working heads need be read only up to one decimal place.

5. The above information should be noted in this register. The date of observation should always be noted in the column provided for the purpose. If an outlet is non-modular, the working head should be underlined in red.

In case of pipe outlets, H means depression head (height from center of pipe at intake or outlet and to water level in the channel whichever is less). In order to avoid confusion the letter 'd' should be added to designate the depression head in Column 4, e.g. 1.45d.

6. The register should not be used for recording any comments, orders or extraneous details.

7. Whenever the register is not with the Sub Engineer, he should carry out the observations, as usual, and record them in his note book, subsequently transferring them to this register.

8. No alterations in R.D., type or designed H or control point should be made without proper authority. Whenever alterations are sanctioned and carried out, the entry in the register should be corrected and initiated by the Sub Engineer. The actual date of carrying out the alterations at the site should also be noted.

9. The sectional Sub Engineer will submit their registers to their Sub-Divisional Officers on the first day of each month. They should sign below the last entry and date their signatures. Along with the register the Sub Engineer should submit a list of alterations to outlets, carried out during the month, in the form printed at the end of these instructions. In case there is no alteration during the month the word 'Nil' should be written on the form.

10. After receipt of the Sub Engineer, register in the Sub-Divisional Office, the Sub-Divisional Munshi will copy the entry from the register to the Sub-Divisional register. The Sub-Divisional Register contains entries for all the channels in the Sub-Division.

11. The Sub-Divisional Officer will then scrutinize the Sub Engineer, registers and make a note of all mistakes or omissions found therein. A copy of this note along with the Sub Engineer Register should be sent to the Sub Engineer concerned for verification of the report.

12. Sub-Divisional Officers should also make it a point during their inspections to check the observations made by the Sub Engineer.

13. A copy of Sub-Divisional Officer's note, along with the Sub-Divisional Register should be submitted to the Divisional Office by the 5th of each month.

14. On receipt of the Sub-Divisional register in the Divisional Office, the Head Draftsman will examine the Sub-Divisional register and after completing the Divisional register will put up the registers to the Executive Engineer by the 10th of the month together with a note detailing the result of his security. The Executive Engineer after scrutinizing the Registers every month will return the Divisional register to the Sub-Divisional Officer. The Executive Engineer will however, forward the Divisional register to the Superintending Engineer for scrutiny at the end of each quarter ending on 15th of March, June, September and December.

15. On receipt of the Divisional register in the Circle Office, the Circle Head Draftsman will prepare H-graphs and put them up to the Superintending Engineer for orders. The Divisional registers should be returned to Executive Engineers by the quarter ending on 25th March, June, September and December.

16. The register is to be carefully preserved. Sub Engineer should not take it out on inspections unless required to do so by Officers inspecting their Sections. When completed the Sub-Divisional and Divisional Registers should be entered in the Register of Library books and preserved for 10 years.

Exhibit II-2
Page-4

STATEMENT SHOWING WORKING OF OUTLETS
(Working Head of non-modular outlets is underlined) NAME OF CHANNEL

R.D. of Outlet	Side	Type of Outlet	Designed			JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER	
			"H"			"H"			"H"			"H"			"H"			"H"			"H"			"H"			"H"			"H"			"H"			"H"			"H"	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41

Exhibit II-3

Instructions for the maintenance of Irrigation Register.

1. Divisional officers, Sub-Divisional Officers, Deputy Collectors and Zilladars will maintain Irrigation Register.

2. The Divisional Register will be maintained by the Revenue Clerk. All alterations will be signed and dated by the Divisional Officer. Other registers will be maintained by the officials to whom they are issued and alterations will be made in the official's own handwriting and signed and dated.

3. Alterarion Will be made by scoring out the original entry in red ind and entering revised figures below the original.

The authority for the alteration should be noted.

4. If the entries regarding any outlet become congested; or the area of a cham is changed by more than 10 percent, further, entries should be made at the end of the entries referring to the channel concerned, a note being made showing the page to which the entries have been transferred. Similarly, when a chak is split up into two or more chaks, the entry should always be transferred to the last page of the entries referrign to the channel concerned.

5. The Sub-Divisional Register will be compared annualy with the Divisional Register by the Revenue Clerk between August 1st adn 15th. The Revenue Clerk will put up a note showing all discrepancies in the register. The Divisional Officer will issue such orders as he thinks fit to rectify discrepancies.

6. The Deputy Collector will compare his Irrigation Register with that maintained in the Divisional Officer between September 1st and 30th and the Zilladar will compare his register with that maintained in the Sub-Divisional Office between the same dates.

The Deputy Collector and Zilladar will record a certicicate in their register that they have carried out this comparison.

7. The Sub-Divisional and Zilladar's Irrigation Register will be inspected by the Divisional Officer at the time of annual inspection of Sub-Divisional Offices. The Deputy Collector's Irrigation Register will be inspected by the Superintending Engineer at the time of annual inspection of Divisional Offices.

IRRIGATION REGISTER

V1-Exhibit II-3

DISTRIBUTARY ______________________

MINOR ______________________

______________________ INTENSITY

______________________ FULL SUPPLY FACTOR AT OUTLET HEAD

______________________ KHARIF RABI RATIO

Serial No.	R.D. of Outlet/Side	Name of village	Gross Area of Chak	Area for which water is to be supplied	Permissible annual Irrigation	Crop	19__ Remitted	19__ Assesed	19__ Remitted	19__ Assesed	19__ Remitted	19__ Assesed	19__ Remitted	19__ Assesed	19__ Remitted	19__ Assesed	19__ Remitted	19__ Assesed	19__ Remitted	19__ Assesed	19__ Remitted	19__ Assesed
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
						K																
						R																
						T																
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						K																
						R																
						T																
						K																
						R																
						T																
						K																

Exhibit II-4

Instructions for the maintenance of outlet Register.

1. Divisional and Sub-Divisional Officers only will maintain outlet registers.

2. The Divisional Register will be maintained by the Revenue Clerk and all alterations therein shall be signed (not initialled) and dated by the Divisional Officer. The Sub-Divisional Register will be maintained by the Sub-Divisional Officer in his own handwriting.

3. When an alteration is made, a fresh entry should be made in accordance with the sample form on the first page.

4. When a chak is split up into two or more chaks, the entry should always be transferred to the last page of the entries referring to the channel concerned.

5. The Sub-Divisional Register will be compared annually with the Divisional Register by the Revenue Clerk between 1st and 15th August. He will put up a note showing all discrepancies in the register. The Divisional Officer will issue such orders as he thinks fit to rectify discrepancies.

Exhibit II-4
Page 2

OUTLET REGISTER.

DISTRIBUTARY
MINOR ________________ FULL SUPPLY FACTOR AT OUTLET HEAD

KHARIF-RABI RATIO

Serial No.	R.D. of Outlet and side	Name of Village	Gross Area of Chak	Area for which water is to be supplied	Date of construction of alteration	Authorised discharge	Type of Outlet	R.L. of crest of outlet	Description/R.D. of refferring bench mark	Date of outlet
1	2	3	4	5	6	7	8	9	10	11
1st ALTERATION SANCTIONED INS.E's.No.									Dated	
2nd ALTERATION SANCTIONED IN S.E's. No.									Dated	
1st ALTERATION SANCTIONED IN S.E's. No.									Dated	
2nd ALTERATION SANCTIONED IN S.E's. No.									Dated	
1st ALTERATION SANCTIONED IN S.E's. No.									Dated	
2nd ALTERATOIN SANCTIONED IN S.E's. No.									Dated	

EXHIBIT II-5

PERFORMANCE STANDARDS FOR CANAL OPERATION

1. **Allocation of Water**

The latest Outlet Register used for rehabilitation provides the sanctioned allocation of water to each watercourse. This defines equity. So long as the inflow to the canal is at the design flow, the allocated amount must be delivered.

2. **Equitable Distribution of Water**

The full supply level, FSL, defines the condition for which the equitable distribution of water was designed to be made to each watercourse. Therefore, at the design discharge the water level in the canal must reflect the FSL at all times; i.e., a deviation indicates a non-equitable condition.

3. **Proportionality**

When inflows at the head of the canal system are less than the design flow, every attempt shall be made to distribute the flow proportionately through out the system in order to maintain equitability.

4. **Equitable Distribution of Sediment**

The design of the turnout includes the consideration of sediment draw. The design of a rehabilitated canal assumes the equitable withdrawal of sediment by each watercourse turnout. Therefore, the sill level of an outlet cannot be raised.

5. **Uninterrupted Delivery**

The uninterrupted delivery provides equitable distribution of water in a continuous flow system. Rotation of flows between canals is required when canal flows are reduced to about 55% of the design discharge. Flows can be reduced to watercourse(s) serving an area having heavy rainfall or a low crop water demand. All changes in distribution must be recorded on operations log.

6. **Maximum-Minimum Flows**

The maximum allowable flow in a canal under certain conditions is limited to 1.2 times the design flow (1.2 Q_d). The duration of a discharge greater than the design discharge should be according requirements. The canals should not be operated at flows less than about 55% of design.

7. **<u>Maximum Water Level</u>**

The maximum water level can never be allowed to exceed one half of the design freeboard (1/2 fb) under any circumstances.

8. **<u>Inspections and Reports</u>**

Inspections and accompanying reports must meet the following minimum:

(i) Sub-engineer must make a weekly inspection and report.

(ii) Sub-division Officer is required to make a fortnightly inspection and report.

EXHIBIT II-6

EMERGENCY INSTRUCTIONS FOR BREACHES

Normally a breach in a canal shall not occur if it is being operated properly and maintenance/inspection of the canal is being carried out periodically. Due to negligence, natural calamity or abnormal conditions, if a breach occurs, it shall be immediately reported by SDO to all his higher officers. The XEN shall inform Accountant General of the Province and local Audit Officer. The XEN shall take the repair under para 127 of the PWD Code after obtaining the approval of the Superintending Engineer. For the commencement of the work, verbal orders should always be confirmed in writing as soon as possible and in case of emergency, a preliminary rough cost estimate should be sanctioned by the Superintending Engineer and Audit Officer who, after being informed, will be responsible for bringing the facts to the notice of higher financial authority of the Province.

The canal shall be closed at the head works or water discharged immediately through the escape structure upstream of the breached canal section whichever is applicable. In case of an escape structure, controlled supply shall be allowed to pass into the canal through the headworks so that the upstream irrigation does not suffer on account of the breach. After stopping canal water from reaching the breached section, work shall commence immediately by removing all the damaged portion. Based on the preliminary findings of the cause of the breach, the repair shall be carried out strictly in accordance with the specifications as per site conditions. The work shall be continually supervised at the site by an official not less than a Sub Divisional Officer. For larger canals where the flow of water cannot be stopped completely, the breach has to be closed under running water conditions. In such cases, a ring bund is constructed at the breach site. This procedure has been dealt with in detail in Part-3 Chapter 5.

CHAPTER 3

MAINTENANCE

3.0 GENERAL.

Canal maintenance is the continuous process of repairing or servicing the canal prism, embankments and appurtenant structures to meet or conform to canal maintenance standards. Canal standards are designed to keep the canal in what is described as "as-built" condition. Because the canal carries moving water containing sediment and the embankments are exposed to weather, animals and people's activities, some leeway is allowed with regard to practical and economic considerations. A primary consideration is to utilize cost effective procedures. There are three general types of systems operation which are defined as: (1) regressive, (2) hold the line, and (3) progressive.

A regressive operation is one where the physical system is mined out. The canals and laterals and appurtenant structures are generally in very poor condition. Equipment is usually old and in very poor condition. As could be expected, service to the water users in this type of operation is generally poor. There is little planning inherent in this type of operation.

A "hold-the-line" operation may be characterized as one that doesn't lose any ground but, by the same token, doesn't gain either. It may be a perfectly acceptable type of operation for the short term. Probably some of the most progressive systems have undergone periods when they indulged in "hold-the-line" operations due to adverse economic factors. Service to water users may range from indifferent to quite good. Planning the budget for this type of operation is relatively simple; it usually consists of using last year's budget modified slightly to reflect inflationary pressures with, perhaps, the replacement of an existing structure or freeboard on a reach of canal. Generally this approach is being practiced in NWFP.

A progressive operation is characterized by efficiency and competency. The distribution and drainage systems are open, weed-free, and in good repair. Structures are in good condition and are repaired or replaced on a planned basis. Needless to say, a great deal of planning goes into a progressive operation. For the long-term period, a progressive operation brings the largest return for the money spent.

3.1 MAINTENANCE OF WORK.

Maintenance work is generally divided into two categories in NWFP (1) Maintenance and Repair (2) Annual Development Plan. Routine maintenance is the everyday maintenance work that includes such items as:

* Repairing rain cuts and rodent holes.
* Removing floating debris.
* Killa bushing and berm trimming.
* Maintaining freeboard, embankment width and outer slopes.
* Maintaining service road in motorable condition.

Some minor repair work is done by the Beldar.
The main tools available to the Beldar are:

* Ring Phatti
* Kassi
* Tokri (basket)
* Small Axe
* String 100 ft. long
* Daranti/talwaar (sickles)
* Ramba (short handled hoe)
* Baalti (water bucket w/rope)
* One Lantern
* 6 - 12 ft. long Bamboo Pole per gang

The Beldar also has operational responsibilities including patrolling a given reach or zone of a canal. The daily patrolling provides the day-to-day inspection of the canal systems which is the back-bone of controlling the maintenance program. The zone of coverage by the Beldar is different i.e. two miles for main canals and 6 miles for smaller channels i.e. distributaries and minors. In view of changed social conditions for different portions, the beat of 6 miles need to be reduced say 3 miles.

A maintenance work project will be defined herein as a large work effort requiring several workers (a labor gang) over a period of time, a large work force, mechanical equipment or a combination of these efforts. Maintenance projects can be performed in two ways; (1) Private Contractor, and (2) Mechanical means.

Another item to consider is the difference between a maintenance work, project work and a rehabilitation project. The rehabilitation project is essentially performing deferred maintenance. The source of funding (budget line item(s)) would be the determining factor. Rehabilitation is usually considered a capital cost expenditure which means the funds must come from the Annual Development Program (ADP) which requires the PC-1 procedures. The ADP budget may or may not be supported by an International Lending Agency, Federal Government or other international financing. Rehabilitation work is carried out by the large private contractors or by the Mechanical Division when the work is to be carried out by the mechanical division equipment. Maintenance, on the other hand, is a recurrent cost that must come from the Non-development Budget (NDB) of the Province.

3.2 IMPROVING MAINTENANCE.

There is a need to develop new methods and to have the use of new materials in performing canal maintenance. Currently, nearly all the work in the wetted section is performed in the winter season during the scheduled maintenance (closure) period. This obviously creates a major scheduling problem and a potential local labor shortage. Equipment can be used more frequently to desilt canals even under running water. The use of sediment traps (constructed on the side of canal) for sediment deposition can be helpful. Sediment traps have the potential of being cleaned during canal use by equipment. Sediment traps, as referred to herein, do not have to be large, formal structures. The subject of sediment traps and their design and operation is presented in detail in Part 4.

Two other problem areas that require new approaches for increased service-ability are; canal bank protection, and a durable or all-weather service road wearing surface. Increased use of the service roads for local access to farm areas and farm-to-market transport of products and inputs causes rapid deterioration of the road and, in some instances, loss of canal freeboard. In the NWFP most of canal roads are either gravel roads or metalloid. These are open to private traffic.

3.3 BUDGET ESTIMATE AND O&M WORK PROGRAM.

The budget allocation for the various items of work relating to the current financial year are made available by the FD, to the PID soon after the close of the financial year on 30th June. Thereafter the SDOs carry out necessary surveys and collect other data for preparation of detailed estimates. These estimates are submitted to the higher officers and are sanctioned by them according to the delegation of financial powers. This procedure is carried on until the first of October when the first review of the current financial year becomes due. All the works provided in the current financial year are reviewed and a statement is prepared which is called the First List of Excesses & Surrenders. This list is based on the actual expenditures for the first three months of the current financial year and the last nine months of the financial year previous to that. The total of these twelve months is compared with the anticipated total expenditure for each item of work. On the basis of this comparison the excessive demand is surrendered or additional demand is made for all the items of works provided in the current financial year.

It is important to plan and estimate each individual canal's work for the next financial year. For this purpose the SDO and the XEN prepares a budget estimate for the O&M Work for the next year by the 1st of October, i.e., nine months ahead of the coming financial year. This budget estimate gives details of all works proposed to be carried out on main canals, branches, distributaries and minors. The costing of the work should be done on the basis of Yardsticks for canals. For this purpose discharges of channels and lengths proposed to be dealt with for each channel should be given. It is recognized that the NWFP Government may not have sufficient funds available to do all the works. The works should be prioritized under the following three headings:

- Main canals and branches
- Distributaries
- Minors and sub-minors

This budget estimate is in fact the Work Program for the next financial year. This should form the basis for budget allocations by the FD. It is to be kept in mind that the existing Yardsticks should be revised yearly taking into account the inflation costs for labour and materials and it should be used for costing work proposed for the next year.

If it is felt that some posts of a temporary nature or some other works of urgent nature are required, a list of all these items is also submitted to the SE by XEN on the 1st October. The budget of the current financial year is again reviewed in the beginning of the next year and a statement is prepared for each item of work. This statement is called the second List of Excesses & Surrenders. The second list is based on the actual expenditure of the first seven months of the current financial year and of the last five months of the previous financial year. In this way a comparison is made of the actual expenditure with the anticipated expenditure or budget allocations and necessary action, to surrender the excessive amount or to demand additional amount, is taken. This second list becomes due in the Finance Department on the 31st of March. The FD then prepares the final budget estimate for that year. A budget calendar showing the dates of submission of various budget returns from SDO to Cabinet is enclosed for reference in Exhibit III-1.

3.4 PLANTS, TOOLS AND BUILDINGS.

The major item of responsibility outside the canals is the maintenance of the permanent facilities of the PID which includes: office buildings, rest houses and similar structures. These facilities must also be maintained in good condition. The rest houses must be staffed and maintained for the touring PID personnel and other authorized government employees as defined in the Irrigation Manual of Orders. Following are also included under this head:

(A) Vehicles

Government vehicles have been provided from the Chief Engineer down to the SDO level. Major and minor repairs are carried out in accordance with standing orders or in the mechanical equipment Workshop at Peshawar. Proper log books should be maintained for the operation and maintenance of these vehicles.

(B) **Telegraph**

The maintenance of the PID's canal telegraph system (where it is still operational) is the responsibility of the Telephone and Telegraph Department. This very old system is not being maintained satisfactorily and works poorly. Now it is desirable to switch over to wireless system. This aspect has been discussed in Chapter-II.

(C) **Plant and Stores**

The XENs and SDOs are responsible for the proper storage of supplies and materials to protect them from weather damage, white ants, rodents etc. The Sub-Engineer and SDO are responsible for maintenance of up-to-date records on the issuance and utilization of all supplies and materials. Materials used in performing maintenance projects must be issued against proper indent forms of the department and charged to the appropriate work for which materials are needed. The operational cost of plant should be charged to work. Materials for emergencies should also be available in stores. A copy of indent is shown in Exhibit-III-2.

(D) **Maintenance Accomplishment**

Responsibility for preparation of estimates with respect to defective structures, facilities or other repairs lies with the SDO and Sub-Engineer. Following the approval of the annual work program (mentioned above) the canal officers will initiate actions for work accomplishment in their areas of responsibility. Most of the works are carried out by contractors. Some works requiring large quantities of earth work or sediment/weed clearance of drains, may be done preferably by machines. This leaves the XEN with preventive type maintenance which is accomplished through small gangs or Beldars. The amount of maintenance work actually performed during a year depends on the available budget.

3.5 REHABILITATION AND IMPROVEMENT.

(A) **Rehabilitation** refers to the system or sub-system wise reconstruction or restoration of facilities and/or structures from a deteriorated condition to a serviceable condition that meets all their original functions as well as meeting all performance standards.

(B) **Improvements** refer to the relocation or addition of a new facility that results in more efficient canal operation for better distribution of water to the farmers. Under the above definitions the need for rehabilitation would only occur as a result of a deferred maintenance program. Deferred maintenance could be the direct result of a governmental policy or the direct result of inadequate budgets, poor management, improper repairs. These two types of improvement programs require the expenditure of funds that must be separated from the regular O&M funds. Thus, these programs should not be confused with replacement. Replacement refers to the periodic replacement of worn out equipment and facilities that have a more or less fixed life span (e.g, The replacement of gates, gate hoists, vehicles, broken sections of lining etc). Rehabilitation and improvements are combined under the term capital improvements, with regard to funding and budgets, for accounting purposes. These two improvement programs should be carried out in conjunction with a long-term canal improvement program. This is accomplished by including a capital improvement program that is funded from a separate budget. In other words the normal M&R budget, which includes all ordinary and extraordinary items required to keep the canal within performance standards, can not be used to carry out these programs. The ADP budget should be used only for capital improvements. The two budgets should not be intermixed. Under current regulations for all ADP projects a PC-I proforma must be prepared.

3.6 FIELD INSPECTION REQUIREMENTS.

Inspection is an important aspect of any canal maintenance program. Inspections reveal the defects of the system. Inspection reports are the basis for making evaluations and preparing maintenance work programs. This aspect has been dealt with in Chapter II. Field inspection requirements laid down for various personnel of the Department are shown in Exhibit III-3.

(A) Prism Standards

Recent hydraulic designs for the rehabilitation of a canal system in the NWFP indicated that there may be considerable differences between existing and design cross-sections. The "Design Criteria" for Rehabilitation of Canal System should be that the existing width should not be more than 1.1 times the design bed width. The design criteria also requires that berms be constructed on all canals with a design flow depth greater than 2.5 feet. Berms are constructed in canals to protect the toe of the canal bank from erosion and loss of safety. They also increase the seepage path and thus tend to lower the phreatic line (HGL). Berm design is based on canal discharge as discussed in Chapter-II, Part-3.

(B) Berm

The operation of the canals in the NWFP essentially requires maintenance of a berm as prescribed in Chapter-II Volume-3. Where berms still exist, they are maintained. Once they have been eroded away, for whatever reason, they are to be replaced. Two factors appear to be responsible for the loss of berms; (1) operating discharges above the original design discharge (2) canals constructed with bed load sediment transport capacities greater than the average annual incoming sediment loads. Replacement of eroded berms would require the widening of the embankments and resetting of the outlets. It might also require the removal and replacement of an embankment in some instances or lining to provide capacity and embankment safety.

Berms are required to protect the toe of the embankment. Their absence places the safety of the canal embankment in a much more critical position. Erosion of berms does not cause a critical safety problem as long as the embankment can withstand the velocity of flow. When a canal bank without berms starts to erode, one of two actions must be taken; (1) killa-bush spurs are constructed or (2) the embankment is set back to accommodate the existing discharge.

3.7 FIELD INSPECTIONS.

(A) Frequency

Field inspections are regularly conducted by the Canal Officers as part of normal duty. The inspections are confined to general and specific observations of the canal. The deficiencies are pointed out for rectification. The inspection of a running canal has limitations. Neither the prism can be observed nor the condition of most of the structures. Parts of a canal or a structure above the water surface can only be inspected. Regular inspections are still very useful and reveal the general condition of a channel, particularly, the embankment free board condition and the safe running of the canal. It would be useful if the following schedule of inspections is adopted by the various categories of officers :

Name of Officer	Frequency of Inspections
Sub-Engineer	He should inspect all channels in his charge every month.
Sub-Divisional Officer	He should inspect all channels in 3 months.
Executive Engineer	He should inspect all channels in 6 months.
Superintending Engineer	He should inspect all channels in 12 months.
Chief Engineer	He should inspect all main canals and Branch canals in 12 months. He should also inspect all accidents on main canals and branches.

The Sub-Engineer should send note of inspection to his Sub-Divisional Officer if some action is required on any observation made in the field.

The Sub-Divisional Officer should write an inspection note and send it to the concerned Sub-Engineer for taking action on the points raised. A copy of the inspection note should be sent to the Executive Engineer indicating any points on which any action is required by the latter.

(B) Category of Channel Conditions

The Executive Engineer and Superintending Engineer should make detailed inspections and write elaborate inspection notes. The deficiencies on bank width and freeboard should be categorized as below :

Category	Definition	Condition as percentage of designed value	
		Bank width	Freeboard
I	Critical	< 40	< 50
II	Poor	40 - 70	50 - 75
III	Fair	70 - 90	75 - 90
IV	Good	90 -100	90 -100

Category I requires immediate action
Category II remedial measures can be delayed to next year
Category III deterioration occurring watch it
Category IV no action required.

Follow up action on the points raised in the inspection note is necessary. The concerned officer should be required to submit a report on the compliance of instructions issued during the inspection.

3.8 ANNUAL INSPECTION.

Annual closure of the canal system is done for about 4 weeks every year for repair of headworks and canal system. During the closure period the Canal Officers carry out most important inspection of the year. A program of inspection for this period should be framed by the Superintending Engineer and Executive Engineer and inspection carried out as quickly as possible. On the basis of inspections a two phased program as discussed below should be framed:

(A) Phase-I Program

Works which are of essential nature and can be carried out during the current closure should be taken up first. Their estimates should be framed after carrying out surveys and work carried out after getting approval from the competent authority. Such works include berm trimming, site clearance, repairs to damaged pitching on downstream of falls and regulators, killa bushing and brushwood spurs, protection against erosion around abutments or piers of bridges, regulators and falls etc. Gallop tenders (if conditions warrant) can be invited and works completed during the closure periods.

(B) **Phase-II Program**

Works that cannot be carried during the current closure due to time consuming surveys or other reasons should be deferred till the next year's closure. For such works data should be collected and necessary surveys carried out for framing estimates. The competent authority should sanction funds against these estimates. Formalities of calling tenders and allotment of work should be carried well in time before the commencement of next year closure. The contractor should collect all the materials well before the construction starts and work should be taken in hand as soon as the closure commences. If any part of work cannot be completed during the closure period, it should be left in such a state that the water flowing over it does not damage it. Such incomplete work should be resumed during the next closure period.

Some parts of closure period works may require use of machines. For this purpose the Mechanical Division should be intimated well in time so that allocation of machinery is made by it for the specific work.

A general check list of items for field and annual inspections is shown in Exhibit III-4.

(C) **INSPECTION OF LARGE WORKS.**

Where a large work is in progress, the Sub-Engineer should submit a daily inspection report in the form shown in Exhibit III-5.

3.9 MAINTENANCE PROGRAMS.

An effective program of maintenance works would include the following activities:

* Routine
* Preventive
* Seasonal
* Annual
* Unscheduled
* Emergency

It requires considerable planning and organizing to implement and utilize these six programs effectively. These programs are discussed below:

(A) **Routine Maintenance**

Routine maintenance is defined as those tasks which must be performed, for the most part, on a daily or weekly basis by an individual, that do not require or utilize check sheets. It is particularly applicable to canal embankment maintenance work such as; vegetation control, raincut repairs, berm cutting (killa bushing), lubrication of gates and hoists, painting etc. Although routine maintenance may be and often is performed by an individual, it does not always have to be. Some of the items listed above could also be accomplished effectively through machinery. It relates back to the organizational concept, sociopolitical situation, and law and order situation with regard to protecting water control structures. The degree of mechanization available also effects who does what. A tractor with a flail mower can cover considerable length of canal bank in a day.

(B) **Preventive Maintenance**

Preventive maintenance consists of an effective but simple method of scheduling the works at specific intervals. Records of inspections and repairs are kept through a checklist so as to ensure that the inspection and work meet certain standards. In the canal maintenance program it should be adapted primarily to structures and the related mechanical equipment. A preventive maintenance program should be mandatory for maintenance of equipment and vehicles.

(C) **Seasonal Maintenance**

Seasonal maintenance work includes such works as the patrol road surface grading program, repair of animal crossings and large scale raincuts or killa bushing programs. Seasonal work is generally considered to be accomplished under force account procedures using casual labor and/or the Mechanical Circle's equipment.

(D) **Annual Maintenance**

Annual maintenance refers to a major work task or program that is scheduled ahead of time. It includes works located in the canal prism area which must be done during the closure period. It also refers to a task that is carried out over the entire year; such as freeboard restoration program. It is separated from the routine category by cost, complexity and equipment requirements. It is separated from seasonal work by using private contractors or Mechanical Division to do the work. Although many annual maintenance programs have been accomplished with crew labor, it is often more cost effective to incorporate equipment as well to ensure that soil compaction specifications and other criteria are met or exceeded. Annual maintenance work is scheduled for specific sites or reaches of canal in advance. It covers the major repair tasks.

(E) **Unscheduled Maintenance**

These are items of work that originate due to weather or other unpredictable causes such as heavy rainfall or occurrence of high floods. These cause widespread damage to the canal systems. Such repairs are unforeseen and unscheduled. There is need to carry out repairs to damaged canals as early as possible because any delay may adversely effect the maturity of Kharif or sowing of Rabi crops.

(F) **Emergency Repairs**

Emergency repairs such as breaches result from deferred maintenance, error in operation of water control structures, unusual weather occurrences or unnoticed burrowing by rodents. Their occurrence cannot be predicted. Contingency funds are held in reserve to cover the cost of these repairs which must be done immediately to contain the damage and to prevent additional loss. Action to be taken in case of a breach is dealt with in Exhibit III-6.

3.91 EQUIPMENT UTILIZATION.

Currently only major workS, involving lot of earthwork, are carried out with mechanical equipment. Little or no equipment is assigned to the Division/XEN for internal use. Contractors may or may not use tractor-trolleys in their operations. Head baskets and donkeys are still used extensively but their use is slowly decreasing as the availability of cheap labor is on decline. Executive Engineer (mechanical) is incharge of all equipment and he details machines for execution of works according to requirements of field engineers.

3.92 CURRENT BUDGET PREPARATION.

The Public Works Department Code, paragraph 246, defines the method for preparing estimates for maintenance and repairs. The Manual of Orders further defines the procedure in Chapter III, paragraph 3.4. The method, with some modifications, is still in general use. Three types of work are carried out; ordinary, special and reserve. The ordinary maintenance and repairs are those which are accomplished at the sub-divisional level. These cover the annually recurring ordinary repairs to banks and patrol roads, masonry works on all channels, repairs to all buildings, repairs to outlets and distance markers and the cost of Establishment.

Special funds are provided for those works which are not annually recurring but are required to be done periodically including, special berm cutting and silt clearance, returning banks to design section, renewing bridge surfaces (metalling), special repairs to masonry works, and special repairs to all buildings. These special funds are also used on those works which require special control by the XENs and SEs and include, special repairs to headworks and emergency repair to canals.

Reserve funds are allocated to the Superintending and Chief Engineers. The funds provided to the SE are used mostly for unforeseen extraordinary repairs and annual payment for telegraph and telephone. The Chief Engineer's reserve funds are used for extraordinary work at headworks, remodelling channels and emergencies such as breaches, etc.

The original maintenance concept was set upon the classical hold-the-line concept as the previous year's budget was included as part of the new budget, and the extraordinary and special requirements were not specified for individual works when the budget was consolidated at the superintending engineers' level. Due to the use of outdated yardsticks and insufficient fund allocations, maintenance has not been able to keep up with the basic needs of the system. This has resulted in continuous deferred maintenance and not in hold-the-line condition.

3.93 YARDSTICKS.

Yardsticks are prepared to allow system personnel to rapidly estimate how much money would be required to maintain the canal in a given system. The data is used to prepare annual budgets as it does not produce a detailed work program. It provides the financial people with a reasonable estimate of the funding required to maintain an irrigation system in good operating condition.

As indicated above, yardsticks should be prepared from sound estimates of the work required. Past records of what has been done and a detailed inspection and evaluation of current conditions will allow reliable estimates to be made. Items such as volume of fill required, all costs of excavation, hauling, placing, rolling etc. should be detailed. Yardsticks have been prepared for NWFP Irrigation Department for canals, drains, flood bunds and tubewells.

3.94 EXECUTION OF MAINTENANCE WORKS.

(A) General.

The XEN is responsible for the preparation of all maintenance contracts to be tendered to private contractors. This includes any necessary design work. The majority of the maintenance repairs or restoration of features to the as-built condition will not require a design, but will require considerable attention to drawing preparation and related details as dimensions and elevations are very important.

(B) Methods of Execution of Works.

In Irrigation Department of NWFP the following methods are in use for execution of maintenance works :

(i) Departmental Labour

Petty or emergency works are carried out under this method. Labour is engaged on daily wage basis by the Sub-Engineer for small works and a format called "muster roll" is maintained for it. Also labour is engaged on daily basis in case of emergencies such as breach in a canal or other similar works which are not easily susceptible to measurements. This systme has been largely abandoned.

(ii) Piece Work or Work Order Basis

In this method a work order is issued to the contractor for carrying out maintenance work. The work order basis contains a description of work to be done and the rate to be paid for various items of work without any reference to the total quantity of work to be executed or to the time within which it is to be carried out. Specifications to be followed for execution of work are either enclosed with this work order or a reference to any book which contains the specifications is given. In order to ensure that the rates given in the work order are current or realistic rates, XEN should publicly call tenders for specific items of work which are to be carried out at least once in a year. Materials such as steel, cement etc. required for the works to be done on work order basis are to be supplied by the department. This mode of execution of work is seldom used now.

(iii) Lumpsum Contracts

In a lumpsum contract tenders are invited from the pre qualified or enlisted contractors to execute the entire quantity of work with all its contingencies for a fixed sum during a certain period. In this mode however the contractor should be required to indicate the rates of material on which he has based his tender and also to give a procedure for claiming escalation if the contract goes beyond the stipulated period of completion or for reasons beyond the control of the contractor such as increase in the rates of wages of labour and cost of materials by the Government which the contractor could not have foreseen at the time of tender.

(iv) Item Rate Contracts

This method of contract comprises of a number of items of work which are to be carried out by the contractor. For each item the quantity is given. Against each item either the rate shown in the Composite Schedule of Rates for that item is given and the contractor is required to quote premium below or over this rate or the contractor has to fill in a rate for each item to cover all his expenses (overheads and profits) for completing all items. The rates given for each item can be used for revising the total amount of contract for any additions or deletions of work by issuance of variation orders.

(C) Departmental Format for Item Rate Tender.

This format has been devised and approved by the NWFP Government and is known as PWD 3-A Format. This is an old format and strictly speaking it is not a balanced contract format. For the changed conditions for execution of works it is now outdated. Therefore it needs to be revised to make it more balanced for item rate contracts. The contractors are demanding a major change in the conditions of contract which according to them, at present are generally one sided to protect the interests of the Government. This format is mostly used for works carried out under Non-Development Budget Allocations by the NWFP Government.

(D) International Civil Engineering (ICE) Contracts Format

For major works, particularly those works which are financed by foreign agencies such as World Bank, USAID, Asian Development Bank etc., ICE contract format with certain modifications is used for contracting work. In some cases the aid giving agencies desire that international bidding should be resorted to . In such cases the ICE contract format with minor modifications (which are required for conditions in Pakistan) is adopted. Such contracts are, however, seldom applicable to maintenance works. There are six general components of most contract documents. The size and details contained in each vary according to work to be done and government requirements. The components are:

* Invitation to Bid
* Pre-qualification of Contractors
* Tender Documents
* General Conditions
* Technical Specifications of Contract
* Contract Drawings

These components are discussed briefly in the following paragraphs.

(E) Invitation to Bid

Appropriate advertisement procedures should be followed. Adequate time for tendering should be allowed. Normally 30 to 60 days are appropriate depending on the size of the maintenance contract and the number of expected bidders. The format of advertisement follows a standard method of defining the work to be done.

(F) Pre-qualification of Contractors

(i) General Requirements

Pre-qualification is often required for civil works contractors. Advertisement for applications for pre-qualification follows the same procedure as for a tender invitation except the period for receipt of applications is normally 30 to 45 days. Instructions to applicants regarding pre-qualification must include a brief description of the nature of works, packages for contracting based on financial limits and spread of works (e.g., embankment sections), source of financing, terms of payment for contract, time schedule, and eligibility of bidders for the contract. The pre-qualification questionnaire (attached to the instructions to applicants) should ask for data on (1) experience, (2) past performance, (3) list of personnel, (4) equipment, (5) financial status and (6) current commitments. Preparation of these instructions should ensure that unreasonable demands are not imposed on the bidders. The criteria for pre-qualifying bidders should be standard or be agreed upon prior to the closing date for receipt of applications for pre-qualification. The selected list of pre-qualified contractors is prepared after ensuring that all applicants were selected or rejected on adequate grounds. All contractors satisfying the minimum criteria have to be pre-qualified regardless of their number.

(ii) Categories of Enlistment of Contractors

On the basis of their experience, contractors are enlisted under the following categories. This enlistment obviates the necessity of undertaking the formality of pre-qualification of contractors for most of the major works.

(a) No Limit Category Contractor

Contractors under this category can bid with no financial limit. Their enlistment is generally done by the Chief Engineer. They have to pay a fee of Rs.20,000 for enlistment. This enlistment has to be renewed every year by payment of a fee of Rs.20,000.

(b) Category " A" Contractor

Contractors enlisted under this category can bid for works costing upto Rs.200 lacs. Their initial enlistment fee is Rs.10,000 and annual renewal fee is Rs.10,000. Their enlistment is done by Chief Engineer of Irrigation Department.

(c) Category "B" Contractor

Contractors of this category can bid for works costing upto Rs.50 lacs. Their initial enlistment fee is Rs.5,000 and annual renewal fee is Rs.5,000. The Chief Engineer is competent to enlist such contractors.

(d) Category "C" Contractors

Contractors of this category can bid for works costing upto Rs.25 lacs. The Chief Engineer is competent to enlist such contractors.

(G) **Tender Documents**

One of the most important parts in this document is the "Instructions to Bidders" which must contain, among other clauses, the following provisions:

* Eligibility of bidders
* Bid bond
* Performance bond requirement
* Terms of payment
* Experience of a bidder
* Completion date desired
* Prices with/without escalation
* Method of evaluation or comparison

Where pre-qualification is carried out, the tender documents are issued only to pre-qualified contractors. The bid bond should be nominal, not exceeding 2 per cent. The period of validity must include the validity period of the tender plus the period within which the performance bond is required to be submitted. The performance bond should not exceed 10 percent. A mobilization advance of 10 to 15 percent against appropriate bank guarantee is generally recommended for bigger civil works contracts. The experience of a bidder, particularly for supply contracts where pre-qualification is not used, must be appropriately described in the tender documents.

(H) **General Conditions of Contract**

The conditions of contract should correspond to those specified by the PID. The provision(s) for arbitration should be stated as it will normally help in attracting bidders. Although not a new concept in Pakistan, the penalty as well as bonus clauses should be used and enforced. An appropriate "penalty or bonus" clause for late or early completion of the works is highly desirable. Contracts which contain such a clause stipulate the consequences of early or late completion of the works. If the work is not completed by the agreed date, the contractor under the "penalty" clause shall pay the PID the stipulated penalty. In the event of early completion of the scheduled work, the PID would pay a bonus to the contractor in accordance with the terms provided. Retention money (maximum of 10 percent) should be included in all maintenance project contracts to ensure that the quality of the work is in accordance with the specifications. Advance payments/escalation clauses, if used, should be explained in detail and should be co-related to the provisions under "Instructions to Bidders." If escalation is to be paid on labour and materials, their basis should be specified.

(I) **Technical Specifications of Contract**

The technical specification are the essence of the contract as each bid package must be such that the widest possible competition could be generated. The specification must be clear regarding the performance of the work and the specific characteristics desired. Alternative bids, if acceptable, may be invited and suitable evaluation criteria for alternative bids must be included in the tender documents to avoid arbitrary decisions and future complaints. The documents must state clearly whether the base bid must be submitted in addition to alternative bids. Alternative bids must meet the performance criteria and objectives of the work to be done and are to be considered if they are more economical than the base bid.

(J) **Contract Drawings**

The contract drawings as prepared by the Department are considered to be construction drawings rather than design drawings. Therefore, the drawings must be prepared in detail to show exactly what is to be done and where it is to be done. Excavation lines must be shown as well as existing ground or canal bed surfaces. The drawings are an integral part of the contract and are considered part of the technical specifications.

(K) **Tender Bid Form**

The tender form must indicate the price, responsiveness to specifications (scope and other essential features of the offer), payment terms, firmness of price or otherwise, and period during which the bid is valid. The use of the Schedule of Composite Rates is applicable as long as the specifications and pay items are prepared accordingly else the tender can be based on item rates. The contractor's overhead and profit are included in the rates used for various items. The specifications for earthwork compaction and testing should be spelled out in detail. The bid bond must be readily cashable in the event of default. To be fair to bidders, the tender document has to be clear and precise with respect to all elements highlighted under "Instruction to Bidders".

3.95 REVIEW AND CHANGES IN CONTRACT DRAWINGS.

Drawings shall illustrate the detailed elements of the structures, earthworks or other component work which will,if carefully followed during construction, produce a product that is consistent with the construction objectives. Particular care must be taken to clearly show existing conditions and the extent upto which the contractor is expected to modify or repair the element. For example, if bricks are to be replaced on a structure, the drawing must show where and to what extent the contractor is to remove and replace. Quantitative and qualitative acceptance criteria shall be set forth in the technical specifications. If Drawings have to be reviewed and some changes have to be made to establish that they are in accordance with the contract drawings then a variation order in accordance with the conditions of the contract should be issued. Each drawing shall have a specific drawing number. Revision in the contract drawings are adequately identified as to what changes have been made. The following items should be taken care of:

(a) **List of Drawings**

A list of drawings issued for contract shall be prepared by the head draftsman in consultation with the XEN and/or the SDO. This list shall be continually updated and serve as an index.

(b) **Drawing Numbers**

Drawings shall be identified with drawing numbers taken from the block of numbers assigned to the project. If a contract drawing is revised then its revision number and date should be shown on it.

(c) **Drafting Standards**

Drawings shall be prepared in accordance with the PID's Drafting Standards. All drawings will be standard size to fit in the contract document.

(d) **Checking Drawings Prior to Issue**

Prior to the submission of completed drawings to the XEN, the head draftsman shall check all completed drawings and note significant comments and required changes on a check print. If it is a large contract, the SDO will also check the drawings prior to the final check by the XEN.
The check should include the following:

- Compliance with design requirements
- Correct and consistent dimensions
- Conformance with PID drafting standards

3.96 BID EVALUATION AND RECOMMENDATION FOR AWARD.

Contract documents are prepared which define specific items, quantity, quality and required construction schedule. Measures shall be established for evaluating bids, and determining whether bids conform to contract document requirements. The following procedure sets forth a system for reviewing and evaluating bids and recommending award of construction contracts. The bid evaluation shall be made by individuals designated to evaluate the following subjects, as applicable to the type of contract:

* Technical considerations
* Quality assurance requirements
* Contractor's capability
* Contractor's past performance
* Alternates
* Exceptions

Other conditions such as warranties, schedule, price, price adjustments and conditions are recognized as factors effecting bid evaluation. Prior to award of contract by the PID, the proposed contractor's past history shall be evaluated in detail including :

(a) Evaluating the contractor's history of constructing similar installations or work performed in a satisfactory manner based on the PID's records accumulated in connection with previous experience.

(b) The experience of other agencies, companies, or individuals regarding the contractor's work.

(c) The success of quality performance is highly dependent upon the contractor's personnel capabilities, physical condition of equipment, and management attitude towards quality. Historical data should be representative of the contractor's current capabilities. If there has been no recent experience with the contractor, the prospective contractor should be requested to submit information on a similar project (type of work) for evidence of his capabilities.

(d) The contractor's technical and quality capability may be determined by a source evaluation.

3.97 Contract Administration

Construction supervision is the process of supervising and inspection of the work of a contractor to ensure that the work is being performed according to the contract specifications, drawings and general conditions. It is sometimes referred to as contract administration, supervision and inspection being individual functions.

Contracts are usually awarded by the divisional officer (Executive Engineer) who acts as the engineer in charge and the work is supervised in the field by the SDO or most likely the SBE in-charge of the canal where the work is being done. Payments and other administrative details are covered by the appropriate conditions of the contract. Control of the quality of the work being done is the responsibility of the SDO and SBE who act as field inspectors. This responsibility is usually delegated to them by the XEN.

Contract/construction supervision requires the canal officers to be completely familiar with the contract and contract documents they are administering. They should be familiar with all plans and specifications including all revisions, changes and amendments. They also need to have a thorough knowledge of all codes, laws and regulations pertinent to construction activities. Inspection and testing become critical items for the canal officer, along with the determination of quantities. Testing is usually required before the work can be accepted; this is particularly true for compacted fill material and sometimes concrete. The following items of the contract need to be carefully studied and administered during the execution of the work. Any omission in the proper application of these items leads the department towards difficulties if the contractor is not satisfied with the payments made to him and opts for arbitration at the end of the contract.

(a) For each contract an engineer-in-charge (usually the XEN) is specified in the contract documents. All correspondence with the contractor should be carried out by the engineer- in-charge because, according to the conditions of the contract, neither the higher officers nor the lower officers of the XEN are authorized to convey any instructions to the contractor. Any instructions issued by any other officer except the engineer-in-charge are not legally valid and therefore such letters and instructions do not serve any purpose in the arbitration proceedings.

(b) No conditional tender should be accepted by the competent authority. If any tender,however, has to be accepted which stipulates certain additional conditions of the contractor, these must be dealt with in the letter of acceptance to the contractor. If these are not dealt with, it can be construed during arbitration proceedings that the conditions submitted by the contractor have been accepted by the department.

(c) The letter of acceptance should be issued within the period of acceptance of tender. If it has not been possible, the contractor (to whom the work is proposed to be allotted) should be asked to extend the validity period of his contract.

(d) The date of commencement of the contract is of vital importance. Therefore the engineer in charge while issuing a letter to the contractor for the commencement of work should specifically mention the date from which the contract work is deemed to have been commenced.

(e) Any additions or alterations made in the contract work should be properly covered by the issuance of a variation order. The rates applicable to additional work should be settled with the contractor unless they are covered by the items given in the contract.

(f) Any deviations from the specifications should be promptly brought to the notice of the contractor by the engineer- in-charge pointing out the deficiencies. The contractor should be asked to rectify the omissions and carry out work according to the specifications and instructions of the engineer-in-charge.

(g) It is the requirement of all the contracts that the contractor will engage qualified engineers for the supervision and execution of all items of work. He would also be responsible for the proper layout of various parts of the works according to the contract drawings.

(h) It is also the requirement of the contract that the contractor should himself prepare and submit his bill for the executed work every month for checking and payment by the engineer-in-charge. It is also laid down in the contract that if the contractor fails to submit his bill then the Sub-Engineer in charge of the work should measure the work and make entries in the measure book for payment of his bill. The contractor should be encouraged and impressed that he should submit the bill every month himself. The responsibility of the Sub-Engineer should be limited to the checking of contractor's bill regarding both the quantities and amount of the bill.

(i) If according to the contract the contractor has to prepare the shop drawings, the engineer-in-charge or his representative should see that these drawings are issued by the contractor and after approval by engineer-in-charge, he should carry out work according to these drawings.

(j) If the contractor writes any letter for any claims or any matters which can lead to arbitration, such letters should be carefully studied and properly replied to safeguard the interest of the department.

(k) The date of completion of work is also very important for the following reasons:

(i) The contractor's responsibility for maintaining the work for three months after its completion will commence from this date.

(ii) The contractor may ask for substantial completion certificates of certain parts of works for a number of items. All these dates should be carefully noted because the period of maintenance will start from that date for each item for which substantial completion certificate has been issued.

(iii) If contractor is to be penalized for delaying the completion of the work beyond the stipulated completion date, then the period of imposing penalties will commence from the date of completion certificate.

(iv) If the contractor is to be paid bonus for completing the job earlier than the stipulated date then again the period for bonus will be reckoned from the date of completion certificate.

3.98 DAILY PROGRESS REPORTS.

Engineer's representative should prepare daily progress reports and deal with the following points for the information of higher officers. Also if some decisions are required from the higher officers, this should be clearly pointed out. This report should include items such as number of laborers present, materials received, equipment and tool utilization. Injury accidents must also be reported. The following information should be part of the daily reporting :

(a) Site conditions that adversely affect the construction operations such as weather, moisture, soil conditions, river stages, etc.

(b) All activities that are related to the execution of the construction contract must be reported in detail, including quantities (unless included in survey reports) and calculations.

(c) Difficulties encountered by the contractor, the client or the PCS.

(d) Controversial matters such as disputes, questionable items, interpretation of conditions.

(e) Deficiencies and violations such as safety, environmental standards, labor, law, etc.

(f) Instructions given and received. Report how and to whom they were transmitted or from whom they were received.

(g) Progress information including delays and reasons for them, action taken or planned, comparison of actual progress with the schedule.

(h) Equipment. Arrival at and removal from site of each major equipment item by stating manufacturer, model, serial No. and capacity. Report equipment in use and comment or reason for idle equipment.

(i) Record of tests and test results. All tests in connection with quality control and results thereof must be carefully recorded and documented.

(j) Claims. Conditions that may lead to claims or disputes almost always exist on construction projects. It is therefore necessary that a comprehensive record is kept in the form of daily reports of facts and conditions that have not been covered correctly or completely in the specifications or drawings. Make sure that adequate and accurate records of facts, quantities, materials, labour, equipment, and time associated with actual or anticipated claims or disputes are kept.

3.99 REVIEW OF SHOP DRAWINGS (DRAWINGS PREPARED BY THE CONTRACTOR.

Shop drawings, if required, shall be reviewed for general conformance with the contract documents. The results of the review shall be documented, with the identification of the reviewer clearly indicated thereon. The documented results shall be retained as a record. Where changes to previously reviewed drawings are made, these changes, and the effect of the changes to the overall design, shall be re-reviewed. Input data from studies, reports, calculations, etc., which previously was reviewed and found acceptable, need not be reviewed again.

Exhibit III-1

BUDGET CALENDAR SHOWING THE DATES FOR SUBMISSION OF VARIOUS BUDGET RETURNS

S. No	Budget Return	From SDO to XEN	From XEN to SE	From SE to CE	From CE to SECY	From SECY to FD	From FD to Cabinet
1.	First List of Excesses and Surrenders for O&M budget for the current Financial year.	1st Sept.	1st Oct.	15th Oct.	25th Nov.	1st Jan.	15th May.
2.	Budget Estimate for O&M budget for the next Financial year.	1st Sept.	1st Oct.	15th Oct.	25th Nov.	1st Jan.	15th May.
3.	Schedule of New Expenditures (SNE) for Non-Development Budget (NDB) for continuing or new items.	15th Sept.	1st Oct.	15th Oct.	5th Dec.	10th Jan.	15th May.
4.	Second List of Excesses and Surrenders (Revised Estimate for the current Financial year.	15th Jan.	1st Feb.	10th Feb.	10th Mar.	31st Mar.	15th May.

INDENT FOR STORES

[Central P.W.A. Code paragraphs 106 to108]

Indent No. **Date** **On**

DESCRIPTION	NO or Quantity	Head of Account	Name of work with name of contractor form whom value is recoverable

The Stores should be delivered---------- to ____________ by ____________

Inenting Officer (Divisional or Sub-divisional Officer)

INDENT FOR STORES

[Central P.W.A. Code paragraphs 106 to 108]

Indent No. **Date** **On**

Description	No or Quantity	Head of Account etc.	Name of work with name of contractor from whom value is recoverable	Signature of Indenting Officer	
				These stores should be delivered/despatched to ___ by ___	Divisional or Sub Divisional

Certificate of Supply

This indent has (not) been complied with in ful.
The alterations, which I have attested, accordingly been made by me

delivered
----------- to________________ on________________ by____________
despatched
Date________________ Supplying Officer

GSAPD, NWFP 175 Rs.10,000 p. of 100-8.5 85

INVOICE

Central P.W.A. Code, paragraphs 106 to 108

Invoice of stores supplied by to

Ordered by Dated Issued by the

Description	No or quantity	Head of Account etc	Name of work (with name of contractor from whom value is recoverable

Supplying Officer

Dated______________ Received
Dated______________

Receiving Officer

* In the case of issues to contractors and private persons this acknowledge sent should set forth all the particulars mentioned in para 210 of the Code.

EXIHIBIT III-3

FIELD INSPECTION REQUIREMENTS

Type of Staff	Area of Coverage	Frequency of Visit
Gangmen (Beldar), Mates	Beldar; 1 to 2 miles every main canals: 1 to 6 miles of Distributaries-Minor	Daily
Sub-Engineer	30 to 50 miles of channels, drains, embankments	Lives in area and may travel almost daily
Sub-Divisional Officer	110 to 160 miles of channels, drains, embankments etc.	Over-night halts out of station as required
Executive Engineer	200 to 700 miles of channels, drains, embankments etc.	Over-night halts out of station as required
Superintending Engineer	900 to 1,500 miles of channels, drains, embankments etc.	Has discretion in scheduling field visits per year
Chief Engineer	6,000 miles of channels, drains, embankments etc.	Has discretion in scheduling field visits per year

Exhibit III-4

CHECK LIST OF ITEMS DURING INSPECTION OF CANALS BY OFFICERS

1. **Head Discharge**

The head gauge to see that the channel is taking the designed or authorized discharge. The water in the parent channel should be as designed. Gauge register is properly maintained.

2. **Canal Prism**

(a) Top width according to design. Does the channel have a tendency to silt up and have side erosion.

(b) Surface water level according to design. Silted bed will have higher water levels.

(c) Erosion of berms. This tendency should be checked by killa bushing.

(d) No plantation on berms of channels. Their roots take water from the channel and lot of water is lost through evapotransporation from the levels of trees.

3. **Canal Embankments**

(a) Width of bank according to design.

(b) Freeboard according to design. If it is less than 50% of design, the channel requires silt clearance or raising of banks is required.

(c) Outer slopes conform to designed section. If slopes are steeper earth work on slopes is required.

(d) The toe of outer banks should not be wet. If it is wet hydraulic gradient is not covered. Earth work pushta is required at such places to cover the hydraulic gradient.

(e) The berms should be according to designed section.

(f) If there is dowel, it should be maintained for the safety of vehicular traffic.

(g) Cattle trespass sites should be carefully watched. These are potential sites for breaches.

(h) Rain cuts on slopes should be promptly repaired after each rainfall.

(i) Any damage to dry stone pitching done on the sides of channel should be noted for early repairs.

(j) Occurrence of rat holes in the embankment should be noted. Action as given on the rodent control chapter should be taken.

(k) Lined sections of any canal should be noted for any bulging of sides. This may be due to pressure of water or saturated clay at the back of the lining. Weep holes may be provided at such site to release pressure.

(l) Inspection road maintained in good motorable condition. Special instructions have been laid down for maintenance of kacha roads in Part 3.

(m) Berm formation encouraged on bigger canals as they ensure safety of canal.

4. Regulators

A. Mechanical parts

(a) Gates should be rust free. Their painting done regularly. Portions of gates which remain under water should be painted with Khaki mixture.

(b) There should be no leakage of water through the sides of gates.

(c) The gears and the threads of worm shaft should be kept greased so that gates can be operated throughout the designed height.

(d) If there is oil sump, it should remain filled with proper grade of oil. The hole through which oil is poured should be leaktight otherwise rain water will get into the sump.

(e) Every gate regulator should be provided with locking device so that the farmers or other people cannot raise or lower the gates.

(f) An operational test should be carried out on the gates during closure period i.e. they should be raised to the fully open position and then closed to the lowest position.

B. Civil Works

(a) Check position of wave and dissipation of energy below the regulator. Watch for any side erosion of banks. If there is erosion, side water rollers are being formed. Some actions such as putting in additional friction blocks is required. For bigger canals model testing may be required.

(b) Generally dry brick or stone pitching is done below the regulators. This gets damaged due to back water roller. In such cases the pitching may be extended or action to stop back water rollers may be taken.

(c) During closure period, bed erosion downstream of regulator should be noted. Excessive erosion may undermine the downstream floor.

Falls

(a) The points listed under civil works for regulators apply to falls.

(b) If a fall serves as contact point, gauges should be in good condition and a gauge register maintained.

Bridges

(a) No debris sticking to the upstream nose of piers.

(b) The ramps along the patrol road and from natural surface should be maintained for easy communication of vehicular traffic.

(c) Cover on slabs or arches maintained to avoid exposure to rain water.

(d) Unauthorized bridges on distributaries and main canal should not be allowed to be constructed as they cause accidents for which Irrigation Department is held responsible.

Outlets

1. Check size of outlets to conform to designed diversion.

2. The outlets, if APM or OF, (open flume), should work modularly for delivering authorized discharge.

3. The H, i.e., the depth of water on the crest of outlet (for APM or OF) should be according to the design.

4. For pipe outlets the head across should be according to design.

Exhibit III-5

DAILY INSPECTION REPORT - GENERAL CONSTRUCTION

Date:
Project: ____________
Location: ____________ Project No. ____________
Weather: Temperature - High _____ Low _____ Clear _____
Partly Cloudy _____ Cloudy _____ Precipitation _____

Contract Section or Division ____________

Contractor ____________ Superintendent ____________

(Inspection) Hours Worked: ____ Reg.: ____ OT Shift ____ to: ___

(Contractor) Hours Worked: ____ Reg.: ____ OT Shift ____ to: ___

Work Force: _____ Equipment: ____________ Activity and Location: ____________

____________ Defective work noted today to be corrected later: ____________

____________ Description:

(List work in progress, Item No., quantity installed, location, comments, problems, visitors, delays and causes, accidents, special instructions received or given, test made etc.)

____

____

____

____

____________ (Continued on other side) Signed ____________
Inspector

Attachments: Yes ___ No ___ Approved ____________
Sub-division Officer

Description ____________
(Compaction Reports, Concrete Placement Reports, etc)
This report is to be completed daily by each inspector.

Exhibit III-6

Emergency Repair (Breach in a Canal).

Normally breach in a canal shall not occur if operation, maintenance and inspection of the canal is being carried out periodically. If it occurs, due to negligence, natural calamity or abnormal conditions, it shall be immediately reported by Sub Divisional Officer to all his higher officers. Executive Engineer shall inform Accountant General of the Province and local Audit Officer. The executive Engineer shall undertake the repair under para 127 of the PWD Code after obtaining the approval of the Superintending Engineer. For the commencement of the work verbal orders should always be confirmed in writing as soon as possible and in case of emergency, a preliminary rough cost estimate should be sanctioned by the Superintending Engineer and Audit Officer. After being informed the account officer will be responsible for bringing the facts to the notice of higher financial authority of the Province.

Canal shall be closed at the head works or water escaped immediately through the escape structure up stream of the canal, breached section which ever is applicable. In case of escape structure controlled supply shall be allowed to pass into the canal through headwork so that the up stream irrigation does not suffer on account of the breach. After having stopped the canal water reaching the breached section, work shall commence immediately by removing all the damaged portion. Based on the preliminary findings of the cause of the breach, the repair shall be started strictly in accordance with the specifications as per site conditions. Throughout the emergency, the work shall be supervised at site by an official not less than a Sub Divisional Officer. To keep record of cuts and breaches on the Government channels, registers must be maintained in each division and sub-division as per practice in the Department. The incident shall be investigated by the Divisional Officer or a committee constituted by Superintending Engineer and a report should be submitted in detail to the Superintending Engineer. The occupiers rates shall be assessed on areas inundated with water flowing from the breach as per para 13. 10-A of the Revenue Manual.

Detailed Procedure for closing breaches in distributaries and minors and main canals and branches has been dealt with in Part-3, Chapter 5.

CHAPTER 4

ADMINISTRATION

4.1 INTRODUCTION

In the NWFP, the old administration and management system established by the Colonial Government is still followed. It is a system of built-in checks and balances that channels decisions up and down a chain of command. Very little is left to the individuals discretion. This system needs to be modified to give more administrative powers to the lower echelon officers. The modification is necessary in the light of changed socio-political conditions. The existing set up for the Irrigation Department is shown in FIG. IV-1.

Considerable emphasis has been placed on O&M functions without regard to the administrative effort required to support the field effort. Administrative duties currently consume about 80% of the Divisional and Sub-division officers time. Various manuals which lay down the administrative requirements are in use in the NWFP and are listed in Table IV-1.

The majority of the legislative acts, ordinances, manuals and other administrative directives are outdated. They contain many references to colonial times. It is imperative that the manuals mentioned above,in particular the O&M Manuals be thoroughly reviewed, revised, updated, published and distributed by the Provincial Government for the guidance of all concerned. This could certainly be done without changing any of the forms, reports and procedures which are still in use. Legislative Acts and Ordinances are periodically revised by the Assembly. Even then, it would be appropriate and helpful to completely revise and update them to reflect Provincial Government orders as existing today. The process of adopting new forms for the PID is a long involved process whereby the proposed form has to be approved by the Finance/Audit Department.

4.2 ADMINISTRATIVE STAFF.

A. General

In the NWFP, PID is headed by a Secretary to the Government of the Province with secretariat staff under the Secretary. There is a Chief Engineer(CE) in charge of a region. The region is divided into a four Circles which are controlled by the Superintending Engineers (SE). Each SE is assisted by a team of XENs. There are a number of SDOs and Revenue staff in each Division. There are a number of Sections which are manned by the Sub-Engineers (SBE). Canal Inspectors, Beldars and Gauge Readers assist the Sub-Engineers in the operation and maintenance of Canal Systems. The Canal Collector also has a lien attached with the Chief Engineer who heads the Revenue Branch of the PID. All of the Revenue establishment is placed under the charge of the Divisions and Sub Divisions for facilitating assessment and other Revenue work. A diagrammatic view of the lines of commands is shown in Fig. IV-1.

ORGANIZATION CHART OF IRRIGATION DEPARTMENT N.W.F.P

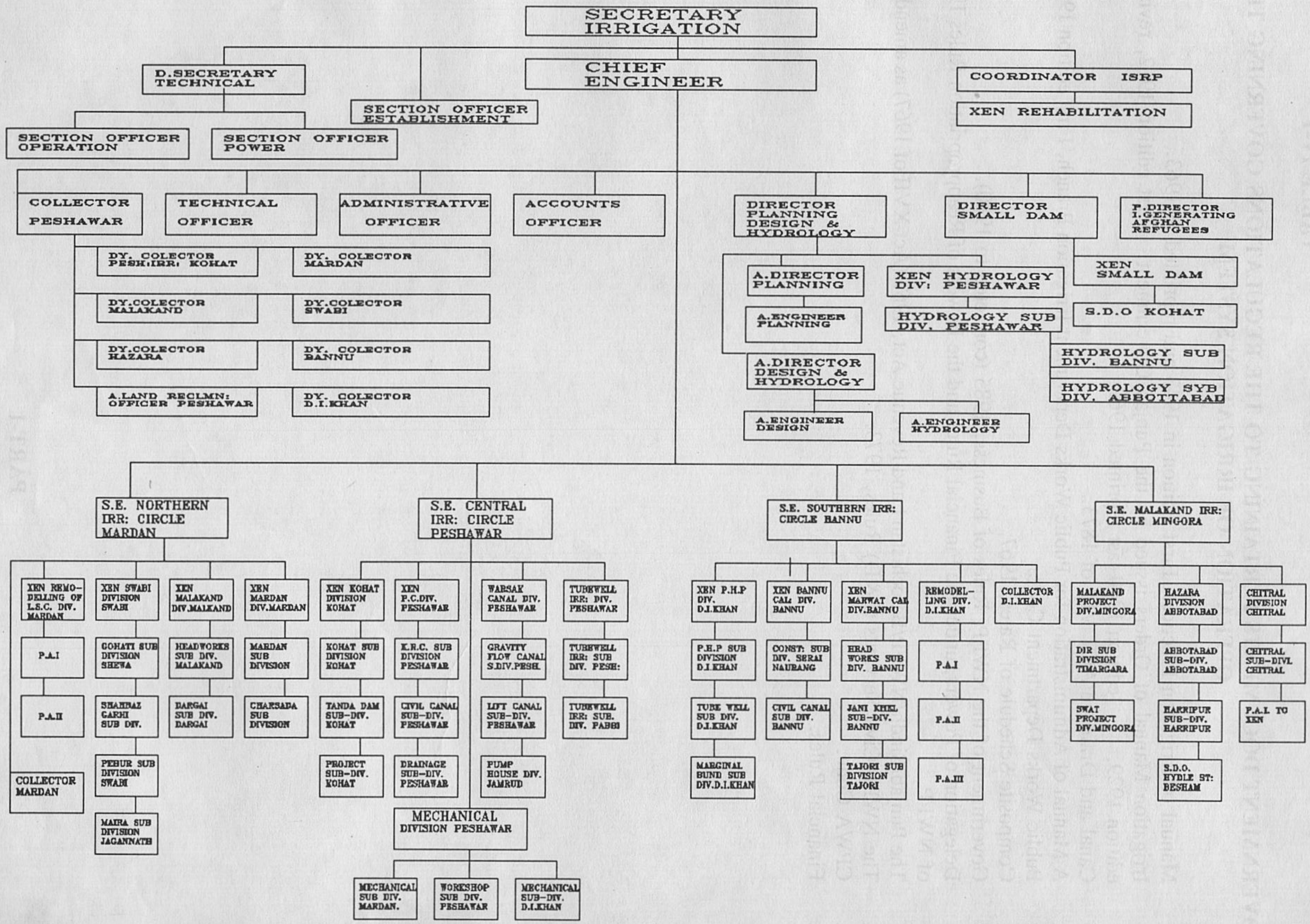


FIG.IV-1

TABLE IV-1

GOVERNMENT DOCUMENTS PERTAINING TO THE REGULATIONS GOVERNING THE OPERATION OF IRRIGATION SYSTEM

1. Manual of Irrigation Practice. First Edition in 1943 and reprinted in 1963.
2. Irrigation Manual of Orders issued by the Punjab Government. First edition 1912, revised edition 1929, edition 1940 last reprinted 1969.
3. Canal and Drainage ACT VIII of 1873.
4. A Manual of Administration for Public Works Department Irrigation Branch, First edition 1945.
5. Public Works Department Code.
6. Composite Schedule of Rates, 1967.
7. Government of the NWFP, Rules of Business, 1985 (corrected to 1980).
8. Delegation of Powers, under the Financial Rules and the Powers of Reappropriation Rules 1987 of NWFP.
9. The Punjab/Sindh/NWFP/Balochistan Land Revenue Act, 1967 (Act XVII of 1967) as amended.
10. The NWFP Civil Servants (E&D) Rules, 1973.
11. CPWA Code.
12. Financial Rules.

Duties of officers other than the Secretary to the Government are given below:

i. **Chief Engineer**

The Chief Engineer (CE) is the administrative and professional head of the department and is responsible for the efficient working of his region. He is also a responsible professional advisor of the Government in all matters relating to his charge. His main duties are given in Exhibit IV-1.

ii. **Superintending Engineer**

The administrative unit of the PID is a Circle in the charge of an SE who is responsible to the CE for administration and general professional control of Public Works within his Circle. His main duties are given in Exhibit IV-2.

iii. **Executive Engineer**

The executive unit of the Department is a Division in the charge of an Executive Engineer (XEN) who is responsible to the SE for the execution and management of all irrigation facilities. His main duties are listed in Exhibit IV-3.

iv. **Sub-Divisional Officer**

His main duties are listed in Exhibit IV-4.

v. **Collector**

His main duties are listed in paras 3.2 to 3.11 of Revenue Manual. and are reproduced in Exhibit IV-4A.

vi. **Sub-Engineer**

His duties are given in Exhibit IV-5.

vii. **Zilladar**

His duties are given in Paras 2.2 and 2.3 of Revenue Manual. These have been reproduced in Exhibit IV-5A.

C. Divisional Office Administration

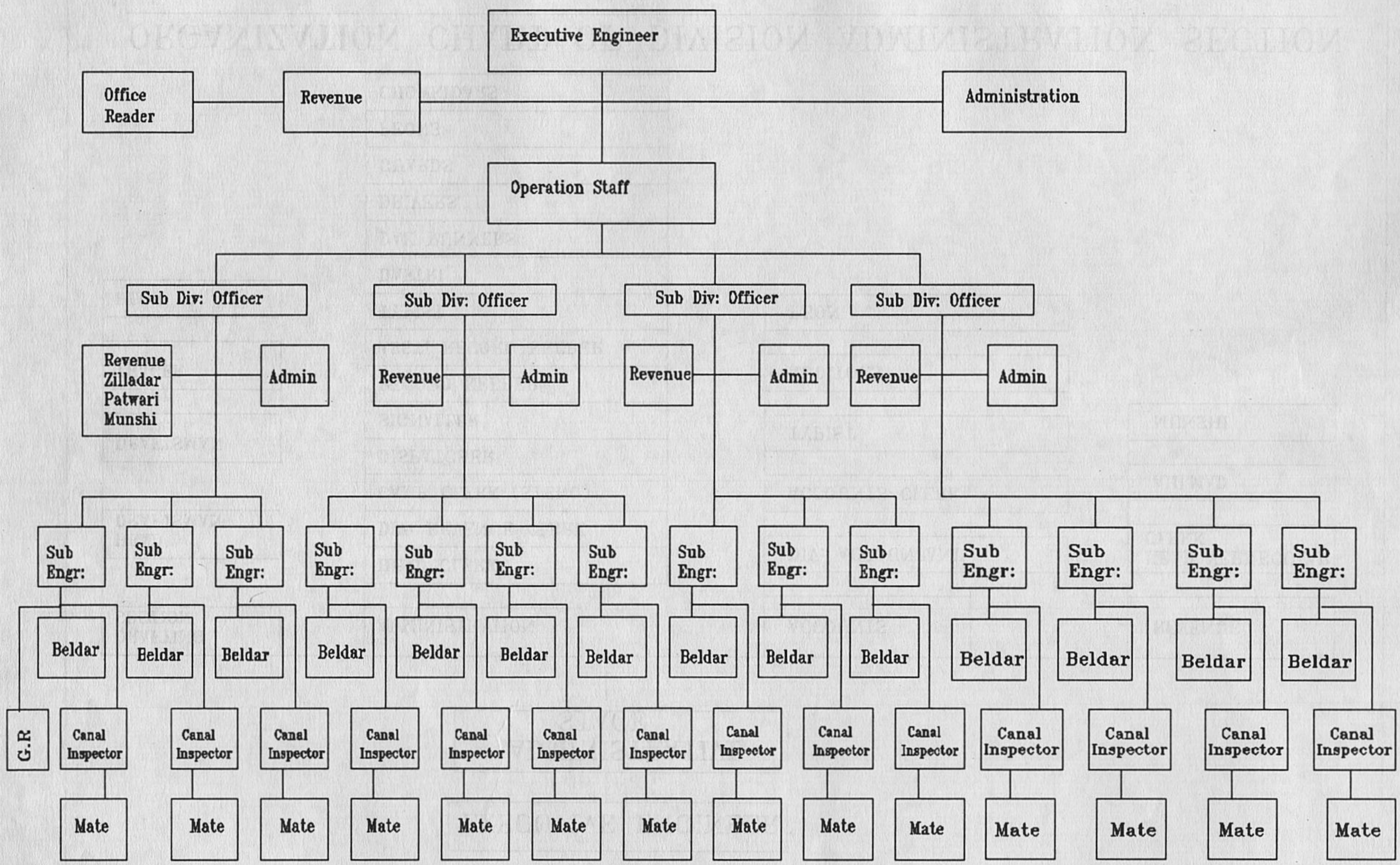
Since the Division is the backbone of the O&M functions, further discussion is confined to the Division and its lower offices.

The Division is the basic level where planning and thus budgeting begins. The Division is divided into three functional units. (1) Operations, (2) Revenue and (3) Administration. See Fig. IV-2(a) for a typical example of Operation and Fig. IV-2(b) for administration. The operations side is nominally divided into two to three sub-divisions but this can vary according to the size of the canal system. The SDOs are under the direct supervision of the XEN. The latter carries out inspection of all Sub-Divisions once a year to see that all the records relating to stock and T&P and accounts are being maintained properly. The revenue side will have a number of Zilladars who supervise upto 10 patwaries in their job of booking irrigation, preparing demand statements and delivering them to the farmers through the Lambardar (the headman of the village). The Zilladars are supervised by a Deputy Collector (DCL). The Zilladars and patwaries are posted to the sub-divisions for administrative support. The administrative staff is there to support the Executive Engineer in performing his duties. Figure IV-2(b) is an illustrative example of a divisional staff. The composition of each divisional staff will vary according to the system and the facilities it is responsible for. Operational activities are carried by the field staff shown in Fig. IV-2(a).

The administrative functions are generally carried out under three sections: drafting, accounts, and ministerial. The Divisional Head Draftsmen is responsible for checking estimates, preparation, checking and filing of all drawings in the division. He maintains eight separate drawing registers which include all physical features of the irrigation system including the buildings owned and operated by the department. All maintenance engineering is performed at the division level. Engineering generally involves repairs to standard structures, repairs to the embankments or resetting outlets. These works are carried out by the SDO and Sub-Engineer. The Head Draftsman is responsible for preparing the needed drawings and checking estimates. The XEN or SDO would review the drawings and make any required corrections. The Head Draftsman assures that the corrections are incorporated and the drawings are properly signed.

The Head Clerk is responsible for most of the daily office routines regarding correspondence, communications and personnel. The typist, dispatcher (signaler), camp clerk, record keepers, guards and messengers are under the Head Clerk. All correspondence and messages to the Field or Superintending Engineer are handled by the head clerk. Normally the Divisional Office is connected to the national telephone system. The canal telegraph system, when available, connects the Divisional office with the cross regulators, the gauge reader and signaler keeps the officers informed about the operation of canals.

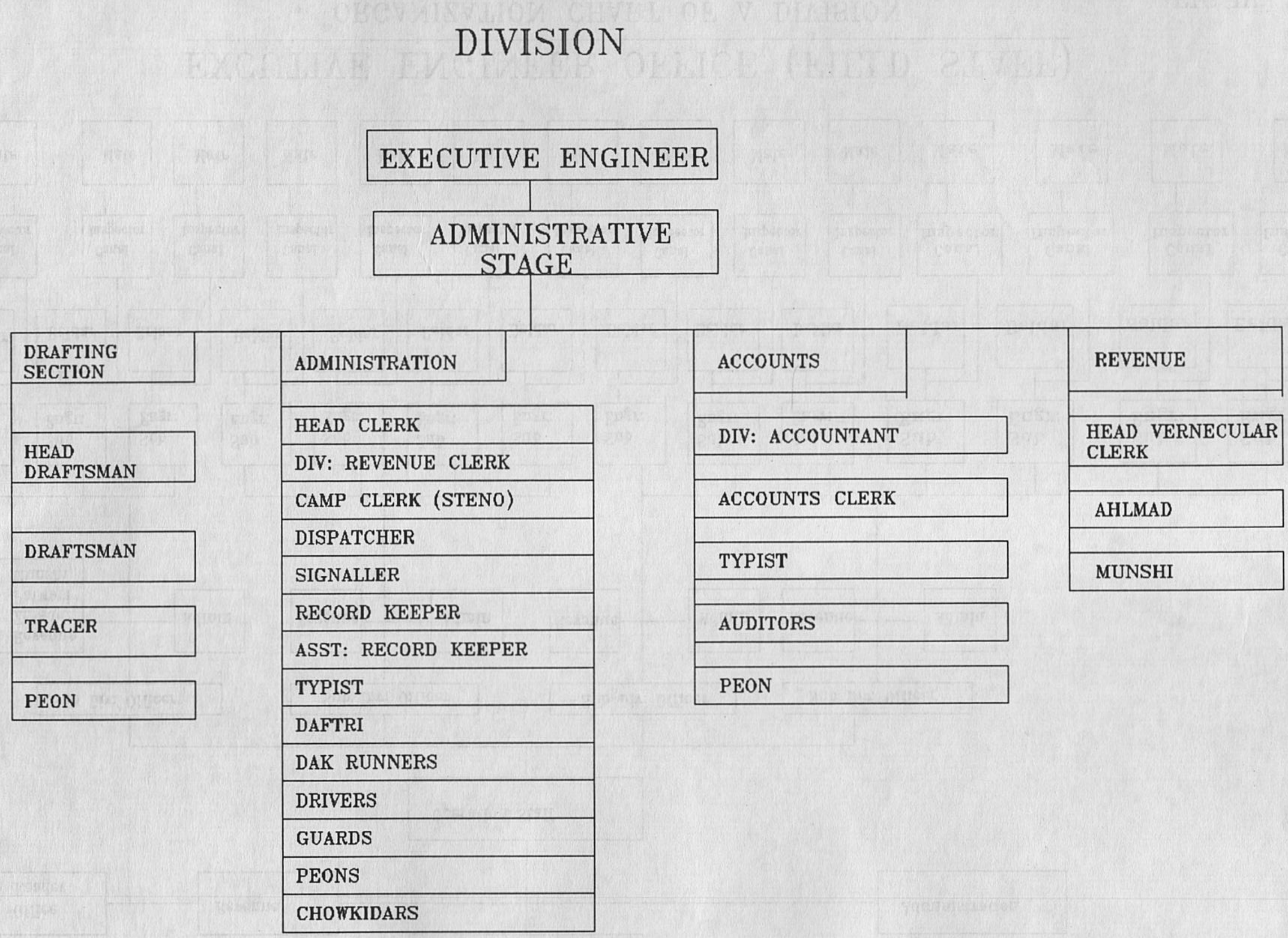
The accounts section is responsible for maintaining all financial accounts/records which includes contracts, materials and other general accounts as prescribed. The Divisional Accountant who mans the accounts branch is assisted by an accounts clerk and two or three auditors (book keepers), one for each sub-division. The Divisional Accountant is the representative of the Accountant General of the NWFP. The camp clerk, who is assigned to the Head Clerk assists in maintaining the records pertaining to the furniture and equipment for all buildings maintained and operated by the division. He accompanies the XEN on tours and acts as stenographer. The Divisional register of plant and machinery is maintained by the Head Clerk. The Revenue Section is headed by a Deputy Collector (DCL). The DCL has five to seven Zilladars under his direct supervision. The Zilladars are assigned to the Sub-divisions for logistical support. They receive their instructions from the DCL. The Zilladars are responsible for collecting and processing information on the area of crops planted and irrigated from



EXCUTIVE ENGINEER OFFICE (FIELD STAFF)

ORGANIZATION CHART OF A DIVISION

FIG.IV–2 (a)



ORGANIZATION CHART OF DIVISION ADMINISTRATION SECTION

FIG.IV-2 (b)

each watercourse. The Revenue Manual provides the details of their work including the appropriate forms. The Zilladar supervises upto 10 Patwaries who perform the actual field work. The Patwaries are responsible for booking irrigation in their field measurement books (khasras) and preparing the demand statements (khataunis), in which the Patwaries account for the remission of areas tawan (penalty for misuse or theft of water), land revenue and fees payable to Lambardars, abstract of areas irrigated and water charges to be collected from the farmers. The completed forms are submitted to Tahsils and Districts for the entire Canal Division for collection of revenue. The work of the Revenue Section does not directly effect the operation nor maintenance activities of the Division. The Zilladars work closely in association with the SDO. The XEN, SDOs and the Deputy Collectors are required to check on the work of the Zilladars and patwaries in the field. This is normally done while on tour or when a question or dispute arises. The amount of booked irrigation to be checked by various officers is shown in Exhibit IV-6.

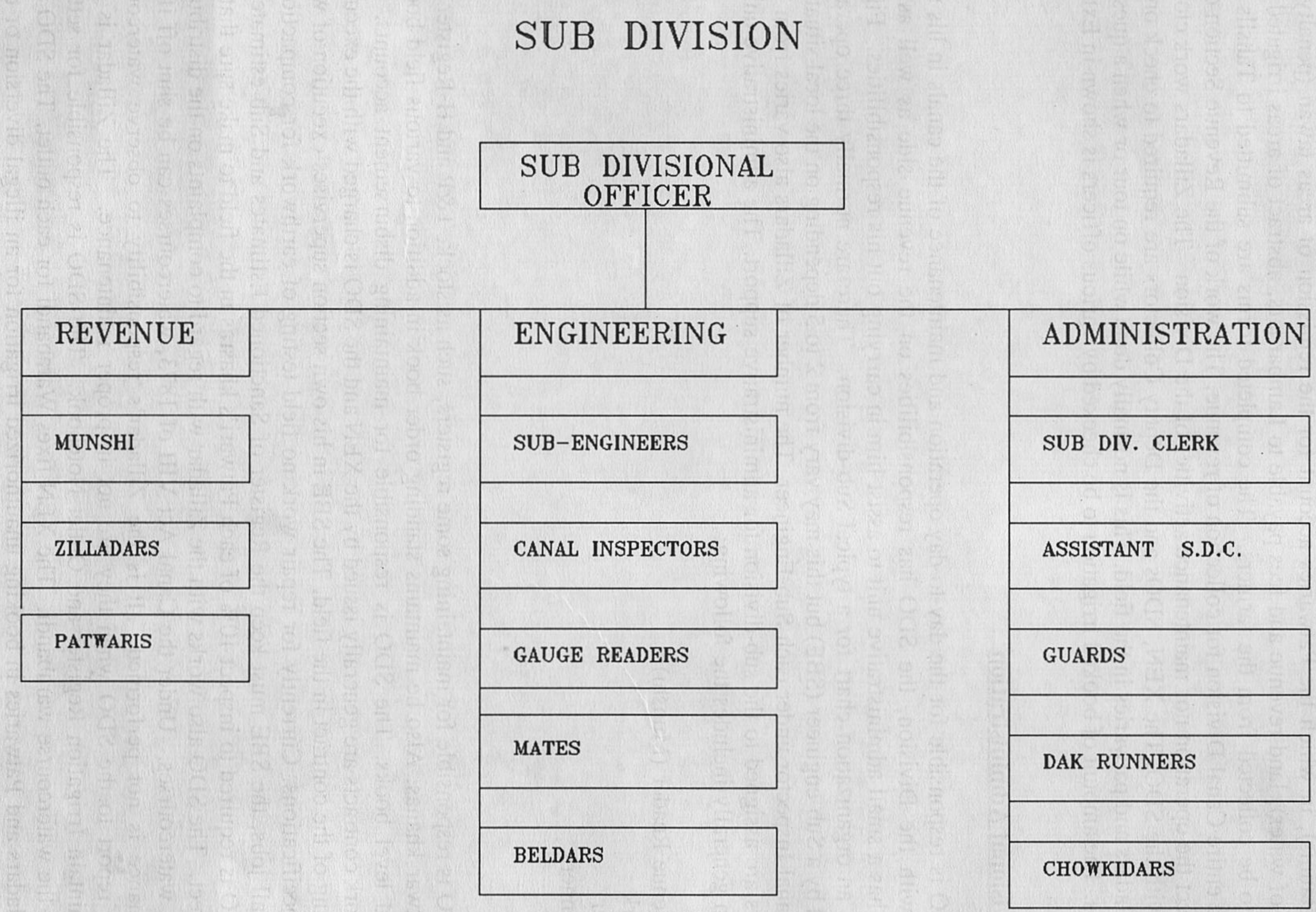
D. Sub-divisional Administration

The SDO is responsible for the day-to-day operation and maintenance of the canals in his sub-division. As with the Division, the SDO has responsibilities on the revenue side as well as the operations and has a small administrative unit to assist him in carrying out his responsibilities. Figure IV-3 illustrates an organization chart for a typical Sub-division. There are normally three operating sections headed by a Sub-engineer (SBE) but this may vary from 2 to 5 depending on the local situation. There is one Canal Inspector under each Sub-Engineer. The number of Zilladars also varies from 2 to 5. The Zilladars are assigned to the sub-division for administrative support. The administrative unit of the sub-division generally includes the following:

- SD Revenue Reader (Munshi)
- SD Clerk
- Signaller
- Dak Runners
- Guards
- Peons

The SDO is responsible for maintaining some registers, such as stock, T&P and H-Register and Register of Putwar khanas. Also he maintains standing order book in addition to various field books, note books and level books. The SDO is responsible for maintaining disbursement accounts. The maintenance work contracts are generally issued by the XEN and the SDO is charged with the execution and administering of the contract in the field. The SBE in his own section supervises execution of work according to specifications. Currently for repair work no field testing of earthwork for compaction is made. For small jobs, the SBE must keep the Register of Sanctioned Estimates and Sub-estimates.

The SDO is required to inspect 10% of each Patwari's khasras in the field to make sure that the entries are correct. The SDO also works with the Zilladar with regard to complaints on the distribution of water in the watercourses. Under the Canal Act VIII of 1873, watercourses can be shut off if the proper maintenance is not performed. It is the Zilladar's responsibility to observe watercourse conditions and report to the SDO when they are not in proper maintenance. The Zilladar is also required to maintain Irrigation Register and Outlet Notebook. The SDO is responsible for settling disputes within the watercourse warabandi. The XEN fixes Warabandi for each outlet. The SDO also utilizes the Zilladars and Patwaries in booking unauthorized irrigation for an illegal diversion or theft



ORGANIZATION CHART OF TYPICAL SUB-DIVISION

FIG.IV-3

of water from a canal and prepares cases for imposing penalties under the Canal Act. When theft of water is noted, the SDO sends the Zilladar and Patwari to the site in order to register the area benefitted by the extra water. The Patwari would measure the area involved and list the crops grown on unauthorized irrigated area. The Zilladar would attempt to determine who actually made the illegal withdrawal. The SDO can also report the matter to the local police to investigate for fixing responsibility for taking water in an unauthorized manner.

E. Checking of Booked Irrigation

XENs, Collectors, SDOs, Deputy Collectors and Zilladars are required to check during each crop i.e. Kharif and Rabi some acreage of irrigated areas which have been booked by the Patwaries. The acreage to be checked is shown in Exhibit IV-6.

F. Service Condition of Officers

The Public Service Commission (PSC) implements the policies of the province through the Secretariat of the PID. They also form lists and test potential government employees (grade 17 and above) to attest their qualifications. Once assigned to the PID, all personnel matters including pay, vacation, seniority, promotion, transfer etc., are handled by the Department in accordance with the civil service regulations. Appeals against decisions of Department are heard by a Provincial Service Tribunal.

G. Non-Departmental Committees

The XEN is also required to serve on a number of district committees as an ex-officio member. The committees are:

(i) District Council.
(ii) District Coordination Committee.
(iii) District Agriculture Advisory Committee.
(iv) District Revenue Officers Committee.

These committees take a good deal of officers's time.

H. Personnel Management/Administration

The Provincial Government controls through the defined set of rules and regulations the employees of the Department. The Provincial Assembly passes an act or ordinance governing employees and their rights. The Services and General Administration Department (S&GAD) administers these Acts or Ordinances by preparing rules and regulations for use by the PID. The Secretariats are responsible for implementing these regulations within their departments. The S&GAD oversees each department's compliance. The regular employees are governed by the Efficiency and Discipline Rules of 1973.

4.3 OFFICE MANAGEMENT.

A. General

Office management refers to the general operational procedures used to run an office. One of its responsibilities is to control paper work. Another of its main functions is information management. Office procedures can be sub-divided into two areas: (1) Administrative and (2) Technical. The administrative side includes; correspondence, personnel, accounts, stores, house keeping etc. The technical side is concerned with contracting, water use data, planning, operations and budgeting, communications and similar efforts.

B. Administrative Procedures

Office procedures in the NWFP are guided by the Irrigation Manual of Orders (IMO) of 1912 as revised. The manual was originally divided into seven chapters, five of which are still retained:

Chapter II	Accounts
Chapter III	Office Procedure
Chapter IV	Land
Chapter VI	Works
Chapter VII	Public Buildings

The IMO requires revision according to changed conditions.
In addition to the above manual, the Public Works Department Code is also used. It is also assumed that there are numerous standing orders from both Chief Engineer and Superintending Engineers which are followed.

C. Office Procedure

Office procedure, as defined in the Manual of Irrigation Orders, (IMO) covers the following general subjects:

(i) Preparation of Estimates and Drawings.
(ii) Government Stores and Money.
(iii) Furniture, Tools and Plants and Instruments.
(iv) Government Records, Registers and Returns.
(v) Miscellaneous.

The IMO covers only those items listed above and it pertains mostly to the O&M side of the Division and Sub-division officers' responsibilities. It does not cover the revenue side except to list the documents on file and available for purchase. It does not cover the enforcement of the various Acts and Ordinances in effect.

The Divisional Head Draftsman is responsible for maintaining nine registers which are listed below :

(i) Register of Buildings.
(ii) Register of Record Plans of Buildings.
(iii) Register of Land Plans of Channels, Buildings and Miscellaneous.
(iv) Register of Record Plans for Channels including Sections of Channels and Drains, Chak Plans, and Masonry Works on Channels and Drains.
(v) Register of Land by Villages, Occupied and Surrendered.
(vi) Register of Well Measurements.
(vii) Register of Bench Marks.
(viii) Register of Estimates for which Completion Plans are required.
(ix) Outlet Register.

The Head Draftsman has a draftsman, tracer, and a peon to help him.

4.4 RECORDS MANAGEMENT.

A. Budgetary Controls

There are three ways to prepare a budget. One is to list the total requirements to both operate the system and to bring it into compliance with the system's maintenance standards. The second, is to take last years budget and increase it by a percentage to cover inflation and other needs. Both of these methods have shortcomings. A much better method is to develop a budget based on Yardsticks for O&M functions, adjusted for increased labor and material costs, and the cost of improvements and betterment. Yardsticks have been prepared for canals, drains, flood bunds and tubewells in the NWFP. Certain budget returns have to be submitted by certain dates from the lower offices to higher officers. Statement showing dates of submission of these returns is called budget calendar. A copy of budget calendar for the NWFP is shown in Exhibit IV-7.

B. Stores

The primary objectives of stores control are: (1) to provide adequate physical protection against loss through carelessness and theft, and (2) to ensure that acquisitions and issues are properly accounted for. In any event, physical protection through proper inside and outside storage facilities and the restriction of access to un-authorized personnel should be enforced as far as practical. A Sub-engineer or a store keeper is in-charge of stores. The justification for stocking materials and supplies is to ensure their availability when needed and to take advantage of favorable prices. Good management practice is to limit the acquisition of materials and supplies to current needs. The advantages of limiting acquisition to current needs are many, including:

* Reduces requirement for storage facilities
* Saves handling
* Minimizes the opportunity of loss
* Does not tie up funds
* Saves record-keeping
* Ensures correct costing through direct charge to the work in which incorporated

Exceptions to this might be equipment fuels and oils, lumber, cement, and possibly pipe (either concrete tile or metal). The SDO does not have a full-time storekeeper. Employees who have access to stores should be impressed with the necessity of accurately reporting all withdrawals. The withdrawal record may be limited to quantities with the pricing or costing to be accomplished by a clerk. Six-monthly reports are prepared by the Sub-Engineer for all stores and T&P in his charge to ensure that the records provide the necessary controls.

C. Equipment

Currently the divisions and sub-divisions have very little investment in equipment. Accountability or internal control over this equipment is exercised through the use of equipment records or ledgers. Much of the equipment is limited to vehicles, typewriters, hand tools or other small items. Some form of custody control is desirable for use of vehicle. Proper log books should be maintained for operation and maintenance of vehicles. All entries in the log book should be made by the person who uses the vehicle. For other equipment six monthly inventories are necessary to ensure that all items are on hand and are accounted for. The inventory also provides assurance that the equipment is being properly cared for. SDO is required to carry out a physical check of all stock and T&P every six months.

D. Land

The Public Works Department Code, Irrigation Manual of Orders, the Canal and Drainage Acts and other publications require the complete documentation of all land owned by the Irrigation Departments. The Divisional Head Draftsman is responsible for maintaining these documents. Land plans should be maintained in the sub-division to check any encroachment on government land.

E. Personnel Records

Employees are a very vital and important part of operations. The XEN and/ or SDO is responsible for their selection, assignments, discipline, and cooperation. He must consider and dispose of their complaints and grievances as well as coordinate their abilities and working into a team. To accomplish this, the canal officer must know his people and he learns this primarily through personal contact. Good personnel records can contribute a great deal in carrying out these responsibilities. Personal Registers are maintained for each individual up to grade 16. Entries in the personnel register are made by XEN and the registers are submitted to SE for his comments. For officers there are separate forms. Assessment report on the working of officers are initiated by XEN and go up to the Secretary through proper channel. Reports are written in duplicate and copies are filed in CE and Secretary's offices.

F. **Payroll**

The principal objectives of payroll or earning records are:

(i) Prompt payment in the proper amount to all persons entitled to be paid.
(ii) Proper accounting for and disposition of all authorized deductions from gross pay.
(iii) Effective communication between employer and employees on all payroll matters.
(iv) Appropriate integration of the payroll records with the cost accounting process.

There is nothing more disconcerting to an employee than not to be paid on time or to be paid in a wrong amount. A procedure for time reporting is most important phase of pay rolling and all personnel should be made aware of their responsibility for reporting time. Time reporting can be accomplished in several ways; time sheets, SBE's daily reports, time reports submitted by individuals and approved by someone familiar with their activities, etc. This aspect can be computerized.

G. **Payments Auditing.**

Auditing, as it relates to the division or sub-division, is generally limited to the inspection by a representative of the Accountant General of the NWFP involving analysis, tests, confirmations and proofs. It may be expanded to include the investigation or appraisal of procedures or operations for the purpose of determining conformity with criteria or policy dictated by Provincial laws or the PID. The general purposes of auditing include:

(i) Determination that funds have been properly administered and accounted for.
(ii) To determine that assets and liabilities are correctly stated.
(iii) To prevent and detect errors.
(iv) To prevent and detect fraud.
(v) To provide assurance that financial reports disclose the relevant and material accounting facts.
(vi) To check that T&P and stock returns have been prepared and submitted for all transactions which have taken place.

H. **Office Equipment and Machines**

Office routine is becoming increasingly mechanized. Types of equipment most common to irrigation system offices are typewriters, adding machines, calculators and photo copier. Computer for data processing might be justified at the division level where it could be used on both the O&M and revenue sides. A good typewriter and adding machine are a must in any office. Electric typewriters have a decided advantage if more than one copy of the material is desired. A calculator will eliminate errors and is a time saver if there is a large volume of computations involved in the billing or assessment process. Printing calculators are available that combine the operations of the adding machine and the calculator.

A large number of computer applications can be programmed at Divisional and Circle levels. A computer cell has been established in the office of the CE. This facility will be expanded to lower formations by training PID personnel in this field and availability of computers.

4.5 LAND ACQUISITION.

A. **Regulations**

The PID of the NWFP is governed by the Canal and Drainage Act VIII of 1873 regarding operation and maintenance of Canal Systems. However two aspects have been discussed below:

i. Borrowing earth for repairs.

The Rules and Regulations which govern the acquisition of land and soil from land adjacent to a canal are governed by the Land Acquisition Act. The above two aspects mentioned as a & b are discussed below in detail:

(i) Borrowing Earth for Repairs

Along main canals and branches, some land is generally left at the time of construction for borrowing earth for repairs. Such land, however, is not available along the distributaries and minors. Therefore earth has to be borrowed from the land of the farmers. It is the best way if an amicable arrangement is reached with the farmers for borrowing earth from their lands. If no agreement,however, is reached and the earth is urgently required for repairs, the DCO can enter upon any land adjacent to the canal under Section 15 of the Canal Act and execute all works which may be necessary for the purpose of repairing the banks. A proper compensation for any damaged crop or borrowed earth should be paid to the farmers. A detailed procedure in this connection is laid down in paras 4.10 and 4.1 of IMO for borrowing earth for repairs. A copy of this procedure is enclosed as Exhibit IV.7.

4.6 PENALTIES FOR UNAUTHORIZED USE OF WATER.

A. **General**

The term "unauthorized manner" refers to the interference with the physical works of the canal and its appurtenant structures to obtain a supply of water to which the individual (s) are not authorized. The most common methods of illegal withdrawals of water are :

i. Cutting the banks of the canal
ii. Erecting a bund or obstruction in the channel below an outlet for heading up water to increase the outflow through the outlet.
iii. Putting an unauthorized outlet in the canal
iv. Enlarging the size of the outlet
v. Taking water out of turn
vi. Applying or using water outside the boundary of the outlet
vii. Syphoning over the canal bank

The above mentioned offenses fall under Section 70 of the Canal Act.

B. **Procedure for levying Penalty**

Upon receiving information or detection of an unauthorized withdrawal of water, the SDO initiates an inquiry for finding out the person responsible for the unauthorized withdrawal so that the entire penalty is levied on him. However, if the person cannot be detected then all the persons who have benefitted from the unauthorized taking of water are punished for it. The Zilladar plays a pivotal role in assisting the SDO in investigating the case. He directs the concerned Patwari to book the un-authorized irrigation of all the persons. The Zilladar and the Sub-Engineer fix the time from which the unauthorized irrigation is to be considered. This provides the basis for the amount of water obtained.

The current maximum penalty for unauthorized use of water in the NWFP is six times the occupiers rate. The penalty can slide between 1 and 6 times the occupiers rate and is discretionary with the XEN who has to use his wisdom while imposing penalties so that no irrigator is unnessarily penalized. In addition to the usual occupier rate levied on the area which has derived benefits from the illegal use of water. The charge is imposed by the Divisional Canal Officer after hearing the offenders.

EXHIBIT IV-1

DUTIES OF CHIEF ENGINEER

The Chief Engineer, (CE), is the professional head of region in his charge and is responsible for its efficient working. He is also the responsible professional advisor of Government in all matters relating to his charge. His main duties are as follows:

a. He is responsible for arranging transfer of Superintending Engineers, Executive Engineers and Sub-Divisional Officers.

b. He is responsible for preparing annually the portion of budget relating to O&M works under his charge and after the closing of financial year a progress report is prepared by him to delineate a clear account of the operations of the Department.

c. He has to ensure that the budget allotments of the year are fully expended and a large expenditure in the closing months of the financial year (to avoid lapse of budget allocation) is prevented. He has to ensure that any money not needed during the year is promptly surrendered so that it can be utilized by other Departments.

d. He has to examine the remodelling scheme prepared for any channel and approve it after discussions with the Superintending Engineer and Executive Engineer.

e. He is responsible for the development of irrigated agriculture, assessment of water rates and review of revenue receipts in light of the O&M Expenditures.

f. He periodically reviews the water rates to judge their adequacy in relation to the O&M Expenditures on Canals.

g. In addition to O&M works of canals he has to devote a good deal of his time to other development works, foreign aided projects, project reviews and miscellaneous meetings, including those with the Federal Government.

DUTIES OF SUPERINTENDING ENGINEER

The administrative unit of the PID is the Circle in the charge of a Superintending Engineer (SE), who is responsible to the CE for administration and general professional control of public works in charge of officers of the Department within the circle. His main duties are as follows:

a. To inspect the state of the various works in his circle and toi satisfy himself that the system of management for operation and maintenance of irrigation facilities prevailing is efficient and economical.

b. To watch that there is no delay in the submission of completion reports of major works. This report has to be submitted on proper form.

c. To ascertain and report on the efficiency of the subordinate offices and petty establishment and to see that staff employed in each division is actually necessary and adequate for its management.

d. To examine the condition of surveying and mathematical instruments at the headquarters of the divisions.

e. To inspect each Divisional Office in his circle once a year to examine initial accounts of stock, tools and plants, register of works and other divisional books, mode of preparation of estimates, contract agreements, contractor's accounts, system of recording plans, etc. The report of inspection should be in tabular form and any unusual matter or serious irregularity should be brought to the notice of the CE.

f. To transfer and post all members of establishment within his circle with the following exceptions:

   (a) Divisional Officers.
   (b) Accountants.
   (c) Officers other than above who have been specifically posted by the Chief Engineer to a particular post or due to special reasons.

g. To arrange mutual transfers of non-gazetted establishment outside the circle.

h. To collect and submit to the CE yearly statistics relating to expenditure and revenue receipts for the canal system under his charge.

i. He is the appellate Authority in respect of Warabandies.

j. He is inter divisional coordinator for all matters.

k. To exercise financial powers for estimates and other matters as delegated by the Government.

l. To sanction construction of cattle and bathing ghats on distributaries and minors.

m. To sanction funds for compensation in case of damage to crops/ borrowing earth for repairs to canal banks.

n. To sanction direct outlets from a branch canal.

o. To sanction change of size or shifting of outlets.

p. To arrange revision of longitudinal section of channels in connection with their remodelling to ensure equitable supply of water to the farmers.

q. To confirm the proceedings carried out by the Divisional Canal Officer under section 20 of the Canal Act.

r. To Inspect irrigation facilities regularly and point out deficiencies for their rectification. He should visit important works or any endangered work under his charge.

s. To scrutinize engineering character, design and estimates of all important works which are approved by him.

EXHIBIT IV-3
Page 1

DUTIES OF EXECUTIVE ENGINEER.

The executive unit of the Department is the Division in charge of a Divisional Officer who is usually an Executive Engineer (XEN). He is responsible to the SE for the execution and management of all irrigation facilities. His main duties are as follows:

1. To maintain all irrigation channels, drains, flood bunds and tubewells, workshops and machinery under his charge in proper state of repairs.

2. To organize and supervise the execution of works so that these can be suitably and economically carried out with materials of good quality. For this purpose laid down procedures and specifications should be followed.

3. To see that no work is undertaken without the sanction of competent authority.

4. To carry out systematic touring and to stay some nights outside his headquarters if necessary.

5. To report to the Superintending Engineer any serious damage to any irrigation facility.

6. To maintain and operate all canals with designed discharges to ensure equitable distribution of water to the farmers. He should watch that the procedures for equitable distribution are followed by SDO and Sub-Engineer.

7. To train young and inexperienced officers by exercising patience, tact and sympathetic treatment.

8. To confine official correspondence with the Sub-Divisional Officer to the minimum so that undue correspondence does not interfere with the performance of field duties.

9. To inspect SDO's Office once a year.

10. To take action under Section 20 of Canal Act for supply of water from a canal through an existing watercourse or change of source of water supply of any land.

11. To take action under Section 15 of Canal Act for entering any land adjacent to a canal and for executing all works necessary for maintaining such canal.

12. To take action under Section 33 and 34 of Canal Act when water is illegally taken or allowed to run to waste from a canal or watercourse.

13. To check 150 acres of the irrigation recorded by the Patwari in each crop season. He can also check irrigation already checked by the Zilladar out of 37 acres.

14. To take action under Section 39 of Canal Act when water supplied through a watercourse is wasted.

15. To take action under Section 65 of Canal Act for settlement of disputes of farmers for use of water by hearing the concerned parties.

16. To take action under Section 70 of Canal Act for penalizing the users of canal water for offenses given under this Act.

17. To prepare O&M Plan and budget estimates for the works under his charge.

18. To prepare complete reports for all the completed works.

19. To monitor the utilization of budget. If some surplus is expected, he should surrender it in time for use by other Divisions.

20. To watch that the maintenance standards for canals are followed by the SDO and Sub-Engineers.

21. To see that there is no encroachment on the Government land along the canals and to take action where encroachment takes place.

22. To investigate new schemes, survey and prepare estimates, arrange approved budget and ensure proper execution of schemes and utilization of budget.

23. To ensure booking of irrigation and its assessment according to present water rates.

EXHIBIT IV-4

DUTIES OF SUB-DIVISIONAL OFFICERS

The main duties of Sub-Divisional Officer (SDO) are listed below:

1. Operation of canal in such a manner that there is equitable distribution of water through the outlets. For this purpose it is important that all channels should be run with authorized discharges at their heads and the off taking outlets should also draw their authorized discharges only.

2. To prevent unauthorized use of water and to take action against the persons who use water in unauthorized manner in accordance with Section 70 of the Canal Act of 1873.

3. To maintain canal prism and its embankments commensurate with the safety of the canal. If adequate berms are not available, berm formation should be induced by spurs and Killa Bushing.

4. To inspect all channels at least once a month and to stay some nights outside his headquarters, if necessary. Inspection notes should be written to point out deficiencies and sent to Sub-Engineers for compliance.

5. To prepare estimates for the maintenance of canals under his charge in accordance with the work plan.

6. To supervise and check the work of Sub-Engineer relating to the survey, preparation of estimates, execution of work, and entries in the measurement book according to instructions issued by the Government.

7. To make payments to work-charged establishment, regular staff and arrange payments to contractors for work done and to maintain proper records of all payments.

8. To check 100% outlets in his charge every year.

9. To check 1000-1500 acres of recorded irrigation in his Sub-Division.

10. To maintain outlet register in the form shown in Exhibit IV-6.

11. To maintain stock and T&P registers. To maintain works register for estimate use. He has to exercise physical check of stores twice a year and T&P once a year.

12. To maintain irrigation register for each channel.

EXHIBIT IV-4A

DUTIES OF COLLECTOR

1. One of the important duties of the Deputy Collector is to assist the SDO in assuring that the Zilladars and Patwaries carry out their work correctly and timely.

2. He should carry out systematic touring in the division to check the work of Zilladars and Patwaries. Any fraud or malpractice that comes to his notice during his checking should be promptly reported to the Divisional Canal Officer and the SDO.

3. He should keep social contacts with farmers to know the proper working of the Zilladars and Patwaries.

4. He should carry out, during his tour, the checking work (kham partal or shudkar). He should also check the final measurements (pacca partal or khasra) of the Patwaries to see that the Patwaries are making out the demand slips (parchas) properly and delivering them to the Lambardars (head man of the village) for distribution to the cultivators.

5. He should examine the lists received from the Zilladars showing names of the Lambardars who failed to distribute the parchas to cultivators. This information should be submitted to the Divisional Canal Officer through the SDO for information.

6. When the Patwaries get together at the Zilladars headquarters for preparing and checking the demand statements (khataunis), the Deputy Collector should tour from one Zilladari section to another to see that the work is being done correctly and is upto date.

7. He should submit the khataunis for each crop (Rabi or Kharif) to the Divisional Canal Officer for his signatures and thereafter he should submit these khataunis to the District Officers for collection of Abiana.

8. When remodelling of a channel is to be carried out, the Deputy Collector should assist the SDO and the Divisional Canal Officer in the preparation of remodelling scheme.

9. He should scrutinize the Zilladar's diaries to see that the Zilladar is moving from one village to another in a systematic manner.

10. He should be responsible for delivering blank khasra to the Patwaries before commencement of each crop period.

11. He should obtain monthly irrigation figures from each Zilladar and submit it to the Divisional Canal Officer promptly.

EXHIBIT IV-5

DUTIES OF SUB-ENGINEER.

1. To operate all channels to their authorized full supply discharges and to ensure equitable distribution of water particularly at the tails. For ensuring that outlets do not underdraw or overdraw water, H (depth of water over the crest of outlet) measurements should be made every month. If H is higher than designed, the outlet is overdrawing water at the cost of downstream outlets particularly the tail outlets. Similarly outlets with H lower than designed will draw less than their authorized discharge and thus equitable distribution of water is not ensured.

2. To maintain embankments of all channels according to their performance standards.

3. To survey, prepare estimates, carry out works for maintenance of canal embankments, work on new schemes and do other miscellaneous works.

4. To inspect all channels and outlets in his charge once a month and to maintain outlets.

5. To carry out discharge observation once a year of all channels and to ensure that designed supplies are being maintained.

6. To carry out hydraulic survey of channels which require remodelling. Hydraulic survey of a channel include the following:
   - (a) Longitudinal section showing bed levels of channel.
   - (b) X-section at every 500 ft. showing bed width; berms embankments, their side slopes and ground levels.
   - (c) Location of regulators, falls, bridges and outlets on the L-Section.

7. To maintain canal patrol road.

8. To supervise work of Beldars in his section.

9. To maintain rest houses in good condition for use of touring officers.

11. To maintain outlet check notebook in the form shown in Exhibit IV-7.

12. To maintain stock and T&P register and keep record of all receipts and memos.

DUTIES OF ZILLADAR

1. He should spend a great deal of his time on tour for making himself accessible to the villagers and tendering them advice on revenue matters wherever necessary.

2. He should check and supervise the work of Patwaris under his control particularly the entries of shudkar and khasra.

3. During checking the work of Patwaris, he should make note of failure of crops due to lack of water or other reasons and bring it to the notice of Divisional Canal Officer. The latter would ask the SDO to check the statement prepared by the Zilladar for failure of the crops.

4. He should observe the working channels, outlets and water courses and bring to the notice of the SDO any unusual happenings particularly if the water course is not being maintained by the cultivators properly (some of the farmers, mostly at the tail end, suffer on account of bad maintenance of water courses).

5. If water is taken or used in unauthorized manner by the farmers, it is the duty of the Zilladar to bring it to the notice of the Divisional Canal Officer and book the irrigation which has been done by unauthorized use of canal water. He should also prepare penalty (Tawan) case for penalizing the farmers who take the water in unauthorized manner.

6. If any case of wrong booking or assessment is brought to his notice by the farmers, he should immediately make local enquiries and submit a report with his recommendations to the SDO.

7. If there is any wastage of water from any water course, he should submit his report to the SDO for his orders. On instructions from the latter he should prepare penalty case for wastage of water by the farmers.

8. He should assist the Divisional Canal Officer in preparation of warabandis for the outlets.

9. He should assist the shareholders in taking their turns of water according to the warabandis prepared by the Divisional Canal Officer. Any infringement of warabandi should be brought to the notice of the SDO for his orders.

10. He should try to settle the disputes of the farmers regarding sharing of water and save the farmers from resorting to the legal procedures.

EXHIBIT IV-6

LIMIT OF PARTAL FIXED FOR OFFICERS IN IRRIGATION DEPARTMENT NWFP.

S No.	Rank of Officer	Kharif Crop			Rabi Crop			Total per annum
		Kham	Pukhta	Total	Kham	Pukhta	Total	
1	Executive Eng:	150	150	300	150	150	300	600
2	Canal Collector	800	500	1300	700	500	1200	2500
3	Sub Divisional Officer	600	400	1000	600	400	1000	2000
4	Deputy Collector	3500	2500	6000	2500	2000	4500	10500
5	Zilladar	2250	1800	4050	2000	1500	3500	7550

Exhibit IV-7

INSTRUCTIONS FOR BORROWING EARTH FOR CANALS.

A. **The banks of Distributary Channels usually do not require much earth for repairs, however, small quantities of** earth are necessary for petty annual repairs and at much longer intervals of 5,10 or 15 years the banks and slopes are eroded by wind and rainfall and require making up to section. As a general rule, no spare land for borrow-pits has been acquired along Distributries of the NWFP Canals. The practice has been, and still is, to procure spoil from borrow-pits dug in privately owned lands along the channels. When standing crops, ploughed fields, sown crops and ploughing operations have not been interfered with, the owners or cultivators of the adjacent lands have usually raised no objection provided the land has been restored to a fit state for cultivation: however, when these conditions have not been fulfilled, discontent, opposition to procuring earth and claims for compensation have occasionally resulted. It is undesirable to acquire land for borrow-pits, but it is essential that Canal Officers except in cases of emergency as provided for in Section 15 of Canal Act, VIII of 1873, should carefully avoid entering upon privately owned lands, at times when loss will result to the cultivator.

It may be remarked that the acquisition of land to obviate the need of procuring spoil from privately owned lands would necessitate the acquisition of enormous areas in this Province and such areas would remain uncultivated, while farmers would permanently lose possessions of land with which they can ill afford to part. It is desirable to regulate the present procedure so as to obviate the objections to it. It is therefore, directed that the following rules be observed with regard to digging borrow-pits in privately-owned land for the supply of spoil of the maintenance of canal channels and to the award of compensation for damage done to such lands:-

(i) Spoil is in no case to be obtained from privately-owned land on which crops are standing or which has been ploughed for cropping, excepting in the case of breaches or prevention of accidents when the procedure laid down in Section 15 of the Canal Act should be followed.

(ii) Borrow-pits area should be left in a clear level condition fit for ploughing by the time the ground has to be prepared for the next crop. Borrow-pits should not exceed one foot in depth measured from the original natural surface level, nor should borrows be put in existing borrow-pits except at the special request of the owners in writing particular attention is called to the above.

(iii) Local Officers are warned to guard carefully against doing avoidable damage by carrying out operations of this kind at times when agricultural interests will suffer. The procedure in these cases must not be left to irresponsible subordinates. The Divisional Officer will be held responsible for proper and timely arrangements being made which will ensure compliance with these rules and obviate loss to the cultivators.

(iv) Where high banks exist likely to require large quantities of spoil for repairs, acquisition of land should be arranged where existing Government land is insufficient for borrow-pits.

When an owner refuses to allow borrow-pits to be made in his land, action should be taken to acquire such land.

B. Compensation for Damages done to Land on account of taking Spoil or Repairs to Banks.

1. i) Compensation for damage done to land must always be offered in the following cases:-

a) Destruction of standing crops.
b) Removal of earth from ploughed or sown land.
c) Compensation must be paid when demanded by the zamindars, for prevention of cultivation for a certain time.

2. Except in the case of paragraph 1 (i) of Article 4.10, it is possible under careful management to execute work at such times and in such a manner as will obviate demands for compensation.

3. When earth has been removed from private lands, the side of borrow-pits should be ploughed down and the bottoms ploughed over so as to make cultivation easy for the owners. These orders should be strictly and promptly complied with.

In tendering compensation for all damage done to land the following general principles should be observed.

Compensation is chargeable to the minor head "Maintenance and Repairs, (1) Headworks, (2) Main Canal and Branches, etc., L (iii) Borrow-pits Compensation." and must be provided for in a separate estimate so as to maintain an easily accessible record of compensation paid. The repairs estimate should contain a note to the effect that a certain amount will probably be required for compensation. Compensation in each of the three cases mentioned in para graph 1 above should be assessed as follows:-

(a) Destruction of standing crops:- The average out turn, as recorded at last settlement in the Assessment Reports multiplied by the probable market price of the next harvest less any fluctuating rates such as Occupiers Rates, will be the amount fairly payable in ordinary occasions. In the case of minor crops the value of which is not worked out in the Assessment Report, the rates given in the Statistical Statement III-E should be used. Average crops should generally be treated as 16 anna crops, but for very poor crops the compensation should be reduced proportionately. Provided a crop is in good condition, its value as a matured crop should be paid irrespective of the stage of its growth.

(b) Compensation for the removal of earth form ploughed or sown land:- Cost of ploughing plus rent for half or whole year, as the case may be according to whether the land is single or double cropped plus 15 per cent latter on account of loss or profits for ploughed land of the occupied for borrow-pit. If sown, an average or good crop rate should be paid according to the quality of the land as described under (a) above.

(c) Compensation for prevention of cultivation for a certain time:- On single cropped land cultivated by the owner the compensation should take the form of one year's rent counting from the ordinary date or preparing the land for the crop not sown, plus 15 per cent on a account of disturbance.

On double cropped land, if neither crop could be grown, compensation should be paid as in the case of single cropped land at the loss of rent for the two crop plus 15 per cent. If only one crop is prevented the compensation paid should bear the same proportion to the total rent that the value of the crop not grown bears to the total value of the two crops. The amount of net profits is not always easy to find out, and the land revenue assessment though based theoretically on the rent is but a poor guide to a Canal Officer in assessing the rent. In the case of land cultivated by the tenants having a right of occupancy, the compensation should comprise a fair allowance for the rent they pay the owner, together with an additional allowance for loss of profits from cultivations. Each Divisional Officer should frame once for all for a period of five years an estimate of the rentals to be assumed for the purpose of these rules for single and double cropped land (1) irrigated by canal, (2) irrigated by wells, and (3) unirrigated. Such estimates should be prepared with the help and advice of the Collector and should be submitted to the Superintending Engineer for approval.

4. In all cases where compensation is due payment must be made promptly and the Divisional Officer should satisfy himself that such compensation is actually paid to the persons to whom it is due.

5. General Remarks:- The above instructions regarding the award of compensation will serve to make it very clear that the best course, except in emergent cases of breaches, is to execute repairs at times when no damage will be done to crops no interruption caused to cultivation and no loss caused to the cultivators, for this procedure exercise of foresight is required coupled with careful consideration for the cultivators.

When spoil is obtained from privately-owned lands, the work should be executed expeditiously, the pits and sides of the same ploughed over quickly so that the land may be occupied for the shortest period possible. carefully attention to these instructions by the Divisional Officer and the Sub-Divisional Officers is necessary.

7. The ploughing up of borrow-pits as provided in paragraph 3 above may be done through the agency of a contractor or on daily labour, but under no circumstances, through the owners or the occupiers of the land from which spoil has been taken, and the amount should be provided in the estimate based on superficial area under the borrow-pits and not on the quantity or earth to be excavated.

PART 2

WATER MANAGEMENT

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CHAPTER-1

GAUGE AND DISCHARGE OBSERVATIONS.

1.1 GENERAL.

Water measurements of rivers at headworks, canals, and distributaries are of utmost importance to the irrigation engineer and therefore these measurements are made regularly. With this information in hand the irrigation engineer knows the quantity of water available in the rivers, the quantity of water entering the main canals, distributaries, minors and the amount reaching the channel tails. Gauges are installed at important points and gauge- discharge curves/tables are prepared for such points. On the basis of these tables the gauge readers regulate supplies in the channels and inform all the concerned officers. This information is used for equitable distribution of water. Water measurements at different points of a channel enable the engineer to monitor the supplies in comparison to design data. This helps him in ensuring equitable distribution of water. Variations in gauge heights for the same discharge indicate siltation or scour in the channel. This condition would upset the equitable distribution of water through the outlets. The engineer can take corrective measures on the basis of this information after determining the cause for it.

Water measurements, when correlated with the irrigation done in the field, justify its increase or decrease in relation to increased or decreased water supply. If, inspite of increased delivery of water, the booked irrigation is less, it is a matter of great concern for the engineer in charge. He would therefore try to find out the reasons for it and take proper measures to account for the water entering the canals. Water measurement records should be properly kept on a daily basis. This data forms the basis for calculating total deliveries of water during kharif or rabi and distribution of supplies between the various canal systems in the same province. This data is also used for estimating and allocating supplies for new projects. In view of the details given above, the importance of correct observations (and maintenance of their proper record) cannot be over-emphasized.

1.2 GAUGES.

Gauges are installed on rivers, canals and flood bunds to indicate water levels. For canals these gauges are used for computing canal discharges from gauge-discharge curves. The zero level of the gauge is sometimes correlated to National bench marks. There are two types of gauges i.e. non-recording and automatic recording types. These two types are discussed below:

A. Non-Recording Gauges

1) Vertical Staff Gauges

Vertical staff gauges can be mounted directly on the control structure walls or in stilling wells associated with larger structures. Standard permanent staff gauges often consist of porcelain-enameled iron or steel sections. Two such standard sizes are 2.5 inches (0.025 m) wide, 3.0 feet (0.915 m) long and graduated every 0.01 foot (0.0033 m); and 4 inches (0.1 m) wide, 3.4 feet (1.04 m) long, and graduated every 0.02 foot (0.0067 m). The background is blue and the numbers are in white. Stilling wells which dampen wave action are recommended particularly on large canals and headworks. Fig. I-1 gives details for reading a staff gauge. The placement of staff gauges on vertical steel channels, iron or wooden posts is generally avoided because they collect weeds and the water levels can not be read.

On each routine visit to a gauging or water measurement station, the Sub-engineer also meets the gauge reader and inspects the record book to check for discrepancies in the observer's readings. The*p518XSub-engineer should also observe the staf gauge(s) and make a reading during the visit to assure himself that the latest entries made by the gauge reader are correct.

2) <u>Inclined Staff Gauges</u>

Inclined staff gauges are used for three general reasons :

(a) Increased accuracy of measuring small changes in head.

(b) Direct flow readings.

(c) Where vertical walls are not available.

An inclined gauge is sometimes painted on a vertical wall to allow the 0.01 foot reading to be more accurately read. The problem is that the associated stilling well becomes large and costly. The normal use of inclined staff gauges is on lined concrete channels and headworks where a vertical post would cause problems with weed collection and reading. The inclined staff gauge can be used with a broad-crested weir constructed in the bottom of the ditch. In most cases two gauges would be required; one upstream and one downstream. Where free flow is always present, the staff gauge can be calibrated to read flow directly. An example of this is shown on Figure I-2. In alluvial canals or ditches where channel control could change with sedimentation, direct reading staff gauges are not recommended.

On inclined gauges the markings are magnified in proportion to the inclination. The magnification of the markings for various slopes is shown below:

$$\textit{For } 1{:}1 \textit{ slope magnification} = \sqrt{1}+\sqrt{1}=\sqrt{2}=1.41$$

$$\textit{For } 1{:}2 \textit{ slope magnification} = \sqrt{2}+\sqrt{2}=\sqrt{5}=2.23$$

FIG-I-1

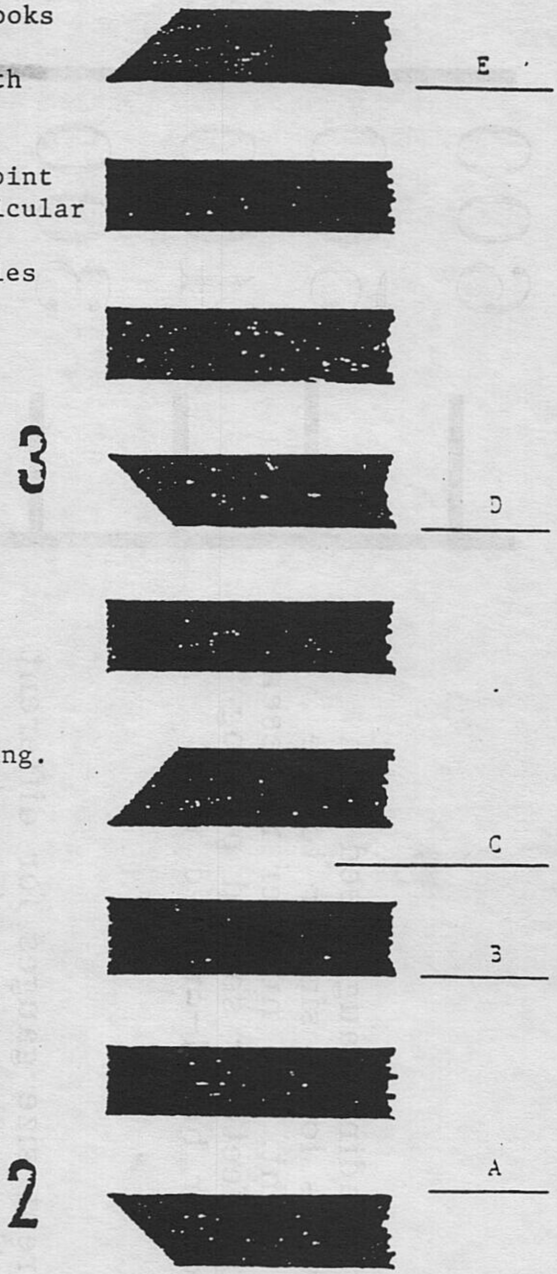
The standard gauge used in Pakistan looks similar to the example at the right. Each horizontal line is 0.10 (one tenth of a foot) from the next.

The numbering starts at a reference point usually the crest level of that particular weir and continues upward in 1 (one) foot increments. Below are some examples of readings from one of these gauges.

If the water level is at:	It is read as
A	2.00'
B	2.30'
C	2.45'
D	2.90'
E	3.50'

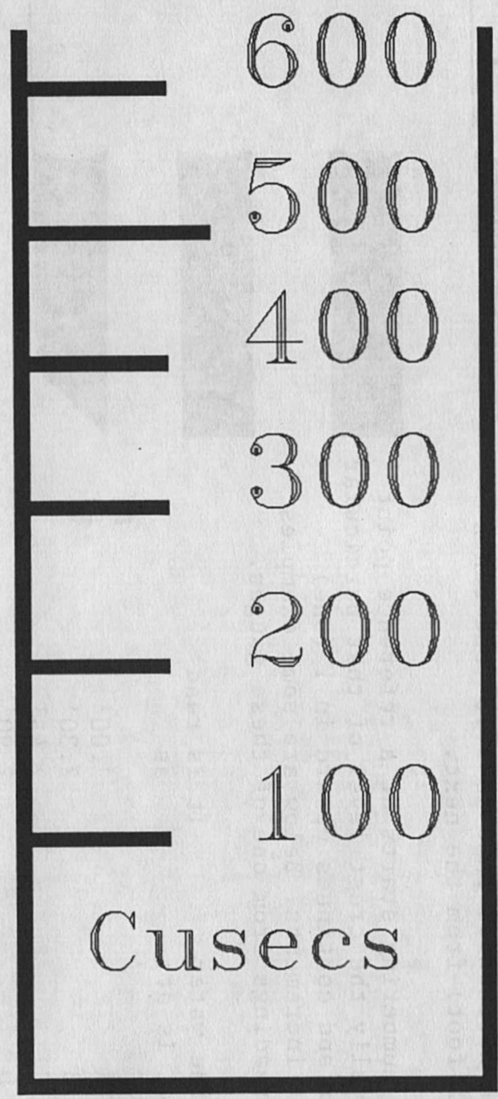
If the water level is "bouncing" take an average between the high bounce and the low bounce. That will be considered a good mean (average) reading. For instance:

If the water is "bouncing"	The mean is
A-B	2.15'
A-D	2.45'
B-D	2.60'
B-E	2.90'



READING A STAFF GAUGE

A typical direct reading gauge used with broad-crested weirs looks similar to the example at the right. The number represents the flow in cubic feet per second passing over that particular broad-crested weir.



There are different size gauges for different size weirs, but they all represent units in cubic feet per second.

If the water level is "bouncing", take an average between the high bounce and the low bounce. That is considered a good average mean reading. For Instance if the water were bouncing between the numbers 200 and 300, it would be read as 250 cfs.

DIRECT FLOW READING STAFF GAUGE

FIG.1-2

$$For\ 1{:}2.5\ slope\ magnification = \sqrt{1} + \sqrt{2.5} = 2.69$$

B. **Automatic Gauge Recorder**

On some canals,continuous record of gauge height is required at certain points. Flood peaks and their duration cannot be missed. For this purpose automatic stage recorders are installed. The Hydrology Directorate of WAPDA is doing this work for the PID of the NWFP. Automatic recording stations have been set up in this province at the following sites.

PESHAWAR.

1) Bundi Nullah
2) Bara River near Bada Ber
3) Kabul River at Warsak
4) K.R.C. at Head
5) W.G.C. at Head
6) Naguman River
7) Shah Alam River at Thakht Abad
8) Tanda Dam Feeder Channel
9) Tanda Dam Main Canal
10) Kohat Toi
11) Swat River at Munda Head Works
12) Lower Swat Canal at Abazai
13) Jindi River at Charssadda
14) Khiali River at Charsadda Road
15) Adezai River at Adezai
16) Muqam Nullah at Shah Baz Garhi
17) Upper Swat Canal at Dargai
18) Kalpani Nullah at Risal Pur
19) Badri Nullah at Swabi
20) Bagiari Nullah at Jalala
21) Shahban Nullah at Aslan
22) Aman Darra Head Works.

ABBOTTABAD.

23) Ichher Nullah at Ogi Road
24) Nandyar Khewar at Batagram
25) Dour River at Rajoya
26) Siran River at Daryal
27) Lower Siran Canal near Head
28) Upper Siran Canal at Head Works
29) Kunnar River at Garhi Habib Ullah
30) Haro River at Khan Pur

BANNU.

31) Kurram Garhi Canal
32) Tochi River at Bannu/Miran Shah Road
33) Kurram River D/S Kurram Garhi Head Works
34) Gambilla River near Cambilla Birdge
35) Changhoz Nullah Karak District
36) Pahar Pur Canal Dera Ismail Khan
37) Banda Daud Shah

C. Stevens Automatic Stage (Gauge) Recorder

The most commonly used stage recorder is one which is known as a Stevens Type A recorder. It is a float operated recorder which provides a permanent, continuous, long-term graphic record of water level fluctuations. A clock movement controls the rate at which a strip chart is advanced. The rise and fall of the float moves a marking stylus laterally across the chart. The stylus will reverse at each margin so that any range can be recorded. The recorder is placed on a sound foundation. Two adjustable hooks are provided for attaching the float line to the float and to the counter weight. Float and counterweight are housed inside a pipe of 18" diameter which is properly secured to a pier of bridge or a pillar. These two devices, i.e., float and counter weight should pass each other freely and should not touch the sides of pipe. After attaching the float and counterweight to their lines, they should be checked to ensure that the float and the counterweight operate through the entire operating range without interference. The float when touching the water surface should record the zero on the gauge. The chart is slipped onto the supply cylinder and the pen is fixed according to instructions. The clock is placed in position and connected to the source of voltage supply. Once the clock starts, the recorder starts recording the water levels on the chart. With a fully wound spring and the clock running, the recorder keeps working for 4.5 months. The chart has to be taken out and replaced after this period.

1.3 DISCHARGE MEASUREMENTS.

Discharge of a river, stream or a canal can be determined by the velocity-area method or by empirical formulae. The accuracy of the latter method depends upon the skill with which the empirical constants involved are chosen.

A. Velocity-Area Method

In this method the canal section is divided into 5 main segments i.e. four on the sides and one in the center. This methodology is dealt with in detail in Chapter-2. The velocity, depth and width are measured at different segments of the canal. The measured depths, widths and velocities permit computation of discharge for each sub area of the cross-section. The summation of these sub areas discharges gives the total discharge of a canal.

B. Measurement of Depth

The depth can be measured in a number of ways. the commonly used methods are presented below:

(i) By Sounding Rods

In this method, the depths at various points are measured by a rod marked in feet and tenths of a foot and having base plate 6" wide to prevent the rod from sinking into the bed. A 25 ft. sounding rod can measure depths upto 20 ft.

(ii) By Drum-wire Weight System

In this system a meter and weight (about 25 lbs.) attached to a drum are lowered until the bottom of the weight just touches the surface of water. The depth dial reading is set at zero. The weight is then lowered until it rests on the stream bed. The depth is read on the dial. For increasing efficiency of depth measurement, the sounding weight can be equipped with an electrical device which gives a signal when the weight touches the bed.

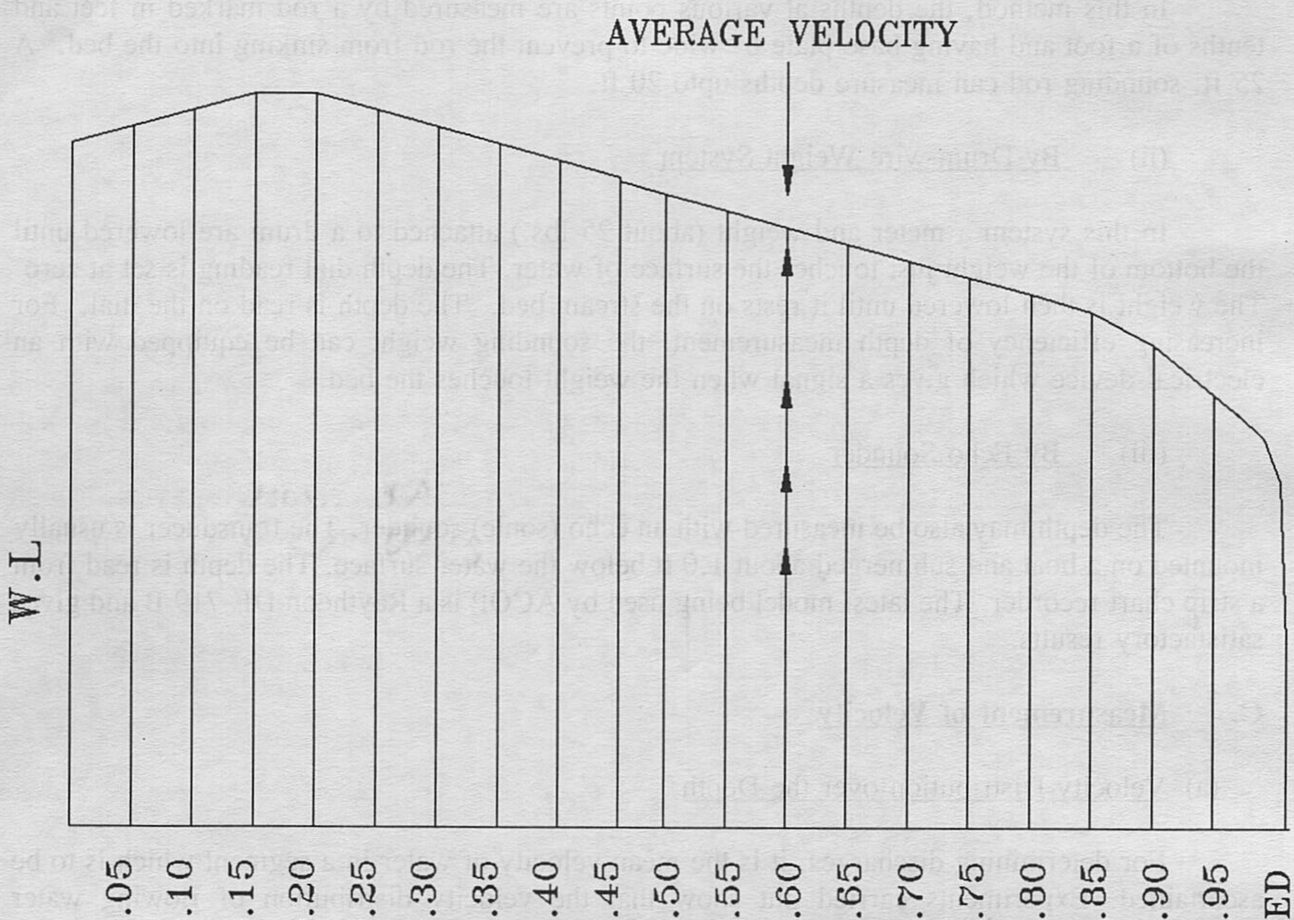
(iii) By Echo Sounder

The depth may also be measured with an echo (sonic) sounder. The transducer is usually mounted on a boat and submerged about 1.0 ft below the water surface. The depth is read from a strip chart recorder. The latest model being used by ACOP is a Raytheon DE-719 B and gives satisfactory results.

C. Measurement of Velocity

(a) Velocity Distribution over the Depth

For determining discharges, it is the mean velocity of water in a segment which is to be ascertained. Experiments carried out show that the velocity distribution of flowing water conforms to the curve shown in Fig. I-3. This curve approximates a parabola and the mean velocity V_m lies at 0.6 of the depth measured from the water surface. For this reason, the practice is to observe a single velocity at 0.6 of the depth to obtain mean velocity. Sometimes it becomes impossible to measure the mean velocity directly. In such cases the surface velocity is measured and multiplied by a factor 0.89 to obtain mean velocity.



VELOCITY DISTRIBUTION CURVE

FIG.I-3

(Not to Scale)

(b) Devices for Measurement of Velocity

There are different devices for measurement of velocity. These are :

(i) Price AA Current Meter
(ii) Pygmy Current Meter
(iii) Velocity rods
(iv) Surface floats
(v) Surface slope observations

These are discussed below:

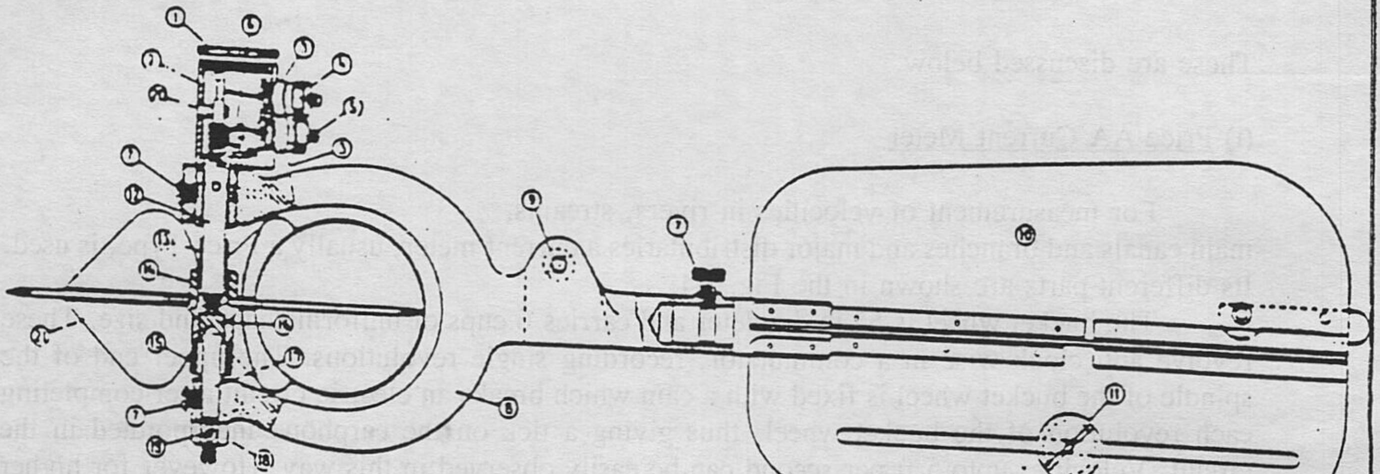
(i) Price AA Current Meter

For measurement of velocities in rivers, streams, main canals and branches and major distributaries a current meter, usually a Price Type, is used. Its different parts are shown in the Fig. I-4.

The bucket wheel is 5" in diameter and carries 6 cups of uniform shape and size. These revolve anti clock wise in a commutator, recording single revolutions. The upper end of the spindle of the bucket wheel is fixed with a cam which breaks an electric circuit after completing each revolution of the bucket wheel, thus giving a tick on the earphone incorporated in the circuit. Velocities upto 5 ft per second can be easily observed in this way. However for higher velocities, this cam is replaced. The replaced cam gives a tick after every five revolutions of the bucket wheel. The current meter has to be periodically (usually after 6 months of use) rated to check its correct working. Necessary instructions for the upkeep of the current meter should be followed.

Procedure for Current Meter Measurement

Having selected the site for the cross-section where velocities are to be observed, the section should be divided into a number of sub-sections, the number depending upon the width of the section.This is dealt with in more detail in Chapter-II. The sub-section should be so spaced that no sub-section passes more than 10% of the discharge. The current meter is then set to make it ready for use. The meter is then suspended from a suspension rod which either is operated mechanically by a rack and pinion fixed on the boat or held by hand in the case of shallow depths. For deep flow the velocity is generally observed at two points; 0.2 & 0.8 depth below the water surface in sub-section. The average of these two observations is taken as the mean velocity in the sub-section. Once the meter is placed at the proper depth, the bucket wheel begins to rotate. When the bucket wheel has adjusted to the current velocity, the number of revolutions made by the wheel are counted for 40 to 70 seconds. The stop watch is started simultaneously with a click which is counted "zero" and not one. The count is ended on a convenient number of clicks which coincide with those given on a rating table. The stop watch is stopped on that count and is read to the nearest second. The number of seconds and the number of revolutions are then recorded. With this data, the velocity is calculated from the rating table.



ASSEMBLY

LIST OF PARTS

1. Cap for contact Chamber
2. Contact Chamber
3. Insulating bushing for contact binding post.
4. Single Contact binding post
5. Penta contact binding post
6. Penta Gear
7. Set screw
8. Yoke
9. Hole for hanger screw
10. Tail piece
11. Balance weight
12. Shaft
13. Bucket wheel hub
14. Bucket wheel hub nut
15. Raising nut
16. Pivot bearing
17. Pivot
18. Pivot adjusting nut
19. Keeper screw for pivot adjusting nut
20. Bearing leg
21. Bucket wheel

Price Current Meters

Current Meter Measurements by Wading

For small distributaries and minors, current meter measurements are best made by wading. This method has the advantage over measurements made from cable ways and bridges that it is usually possible to select the best site for cross-sections. The following table will serve as a guide for wading measurements at various depths.

Depth	Velocity method
2.5 ft or more	Two point depth (0.2D & 0.8D)
1.5 ft -2.5 ft	0.6 D
0.3 - 1.5*	0.6 D

(* For these small depths Pygmy current meters should be used).

(ii) Pygmy Current Meter

A Pygmy current meter is similar to a Price current meter in that both contain a cup type bucket and a wheel mounted on a vertical shaft. However the Pygmy bucket wheel is 2 inches in diameter as compared to the five inches diameter of a Price meter. It has no tail piece and no provision for cable suspension. Its rotational speed is more than twice that of a Price meter. It is therefore useful for measuring small discharges which have a depth upto 1.5 ft. Discharges of small channels and water courses can be conveniently and accurately measured with this meter. A sketch of Pygmy current meter is shown in Fig. I-5.

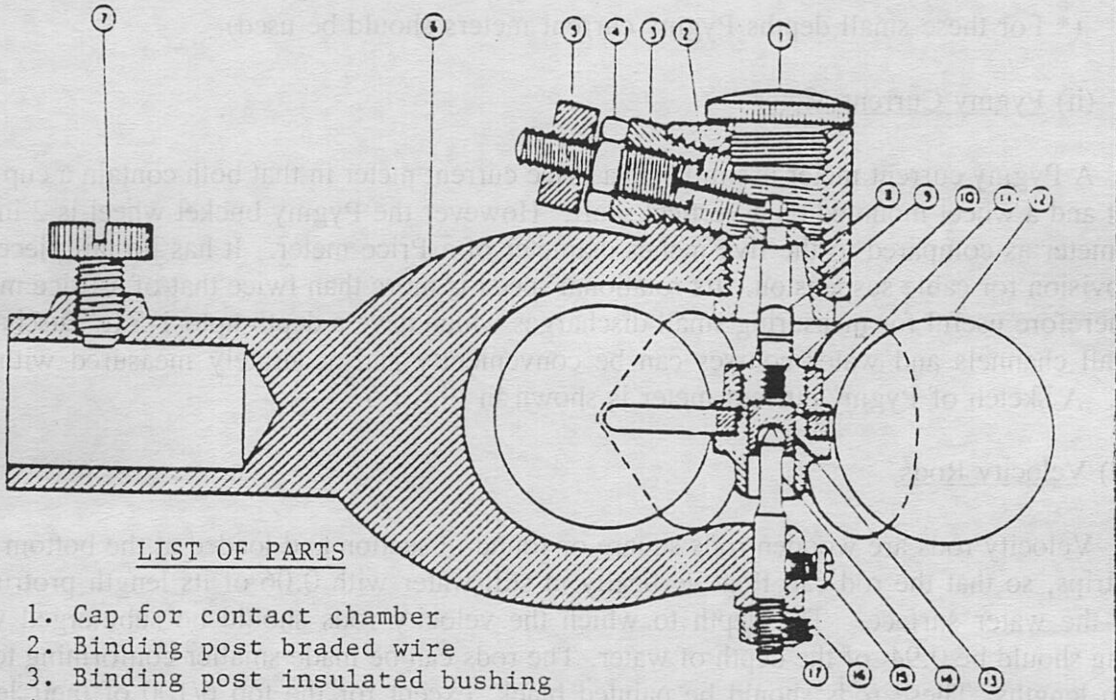
(iii) Velocity Rods

Velocity rods are wooden rods square or round in section and loaded at the bottom with iron strips, so that the rod can float vertically in still water with 0.06 of its length protruding above the water surface. The depth to which the velocity rods should be submerged when floating should be 0.94 of the depth of water. The rods can be made smaller conforming to 1/4 foot in lengths. These rods should be painted black, except for the top 6/100 of their length which should be painted white. The full length of the rod should be inscribed on the rod in red. Each foot length on the rod may be marked by a thin white line. The length of red selected for each segment should preferably be the same as the depth of water in each segment.

Selection of Site for use of Velocity Rods

Three cross-sections should be selected along a straight reach of a channel. The cross sections should be spaced far enough apart so that the time taken by the float to pass from one cross section to another is adequate. A travel time of 20 seconds is recommended.

FIG. 1-5



LIST OF PARTS

1. Cap for contact chamber
2. Binding post braded wire
3. Binding post insulated bushing
4. Binding post body
5. Binding post nut
6. Yoke
7. Yoke set screw
8. Upper bearing
9. Shaft
10. Bucket wheel hub
11. Bucket wheel hub nut
12. Bucket wheel
13. Pivot bearing
14. Pivot
15. Pivot set screw
16. Pivot adjusting nut keeper screw
17. Pivot adjusting nut

PYGMY METER

Observation of Velocity by Velocity Rods

The rods should be placed into the stream about 50 ft. above the first cross-section. The permissible deviation from the pendents at the upper rope where the rods are intended to pass is, for the central segment 1/2 the width of each sub-segment. For the side and slope segments, the deviation should not exceed $W_2/2$. For greater deviation, the velocities observed should be rejected. Three velocities should be recorded at each station except for three middle segments where five observations should be taken. Timings should be noted with the stop watch. The velocity of float is equal to distance travelled between cross-sections divided by time of travel. The mean velocity of flow in the sub-section is equal to the float velocity multiplied by a coefficient which is based on the shape of sub-section and relative depth of immersion of the float. The following coefficients should be applied.

Ratio of Immersion of Float to Channel Depth	Adjustment Coefficient
0.25	0.88
0.50	0.90
0.75	0.94
0.95	0.98

Computation of Discharge

Discharge in each panel is computed by multiplying the average area of cross-section of the panel by the mean velocity of flow in the panel as determined by float observations. The total discharge is the sum of discharges in the panels.

(iv) Surface Floats

Surface floats are used in very small shallow channels and at discharge sites in the hills where velocities are excessive. In the latter case wooden discs are introduced by a person into the stream a little above the float run, so that they travel through the points of observations. In case the divergence is greater than half the width of segment, the mean of three successful runs at station is accepted as the surface velocity at that station. The timing of any float path which is not under the desired series of points is rejected.

(v) Discharge Measurement by Surface Slope Observations

A rough method of measuring the discharge of main canals and branches is by measuring the water surface slope between two points for which the distance is known. Cross sections are taken at both the points and cross sectional areas are worked out for the two positions. The average cross sectional area is obtained by taking the mean of the areas measured at the two points. Water levels are taken at the two points by a levelling instrument and the difference between the two readings gives the water surface slope. The average velocity between the two points is computed from the Chezy's formula given below:

$$V = C\sqrt{(RS)}$$

Where V = velocity in the canal
R = hydraulic mean radius in feet
C = a co-efficient depending principally on the roughness of the canal sides and bed.

The value of C can be determined from the Manning's formula given below:

$$C = \frac{1.486}{n} \quad R^1/6$$

The value of n for canals and ditches is given in Table 1-1. The discharge of the canal is worked out by multiplying the average cross sectional area between the two points and the average velocity worked out in the manner given above.

TABLE 1-1

VALUES OF MANNING'S "n" FOR CHANNELS

Value of n	Channel Condition
0.016-0.017	Smoothest natural earthen channel, free from growth with straight alignment.
0.020	Smooth natural earthen channel, free from growth little curvature.
0.0225	Average well-constructed, moderate sized earth channels in good condition.
0.025	Small earth channels in good condition or large earth channels with some growth on banks or scattered cobbles in bed.
0.030	Earth channels with considerable growth, natural streams with good alignment, fairly constant section, large floodway channels, well maintained.
0.035	Earth channels considerably covered with small growth, cleared but not continuously maintained flood ways.
0.018	Lined channels with smooth sides and bed.
0.0200	Lined channels with rough sides due to deposition of mud.
0.0250	Lined channels with dry stone on sides and earthen bed.
0.040-0.050	Mountain streams in clean loose cobbles. Rivers with variable section and some vegetation growing on banks. Earth channels with thick aquatic growth.

CHAPTER 2

Measurements of Canal Discharge

2.1 MAKING SEGMENTS OF A CANAL X-SECTION.

For measurement of discharge of main canals and branches, two steel wire ropes are stretched across the section of the canal where the discharge is to be measured. The wire should be fixed in such a way that the cross-section can be divided into five main segments as shown in Fig II-1: The five segments are (a) one central segment,(b) Two side segments,(c) Two slope segments. The central segment should be a multiple of 6 if possible so that W3 is a whole number. If this cannot be arranged it should be a multiple of 3. The width of W2 and W4 should be equal to each other. Depth D1, D2, D3...... are observed at each pendent at three sections. The velocities V1,V2,V3,.... are observed at the same points at three section by current meter.

2.2 COMPUTATION OF DISCHARGES.

(A) Discharge of Central Segment

The area of central segments is computed by Weddle's rule. According to this rule area is given as;

$$A=\frac{3}{10}X\ W_3[(D_3+D_5+D_7+D_9)+(D_4+D_6+D_8)+D_6]$$

Q= 3 /10xW3 (D3xV3+5D4xV4+D5xV5+6xD6xV6+D7xV7+5DBxV8+D9xV9)

(B) Discharge of side segments.

In case of side segments area is computed as;

$$A=\frac{1}{2}W_2(D_2+D_3+D_9+D_{10})$$

Q= W2/2 [D2xV2+D3xV3+D9xV9+D10xV10]

ARRANGEMENT OF SEGMENTS IN CANAL FOR FIRST CLASS DISCHARGE OBSERVATIONS

(SOUNDINGS TO BE TAKE ON FIRM VERTICALS)

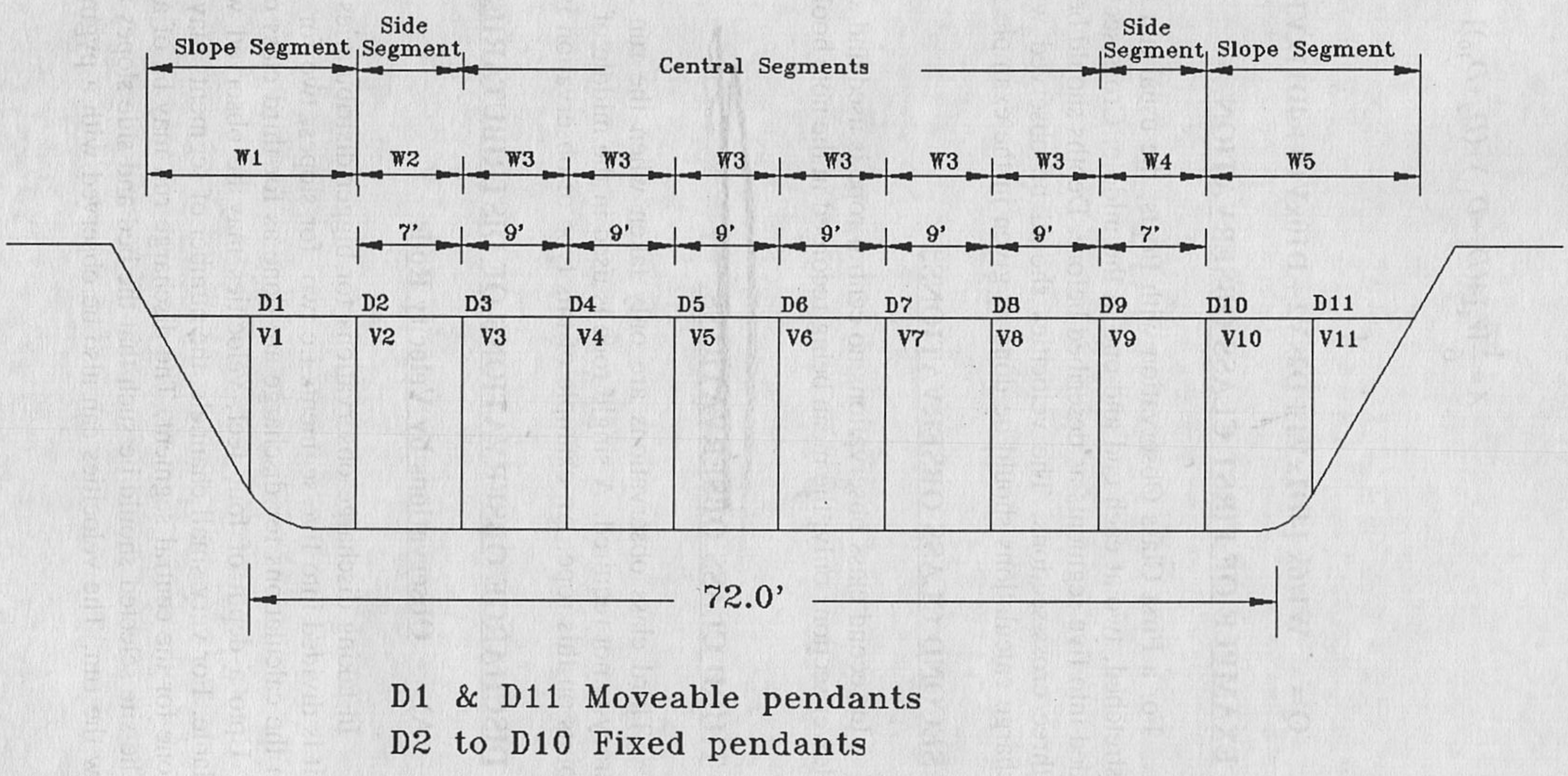


FIG.II-1

(Not to Scale)

C. **Discharge of slope segments.**

For slope segments, area is calculated by Simpsons Rule. According to this rule:

$$A=\frac{1}{6}W_1[4(D_1+D_{11})+(D_2+D_{10})]$$

Q= W1/6x [4D1xV1+D2xV2+D10xV10+4D11xV11]

2.3 EXAMPLE OF FIRST CLASS OBSERVATION.

For a First Class Observation with floats, the usual run is 100 ft. Three wires or ropes are stretched, two at each end and one in the middle. Cross-sections at each end are taken and divided into five segments as described before. Depths should be taken at each pendent point on the three cross-sections. The velocities should be observed with floats as described earlier. Discharge calculations should be done as given in the example in Table II-1.

2.4 SECOND CLASS OBSERVATIONS.

In second class observations no central rope is used and sounding are taken on the upper and lower sections only; the mean being recorded in the note book. This example is shown Table II-2.

2.5 THIRD CLASS OBSERVATIONS.

Third class observations are only taken when the run is very regular or when great accuracy is not required. A single rope is used in the middle of the run and sounding are taken at points on this rope. An example of this type of observation is shown in Table II-3.

2.6 DISCHARGE OBSERVATIONS OF DISTRIBUTARIES AND MINORS.

A) Observations by Velocity Rods

In taking discharge observations for bigger distributaries, one cross section is observed and it is divided into five segments i.e two for slopes, two for sides and one for each section. Then the calculations for discharge are done as for third class observations as shown in Table II-3. Upto a depth of four feet, velocities may be observed with a pygmy current meter if available. For very small channels, the number of segments may be only three i.e two for slope and one for the central segment. The discharge run may be of any convenient length, 10 to 50 ft. The site selected should be such that the bed and side slopes are regular for 50 ft above and below the run. The velocities can also be observed with a pygmy current meter.

TABLE II-1

FIRST CLASS OBSERVATIONS

Discharge taken on ______________________.

At R.D. ________________________________.

Between 10:00 A.M. 10:00 P.M.

By __________________ Assistant Engineer.

Assisted by _______________ Sub Engineer.

Reading of gauge at R.D. 1,000 regulator.

Before observation .... 6.0 }
After observation .... 6.1 } Mean 6.05

Surface Slope

R.L. 500 feet above center of run ..

R.L 500 feet below center of run ..

Difference or fall in 1,000 feet run ..

Fall in 1,000 feet 0.18 or S= ..

Wind direction and strength..]
Very slight----->-->
Slight-------------->
Strong-------------->
Very strong--------->

Current ....------------>

Table II–1

	FIRST CLASS OBSERVATIONS					**SHEET**	**1 OF 7**	
Length of run=		**100**	**feet**					
Timing done with.........			**Chronograph**					
Foats used.................			**Loaded tin tube**					
Surface width=		**126**	**feet**	**Central Segment width=**			**108**	**feet**
Width of slope segments=W1=W5=				**4**	**feet**			
Width of end segments=W2=W4=				**5**	**feet**			
Width of Middle Segments=W3=				**18**	**feet**			
			TABLE OF SOUNDINGS					
Segment width for the reach	**Dist from R.Bank**	**SOUNDINGS @ 3 ROPE LOCATIONS**					**MEAN**	**notation for Mean**
						TOTAL	**SOUNDING**	
		notation	**Upper**	**Mid**	**Lower**			
	0	--	--	--	--	--	--	--
W1	**2**	**d1**	**2**	**2.3**	**2.1**	**6.40**	**2.13**	**D1**
	4	**d2**	**3.5**	**4.2**	**4**	**11.70**	**3.90**	**D2**
W3								
	9	**d3**	**4.7**	**5.1**	**4.8**	**14.60**	**4.87**	**D3**
W3								
	27	**d4**	**5.4**	**5.6**	**6.1**	**17.10**	**5.70**	**D4**
W3								
	45	**d5**	**6**	**6.4**	**6.4**	**18.80**	**6.27**	**D5**
W3								
	63	**d6**	**6**	**5.6**	**5.7**	**17.30**	**5.77**	**D6**
W3								
	81	**d7**	**6.2**	**6.5**	**5.2**	**17.90**	**5.97**	**D7**
W3								
	99	**d8**	**5.7**	**6.6**	**5.6**	**17.90**	**5.97**	**D8**
W3								
	117	**d9**	**5.5**	**5.7**	**5.4**	**16.60**	**5.53**	**D9**
W4								
	122	**d10**	**4**	**4.9**	**4.2**	**13.10**	**4.37**	**D10**
W5								
	124	**d11**	**2.2**	**2.8**	**2.5**	**7.50**	**2.50**	**D11**
W5								
	126	--	--	--	--	--	--	--

Table II–1

	FIRST CLASS OBSERVATIONS (Contd)							Sheet 2 of 7	
		VELOCITY OBSERVATIONS							
Notat–ion	Dist. from right bank	Length of Rod used	Time of passing first rope		Time of ending run		Total	Mean	Velocity ft/s
			M	S	M	S			
			1	3	2	15	72.00		
V1	2	2	2	31	3	40	69.00	69.33	1.44
			4	2	5	9	67.00		
							0.00		
			7	0	8	4	64.00		
V2	4	0.75	8	15	9	20	65.00	64.33	1.55
			9	30	10	34	64.00		
			12	0	12	59	59.00		
V3	9	4.5	13	17	14	15	58.00	59.67	1.68
			14	40	15	42	62.00		
			20	5	20	50	45.00		
			21	10	21	52	42.00		
V4	27	5.25	23	0	23	47	47.00	45.00	2.22
			25	2	25	48	46.00		
			28	10	28	55	45.00		
V5	45	5.75	0	14	0	54	40.00		
			1	20	1	56	36.00	37.33	2.68
			2	31	3	7	36.00		
			5	12	5	54	42.00		
			6	40	7	21	41.00		
V6	63	5.5	8	0	8	44	44.00	42.00	2.38
			9	10	9	53	43.00		
			10	50	11	30	40.00		

Table II–1

	FIRST CLASS OBSERVATIONS (Contd)							Sheet 3 of 7	
			13	1	13	45	44.00		
V7	81	5	14	0	14	41	41.00	41.33	2.42
			14	59	15	38	39.00		
			0	0	0	37	37.00		
			1	12	1	52	40.00		
V8	99	5.5	2	15	2	55	40.00	40.80	2.45
			3	2	3	45	43.00		
			4	12	4	56	44.00		
			6	0	6	49	49.00		
V9	117	5.25	7	0	7	52	52.00	51.00	1.96
			8	16	9	8	52.00		
			10	40	11	42	62.00		
V10	122	3.75	12	8	13	11	63.00	63.00	1.59
			15	0	16	4	64.00		
			18	0	19	10	70.00		
V11	124	2	19	30	20	42	72.00	71.67	1.40
			21	12	22	25	73.00		

		FIRST CLASS OBSERVATIONS (contd)				**Sheet 4**	
						of 7	
		CALCULATION OF DISCHARGE					
CENTRAL SEGMENT(Weddle's Rule)						**DISCHARGE**	
D3 X V3 =		**4.87 X 1.67**			**8.16**		
5 X D4 X V4=		**5 X 5.7 X 2.22**			**63.33**		
D5 X V5=		**6.27 X 2.68**			**16.79**		
6 X D6 X V6=		**6 X 5.77 X 2.38**			**82.38**		
D7 X V7=		**5.97 X 2.42**			**14.44**		
5 X D8 X V8=		**5 X 5.97 X 2.45**			**73.12**		
D9 X V9=		**5.53 X 1.96**			**10.85**		
				SUM=	**269.06**		
		DISCHARGE=				**1452.9374**	
SIDE SEGMENTS							
D2 X V2=		**3.9 X 1.56**			**6.06**		
D3 X DV3=		**4.87 X 1.68**			**8.16**		
D9 X V9=		**5.53 X 1.96**			**10.85**		
D10 X V10=		**4.4 X 1.59**			**6.93**		
				SUM=	**32.00**		
		DISCHARGE=				**79.998727**	

Table II-1

		FIRST CLASS OBSERVATIONS (contd)				**Sheet 5**	
						of 7	
SLOPE SEGMENTS(Simpsons rule)							
4 x D1 X V1=		**4 X 2.13 X 1.44**			**12.31**		
D2 X V2=		**3.9 X 1.55**			**6.06**		
D10 X V10=					**6.93**		
4 X D11 X V11=					**13.95**		
				SUM=	**39.25**		
		DISCHARGE				**26.169715**	
				TOTAL DISCHARGI		**1559.1059**	

Table II–1

FIRST CLASS OBSERVATIONS (contd)					**Sheet 6 of 7**		
OTHER CALCULATIONS							
		AREAS					
						WETTED	
CENTRAL SEGMENT			**SLOPE & SIDE SEGMENTS**			**PERIMETER**	
D3	**4.87**		**D2**	**3.90**		**FIRST**	**5.58659**
						SLOPE	
5 X D4	**28.50**		**D3**	**4.87**		**SEGMENT=**	
D5	**6.27**		**D9**	**5.53**		**SECOND**	
						SLOPE	
6 x D6	**34.60**		**D10**	**4.37**		**SEGMEN**	**5.92180**
D7	**5.97**		**SUM=**	**18.67**		**SIDE**	
						SEGMEN	**10**
5 X D8	**29.83**		**W2/2=**	**2.50**			
						CENTRAL	
D9	**5.53**		**AREA OF**			**SEGMEN**	**108**
			SIDE				
			SEGMEN	**46.67**			
	115.57						
3W3/10=	**5.40**		**4 X D1**	**8.53**			
AREA=	**624.06**		**4 X D11**	**10.00**			
			D2	**3.9**			
			D10	**4.37**			
			SUM	**26.80**			
			W1/6	**0.67**			
			AREA OF	**17.87**		**TOTAL**	**129.508**
			SLOPE			**WETTED**	
			SEGMENT=			**PERIMETER**	

Table II–1

FIRST CLASS OBSERVATIONS (contd)					Sheet 7 of 7
AREA OF CENTRAL SEGMENT=					624.06
AREA OF SLOPE SEGMENTS=					46.67
AREA OF SIDE SEGMENTS=					17.87
TOTAL AREA=		624.06+46.67+17.87=			688.59
TOTAL WETTED PARAMETER					129.51
HYDRAULIC MEAN DEPTH=A/P=					5.32
A X SQRT(R.X S)=					21.30
DISCHARGE=		Q=			1559.11
Coefficient=		Q/A(SQRT(S X R)=			73.19

Table II–2

	SECOND CLASS OBSERVATIONS					SHEET 1 OF 7		
Length of run=			100 feet					
Timing done with.........			Chronograph					
Foats used.................			Loaded tin tube					
Surface width=			126 feet	Central Segment width=			108 feet	
Width of slope segments=W1=W5=				4 feet				
Width of end segments=W2=W4=				5 feet				
Width of Middle Segments=W3=				18 feet				
			TABLE OF SOUNDINGS					
Segment width for the reach	Dist from R.Bank	SOUNDINGS @ 3 ROPE LOCATIONS				TOTAL	MEAN SOUNDING	notation for Mean
		notation	Upper	Mid	Lower			
	0	--	--	--	--	--	--	--
W1	2	d1	2		2.1	4.10	2.05	D1
	4	d2	3.5		4	7.50	3.75	D2
W3								
	9	d3	4.7		4.8	9.50	4.75	D3
W3								
	27	d4	5.4		6.1	11.50	5.75	D4
W3								
	45	d5	6		6.4	12.40	6.20	D5
W3								
	63	d6	6		5.7	11.70	5.85	D6
W3								
	81	d7	6.2		5.2	11.40	5.70	D7
W3								
	99	d8	5.7		5.6	11.30	5.65	D8
W3								
	117	d9	5.5		5.4	10.90	5.45	D9
W4								
	122	d10	4		4.2	8.20	4.10	D10
W5								
	124	d11	2.2		2.5	4.70	2.35	D11
W5								
	126	--	--	--	--	--	--	--

Table II–2

		SECOND CLASS OBSERVATIONS (Contd)						Sheet 2 of 7	
		VELOCITY OBSERVATIONS							
Notat–ion	Dist. from right bank	Length of Rod used	Time of passing first rope		Time of ending run		Total	Mean	Velocity ft/s
			M	S	M	S			
			1	3	2	15	72.00		
V1	2	2	2	31	3	40	69.00	69.33	1.44
			4	2	5	9	67.00		
			7	0	8	4	64.00		
V2	4	0.75	8	15	9	20	65.00	64.33	1.55
			9	30	10	34	64.00		
			12	0	12	59	59.00		
V3	9	4.5	13	17	14	15	58.00	59.67	1.68
			14	40	15	42	62.00		
			20	5	20	50	45.00		
			21	10	21	52	42.00		
V4	27	5.25	23	0	23	47	47.00	45.00	2.22
			25	2	25	48	46.00		
			28	10	28	55	45.00		
V5	45	5.75	0	14	0	54	40.00		
			1	20	1	56	36.00	37.33	2.68
			2	31	3	7	36.00		
			5	12	5	54	42.00		
			6	40	7	21	41.00		
V6	63	5.5	8	0	8	44	44.00	42.00	2.38
			9	10	9	53	43.00		
			10	50	11	30	40.00		

Table II–2

	SECOND CLASS OBSERVATIONS (Contd)							Sheet 3 of 7	
			13	1	13	45	44.00		
V7	81	5	14	0	14	41	41.00	41.33	2.42
			14	59	15	38	39.00		
			0	0	0	37	37.00		
			1	12	1	52	40.00		
V8	99	5.5	2	15	2	55	40.00	40.80	2.45
			3	2	3	45	43.00		
			4	12	4	56	44.00		
			6	0	6	49	49.00		
V9	117	5.25	7	0	7	52	52.00	51.00	1.96
			8	16	9	8	52.00		
			10	40	11	42	62.00		
V10	122	3.75	12	8	13	11	63.00	63.00	1.59
			15	0	16	4	64.00		
			18	0	19	10	70.00		
V11	124	2	19	30	20	42	72.00	71.67	1.40
			21	12	22	25	73.00		

Table II−2

		SECOND CLASS OBSERVATIONS (cont				Sheet 4 of 7	
		CALCULATION OF DISCHARGE					
CENTRAL SEGMENT(Weddle's Rule)						DISCHARGE	
D3 X V3 =		4.87 X 1.67			7.96		
5 X D4 X V4=		5 X 5.7 X 2.22			63.89		
D5 X V5=		6.27 X 2.68			16.61		
6 X D6 X V6=		6 X 5.77 X 2.38			83.57		
D7 X V7=		5.97 X 2.42			13.79		
5 X D8 X V8=		5 X 5.97 X 2.45			69.24		
D9 X V9=		5.53 X 1.96			10.69		
				SUM=	265.75		
		DISCHARGE=				1435.0237	
SIDE SEGMENTS							
D2 X V2=		3.9 X 1.56			5.83		
D3 X DV3=		4.87 X 1.68			7.96		
D9 X V9=		5.53 X 1.96			10.69		
D10 X V10=		4.4 X 1.59			6.51		
				SUM=	30.98		
		DISCHARGE=				77.460301	

Table II-2

		SECOND CLASS OBSERVATIONS (contc				Sheet 5 of 7
SLOPE SEGMENTS(Simpsons rule)						
4 x D1 X V1=		4 X 2.13 X 1.44			11.83	
D2 X V2=		3.9 X 1.55			5.83	
D10 X V10=					6.51	
4 X D11 X V11=					13.12	
				SUM=	37.28	
		DISCHARGE				24.853436
		TOTAL DISCHARGE=				1537.3375

Table II–2

SECOND CLASS OBSERVATIONS (contd)					Sheet 6 of 7		
OTHER CALCULATIONS							
			AREAS				
						WETTED	
CENTRAL SEGMENT			SLOPE & SIDE SEGMENTS			PERIMETER	
D3	4.75		D2	3.75		FIRST	5.48292
						SLOPE	
5 X D4	28.75		D3	4.75		SEGMENT=	
D5	6.20		D9	5.45		SECOND	
						SLOPE	
6 x D6	35.10		D10	4.10		SEGMEN	5.72800
D7	5.70		SUM=	18.05		SIDE	
						SEGMEN	10
5 X D8	28.25		W2/2=	2.50			
						CENTRAL	
D9	5.45		AREA OF			SEGMEN	108
			SIDE				
			SEGMEN	45.13			
	114.20						
3W3/10=	5.40		4 X D1	8.20			
AREA=	616.68		4 X D11	9.40			
			D2	3.75			
			D10	4.10			
			SUM	25.45			
			W1/6	0.67			
			AREA OF	16.97		TOTAL	129.210
			SLOPE			WETTED	
			SEGMENT=			PERIMETER	

Table II–2

SECOND CLASS OBSERVATIONS (contd)					**Sheet 7 of 7**	
AREA OF CENTRAL SEGMENT=					**616.68**	
AREA OF SLOPE SEGMENTS=					**45.13**	
AREA OF SIDE SEGMENTS=					**16.97**	
TOTAL AREA=		**624.06+46.67+17.87=**			**678.77**	
TOTAL WETTED PARAMETER					**129.21**	
HYDRAULIC MEAN DEPTH=A/P=					**5.25**	
A X SQRT(R X S)=					**20.87**	
DISCHARGE=		**Q=**			**1537.34**	
Coefficient=		**Q/A(SQRT(S X R)=**			**73.65**	

Table II–3

	THIRD CLASS OBSERVATIONS					SHEET 1 OF 7		
Length of run=		100	feet					
Timing done with.........			Chronograph					
Foats used.................			Loaded tin tube					
Surface width=		126	feet	Central Segment width=			108	feet
Width of slope segments=W1=W5=				4	feet			
Width of end segments=W2=W4=				5	feet			
Width of Middle Segments=W3=				18	feet			
			TABLE OF SOUNDINGS					
Segment width for the reach	Dist from R.Bank	SOUNDINGS @ 3 ROPE LOCATIONS notation	Upper	Mid	Lower	TOTAL	MEAN SOUNDIN(	notation for Mean
	0	--	--	--	--	--	--	--
W1	2	d1					2.30	D1
	4	d2					4.20	D2
W3								
	9	d3					5.10	D3
W3								
	27	d4					5.60	D4
W3								
	45	d5					6.40	D5
W3								
	63	d6					5.60	D6
W3								
	81	d7					6.50	D7
W3								
	99	d8					6.60	D8
W3								
	117	d9					5.70	D9
W4								
	122	d10					4.90	D10
W5								
	124	d11					2.80	D11
W5								
	126	--	--	--	--	--	--	--

Table II–3

	THIRD CLASS OBSERVATIONS (Contd)							Sheet 2 of 7	
		VELOCITY OBSERVATIONS							
Notat––ion	Dist. from right bank	Length of Rod used	Time of passing first rope		Time of ending run		Total	Mean	Velocity ft/s
			M	S	M	S			
			1	3	2	15	72.00		
V1	2	2	2	31	3	40	69.00	69.33	1.44
			4	2	5	9	67.00		
			7	0	8	4	64.00		
V2	4	0.75	8	15	9	20	65.00	64.33	1.55
			9	30	10	34	64.00		
			12	0	12	59	59.00		
V3	9	4.5	13	17	14	15	58.00	59.67	1.68
			14	40	15	42	62.00		
			20	5	20	50	45.00		
			21	10	21	52	42.00		
V4	27	5.25	23	0	23	47	47.00	45.00	2.22
			25	2	25	48	46.00		
			28	10	28	55	45.00		
V5	45	5.75	0	14	0	54	40.00		
			1	20	1	56	36.00	37.33	2.68
			2	31	3	7	36.00		
			5	12	5	54	42.00		
			6	40	7	21	41.00		
V6	63	5.5	8	0	8	44	44.00	42.00	2.38
			9	10	9	53	43.00		
			10	50	11	30	40.00		

Table II–3

	THIRD CLASS OBSERVATIONS (Contd)							Sheet 3 of 7		
			13	1		13	45	44.00		
V7	81	5	14	0		14	41	41.00	41.33	2.42
			14	59		15	38	39.00		
			0	0		0	37	37.00		
			1	12		1	52	40.00		
V8	99	5.5	2	15		2	55	40.00	40.80	2.45
			3	2		3	45	43.00		
			4	12		4	56	44.00		
			6	0		6	49	49.00		
V9	117	5.25	7	0		7	52	52.00	51.00	1.96
			8	16		9	8	52.00		
			10	40		11	42	62.00		
V10	122	3.75	12	8		13	11	63.00	63.00	1.59
			15	0		16	4	64.00		
			18	0		19	10	70.00		
V11	124	2	19	30		20	42	72.00	71.67	1.40
			21	12		22	25	73.00		

Table II–3

	THIRD CLASS OBSERVATIONS (contd)			Sheet 4 of 7
	CALCULATION OF DISCHARGE			
CENTRAL SEGMENT(Weddle's Rule)				DISCHARGE
D3 X V3 =	4.87 X 1.67		8.55	
5 X D4 X V4=	5 X 5.7 X 2.22		62.22	
D5 X V5=	6.27 X 2.68		17.14	
6 X D6 X V6=	6 X 5.77 X 2.38		80.00	
D7 X V7=	5.97 X 2.42		15.73	
5 X D8 X V8=	5 X 5.97 X 2.45		80.88	
D9 X V9=	5.53 X 1.96		11.18	
		SUM=	275.70	
	DISCHARGE=			1488.7648
SIDE SEGMENTS				
D2 X V2=	3.9 X 1.56		6.53	
D3 X DV3=	4.87 X 1.68		8.55	
D9 X V9=	5.53 X 1.96		11.18	
D10 X V10=	4.4 X 1.59		7.78	
		SUM=	34.03	
	DISCHARGE=			85.075579

Table II–3

		THIRD CLASS OBSERVATIONS (contd)					Sheet 5 of 7
SLOPE SEGMENTS(Simpsons rule)							
4 x D1 X V1=		4 X 2.13 X 1.44			13.27		
D2 X V2=		3.9 X 1.55			6.53		
D10 X V10=					7.78		
4 X D11 X V11=					15.63		
				SUM=	43.20		
		DISCHARGE					28.802275
				TOTAL DISCHARGE=			1602.6427

Table II-3

THIRD CLASS OBSERVATIONS (contd)					Sheet 6 of 7		
OTHER CALCULATIONS							
		AREAS					
						WETTED	
CENTRAL SEGMENT			SLOPE & SIDE SEGMENTS			PERIMETER	
D3	5.10		D2	4.20		FIRST	5.8
						SLOPE	
5 X D4	28.00		D3	5.10		SEGMENT=	
D5	6.40		D9	5.70		SECOND	
						SLOPE	
6 x D6	33.60		D10	4.90		SEGMEN	6.32534
D7	6.50		SUM=	19.90		SIDE	
						SEGMEN	10
5 X D8	33.00		W2/2=	2.50			
						CENTRAL	
D9	5.70		AREA OF			SEGMEN	108
			SIDE				
			SEGMEN	49.75			
	118.30						
3W3/10=	5.40		4 X D1	9.20			
AREA=	638.82		4 X D11	11.20			
			D2	4.2			
			D10	4.90			
			SUM	29.50			
			W1/6	0.67			
			AREA OI	19.67		TOTAL	130.125
			SLOPE			WETTED	
			SEGMENT=			PERIMETER	

Table II–3

THIRD CLASS OBSERVATIONS (contd)					Sheet 7 of 7	
AREA OF CENTRAL SEGMENT=					638.82	
AREA OF SLOPE SEGMENTS=					49.75	
AREA OF SIDE SEGMENTS=					19.67	
TOTAL AREA=		624.06+46.67+17.87=			708.24	
TOTAL WETTED PARAMETER					130.13	
HYDRAULIC MEAN DEPTH=A/P=					5.44	
A X SQRT(R X S)=					22.17	
DISCHARGE=		Q=			1602.64	
Coefficient=		Q/A(SQRT(S X R)=			72.30	

B. **Discharge Calculations at Falls and Regulators**

For working out the discharge at falls and regulators where gates have been installed, weir formulae as shown in Exhibit II-I may be used.

2.7 GAUGE-DISCHARGE TABLES FOR MODULAR FLOW.

Preparation of gauge-discharge tables for all the regulating points on main canals, branches and distributaries is very important because the gauge readers regulate water supplies in the various channels on the basis of theses tables. There are two ways of preparing these tables.

(a) By Calibrating Meter Flumes

The theoretical modular flow of meter flume is given by the following general formula.

$Q = C\,B\,(H+Ha)^n$ ____________ (i)

Where

Q = Discharge
B = Width of Crest
C = Coefficient
H = Depth of water on crest

Ha= Head due to the velocity of approach and is calculated from the formula $Va = (2g\,Ha)^{1/2}$. Va is calculated by dividing the discharge by area of cross-section (Va= Q/A).

This equation does not take into account the effect of end contraction and the head lost due to friction. The U/S gauge should be installed outside the effect of draw down and its zero should be at the crest level of the meter flume. By taking logs of both sides the equation (i) can be written in the following form.

$\log Q = \log CB + n \log(H+Ha)$ ____________ (ii)

Observations, Q, are made for the various ranges of 1/4, 1/2, 3/4 and full supply discharge. The values of log Q are plotted against log(H+Ha). A straight line is drawn through the mean position. By putting values of log Q and log (H+Ha) for any two points on the graph, the values of CB and n are obtained. Then a gauge discharge table can be prepared for various values of the gauge.

The best time for preparing theses tables is just after the closure period. The cross-section are observed during the closure period. When the channels are opened after the closure period the discharges can be observed for various gauges particularly of distributaries and minors. Theses tables should be revised if there is silt deposition or scour in the channel.

(b) Empirical Formula for Channels

Gauge discharges can also be prepared by the following empirical formula.

$$Q = K D^n$$

where

Q = discharge
K = discharge coefficient
n = exponent
D = water depth at gauge

Sometimes the value of n is taken as 5/3 but it is not correct to do so. This value varies from site to site. For greater accuracy, it should be determined by actual observation. A series of discharge observations for Q for various values of the gauge cross-sections at the discharge site are observed and plotted. The area A is worked out from this cross section. This area A is divided by the width of the channel to get an average value of D. Knowing two or more values of Q, the values of K and n can be determined. Knowing theses values, Q can be worked out for various values of D from the observed X-section. D can be correlated to the gauge when the discharge table is prepared for any particular site of a channel. During the discharge observation, if a variation of gauge takes place then the average of two gauge readings should be taken for the observed discharge.

Practical Example

A practical example for preparing the gauge discharge table is given below:

The Empirical formula is :

$Q = KD^n$ (1)

Taking logrithms of both sides the equation becomes as below :

$\log Q = \log K + n \log D$

Suppose for a given gauge G-1, the depth is D-1 and discharge comes to Q-1. Similarly for gauge G-2, the depth is D-2 and the observed discharge is Q-2. Putting these values in the above equation I, the two equations are as below.

$\log Q1 = \log K + n \log D1$ (2)
$\log Q2 = \log K + n \log D2$ (3)

subtracting equation 3 from equation 2 we get
$\log Q1 - \log Q2 = n (\log D1 - \log D2)$ (4)

From equation 4, we can work out the value of n because the other values of Q1, Q2, D1 and D2 are known. After this the value of n is put in equation 2 above and value of K is found out. Thus the values of k and n are known in the equation (1). By changing values of D, the values of Q are worked out and these are correlated to the gauge in the canal at the discharge site. In this way a table is prepared for discharges and corresponding gauges. A curve can also be plotted from these values.

2.8 DISCHARGE OF OUTLETS AND WATER COURSES.

A. Outlets

The following three types of outlets are being used in the NWFP.

i. Pipe or orifice
ii. Open Flume (OF)
iii. Adjustable Proportionate Module (APM)

2.811 Pipe outlet

These are generally concrete pipes and their discharge is given by

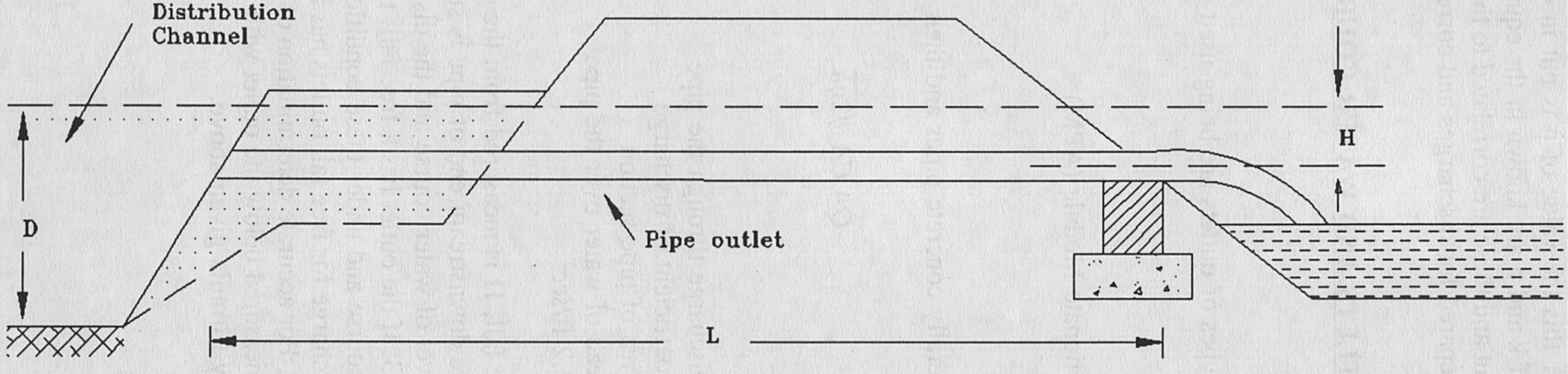
$$Q = CA\sqrt{2gh}$$

where

Q = Discharge through the pipe
C = Coefficient of discharge
A = Area of pipe section
h = Head of water over the pipe
g = 32.2 ft/sec^2

If the outlet has a free fall, H is measured from the center of the pipe to the full supply level in the distributary. If the downstream end of pipe is submerged in the water course, H is the difference in the water level of water course and the distributary. These two conditions are shown in Fig II-2 and Fig.II-3. If the outlet has a free fall, then the discharge is independent of the water level in the water course and under these conditions, it is semi-modular.

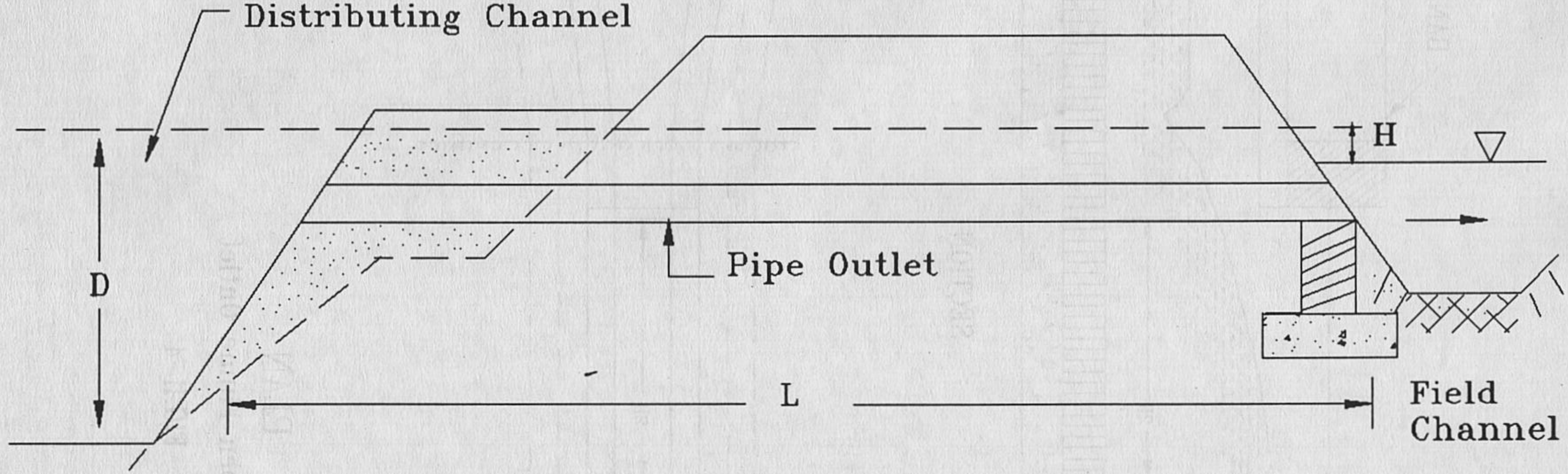
The co-efficient of discharge for free fall outlets has a value between 0.60 and 0.70. For non modular outlets,it is 0.74. For accurate determination of its value, the discharge in the water course should be accurately measured below the outlet with a portable flume and then the value of C should be determined by formula given above.



Free Fall Pipe outlet.

Fig. II–2

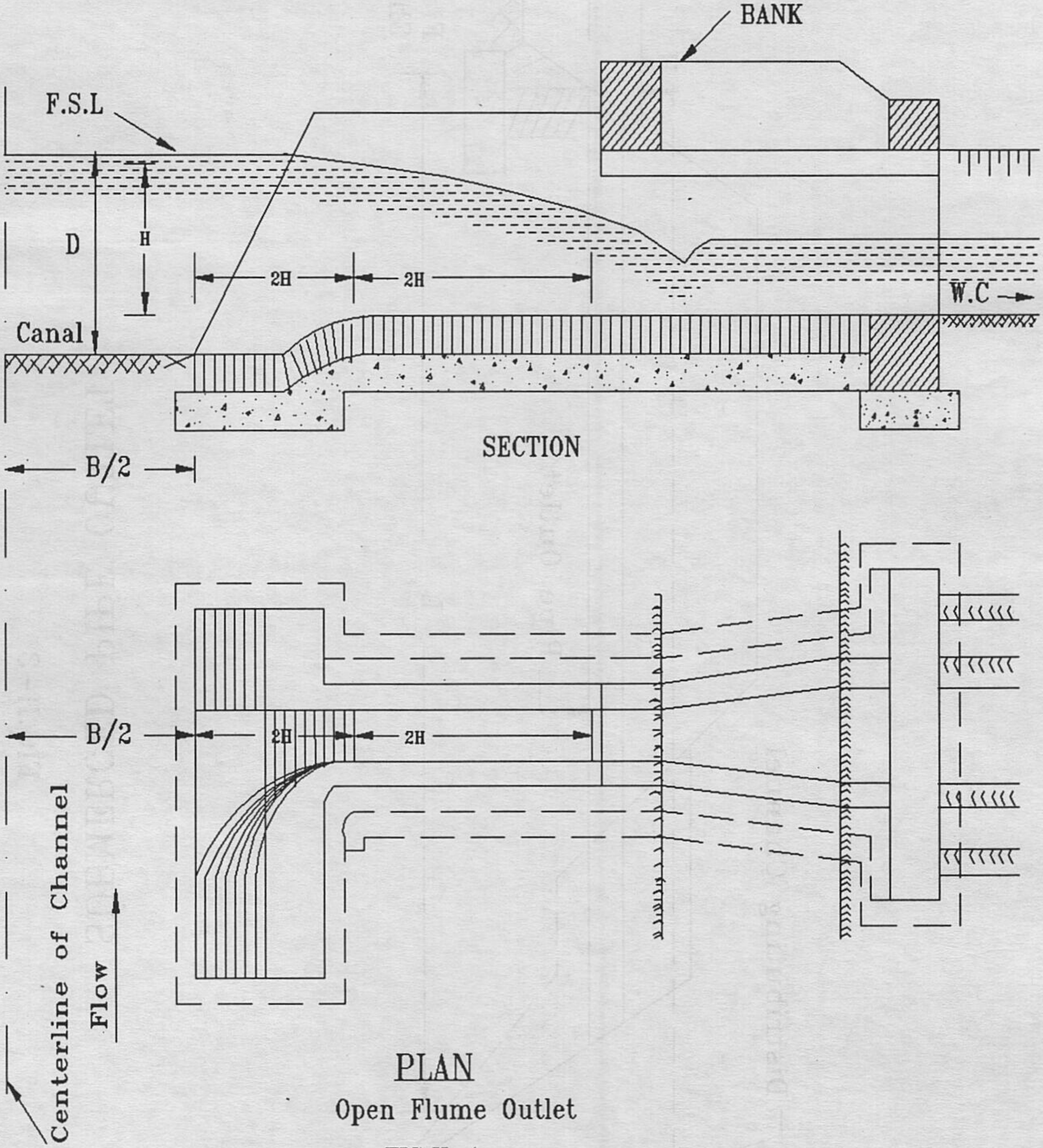
(Not to Scale)



SUBMERGED PIPE OUTLET

FIG.II–3

(Not to Scale)



Open Flume Outlet

FIG.II-4

(Not to Scale)

1. Open Flume (O.F) outlet

The open flume outlet (shown in Fig.II-4) is simply a smooth weir with a throat constructed sufficiently long to ensure a velocity above the critical velocity and the control section remains within the parallel throat at all discharges upto the maximum. A gradually expanding flume is provided at the end to obtain maximum recovery of head. The entire work is built in brick masonry but the controlling section is provided with cast iron plates to prevent tampering by the farmers. The discharge of an open flume is given by the formula:

$$Q = K B_t H^{3/2}$$

where:
Q = discharge in CFS
K = Coefficient of discharge
B_t = Throat width
H = Head of water on the crest in ft

The value of K is 3.0 or less depending on the throat width as shown below:

For Bt 0.2 to 0.3 ft	K = 2.90
For Bt O.3 to 0.4 ft	K = 2.95
For Bt more than 0.4 ft	K = 3.00

In practice Bt is never kept less than 0.20 ft. For proportionality, the crest of the outlet is kept at 0.90 of the depth of the channel. For lesser heads, the outlet becomes hyper proportional and for bigger heads it tends to be rigid. The table below gives the minimum discharge for which the outlet can be designed.

B_t = 0.2 ft and K =2.9

*D=	1.0	1.5	2.0	2.5	3.0	3.5	4.0 ft
Q=	0.58	1.07	1.64	2.29	3.01	3.8	4.64 cfs

(* D= depth of water in the channel in ft.)

From the above, it is apparent that except for small channels, it is seldom possible to place the crest of an open flume outlet at the bed of the channel. The working head required in an open flume outlet with a 1:5 glaces and side wall splaying at 1:5, is 20 % of depth of water above the crest of the outlet. This type of outlet is suited to :

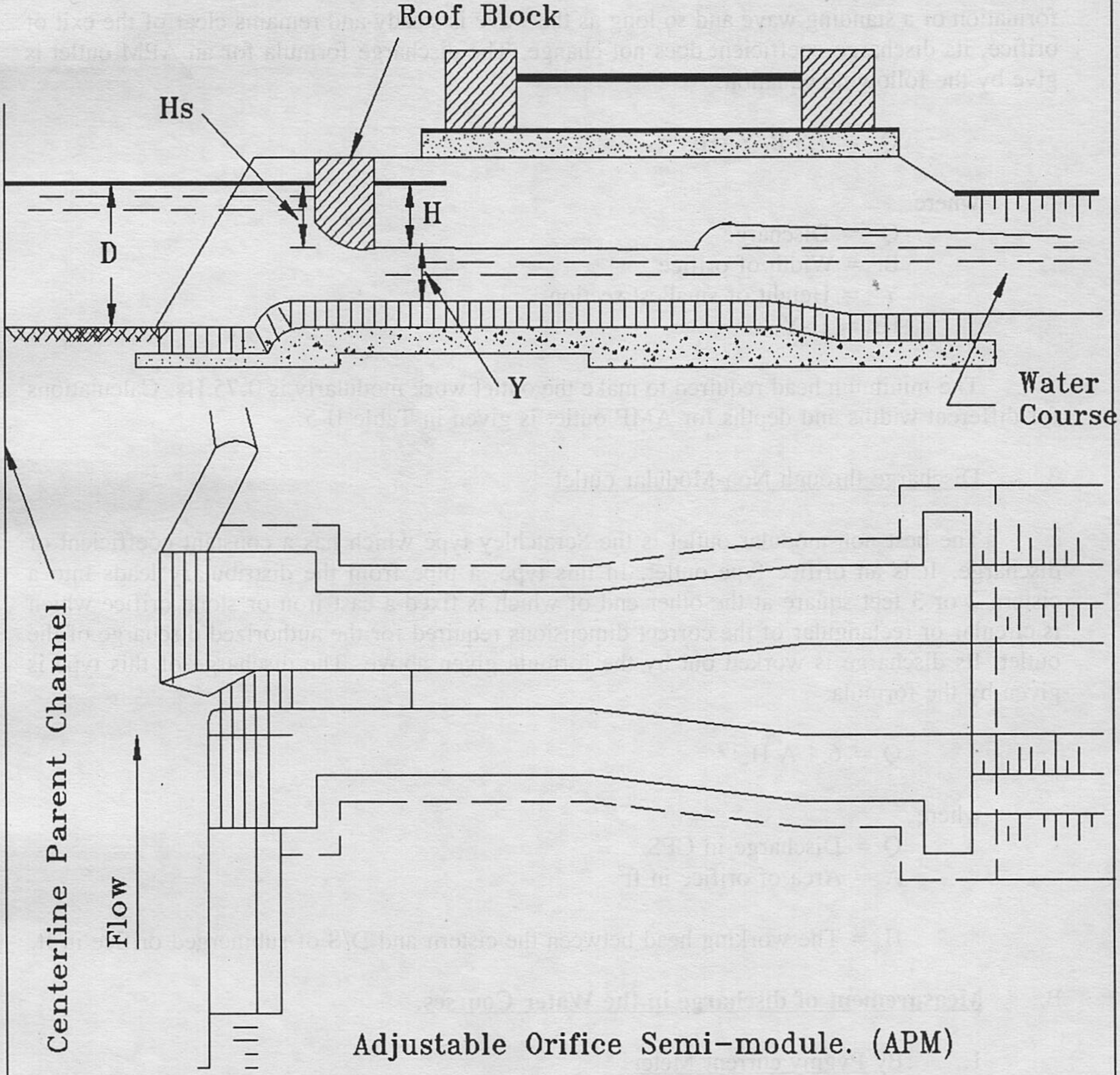
(a) Tail clusters
(b) U/S of proportionate regulators.

Calculations for various widths and heads of an open flume outlet are given in Table II-4.

Table II-4
Page-1

OPEN FLUME OUTLET DISCHARGE
(cfs)

Depth of Crest G ft	Throat width - ft (K=290) 0.2	(K=2.925) 0.25	(K=2.95) 0.3	(K=2.975) 0.35	(K=3.0) 0.4
1.0	0.58	0.73	0.89	1.04	1.20
1.5	1.07	1.34	1.63	1.91	2.20
2.0	1.64	2.07	2.50	2.95	3.39
2.5	2.29	2.89	3.50	4.16	4.74
3.0	3.01	3.80	4.60	5.41	6.24
3.5	3.80	4.79	5.79	6.82	7.86
4.0	4.64	5.85	7.08	8.33	9.60



Adjustable Orifice Semi-module. (APM)

FIG.II-5

(Not to Scale)

2. Adjustable Proportionate Module (A.P.M)

Structurally the APM (shown in Fig. II-5) is an open flume with a roof block which enables vertical adjustment of the orifice of the outlet. Modularity of an APM is assured by the formation of a standing wave and so long as the wave is steady and remains clear of the exit of orifice, its discharge coefficient does not change. The discharge formula for an APM outlet is give by the following equation:

$$Q = 7.3\, B_t\, Y\, (Hs)^{1/2}$$

where

Q = Discharge
Bt = Width of orifice
Y = Height of smallest section
Hs = H-Y

The minimum head required to make the outlet work modularly is 0.75 Hs. Calculations for different widths and depths for AMP outlet is given in Table II-5.

3. Discharge through Non-Modular outlet

The best non-modular outlet is the Scratchley type which has a constant coefficient of discharge. It is an orifice type outlet. In this type, a pipe from the distributary leads into a cistern 2 or 3 feet square at the other end of which is fixed a cast iron or stone orifice which is circular or rectangular of the correct dimensions required for the authorized discharge of the outlet. Its discharge is worked out by the formula given above. The discharge of this type is given by the formula:

$$Q = 6.4\, A\, H_w^{1/2}$$

where

Q = Discharge in CFS
A = Area of orifice in ft^2

H_w = The working head between the cistern and D/S of submerged orifice in ft.

B. **Measurement of discharge in the Water Courses.**

1. By Pygmy current Meter

The Pygmy current meter,as already described above,is specially designed for measurement of small discharges. For measuring the discharge of a water course a straight reach of 50 ft is selected.

TABLE II-5
TABLE FOR APM OUTLETS

$B_t = 0.20$

Depth D ft	Height Orifice Opening- y in ft 0.10D	0.15D	0.20D	0.25D	0.30D	0.35D	0.40D
1.0	0.13	0.19	0.24	0.29	0.34	0.38	0.41
1.5	0.24	0.35	0.45	0.54	0.62	0.70	0.76
2.0	0.37	0.54	0.69	0.83	0.96	1.07	1.17
2.5	0.52	0.75	0.97	1.16	1.34	1.50	1.63
3.0	0.68	0.99	1.27	1.53	1.76	1.97	2.15
3.5	0.86	1.24	1.60	1.93	2.22	2.48	2.70
4.0	1.04	1.52	1.95	2.35	2.71	3.03	3.30
4.5	1.25	1.81	2.33	2.81	3.24	3.62	3.94
5.0	1.46	2.12	2.73	3.29	3.79	4.24	4.62

$B_t = 0.25$

1.0	0.16	0.24	0.31	0.37	0.42	0.47	0.52
1.5	0.30	0.44	0.56	0.68	0.78	0.87	0.95
2.0	0.46	0.67	0.86	1.04	1.20	1.34	1.46
2.5	0.65	0.94	1.21	1.45	1.68	1.87	2.04
3.0	0.85	1.23	1.59	1.91	2.20	2.46	2.68
3.5	1.07	1.55	2.00	2.41	2.78	3.10	3.38
4.0	1.31	1.90	2.44	2.94	3.39	3.79	4.13
4.5	1.56	2.26	2.92	3.51	4.05	4.52	4.93
5.0	1.83	2.65	3.41	4.11	4.74	5.30	5.77

$B_t = 0.32$

1.0	0.21	0.30	0.39	0.47	0.54	0.61	0.66
1.5	0.38	0.56	0.72	0.86	1.00	1.11	1.21
2.0	0.59	0.86	1.11	1.33	1.54	1.72	1.87
2.5	0.83	1.20	1.55	1.86	2.15	2.40	2.61
3.0	1.09	1.58	2.03	2.45	2.82	3.15	3.43
3.5	1.37	1.99	2.56	3.08	3.55	3.97	4.33
4.0	1.67	2.43	3.13	3.77	4.34	4.85	5.29
4.5	1.99	2.90	3.73	4.49	5.18	5.79	6.31
5.0	2.34	3.39	4.37	5.26	6.07	6.78	7.39

$B_t = 0.40$

1.0	0.26	0.38	0.49	0.59	0.68	0.76	0.83
1.5	0.48	0.70	0.90	1.08	1.25	1.39	1.52
2.0	0.74	1.07	1.38	1.66	1.92	2.14	2.34
2.5	1.03	1.50	1.93	2.33	2.68	3.00	3.26
3.0	1.36	1.97	2.54	3.06	3.53	3.94	4.29
3.5	1.71	2.48	3.20	3.85	4.44	4.96	5.41
4.0	2.09	3.03	3.91	4.71	5.43	6.06	6.61
4.5	2.49	3.62	4.66	5.62	6.48	7.24	7.88
5.0	2.92	4.24	5.46	6.58	7.59	8.47	9.23

Three cross sections, two at the ends and one in the middle, are observed. The area of these three sections is observed and the mean area is calculated. Velocity in the water course is observed at three sections (at 0.6 depth) with the Pygmy Meter and the mean velocity is calculated. The discharge of the water course is obtained by multiplying the average area with the average velocity. For greater accuracy the section can be divided into three segments and the velocity observed in each segment. The discharge can then be computed as for channels.

2. Discharge measurement with Portable Flumes

The following three flumes are used for measurement of water course discharges.

a) Parshall Flume

This flume is a critical flow flume. It is not used extensively in NWFP.

b) Long Throated Flume

This long throated portable flume is comprised of a throat for which the bottom is truly horizontal. There are U/S and D/S glaces like the open flume outlet. It is fitted in the water course bank in such a way that a standing wave is formed when water passes through it. For using it, a bund is put in the water course so as to divert all the flow into the flume. The depth on the crest is measured and discharge is calculated with an open flume outlet formula i.e:

$Q= K B_t H^{3/2}$

c) Cut throat Flume

This flume is a throttles flume. Its principal advantage is its flat bottom.It is being extensively used in the NWFP by the On-Farm Water Management Organization. For each size there are discharge tables. The flume is fitted in the water course and when all the flow of the water course passes through it, the head of water is observed. The discharge is found from the tables corresponding to this head.

3. By Surface Floats

For quick and rough estimation of discharge the water course x-sections are observed at three points and the mean sectional area is worked out. For lined water courses the section does not vary with length, therefore, one cross section should be observed. A wooden float is put in the water course and its travel time for 25 ft is observed. In this way, the velocity can be worked out. It should be multiplied by 0.85 for lined water courses and by 0.8 for unlined water course to get the average velocity. The product of the average velocity and the average x-sectional area gives the discharge of the water course.

4. Discharge Measurement by Weirs

Where high accuracy is desired, sharp crested weirs are installed in the water course in such a way that they work modular, i.e, they have free fall over them. The commonly used shapes are rectangular, trapezoidal, and triangular or V-notch. Rectangular and V-notch are mostly used.

(a) Rectangular thin plate Weir

The discharge equation for this type of weir is:

$$Q = C_d.W\ H^{3/2}$$

where

Q = discharge
Cd = Discharge Coefficient
W = Length of weir crest normal to flow
H = Head of water on the weir crest

The value of Cd is taken as 3.3

(b) Triangular or V-Notch Thin Plate Weir

Generally the V-notch angle is 90. The formula for its discharge is :

$$Q = 2.47\ H^{2.5}$$

where

Q = Discharge
H = is head of water or lower end of V.

(c) Saleem's Null Point Discharge Meter.

A special technique has been developed in the Irrigation Research Institute to measure accurately the discharge in a running watercourse. This has a special application in the accurate measurement of conveyance losses in running watercourses. This technique is based on the principle that at the selected site the entire discharge is bye-passed through a pumping unit, fitted through a water meter. The water is again discharged in the same watercourse at a distance of about 25 feet downstream. The water lying in the watercourse between the two points, viz. the point where water is sucked and the point where it is re-discharged, is subjected to three states:

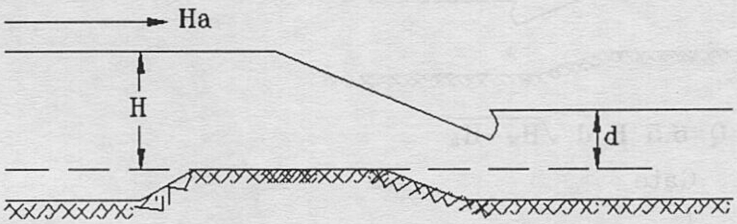
- The water in this section flows in the forward direction (with reduced velocity of course) if the pumped water is less than the total discharge in the watercourse.
- It flows in the backward direction if the pumped water is more than total incoming discharge.

- It is stationary if the pumped water is exactly the same as the incoming water in the watercourse.

To indicate the Null Point accurately, a special apparatus has been devised which has a very sensitive flapper. When the Null Point is attained, the meter reading in the water meter gives accurately the discharge flow in the watercourse. The pumping unit is mobile, handy and runs with a small diesel engine. A similar observation can be carried out at some suitable station downstream in the watercourse. This will give the conveyance losses between these two stations. The apparatus thus works without altering the conditions in the watercourse. The disadvantage of this device is that a prime mover and a pumping unit is required for it. Therefore it is more suited in the laboratory than in the field.

WEIR FORMULAE FOR VARIOUS GATE OPENINGS

Condition of flow	Formula
1 (a) Standing wave with or without raised crest.	$Q = CB(H+H_a)^{3/2}$ Where C = 3.30
(b) Same conditions as above but standing wave not fully formed.	As above but with different values of C as given below:-



Drowning ratio $\frac{d}{H}$ = 0.95–0.96 C=3.00

Ditto	0.93–0.94	C=3.05
Ditto	0.90–0.92	C=3.10
Ditto	0.80–0.90	C=3.15
Ditto	0.70–0.80	C=3.20

2. (a) Weir and under-sluices with gates partially down and raised crest with a standing wave.

$$Q=CB\left\{(H_1+H_a)^{\frac{3}{2}}-(H_2+H_a)^{\frac{3}{2}}\right\}$$

Where C=3.20

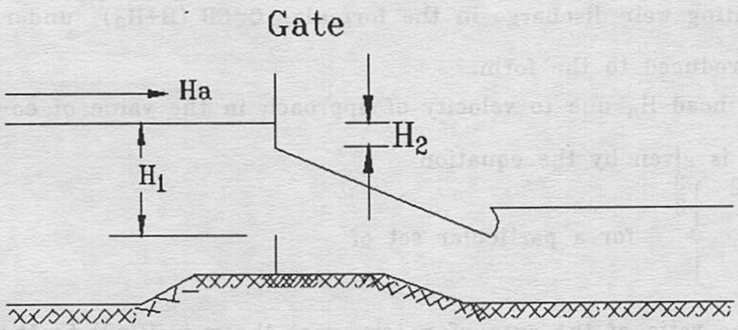
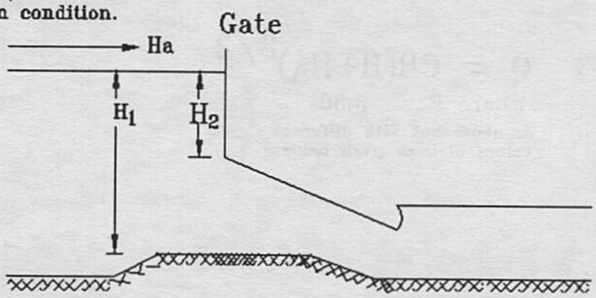


Exhibit.ii–1 Page.1

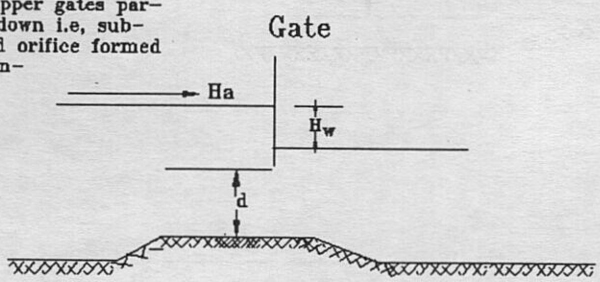
(Not to scale)

(b) The same condition 2(a) with no raised crest. — As for 2(a) but with $C = 3.1$

3. Weir and undersluices with opening between an upper & lower gate, & with a standing wave, i.e, free fall down stream condition. — As for 2(a) with $C = 3.3$



4. Weir and undersluices with upper gates partially down i.e, submerged orifice formed between— $Q=6.5\ B\ d\ \sqrt{H_w+H_a}$



1. Gate and raised crest.
2. Gate and flat floor.
3. Gate & a lower Gate, with no standing wave.

(i) For facility in calculating weir discharge in the formulae $Q=CB\ (H+H_a)^{3/2}$ under condition.

No. (1) prepage may be reduced to the form.
$Q=C_1 B\ H^{\frac{3}{2}}$ by accounting head H_a due to velocity of approach in the value of co-efficient C.

(ii) The value of C is given by the equation

$$C_1 = c\left\{1+\frac{C_1^2\ n^2}{64}\right\}^{\frac{3}{2}}$$ for a particular set of

Conditions, where n is the ratio of the area of waterway at the weir (HxB) to the area of waterway in the channel at the gauging site.

The choice of coeffieient is a matter requiring great care and it is best determined from actual discharge observations at times when observation is possible.

(Not to scale)

CHAPTER 3

SEEPAGE LOSSES

3.1 GENERAL

As a part of monitoring the operation of canals, the officer in-charge of the canal must know where all the water is going. The major quantity of water running in the canals and water courses is visible, but some invisible quantity of water seeps into ground and is stored as ground water. Estimation of this seepage loss is important for computing the head discharge of canal so that there is an equitable distribution of water and the outlets also get their due share. There are many methods of measuring seepage losses; thumb rules, empirical formulae and actual measurements in the field. These methods are discussed in the following sections.

3.2 THUMB RULES

Initially, the simplest method for determining seepage losses was to allow 10% of the total draw off of water through the outlets or channels in a given reach. This method, however, is very unsatisfactory. It may give approximately the required discharge at the head of channel, but if an attempt is made to meter the discharge at any section of a channel on this basis, generally a faulty distribution is indicated. An improvement on this method is to add or subtract one percent of discharge at any point for each thousand feet length of reach above or below it. However this method is also liable to give large errors.

Another method, which has been in use for many years for large channels, is to take as seepage losses 8 cusecs per million sq ft of wetted perimeter of channel. This can be converted to a daily volume rate by multiplying it by 86,400 sec/day so that the equivalent rate is 0.69 cubic ft/sq.ft/day. This rule is independent of discharge in the channel. The figure of 8 cusecs per million sq.ft. of wetted perimeter may be lower for canals in the NWFP which were designed on Kennedy's Equations. Actual discharge observations need to be carried out for bigger and smaller channels to actually work out the seepage losses in terms of wetted perimeter. The wetted perimeter for trapezoidal canals is given by the formula:

$$W_p = b + 2h\,(1+z)^{1/2} \text{ sq.ft./ft. length}$$

where

h = Height
Wp = wetted perimeter
b = bed width of canal
z = side slopes, z horizontal to one vertical

The wetted perimeter changes as the discharge changes. For smaller channels up to 20 cusecs a rate of 6 cusecs per million sq.ft. of wetted perimeter is taken.

3.3 EMPIRICAL FORMULAE

The Lacey formula presented below gives the wetted perimeter of the channel in terms of its discharge.

$Pw = 2.67x(Q)^{1/2}$ sq.ft. ------(i)

Some field conditions in the NWFP for alluvial channels are such that a trapezoidal shape is not maintained. Therefore Lacey's equation given above should be used.

If K represents the seepage loss per million sq.ft. of wetted perimeter and Q the discharge in any reach of a channel, then the following empirical formula gives the seepage losses :

$K = 5.0 \times Q^{0.0625}$ --------(ii)

Fig III-1 gives the value of K for various discharges. Combining equations (i) and (ii) the seepage loss Q_a is given by the following equation :

$Qa = 0.0123xLxQ^{0.0133}$

where L is the length of reach in thousands of feet and Qa is seepage loss in the regime of channel per thousand feet in length. Fig III-2 gives seepage losses on the basis of this formula.

3.4 FIELD MEASUREMENT

There are two methods of field Measurements.

- Inflow-Outflow method
- Ponding method

These are discussed below:

(A) Inflow - Outflow Method.

A reach of canal is selected. Water flow measurements are made accurately with a current meter at the upstream and downstream ends of this reach. The difference in discharge at the two ends is all attributed to seepage. These measurements can be done easily and do not interfere with the operation of the canal.

(B) Ponding Method

This method can be used during the closure period of a main canal, branch or a distributary. Towards the end of the closure of a main canal, branch or distributary, water is stored above a regulator. In the downstream portion of a channel whose seepage test is to be carried out, an earthen dike or bund is constructed in the channel. Polytene sheet is inserted on the slope of bund which faces the pond side. This is done to prevent any seepage through the

FIG.III-1

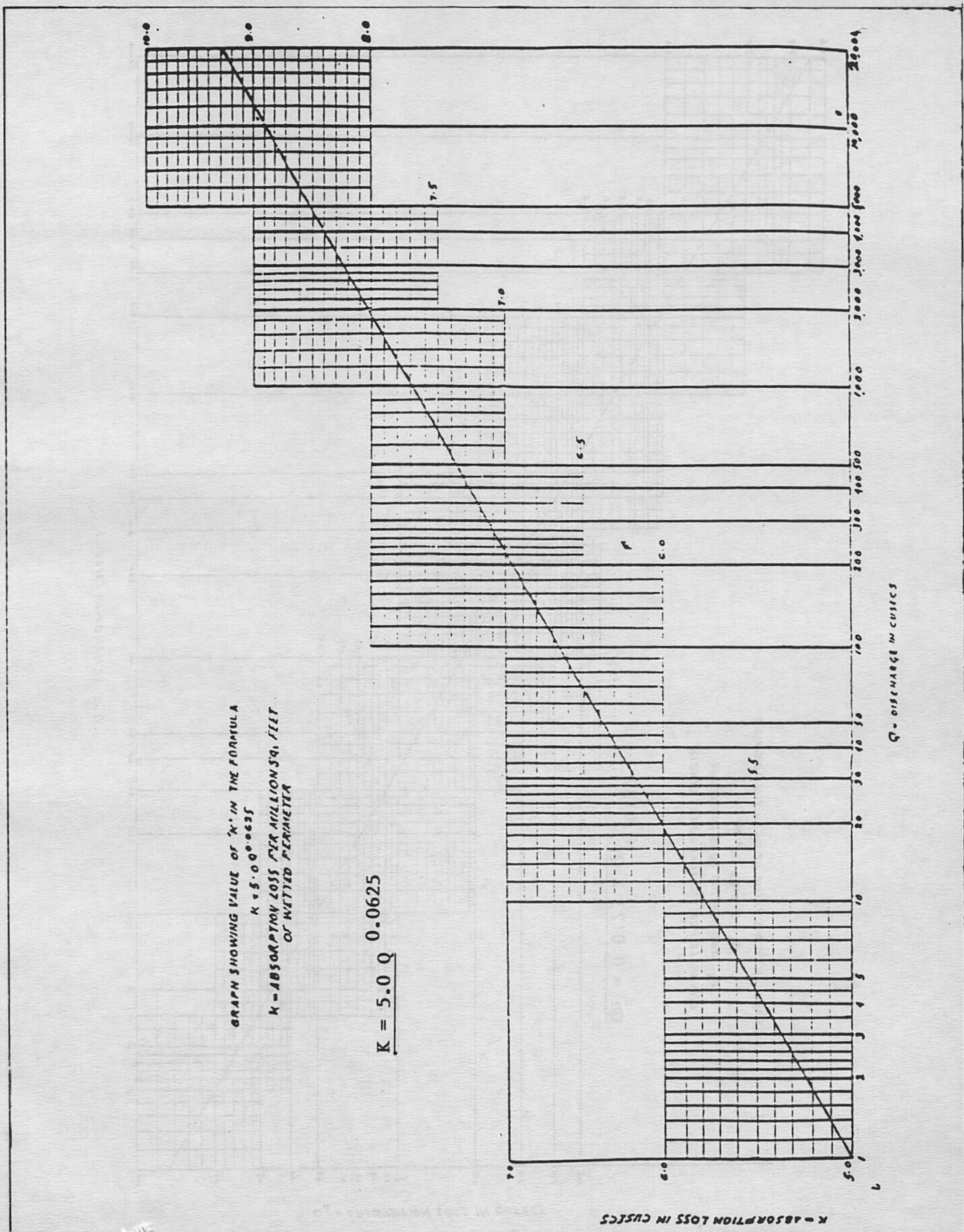
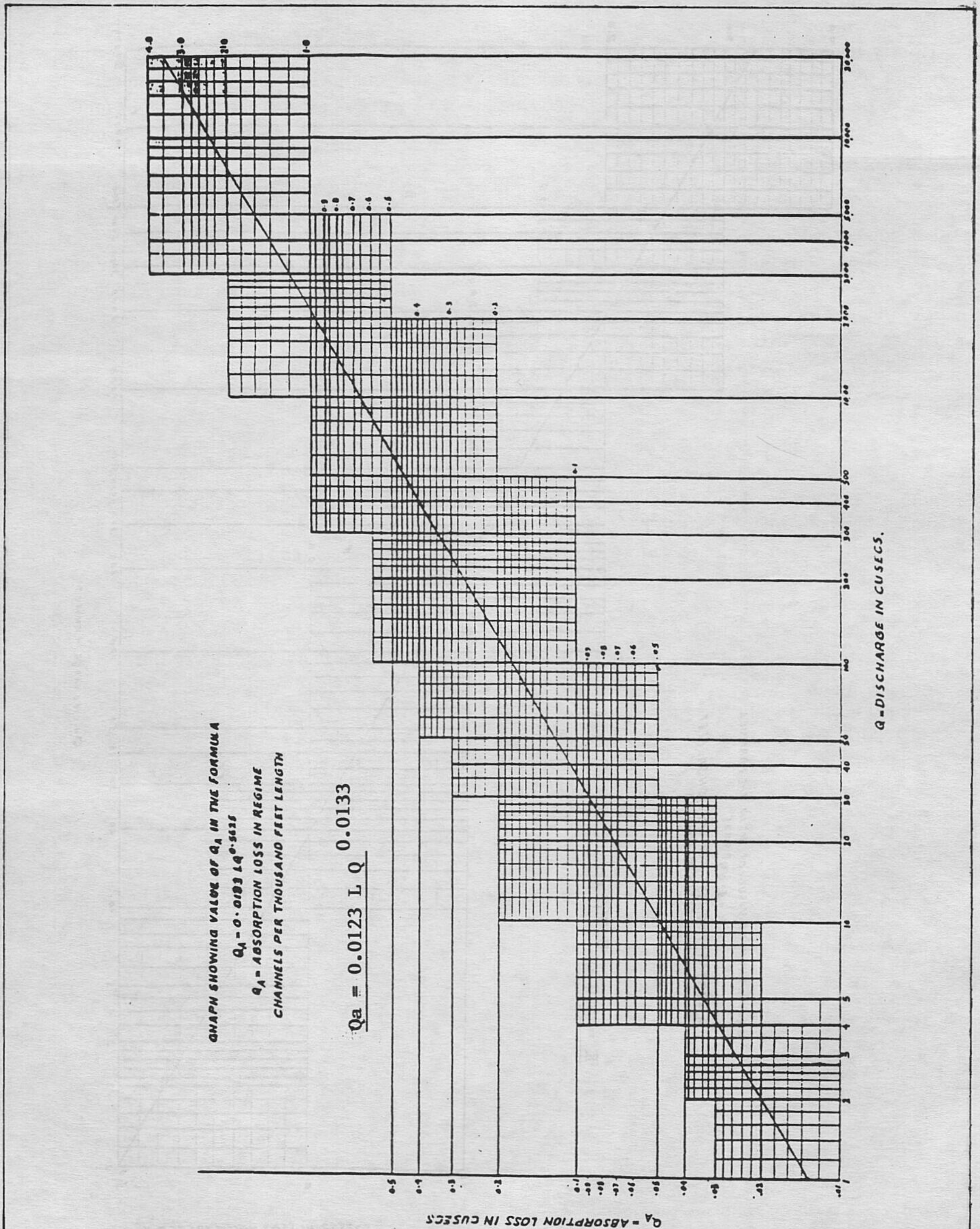

GRAPH SHOWING VALUE OF 'K' IN THE FORMULA
K = 5·0 Q^0·0625
K = ABSORPTION LOSS PER MILLION SQ. FEET OF WETTED PERIMETER
K = 5.0 Q 0.0625
Q - DISCHARGE IN CUSECS
K - ABSORPTION LOSS IN CUSECS
5.0
5.5
6.0
6.5
7.0
7.5
8.0
9.0
10.0
1
2
3
4
5
10
20
30
40
50
100
200
300
400
500
1000
2000
3000
4000
5000
10,000
20,000

FIG.III-2


GRAPH SHOWING VALUE OF Q_A IN THE FORMULA
$Q_A = 0 \cdot 0133\ LQ^{0 \cdot 5625}$
Q_A = ABSORPTION LOSS IN REGIME
CHANNELS PER THOUSAND FEET LENGTH
$Qa = 0.0123\ L\ Q^{0.0133}$
Q-DISCHARGE IN CUSECS.
Q_A = ABSORPTION LOSS IN CUSECS

bund. The water stored upstream in the channel is released to fill the pond downstream up to the maximum possible level. A gauge is installed in the pond area before starting the test. Hourly readings of the gauge are taken for one week or more if the closure period permits. Cross sections are taken at both the ends of the pond and one in the middle. Water levels are marked on the X-sections. The lengths between the cross sections are also measured. From this data, the volume of water is calculated and decrease in volume with passage of time is noted. This gives the seepage loss rates.

A modification of the ponding method involves addition of water to the pond to maintain a constant water surface elevation. The volume of added water is carefully measured and is considered to be equal to water loss. The rate of loss is given by the elapsed time. For this test, installation of a tube well may be necessary. Based on this principle, the Punjab Irrigation Research Institute has developed a technique for measuring seepage losses in a pond. The details are given below:

AUTOMATIC WATER LEVEL STABILIZER SYSTEM FOR SEEPAGE MEASUREMENT IN A PONDED SECTION.

Intensive research has been conducted in the Irrigation Research Institute, Lahore, for devising some reliable, direct and accurate seepage measurement technique and especially an automatic one. Water level stabilizer technique has been devised and perfected. The system works on the principle that the quantity of water loss as seepage and evaporation from a free water surface in a section is automatically added up by keeping a fixed pond water level.

The model works on the principle that when there is a gap between the ponded water level in the test section and the upper end of the float rod, an electric circuit is automatically switched on and the pumping system starts functioning, taking the water supply from the storage and delivering it into the test section. The pumping continues and the aluminum rod of the float goes on rising until it touches the level on a pointer gauge whereby the stipulated level is attained in the section and the electric circuit gets disconnected. The readings in the water meter are recorded over a certain period. The addition of water in the test section as given by the water meter is calculated as water loss. From this the loss per million sq.ft. of wetted perimeter can be worked out but the evaporation losses have to be accounted for.

3.5 EXAMPLE OF DETERMINING SEEPAGE LOSSES

In the NWFP seepage losses were actually observed on Warsak Gravity Canal at the following points from RD 73,800 to 103,000 by the Experts from Utah State University (USA) during a training course for the Irrigation Engineers of the NWFP.

a. RD 73,800
b. RD 77,000
c. RD 83,350
d. RD 85,700
e. RD 96,200
f. RD 203,000

This exercise was carried out from February 21 to March 5, 1987 as a part of training course by Utah State University. There are many outlets in this reach of 29200 feet. Their flow has been deducted. Actual discharge observations were made at these six points and the difference in discharges was attributed to seepage losses. For instance the discharge observed at RD 73,800 was 205.68 cusecs and at RD 77,000 it was 204.55. The difference of 1.13 cusecs (205.68-204.55) indicates seepage loss. For working seepage losses in other reaches the water taken by outlets has been deducted. The results of observations and computations are shown in Table III-1. Column 6 of this table shows seepage losses. For working out the seepage loss in cusecs for million sq.ft. of wetted perimeter, the Wp has been worked out in two ways as presented below:

(i) by physical observation of cross section
(ii) by Lacey's formula Pw= $2.67x(Q)^{1/2}$ sq.ft.

Column 7 of the table lists the wetted perimeter based on the physical conditions and the corresponding seepage loss is shown in column 9. Column 10 shows wetted perimeter worked out by the Lacey's formula and column 12 shows corresponding seepage losses. A comparison of seepage losses worked out from the two methods is given below:

Seepage losses in cusecs per million sq.ft. of wetted perimeter

	On basis of physical observation of X-sections	On basis of Lacey's Formula
(a)	12.1	9.2
(b)	17.7	12.1
(c)	28.2	19.6
(d)	0.9	0.9
(e)	59.6	52.0

This comparison shows that Lacey's Formula gives smaller seepage losses. It is noteworthy that the actual seepage losses vary from 0.9 to 59.6. The total seepage loss in the selected reach is 17.87 cusecs/million sq.ft. whereas the thumb rule is 8.0 cusecs/million sq.ft, which is about 50% of actual. This indicates that the actual loss is twice as much as the thumb rule implies and therefore the thumb rule should be used with caution.

The great variation in the seepage losses in various reaches is attributable to the different conditions of soil and the channel. For instance, where the seepage loss is only 0.9 cusec per million sq.ft. of wetted perimeter, the channel has concrete lining. In the tail reach where this channel is unlined and soil is very porous the seepage loss is very high. From these observations it is obvious that the nature of the soil, which makes up the banks of the channel, has great effect on the seepage losses.

EXAMPLE SEEPAGE LOSS DETERMINATION Table III-1

Station RD	Description	Canal Discharge Q-cfs	Change Q cfs	Total outlet Flow (cfs)	seepage Loss (cfs)	Calculated Wetted Area 2/ (sq.ft)	Seepage Loss Rate 2/ cu.ft/sq.ft/day	cfs x 10-6	P = 2.67 (Q)0.5 sq.ft/ft	Length ft	Seepage Loss Rate 3/ cfs x 10-6
1	2	3	4	5	6	7	8	9	10	11	12
73800	U/S Conduit	205.68	1.13	0	1.13	93415	1.05	12.1	6	3200	9.2
77000	D/S Exit of Conduit	204.55	11.55	8.61	2.94	165771	1.53	17.7	38.19	6350	12.1
83350	Bench Flume	193	11.66	9.95	1.71	60601	2.44	28.2	37.09	2350	19.6
85700	Bara River Inverted Syphon	181.34	26.91	26.57	0.34	354087	0.08	0.9	35.95	10500	0.9
96200	Khoat Road Inverted Syphon	154.93	17.43	5.68	11.75	196954	5.15	59.6	33.23	6800	52
103000	Aqueduct	137									
			68.68	50.81	17.87					29200	

Note:-

1. Calibration performed on Warsak Gravity Canal, NWFP 21 Feb. -05 March 1987. Utah State University Training Course.
2. based on physical dimensions.
3. Based on Lacey's value of wetted perimeter P.

CHAPTER 4

RAINFALL MEASUREMENT

4.1 PURPOSE

Study of rainfall conditions are most important for an irrigation engineer. This study should not only relate to the area where crops are to be irrigated but also to the catchment area from which rainfall feeds the streams and rivers which traverse areas proposed to be irrigated. In the former case, the study will help in deciding the amount and period of supply of irrigation water required for crops and in the latter case, the rainfall data will help to forecast seasons of good river supplies. Rainfall figures and intensities (rainfall in one hour) are very important for estimation of river floods and spread of drainage water. Timely knowledge of rainfall in the catchment area is required by the engineer-in-charge of headworks for their safety. Rainfall data is also useful for estimation of cropped area and anticipated financial return.

4.2 LOCATION OF RAINFALL GAUGES.

The erection of rain gauges must be carried out with care and precision and the selection of the sites be decided on the following recognized principles :

(i) It is accepted that a rain gauge located in an open unprotected space registers less than the actual rainfall because wind eddies (near the gauge) cause rain drops to miss the gauge opening. Thus a certain amount of protection from the wind is desirable. Accordingly gauge sites should be selected so that the nearest standing object is more distant than twice the height of the object. Trees should not exist within 30 yards of the gauge.

(ii) A rain gauge should not be constructed on the sides or top of a hill nor should it be located on a building except in very special circumstances.

(iii) Before work is carried out, the site selected should be approved by the XEN of the division.

4.3 MEASUREMENT OF RAINFALL.

The amount of rainfall is expressed as the depth in inches (or millimeters) which falls on a level surface. There are two types of rain gauges for measuring rain fall :

(i) Non-automatic rain gauges
(ii) Automatic rain gauges

Their description is given below :

A. Non-Automatic rain gauge

Symon's rain-gauge is most commonly used by the PID, WAPDA and the Meteorological Department in the NWFP. It has three parts which are described below :

- the base, which is built into a masonry or concrete foundation;
- the body, in which is housed the glass bottle for collecting the rainwater;
- the funnel, which collects the rainfall. A measuring glass cylinder (together with a spare one) is kept with the gauge reader.

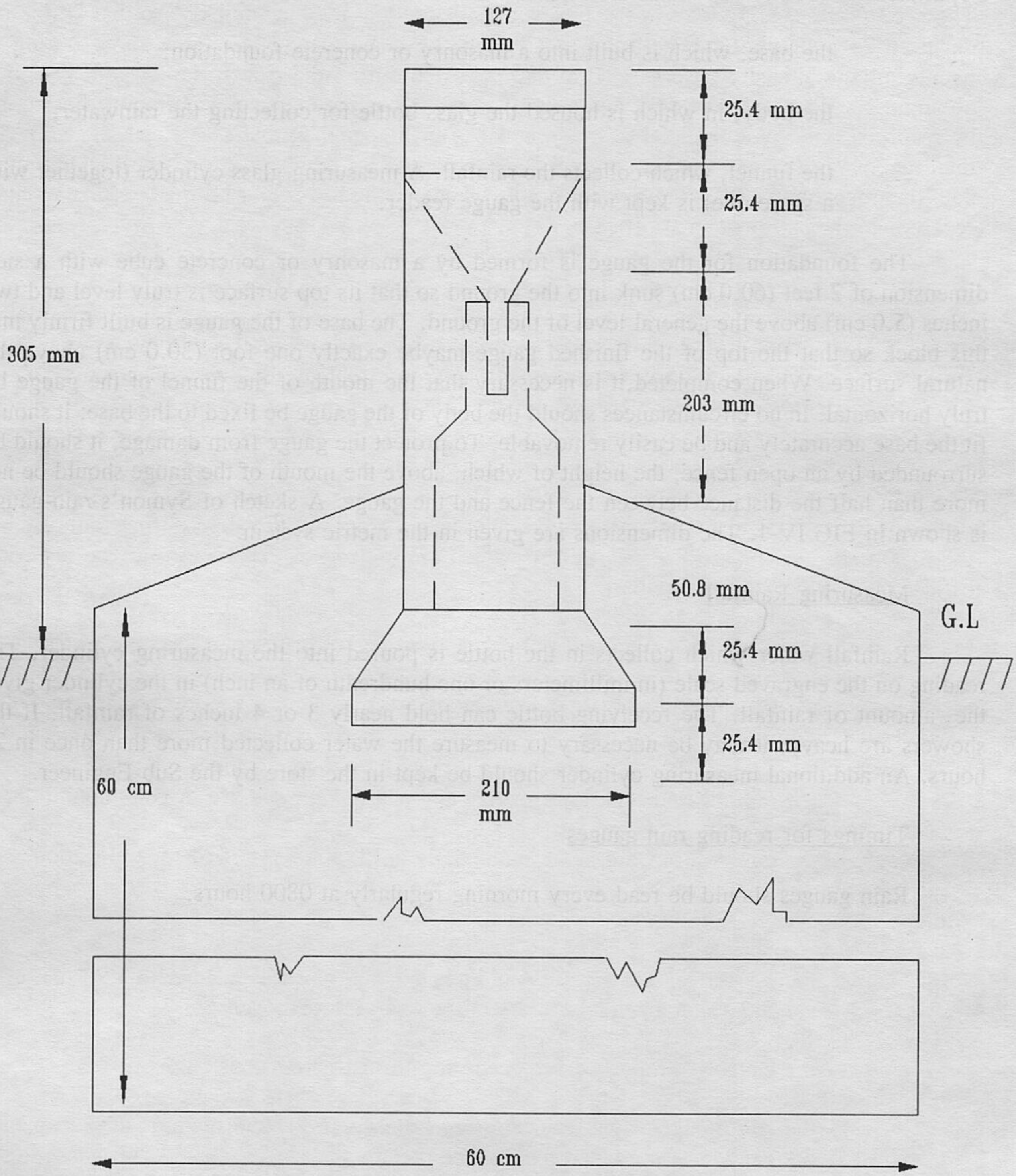
The foundation for the gauge is formed by a masonry or concrete cube with a side dimension of 2 feet (60.0 cm) sunk into the ground so that its top surface is truly level and two inches (5.0 cm) above the general level of the ground. The base of the gauge is built firmly into this block so that the top of the finished gauge maybe exactly one foot (30.0 cm) above the natural surface. When completed,it is necessary that the mouth of the funnel of the gauge be truly horizontal. In no circumstances should the body of the gauge be fixed to the base; it should fit the base accurately and be easily removable. To protect the gauge from damage, it should be surrounded by an open fence, the height of which, above the mouth of the gauge should be not more than half the distance between the fence and the gauge. A sketch of Symon's rain-gauge is shown in FIG IV-1. The dimensions are given in the metric system.

Measuring Rainfall

Rainfall water which collects in the bottle is poured into the measuring cylinder. The reading on the engraved scale (in millimeters or one hundredth of an inch) in the cylinder gives the amount of rainfall. The receiving bottle can hold nearly 3 or 4 inches of rainfall. If the showers are heavy, it may be necessary to measure the water collected more than once in 24 hours. An additional measuring cylinder should be kept in the store by the Sub-Engineer.

Timings for reading rain gauges

Rain gauges should be read every morning regularly at 0800 hours.



Symon's Rain-gauge

FIG.IV-1

(Not to scale)

Intensity of Rainfall

For convenience of rain fall intensity measurement, two receiving bottles are provided. The intensity of rainfall is obtained by measuring the water collected during a 20 minutes period. The necessary changing over of the receiver bottles should be done quickly, so that all the rain during a 24 hour period is collected. Care must be taken to add water measured during the twenty minute intensity observations to that collected during the rest of the 24-hour period, in obtaining the rainfall of the day. Intensity of rainfall observations over a 20-minute period may be recorded only by an official of grade equal to or higher than that of a canal signaller. The intensity of rainfall per hour is computed and recorded by the Overseer or the SDO from the data recorded for the 20-minute observations whenever he inspects a rain gauge or the data is received in the sub-divisional office.

Rainfall Register

The observed rainfall data should be entered in a register similar to that shown in Table IV-1 Copies of the monthly rainfall statement should be sent by the Sub-engineer to SDO and XEN in the first week of the following month.

Inspection of Rain gauge Sites

It is essential that rain gauge sites be inspected from time to time during tours by both the SDO and the XEN so that any defects which are noticed can be removed. The inspecting officers should determine whether-

- the instrument is suitably placed and all parts are in good working order;
- the observer is able to make rainfall measurements correctly and to enter them properly in his register;
- the rainfall registers are properly and neatly kept and are in good condition;
- the observations are being made daily at the time specified for the station.

Along with above, it is to be noted whether:

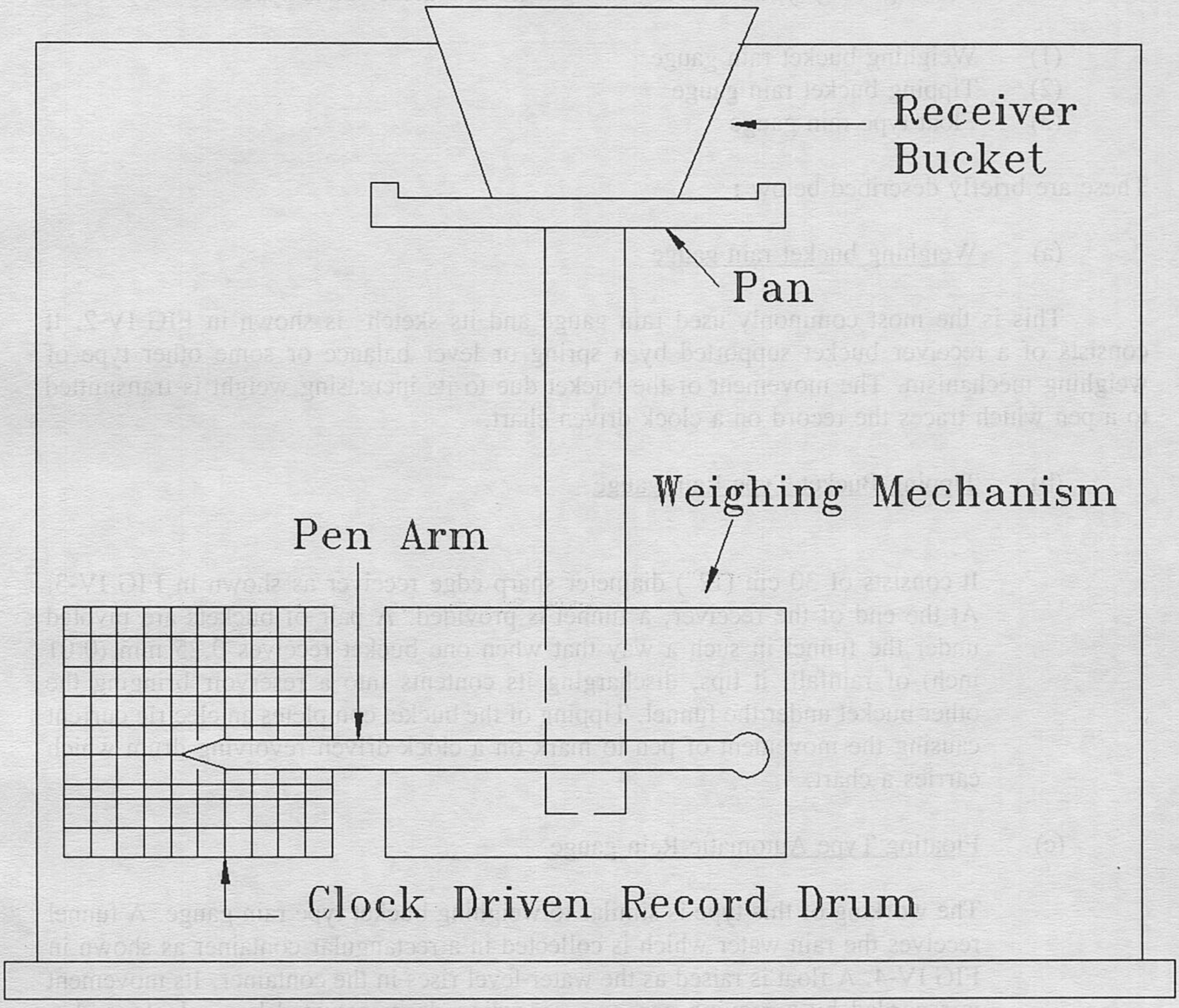
- there are trees growing or buildings existing or anticipated within 90 feet of the gauge, which are likely to affect the degree of exposure;
- the gauge is properly fixed according to instructions;
- the rim of the funnel when pressed home is level, and obvious displacement of the gauge has not taken place since erection;

Table IV-1

RAINFALL RECORDED AT RAINGAUGE STATION.

_______Sub Division, _______Division,
Canal

YEAR						
Month	January			March		
Date	Rainfall	Amount of rain collected in 20 minutes during heavy shower.	Remarks	Rainfall	Amount of rain collected in 20 minutes during heavy shower.	Remarks
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
Total					Observer	



Weighing Bucket Type Rain–gauge

FIG.IV–2

(Not to scale)

- the rim of the funnel is circular and free from distortion or damage;

- the joints of the funnel are intact and without leaks.

B. **Automatic or Self Recording Rain gauges**

These are integrating type recording rain gauges and are of three types:

(1) Weighing bucket rain gauge
(2) Tipping bucket rain gauge
(3) Float type rain gauge

These are briefly described below :

(a) Weighing bucket rain gauge

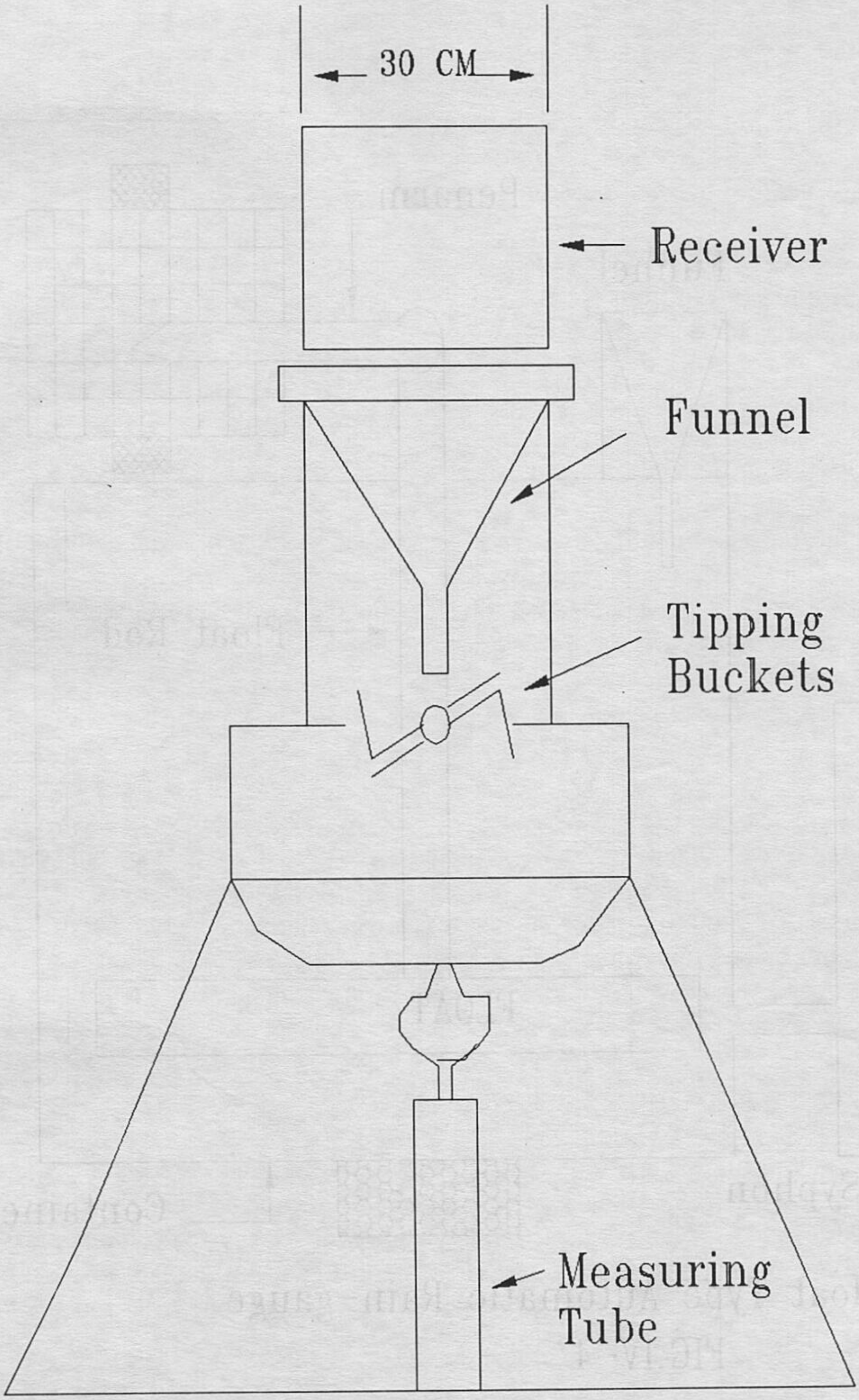
This is the most commonly used rain gauge and its sketch is shown in FIG IV-2. It consists of a receiver bucket supported by a spring or lever balance or some other type of weighing mechanism. The movement of the bucket due to its increasing weight is transmitted to a pen which traces the record on a clock-driven chart.

(b) Tipping Bucket Type Rain gauge

It consists of 30 cm (12") diameter sharp edge receiver as shown in FIG IV-3. At the end of the receiver, a funnel is provided. A pair of buckets are pivoted under the funnel in such a way that when one bucket receives 0.25 mm (0.01 inch) of rainfall, it tips, discharging its contents into a reservoir bringing the other bucket under the funnel. Tipping of the bucket completes an electric current causing the movement of pen to mark on a clock driven revolving drum which carries a chart.

(c) Floating Type Automatic Rain gauge

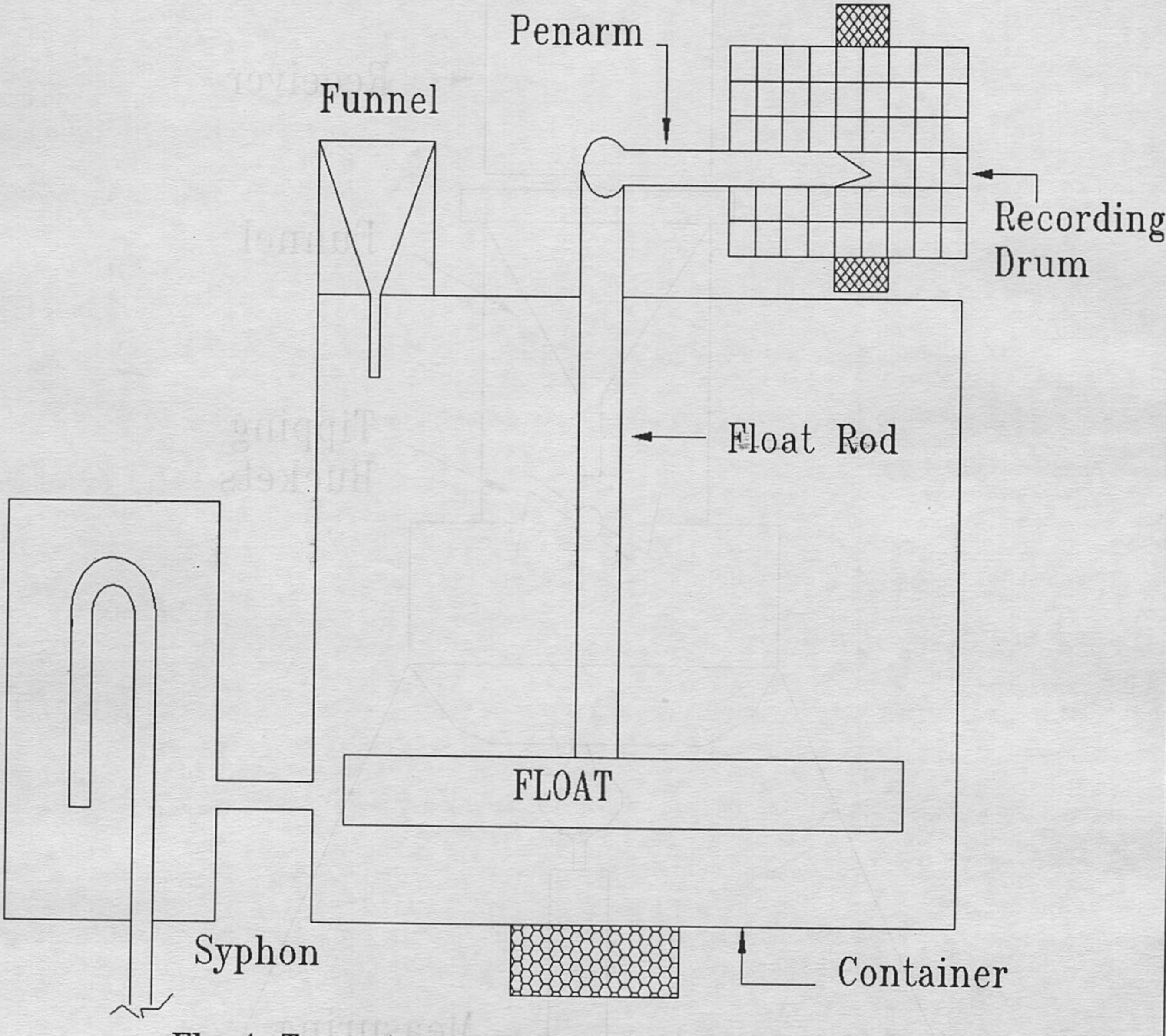
The working of this type is similar to weighing bucket type rain gauge. A funnel receives the rain water which is collected in a rectangular container as shown in FIG IV-4. A float is raised as the water level rises in the container. Its movement is recorded by a moving pen or a recording drum actuated by a clock works. When the water level in the container rises so that the float touches the top, the syphon comes into action and releases water. Thus all the water in the box is drained out.



Tipping Bucket Type Rain-guage

FIG.IV-3

(Not to scale)



Float Type Automatic Rain-gauge
FIG.IV-4

(Not to scale)

(d) Advantages and Disadvantages of Recording Rain gauges

Following are the advantages of recording type rain gauges over the non-recording types:

i. The rainfall is recorded automatically and, therefore, there is no necessity of any attendant.

ii. The recording rain gauges also give the intensity of rainfall at any time while the non-recording rain gauge gives the total rainfall in any particular interval of time.

iii. As no attendant is required, such rain gauges can also be installed in far off places.

iv. Possibility of human error is removed.

Disadvantages

i. It is costly in comparison with non-recording gauges.

ii. A fault may develop in the electrical or mechanical mechanism when recording rainfall.

iii. Spare parts are not locally available for maintenance.

4.4 SOURCES OF ERRORS IN RECORDING THE MEASUREMENTS.

A. Mistakes in reading the scale of the gauge.

B. Some amount of water will be displaced by the measuring stick of water and may creep up the stick; this may increase the error by 1%.

C. Dents in the collector rim may change its receiving area.

D. Funnel and inside surface require about 2.5 mm of rain to get moistened when the gauge is initially dry. This may amount to the extent of 25 mm per year in some areas.

E. There is some loss resulting from rainfall splash from the collector.

F. The most serious error is the deficiency of measurements due to wind. Vertical acceleration of air forced upwards over a gauge gives an upward acceleration to precipitation about to enter the gauge and results in a deficient catch.

G. Inclination of gauge may cause lesser collection. A 10% inclination gives about a 1.5% low catch.

4.5 MICROWAVE RADAR FOR MEASUREMENT OF RAINFALL.

A microwave radar (1 to 20 cm wavelength) can be used to obtain, roughly, information on rainfall distribution within its scanning area. The image on the radar screen can be interpreted as an approximate indication of rainfall intensity, since the amount of reflected energy is dependent on the raindrop size and the distance from the transmitter and the drop size is roughly correlated with rain intensity. A calibration may also be made from actual rain gauge measurements in the area scanned by the radar. Scanning area may be about 50 miles.

4.6 LOCATION OF NON-RECORDING AND RECORDING TYPE RAINGAUGES IN THE NWFP WHICH ARE MAINTAINED BY PID.

The list regarding location of non-recording and recording type rain gauges in NWFP, which are maintained by Irrigation Department, is shown in Table IV-2.

TABLE IV-2

RAIN GAUGES MAINTAINED BY IRRIGATION DEPARTMENT NWFP

Location of Rain gauge	Civil District in which rain gauge is located	Year of installation	S.No.	Name of Circle
NON-RECORDING TYPE.				
Rain Gauge at Mardan			1	N.I.C
Rain Gauge at Swabi			2	N.I.C
Rain Gauge at Irrigation Rest House Kababyan			3	C.I.C
Rain Gauge at Dag Besud Pabbi			4	C.I.C
Rain Guage at Gandiali Dam Site			5	C.I.C
Rain Guage at Tanda Dam Colony			6	C.I.C
Rain Guage at Aman Darra Irrigation Rest House			7	N.I.C
Rain Gauge at Totakan			8	N.I.C
Rain Gauge at Charbagh			9	N.I.C
Rain Gauge at Karora			10	M.I.C
Rain Gauge at Mingora			11	M.I.C
Rain Gauge at Munda Head Works			12	N.I.C

Rain Gauge at Bara Gali	13	M.I.C
Rain Gauge at Thadiani	14	M.I.C
Rain Gauge at Batagram Area	15	M.I.C
Rain Gauge at Dera Ismail Khan Site	16	S.I.C
Rain Gauge at Baran Dam Rest House	17	S.I.C
Rain Gauge at Karak Changhoz	18	S.I.C
Rain Gauge at Irrigation Colony Tajori	19	S.I.C
Rain Gauge at Karak Thehsil	20	S.I.C
Rain Gauge at Inspection House Kotla D.I.Khan	21	S.I.C

RECORDING TYPE.

Rain Gauge at Nuseri	1	M.I.C
Raing Gauge at Thandiani	2	M.I.C

PART 3

CANAL EMBANKMENT

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PART-3

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FIGURES

CHAPTER 1

CANAL EMBANKMENTS AND PRISM

1.1 GENERAL

The canal embankments are the most important feature of the systems as they confine the water and carry it to the far end of cultivated land from the supply source. These embankments are constructed from locally available soil and the water level in the canals at most places is well above the surrounding land for commanding the areas served by the canal. The failure of an embankment can cause considerable economic damage to the surrounding areas. The standing crops are damaged, the adjacent farm land is covered with a layer of sandy bed material and a good deal of time and money is spent for repairing of banks. A failure also interrupts the water supply to the downstream users. They can suffer considerable financial damage if the water supply is not quickly restored.

1.2 DESIGN STANDARDS FOR CANAL EMBANKMENT.

The main parameters for canal embankment are:

- Bank width
- Free Board
- Side slopes
- Berms
- Dowels.

The design standards of these items adopted in the NWFP are given below.

A. Bank Width

The bank width should be correlated to the discharge carried by a channel. Sometimes it is based on the nomenclature of a channel. This is not a proper criteria. A distributary having a higher discharge than a branch canal may have a smaller bank width because it is classified as a distributary. On the basis of discharge of channels, the following widths should be used in the NWFP:

Discharge in cusecs	Bank width required	
	For Patrol Banks	For Non-Patrol Banks
Upto 49	15.0'	4.0'
From 50 - 199	15.0	5.0
From 200- 350	15.0	6.0
From 350- 499	20.0	8.0
From 500-1000	20.0	12.0
From 1000-3000	20.0	12.0
Above 3000	20.0	12.0

For certain distributaries an inspection road has been provided at natural surface levels. In such cases 100 ft long inspection ramps should be provided at every half a mile. These days when inspection is done on vehicles, it is desirable to have patrol roads all along the distributaries and minors for proper inspection of channels.

According to past practices, five feet of additional width is provided for channels above 500 cusecs (for O&M equipment access). The existing trees should be removed under a phased program because they offer obstruction to the use of machinery for bank repair. If possible the trees should be planted at the Natural Surface level at a distance of about 15 feet (according to availability of land) from the toe of the bank.

B. **Free Board**

The present practice in the NWFP, on the basis of discharge of channels, is as below:

Discharge in cusecs	Free Board (Ft)
For discharge upto 200	1.5
For discharge upto 200-350	2.0
For discharges on 350-1000	2.5
For discharges above 1000	3.0

C. **Side Slopes**

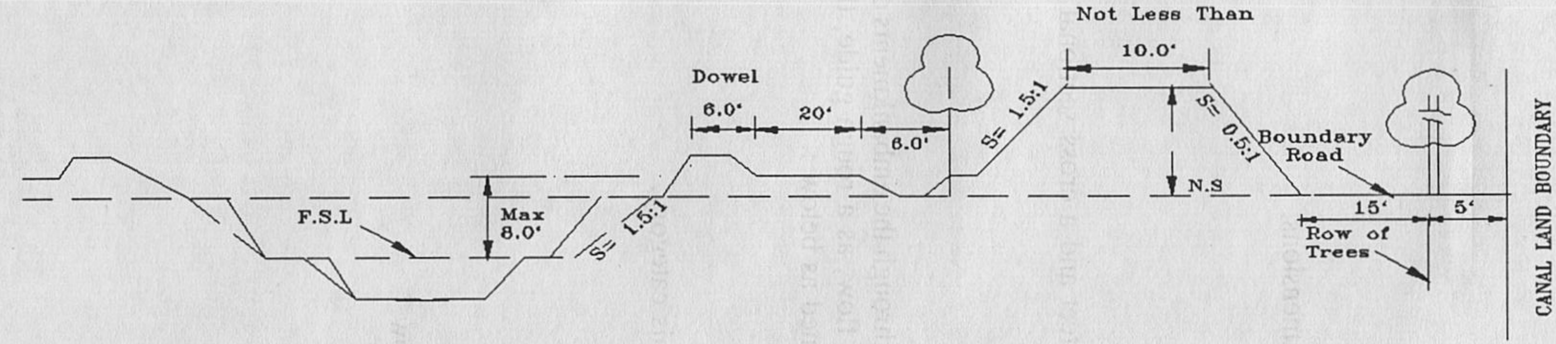
Discharge	Slope of Bank
For all discharges	1.5:1
For Pushtas	2:1

where the channel is in high filling and the hydraulic gradient is not covered due to bad soil, a 6.0 ft wide pushta should be provided to cover the hydraulic gradient as shown in Fig.I-1 Position 3.

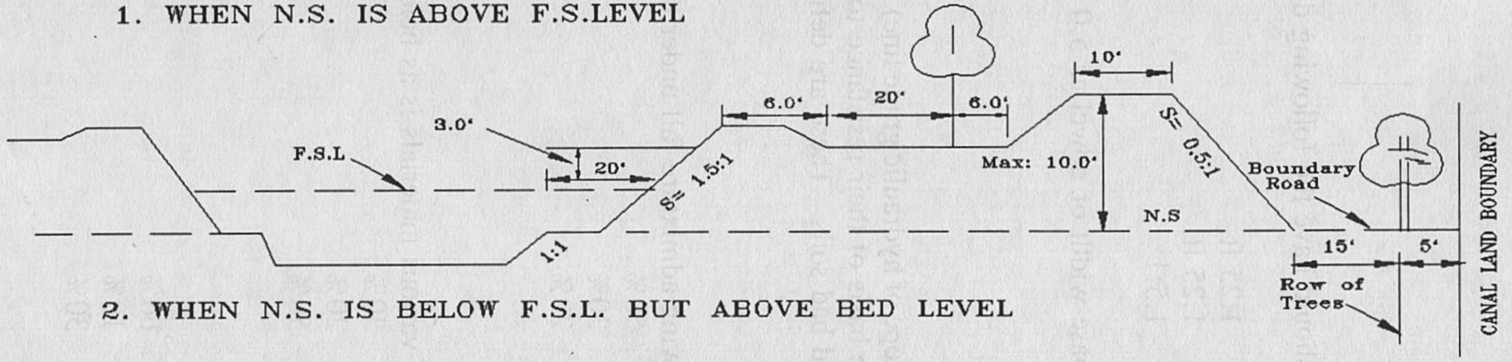
D. **Berms**

Good strong berms ensure the safety of a channel. On new canals there are no berms. They grow gradually some times naturally and sometimes as a result of killa bushing and spurs. In NWFP a number of channels are without berms and are working satisfactorily. Where berms are required, however, the following criteria should be followed :

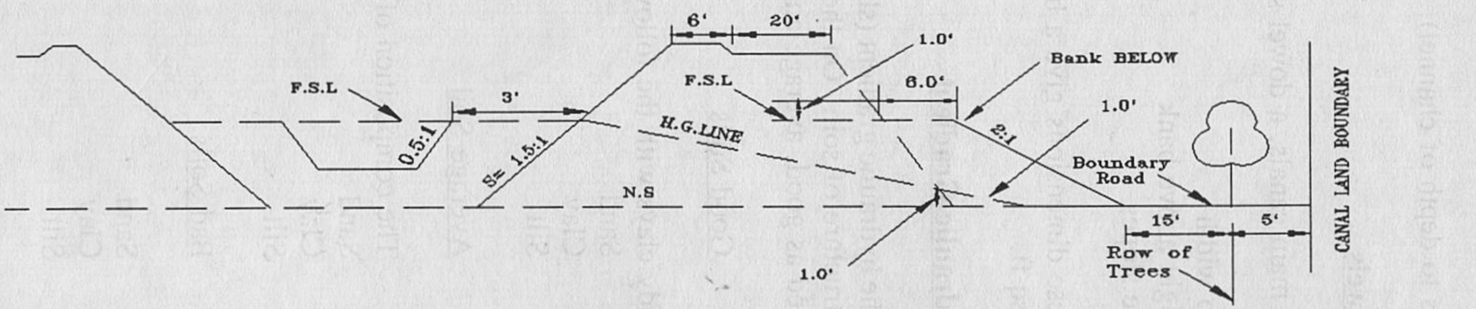
TYPE CROSS SECTIONS OF MAIN CANAL AND BRANCHES



1. WHEN N.S. IS ABOVE F.S.LEVEL



2. WHEN N.S. IS BELOW F.S.L. BUT ABOVE BED LEVEL



3. WHEN N.S. IS BELOW BED LEVEL AND THE REACH IS NOT SHORTER THAN 1000

FIG.I–1

(Not to scale)

Condition of Channel		Berm required
(1)	Channels in complete cutting	1.5 D*
(2)	Channel in partial cutting and filling	2.0 D
(3)	Channel in complete filling	3.0 D

(* D refers to depth of channel).

E. Dowels

On main canals, a dowel should have the following dimensions:

Top width	1.25 ft.
Height above bank	1.25 ft.
Side slopes	1.5:1

These dimensions give a base width of dowel as 5.0 feet and a cross sectional area of about 4.0 sq ft.

F. Hydraulic Gradient

The hydraulic gradient (slope of hydraulic grade line) through the embankments depends upon the structure of soil. On the basis of their resistance to flow, as a rough guide, the soils are classified as good, average and bad soils. These are defined as below :

(1) Good Soils

Sandy clays with the following admixture fall under this category.

Sand	50%
Clay	30%
Silt	20%

(2) Average Soil

The composition of various materials is as below :

Sand	30%
Clay	20%
Silt	50%

(3) Bad Soils

Sand	60%
Clay	10%
Silt	30%

Thumb Rule for Classification

A thumb rule for these classifications is that a handful of moist earth (at optimum moisture content) should be taken and pressed in hand. The hand then should be opened if an earth ball made by pressing does not show any signs of cracking, it is good earth. If minor cracks appear on the surface of the ball, the soil is average soil. However, if a large number of wider cracks appear on the surface of the ball, it indicates bad soil. The definitions of sand, clay and silt have already been given in the glossary of terms in volume 1 of the O & M Manual. The hydraulic gradient for the three types of soils given above is presented below :

1. Good soils	1:4 (V:H)
2. Average soils	1:5
3. Bad soils	1:6

Cover of embankment over the hydraulic grade line should be at least 1.0 ft.

G. **Typical Sections**

1) For main canals and branches

Three types of sections are given for the following conditions in FIG 1-1.

(a) Natural surface (N.S.) above full supply level (channel in cutting).

(b) N.S. level below F.S. level but above bed level i.e. in partial filling and cutting.

(c) N.S. level below bed level. (channel in filling).

If a full cross-section required to indicate the complete right of way is required then a fresh cross-section should be drawn.For category (iii) if the hydraulic gradient is not covered, a Pushta with the following specifications should be added :

(a) Top level of the pushta 1.0 below F.S.L.
(b) Top width of Pushta 6.0'
(c) Outer slopes of Pushta 2:1.

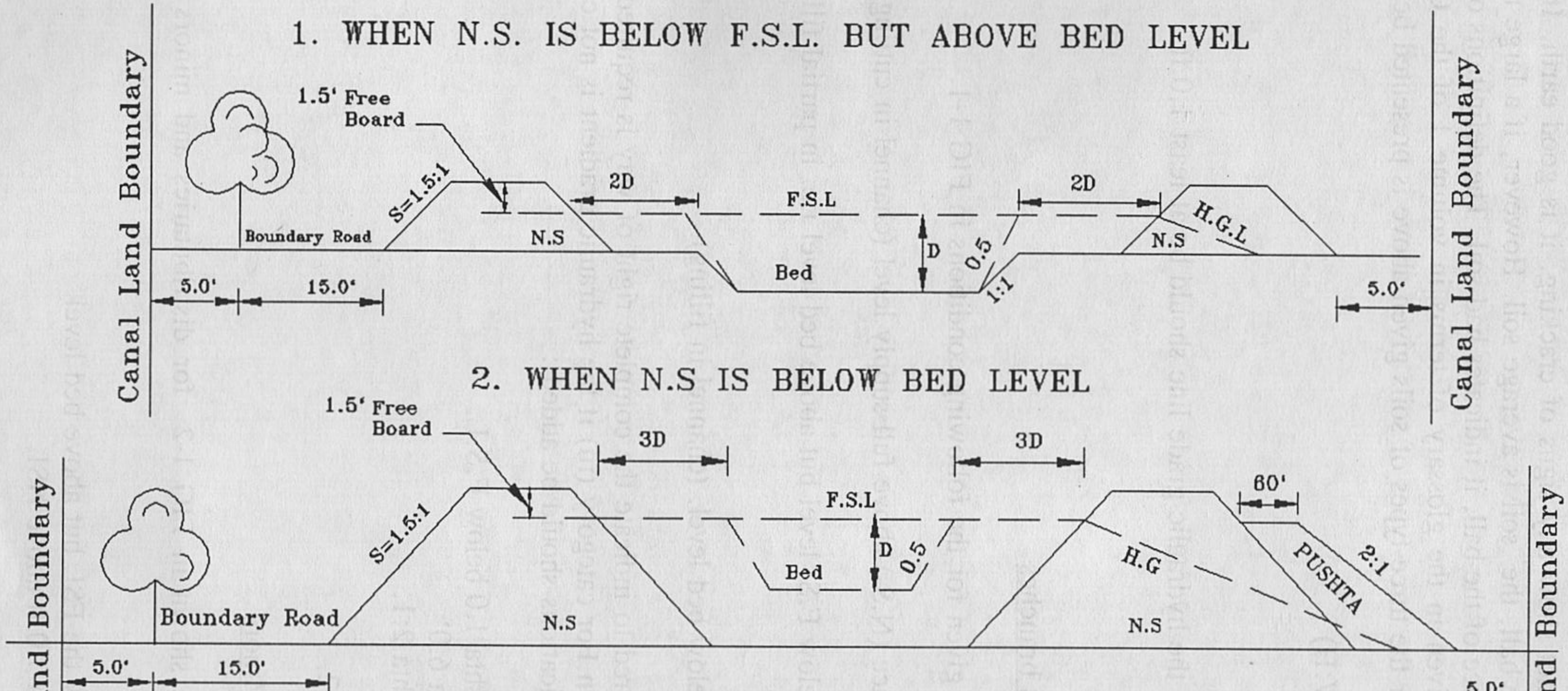
Details are shown in Fig.I-2.

2) Distributaries and Minors

Two types of sections are shown in FIG 1-2 for distributaries and minors for the following conditions :

a. When NSL is below the FSL but above bed level
b. When FSL is 4.0 to 5.0 ft above NSL

TYPE CROSS SECTIONS OF DISTRIBUTARIES



NOTES:– WIDTH OF BANKS

1. FOR CHANNELS WITH DISCHARGE UP TO 49 CUSECS 4.0 FT
   I. DO FROM 50 TO 199 CUSECS 5.0 FT
   II. DO FROM 200 TO 350 CUSECS 6.0 FT

2. HYDRULIC GRADIENT
   I. 1 IN 4 WHEN F.S.L. IS UP TO 4.0' ABOVE N.S.
   II. 1 IN 5 DO 4.0' TO 5.0' DO
   III. 1 IN 5 DO 5.0' OR MORE DO

3. PUSHTA
   I. TOP WIDTH 3.0'
   II. SHOULD COVER 1.0' H.G.LINE
   III. TOP LEVEL 1.0' BELOW F.S.L

FIG.I–2

(Not to scale)

Since most of the distributaries are in filling, the following specifications have been laid for the hydraulic gradient:

1 in 4 when FSL is 4.0 ft above NS
1 in 5 when FSL is 4.0 to 5.0 ft. above NS
1 in 6 when FSL is 5.0 ft or more above NS

In cases where hydraulic gradient is not covered by the prescribed widths of the banks, a Pushta with following specifications should be provided :

Top width - 3.0 ft.
One foot cover over H.G. Line
Top level should be 1.0 ft below FSL.
Details are shown in Fig.I-2 position 2.

CHAPTER 2

MAINTENANCE STANDARDS FOR EMBANKMENT

After rehabilitation of a canal to its design standard, it is necessary to keep the canal embankments and its appurtenant facilities in "as built" state of repairs.The canal system components requiring annual maintenance are channel embankments, bed, and structures. The work items required are repair of inside and outside slopes and top of embankments, maintenance of channel bed levels (requiring removal of deposited silt), berm trimming on inside slopes, maintenance of structures (requiring painting of metal surfaces and repairs of downstream stilling basins). The maintenance standards are detailed below :

Facilities		Maintenance Standards
Top of Embankment	a.	Replace 5 inches of material along 20% of total length of channels each year.
	b.	Grade kacha inspection road 6 times a year with a motor grader if available.
	c.	Repair 10% of gravel roads along canals every year.
	d.	Repair 5% of metalled road along canals every year.
Outside Embankment	a.	Replace 5 inches of material along 20% total length of channels every year.
Slopes.	a.	Annually repair about 400 rain cuts and cattle ghats per mile on main canals and branches and 200 rain cuts and cattle ghats per mile along distributaries and minors.
	b.	Remove all trees, brush wood and weeds from outer slopes to facilitate inspection of any seepage or rodent holes.
	c.	Provide turfing on 5% of total length of slopes of all channels every year.

Inside embankment Slopes and berms.	a.	Maintain existing turf on inside slopes and berms.
	b.	Cut weeds brushwood and trees from inside slopes and berms for visual inspection of canal prism.
	c.	Provide 50 ft. of killa bushing per mile per year to correct and prevent erosion where necessary along channel above 200 cusecs discharge.
	d.	Carry out berm trimming along 5% length of unlined channels below 200 cusecs discharge.
	e.	Carry out lining repair along 5% of lined distributaries and minors.
Bed level Control.	a.	Remove an average of 6" of silt from all distributaries and minors which are prone to siltation and from main canals according to requirements.
	b.	Sediment removed should be placed along outer toe of embankments or carried away where the channel passes through populated areas.
	c.	Observe H. (head of water on crests of outlets) every six months to know the silting or scouring tendency of the distributaries and minors.
Structures	a.	Inspect all gates, gate hoists, gears and oil sumps annually to know their wear and tear. Grease all gearing attachments and top up or change oil in the sumps if necessary.
	b.	Repaint all exposed surfaces after every three years. Inspect and repair, if necessary, every year submerged surfaces during annual closure of the canals.
	c.	Provide 50 ft. killa bushing and 25 ft stone pitching/lining per mile length of channel every year below the falls and regulators.

CHAPTER 3

EMBANKMENT MAINTENANCE

3.1 ROUTINE MAINTENANCE.

This maintenance refers to six work items which can be performed by beldars either working individually or as a gang. These are discussed below :

A. Repair to Patrol Road

Each beldar working on a main canal or branch should keep the patrol road in his charge in a motorable condition. He should repair any pot holes or ruts in the road and remove any humps so that there is smooth driving along the road.

B. Remove Fallen Trees from Canal

Trees growing on the berms or on the edge of patrol road may fall into the canal due to wind storm and cause obstruction to the flow of water. Such trees/branches should be cut into pieces by the beldars. They should be placed on the canal bank and the concerned agency informed.

C. Rain cut Repairs on the Slopes

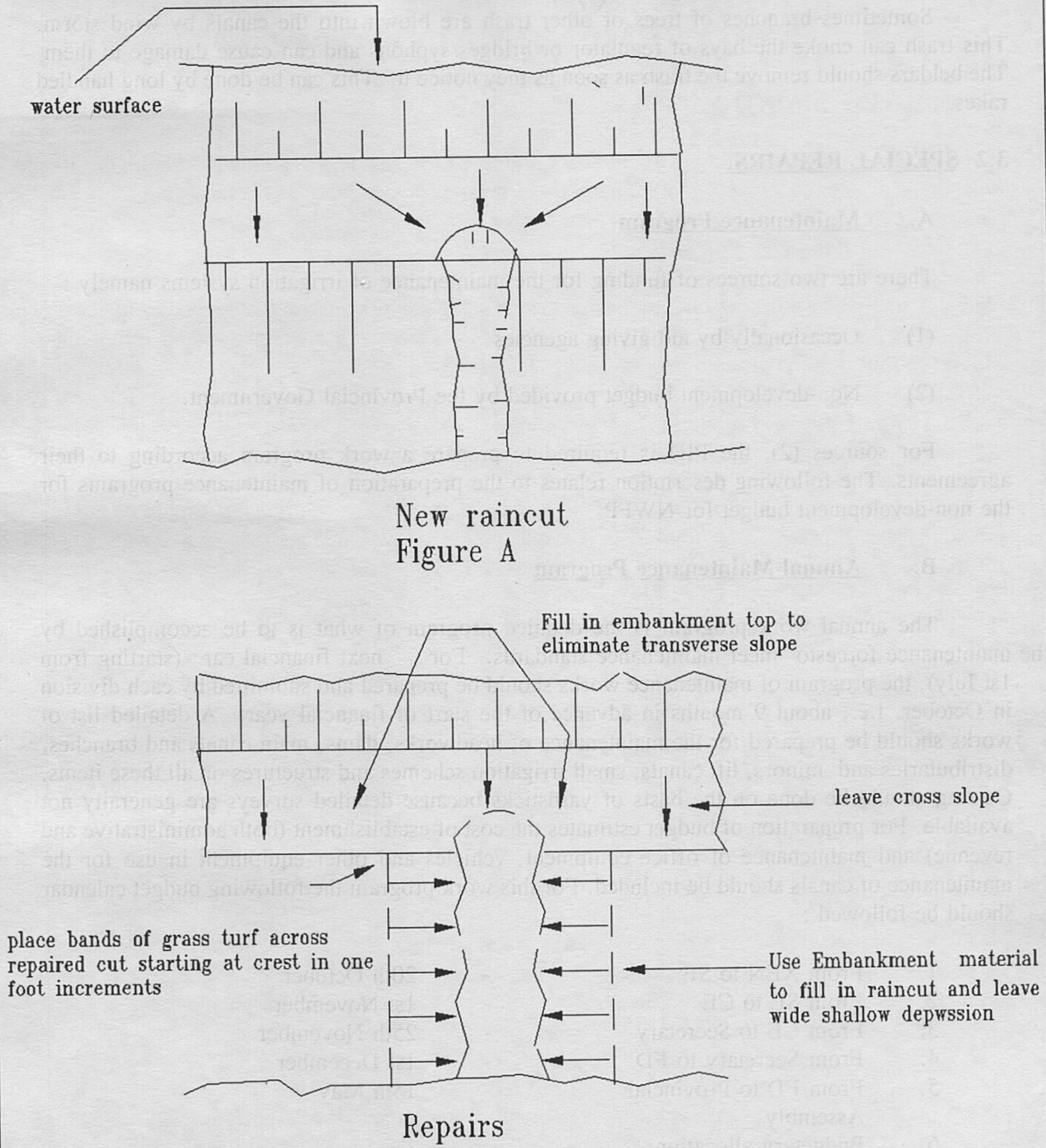
During rains, water flowing from the road causes cuts in the outer slope of the embankment. These rain cuts if upto 1.5 ft wide and 1.0 ft. deep should be dug and filled with earth borrowed from the adjoining slope. No earth should be borrowed from outside. This process is shown in FIG. III-1. The depression caused on the slopes can be filled up during strengthening of banks program. If the rain cuts are bigger and in large number, the work should be done through a contractor.

D. Cattle cut Repairs

At a number of sites where villages are located along the canals, the farmers drive their cattle to the canals for drinking water. The passage of cattle cut the banks and free board is gradually reduced at such sites. The beldars should regularly repair such ghat sites.

E. Vegetation Control

Any tree or brushwood growth on berms or outer slopes should be removed by beldars.



Repairing Raincuts

FIG.III-1

(Not to scale)

F. **Removing Floating Trash from front of Structures**

Sometimes branches of trees or other trash are blown into the canals by wind storm. This trash can choke the bays of regulator or bridges/syphons and can cause damage to them. The beldars should remove the trash as soon as they notice it. This can be done by long handled rakes.

3.2 SPECIAL REPAIRS.

A. **Maintenance Program**

There are two sources of funding for the maintenance of irrigation systems namely :

(1) Occasionally by aid giving agencies

(2) Non-development budget provided by the Provincial Government.

For sources (2), the PID is required to prepare a work program according to their agreements. The following description relates to the preparation of maintenance programs for the non-development budget for NWFP.

B. **Annual Maintenance Program**

The annual work program is the detailed program of what is to be accomplished by the maintenance forcesto meet maintenance standards. For next financial ear (starting from 1st July), the program of maintenance works should be prepared and submitted by each division in October, i.e., about 9 months in advance of the start of financial year. A detailed list of works should be prepared for the maintenance of headworks, dams, main canals and branches, distributaries and minors, lift canals, small irrigation schemes and structures on all these items. Costing should be done on the basis of yardsticks because detailed surveys are generally not available. For preparation of budget estimates the cost of establishment (both administrative and revenue) and maintenance of office equipment, vehicles and other equipment in use for the maintenance of canals should be included. For this work program the following budget calendar should be followed :

1.	From XEN to SE	-	20th October
2.	From SE to CE	-	1st November
3.	From CE to Secretary	-	25th November
4.	From Secretary to FD	-	1st December
5.	From FD to Provincial Assembly	-	15th May
6.	Budgetary allocation to PID by FD	-	1st week of July

The list of proposed work for the next year should be prioritized. If allocation of funds is not made by FD according to the demand made by the Department, the works on low priority should be deleted so that the program of works is tailored according to the availability of funds.

3.3 DAMAGE TO BANKS BY TRAFFIC.

At isolated sites near villages, unbridged foot paths, village roads and bridges/other masonry works, banks of channels require special attention. Buffalos and cows are very destructive for canal embankments and berms. The routine in-and-out movement of these animals in the canal several times a day (for drinking water and bathing) causes most of the damage due to removal of soil from the bank/berms with their hooves. One way of protecting the banks is to line/stone pitch the canal with a slope of 1:1. This slope will prevent the cattle from entering into the canal. Another way is to continuously strengthen these sites either through gang men or through contractors. Animal traffic may be channelized by building mud walls so as to ensure that all animals pass over the bridge and not through channels.

Where it is impossible to prevent cattle trespass, semi-permanent or pacca cattle ghats should be provided. Flatter slopes are provided in case of semi permanent ghats. The animals can negotiate an earth slope of 3:1 without excessive displacement of soil. A typical section is shown in FIG III-2. For pacca ghat sites, design shown in FIG.III-3, should be followed. The length of embankment lining may vary from 100 to 200 ft. For economy, a ramp may be provided on the village side and simple stone pitching/ lining with 1:1 slope on the opposite bank, so that the cattle cannot get out from the other side of channel.

3.4 DAMAGE TO BANKS BY RAINFALL.

Rainfall affects banks by gradual washing of soil from their tops and forms rain cuts about 1 ft. wide and 1 ft deep on the slopes. Good maintenance consists in closing of these rain cuts as soon as they are formed. If the damage is wide spread, it is beyond the capacity of beldars to repair this damage. In such cases the work should be accomplished through contractors. The damage by rain can be considerably reduced by turfing of slopes. Turfing reduces soil erosion and hence formation of rain cuts. For turfing purposes the grass should be:

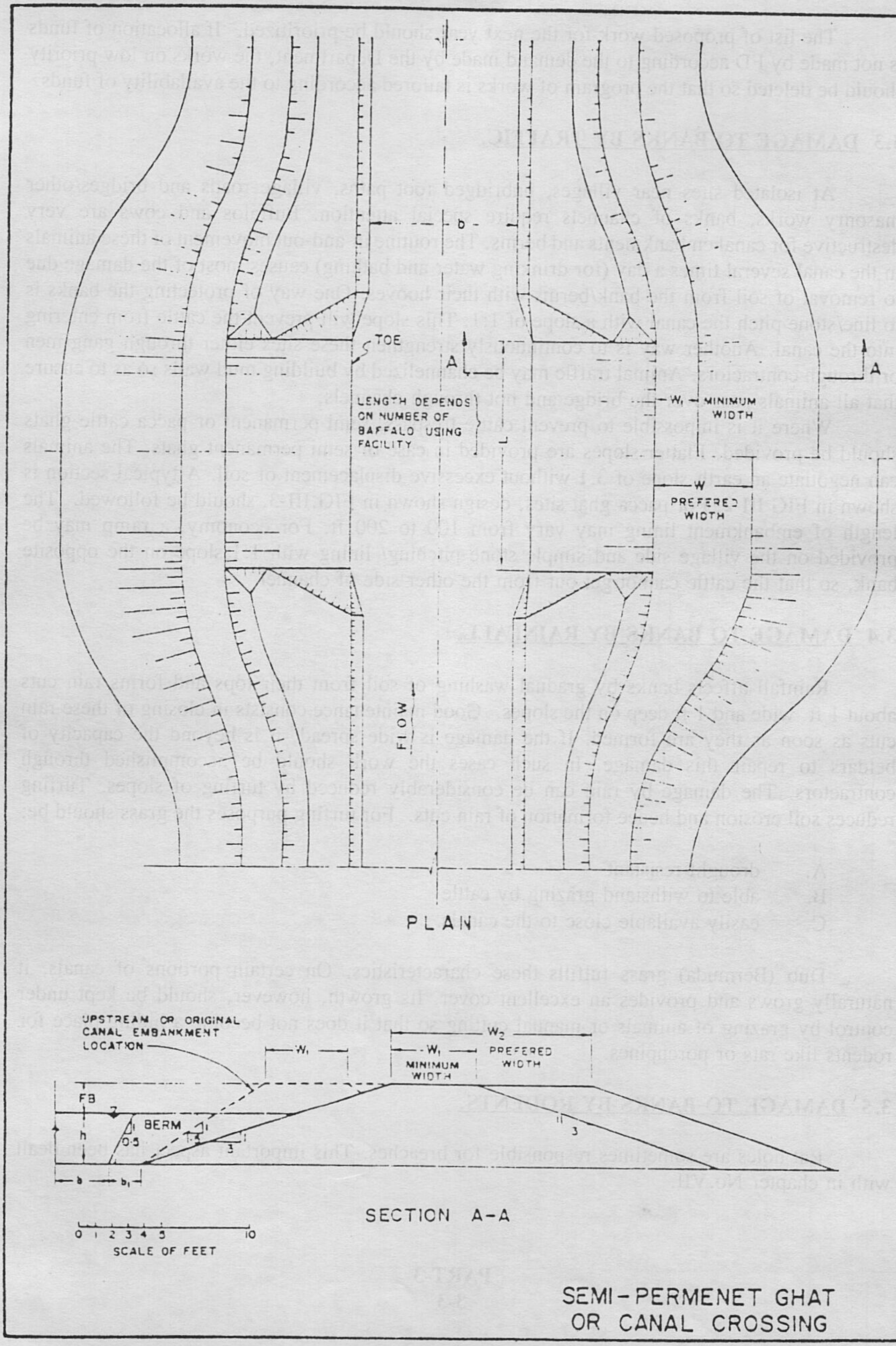
A. drought resistant
B. able to withstand grazing by cattle
C. easily available close to the canals.

Dub (Bermuda) grass fulfills these characteristics. On certain portions of canals, it naturally grows and provides an excellent cover. Its growth, however, should be kept under control by grazing of animals or manual cutting so that it does not become a hiding place for rodents like rats or porcupines.

3.5 DAMAGE TO BANKS BY RODENTS.

Rat holes are sometimes responsible for breaches. This important aspect has been dealt with in chapter No.VII.

FIG.III-2



SEMI-PERMENET GHAT OR CANAL CROSSING

Cattle Ghat at RD 140100 K.R.C Scale=1/100

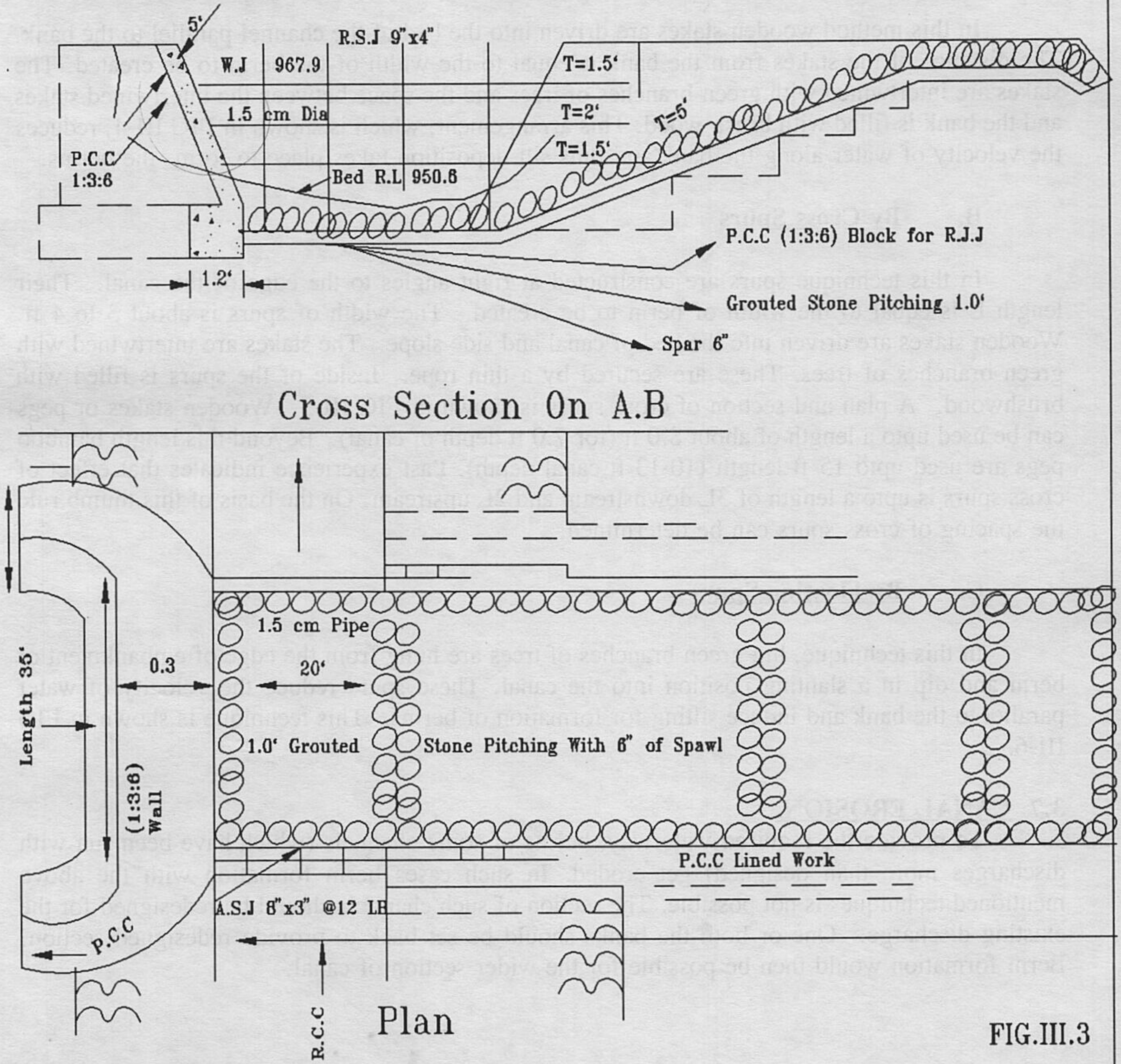


FIG.III.3

(Not to scale)

3.6 FORMATION OF BERMS.

A good strong berm ensures the safety of canals. There are normally no berms on new canals. They grow gradually, some naturally and some as a result of special efforts. Berm formation is induced by the following methods.

A. By longitudinal Staking and Bushing

In this method wooden stakes are driven into the bed of the channel parallel to the bank. The distance of the stakes from the bank is equal to the width of the berm to be created. The stakes are intertwined with green branches of trees and the space between the intertwined stakes and the bank is filled with brush wood. This arrangement, which is shown in FIG III-4, reduces the velocity of water along the bank and thus silt deposition takes place to form the berms.

B. By Cross Spurs

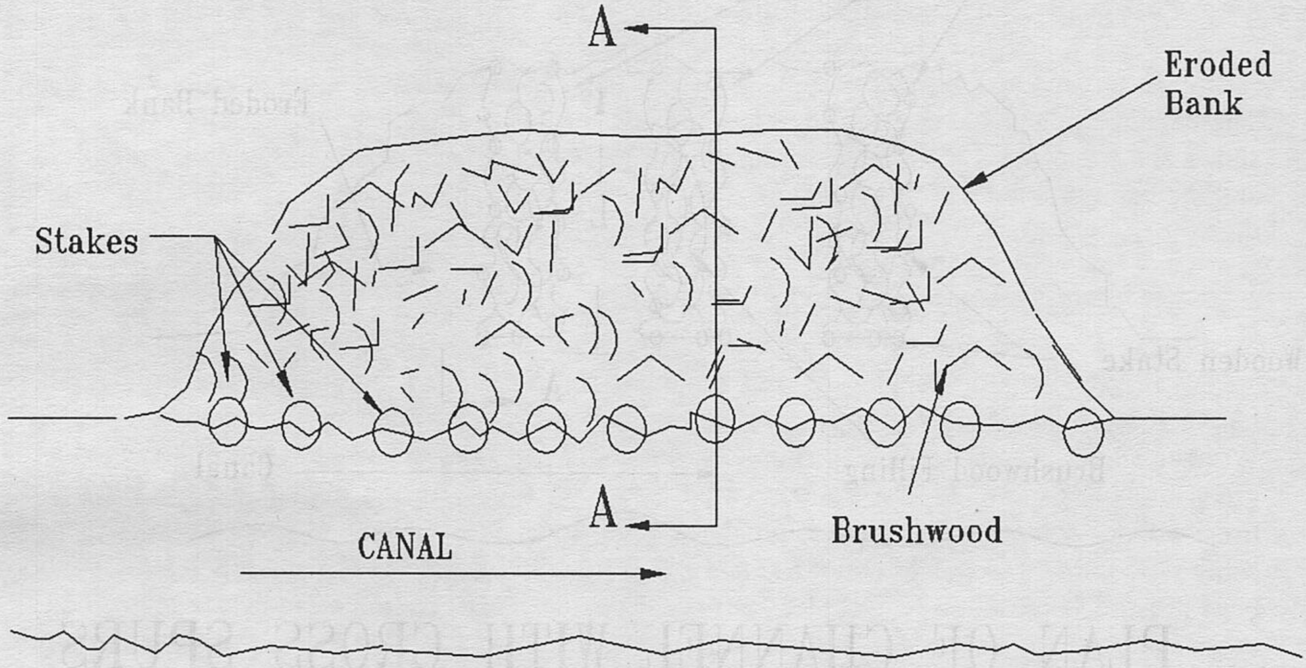
In this technique spurs are constructed at right angles to the edge of the canal. Their length L is equal to the width of berm to be created. The width of spurs is about 3 to 4 ft. Wooden stakes are driven into the bed of canal and side slope. The stakes are intertwined with green branches of trees. These are secured by a thin rope. Inside of the spurs is filled with brushwood. A plan and section of cross spurs is shown in FIG III-5. Wooden stakes or pegs can be used upto a length of about 8.0 ft (for 7.0 ft depth of canal). Beyond this length bamboo pegs are used upto 15 ft length (10-13 ft canal depth). Past experience indicates that effect of cross spurs is upto a length of 3L downstream and 2L upstream. On the basis of this thumb rule the spacing of cross spurs can be determined.

C. By Floating Spurs

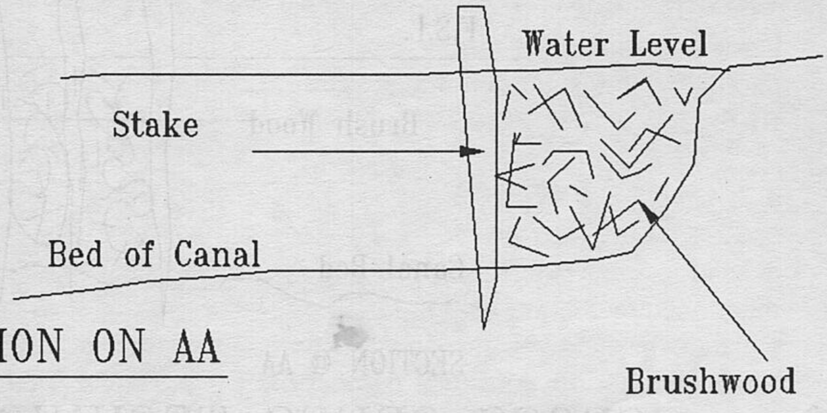
In this technique, big green branches of trees are hung from the edge of embankment or berm and dip in a slanting position into the canal. These spurs reduce the velocity of water parallel to the bank and induce silting for formation of berms. This technique is shown in FIG III-6.

3.7 CANAL EROSION.

To provide the required waterway, berms of some channels (which have been run with discharges more than designed) get eroded. In such cases berm formation with the above mentioned techniques is not possible. The section of such channels should be redesigned for the existing discharge. One or both the banks should be set back to provide redesigned section. Berm formation would then be possible for the wider section of canal.



PLAN OF CHANNEL WITH LONGITUDINAL SPURS

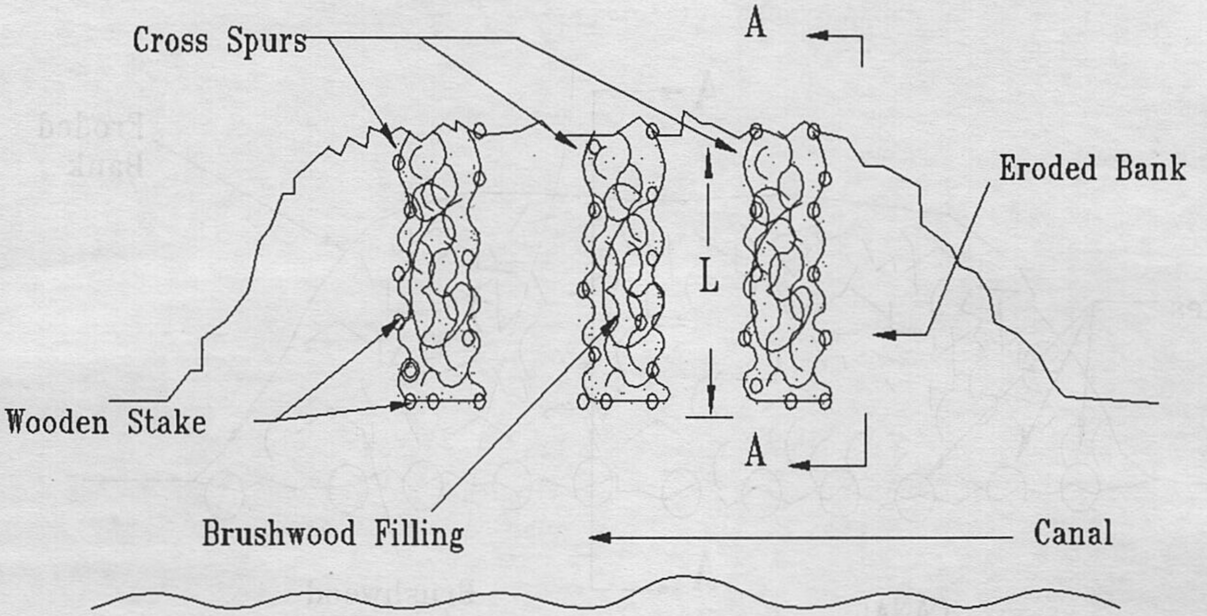


SECTION ON AA

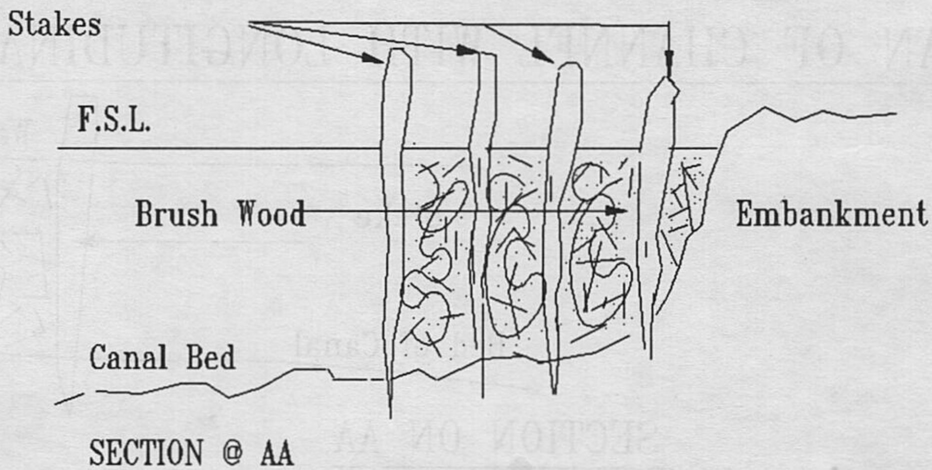
LONGITUDINAL SPUR TECHNIQUE

FIG.III.4

(Not to scale)



PLAN OF CHANNEL WITH CROSS SPURS

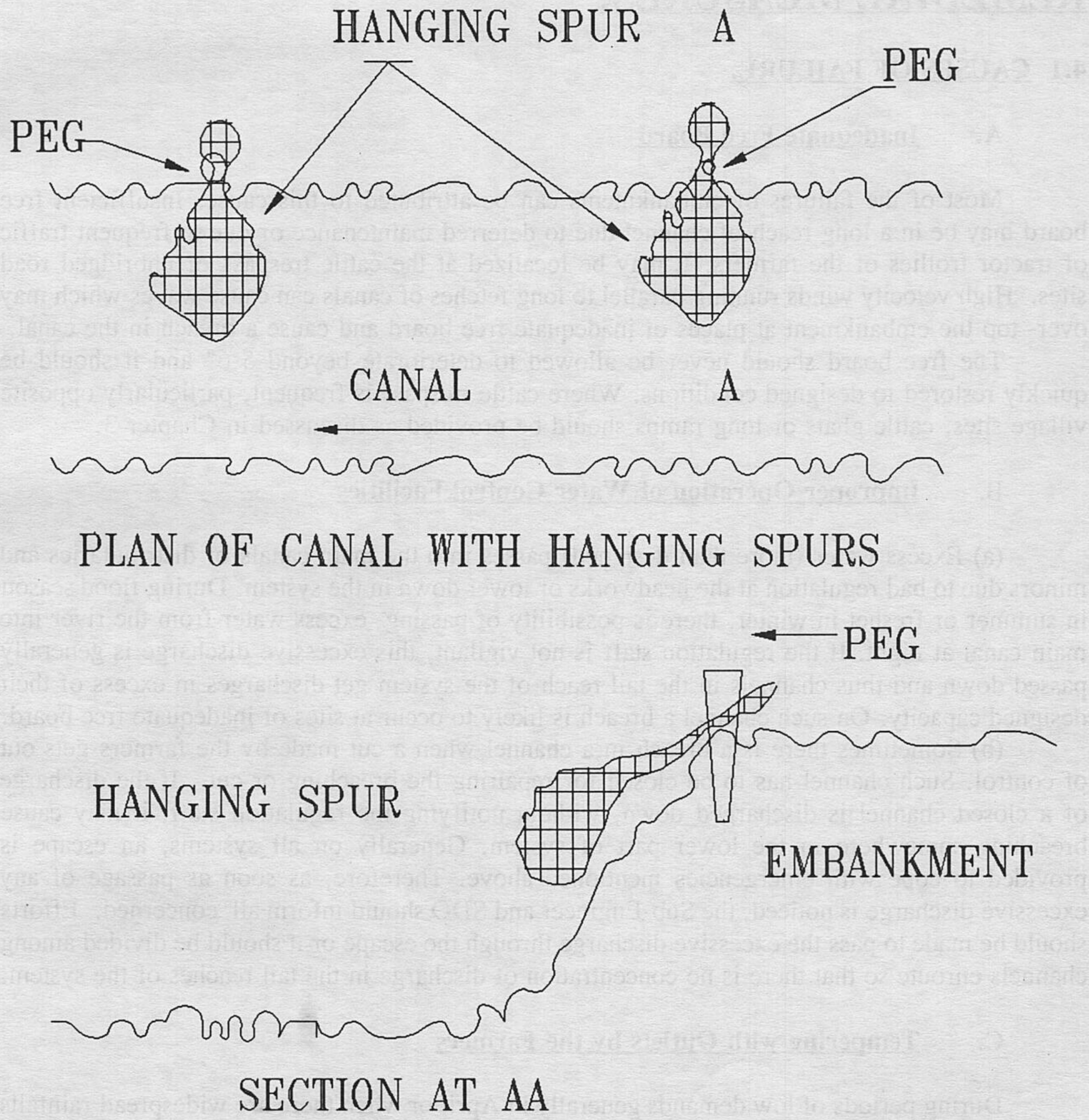


SECTION @ AA

CROSS SPURS TECHNIQUE

FIG. III–5

(Not to scale)



TECHNIQUE OF HANGING SPURS
FIG III-6

(Not to scale)

CHAPTER 4

CAUSES OF FAILURE OF EMBANKMENTS AND REMEDIAL MEASURES.

4.1 CAUSES OF FAILURE.

A. Inadequate Free Board

Most of the failures of embankments can be attributed to this cause. Insufficient free board may be in a long reach of channel due to deferred maintenance or due to frequent traffic of tractor trollies of the farmers. It may be localized at the cattle trespass or unbridged road sites. High velocity winds running parallel to long fetches of canals can cause waves which may over- top the embankment at places of inadequate free board and cause a breach in the canal.

The free board should never be allowed to deteriorate beyond 5-6" and it should be quickly restored to designed conditions. Where cattle trespass is frequent, particularly opposite village sites, cattle ghats or long ramps should be provided as discussed in Chapter 3.

B. Improper Operation of Water Control Facilities

(a) Excess water (more than designed) passes into the main canals or distributaries and minors due to bad regulation at the headworks or lower down in the system. During flood season in summer or freshet in winter, there is possibility of passing excess water from the river into main canal at night. If the regulation staff is not vigilant, this excessive discharge is generally passed down and thus channels in the tail reach of the system get discharges in excess of their designed capacity. On such channel a breach is likely to occur at sites of inadequate free board.

(b) Sometimes there is a breach in a channel when a cut made by the farmers gets out of control. Such channel has to be closed for repairing the breaching or cut. If the discharge of a closed channel is discharged down, without notifying the regulation staff, it may cause breaching somewhere in the lower part of system. Generally on all systems, an escape is provided to cope with emergencies mentioned above. Therefore, as soon as passage of any excessive discharge is noticed, the Sub-Engineer and SDO should inform all concerned. Efforts should be made to pass the excessive discharge through the escape or it should be divided among channels enroute so that there is no concentration of discharge in the tail reaches of the system.

C. Tempering with Outlets by the Farmers

During periods of low demands generally in April or when there are widespread rainfalls in certain areas, the farmers are prone to plug their outlets to save their crops from excessive watering. This can cause flooding of the tail reach of the channel and may result in a breach at the site of insufficient free board. The Zilladars and Sub-Engineers should remain vigilant during such periods and ask for reduction of water in the channel whose command area has received heavy rainfall. Executive Engineer gets rainfall figures telegraphically if this facility exists from the rest houses or other locations where departmental rain gauges have been installed. On receipt of rainfall figures he should take action to reduce the water supplies in the channels which are likely to be effected by the rainfall.

D. Failure to Maintain Canal Capacity

Silt deposition in the channels should be watched carefully through the observations made monthly in the H register. If there is excessive silt deposition in a channel, its free board would be reduced. Silt clearance of such channels should not be deferred till the annual closure period. Its silt should either be removed through mechanical means in running water, or an emergency closure of channel should be arranged for silt clearance.

E. Rodent Holes

Sometimes rodent holes are responsible for breaches. Chapter-6 deals with this menace.

F. Piping or Inadequate Coverage of Hydraulic Gradient

Reaches of all channels which pass through heavy filling should be kept under watch. The toe of outer slopes should be inspected when the channels carry full supply discharges. If any wetness is noticed at the toe, it is an indication that the hydraulic gradient at that point is not covered by the embankments. Such sites, if left unattended, are prone to piping action and ultimate failure of the embankment. The remedy for such sites is to provide a pushta as shown in the typical section of the channels.

4.2 CLOSING OF LEAKAGES AND BREACHES IN CANALS.

A. Closing Leakages

Cracks in embankments and rodent holes are major causes of leakages. If the water flowing through a leak is sluggish and clear, it may be seepage water and there is no immediate danger. If, however, it is muddy, fast moving and carries the soil particles of the bank, the leak needs immediate attention. Correct location of the hole on both sides of the bank which may not always be perpendicular to the bank is essential. If the hole is of a large size there is a whirling action in the water just above the hole. If it is small one,the location of the leakage site from the water level is not very deep. For detecting the leakage point a beldar should get into water and try to locate the hole with his feet. Once he has hit the hole another beldar should hand over to him heavy turf sods taken from the berms. The beldar standing in water should put these sods on the hole and tamp them down into the hole with his feet. For bigger holes gunny bags filled with sand should be dumped. Small leakage can also be closed by throwing sawdust, bran, powdered dung, etc. just upstream of the leaks. The stuff is carried by water into the leaks where it swells and stops the leaks. A method for closing big leaks is to cut an inverted T-shaped trench a little above the water line outside the bank on the outer slope. The entire leak is then opened out starting from the exit side. The leakage path is then filled with best available material. This process is shown in Fig. IV-1.

B. **Closing of Breaches in Distributaries and Minors**

Before starting to close a breach, labour and material (such as earth, sand, gunny bags, stakes, brushwood) should be collected at site in sufficient quantity. If earth is not available it can be obtained by cutting the outer slope of the outer bank. Enough earth should be collected on both sides of the breach on the existing bank. The ends of the banks should be protected first to prevent further widening. The process starts from both ends by slipping the earth from the heaps and protecting channel sides by grassy clods usually available from the berms. Earth baskets should never be thrown in the water. A semi-circular bund (ring bund) may be constructed on the water side with stakes, brushwood, mass, earth etc., and water bailed out. The sides and bottom of the existing bund at the breach site should be cut into steps to remove all loose material and to form good bond with the new material. In case good soil is not available, a core wall should be provided. Closing of breaches on distributaries and minors becomes easier if a closure can be arranged by escaping water through an escape.

C. **Closing Breaches on Main Canals and Branches**

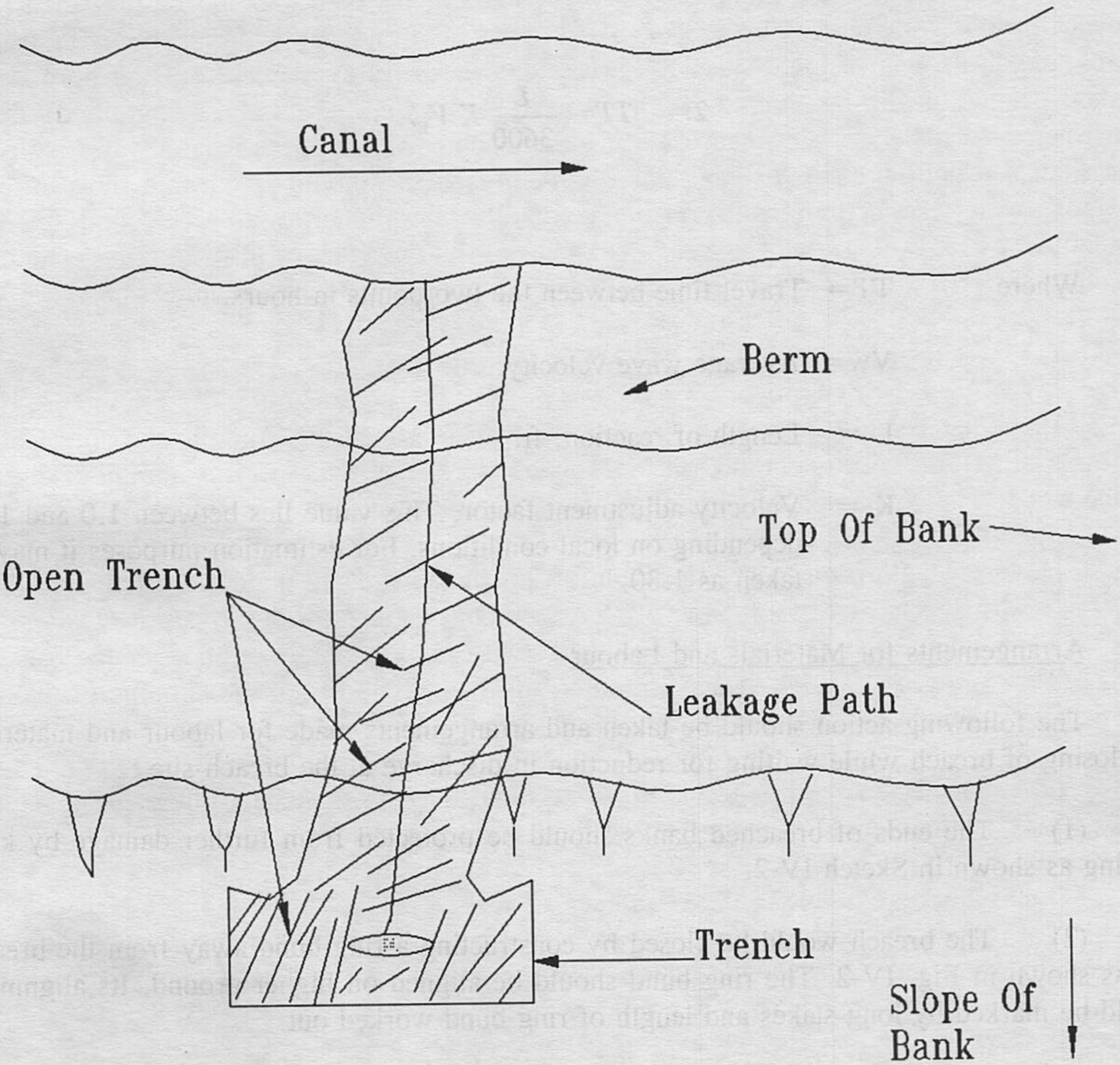
Immediately after a breach in a main canal or a branch has come to the notice of Sub-engineer or SDO, the latter should ask for telegraphic reduction of specific amount of discharge in the canal. The concerned officers of the canal should take the following two actions :

(1) If there is an escape upstream of the breach site and the desired reduction can be escaped through it, the officer incharge of escape should open it. The escapage should be done according to procedure laid for the operation of the escape. If discharge is escaped too rapidly, there is possibility of the slipping of the berms in the downstream portion of the canal.

(2) If necessary the discharge in the canal may be reduced from its head regulator although its effect will reach the breach site in longer time.

It may not be possible to dry out the canal at the breach site particularly if there is keen demand for water. Therefore the breach will have to be closed with some discharge in the canal. The approximate time taken for the reduced discharge to reach the breach site can be calculated from the following formulae.

1. $$Vw = \frac{Q_1 - Q_2}{A_1 - A_2}$$



CLOSING A LEAKAGE

FIG.IV-1

(Not to scale)

Where Vw = Average wave velocity of falling water

Q, and A, are discharge and sectional Area at the site from where reduction in discharge starts and Q2 and A2 are discharge and area of canal at the breach site.

$$2. \quad TT = \frac{L}{3600} K V_W$$

Where TT= Travel time between the two points in hours.

Vw= Average wave velocity.

L = Length of reaction, ft.

K = Velocity adjustment factor. This value lies between 1.0 and 1.60 depending on local conditions. For estimation purposes it may be taken as 1.30.

Arrangements for Materials and Labour

The following action should be taken and arrangements made for labour and materials for closing of breach while waiting for reduction in discharge at the breach site :

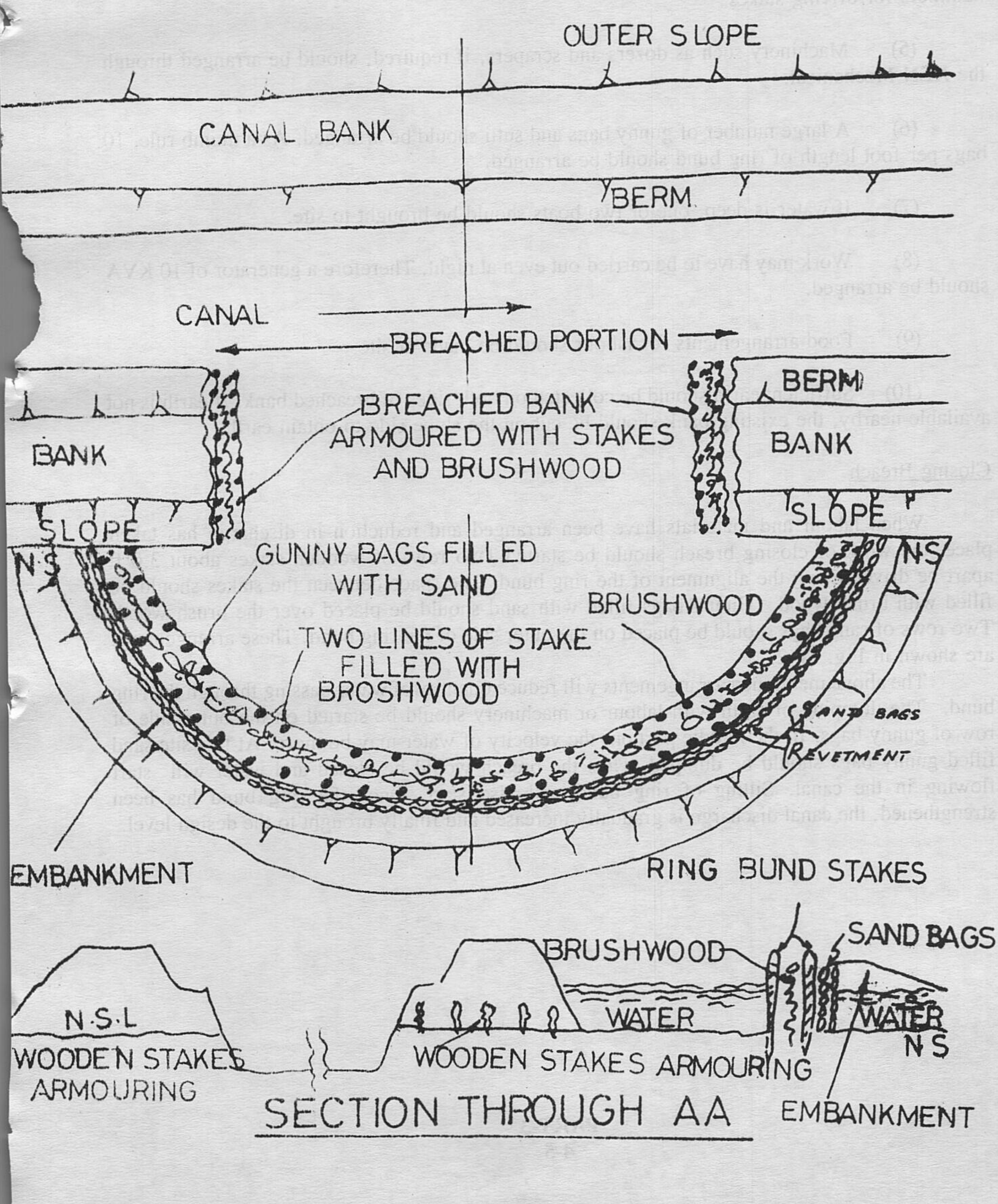
(1) The ends of breached banks should be protected from further damage by killa bushing as shown in Sketch IV-2.

(2) The breach would be closed by constructing a ring bund away from the breach site as shown in Fig. IV-2. The ring bund should be aligned on higher ground. Its alignment should be marked by long stakes and length of ring bund worked out.

(3) Wooden stakes from the canal plantation should be arranged. The stakes should be driven in the ground at intervals of 1.5 ft. Thus the number of stakes can be worked out. The actual number arranged should be 25% more that the calculated quantity to cater for damage in driving. The average diameter of stakes should not be less than 4 inches. Their length may be 6-8 feet or longer if conditions warrant.

FIG. IV_2

SKETCH FOR CLOSING A BREACH ON A MAIN CANAL



(4) An estimate of labourers required should be made. If the contractor is unable to arrange the required labourers, assistance of Civil Authorities should be sought. They would muster labour from the neighboring villages through Tehsildars and Civil Patwaris. As a thumb rule one labourer per foot of ring bund should be arranged. The labour force should include three or four carpenters for sharpening of stakes. They should be provided with a saw and heavy hammers for driving stakes.

(5) Machinery such as dozers and scrapers, if required, should be arranged through the XEN Mechanical.

(6) A large number of gunny bags and sutli should be arranged. As a thumb rule, 10 bags per foot length of ring bund should be arranged.

(7) If water is deep, one or two boats should be brought to site.

(8) Work may have to be carried out even at night. Therefore a generator of 10 KVA should be arranged.

(9) Food arrangements for labour should be made at site.

(10) Sufficient earth should be collected on both sides of breached bank. If earth is not available nearby, the existing bank should be cut on the slope side to obtain earth.

Closing Breach

When labour and materials have been arranged and reduction in discharge has taken place, the work of closing breach should be started.Two rows of wooden stakes about 3.0 ft apart be driven along the alignment of the ring bund. The space between the stakes should be filled with brush wood. Gunny bags filled with sand should be placed over the brush wood. Two rows of sand bags should be placed on the outer side of the ring bund. These arrangements are shown in Fig. IV-2.

The above mentioned arrangements will reduce quantity of water passing through the ring bund. The dumping of earth with labour or machinery should be started on the outer side of row of gunny bags. In the middle portion, the velocity of water may be more. At this site sand filled gunny bags should be dumped. Thus the breach would be closed and water will start flowing in the canal. Silting of ring bund will also start. Once the ring bund has been strengthened, the canal discharge is gradually increased and finally brought to the design level.

CHAPTER-5

MAINTENANCE OF PATROL ROADS

5.1 GENERAL.

There are the following three types of canal patrol roads in the NWFP :

A. **Dirt (kacha) Roads**

These roads are found along most of the canals, branches, distributaries and minors. Their total length is 824 miles.

B. **Shingle Roads**

Along most of small channels, shingle roads have been constructed. These roads are open to public traffic and serve as farm to market roads for the farmers. Their total length is 240 miles.

C. **Metalled Roads**

Roads along some of distributaries and minors have been black topped. These canals are also open to the public but they are maintained by the PID. The total length of these roads is 212 miles.

5.2 MAINTENANCE OF DIFFERENT TYPES OF ROADS.

A. **Dirt or kacha roads**

B. General

The present practice is the daily wetting of road surfaces by Beldars by fetching water from the canals via buckets. The ups and downs of road are levelled by ring phatti. The following procedure should replace the old practices.

(i) Wetting of Road

This wetting should be done by a tractor trolley equipped with a water tank provided with perforated pipe spray boom and a power take off pulley which operates a centrifugal pump with inlet and outlet hose. This is one-man operation. Water is pumped out of the canal to fill the tank which is then driven along the road for spraying water. Tractor speed should be 2 to 4 mph.

(ii) Grading of the Road

After wetting the roads a motor grader should be used to grade the road. Motor grading of the road six times a year should be sufficient. Normal wetting of the road by Beldars should keep the road in motorable condition.

C. Instructions for keeping the road motorable

The following instructions should be followed to keep the road in motorable condition:

i. Dimensions

For roads on main canal banks and branches, a minimum of 15 ft. should be provided exclusive of the dowel. For inspection roads along distributaries and minors, the road width should also be 15 ft. as no dowel is provided.

ii. Cross-Slope

In order to drain out rain water rapidly a good cross slope of 1 in 40 or 60 should be provided towards the bank toe. Non-patrol road bank tops should also be sloped towards the dry side. If the proper slope is not provided, the road surface becomes depressed and rutted. Rainfall will collect and pond. The shoulders will become high as shown in Fig. V-1.

iii. Drainage Requirements

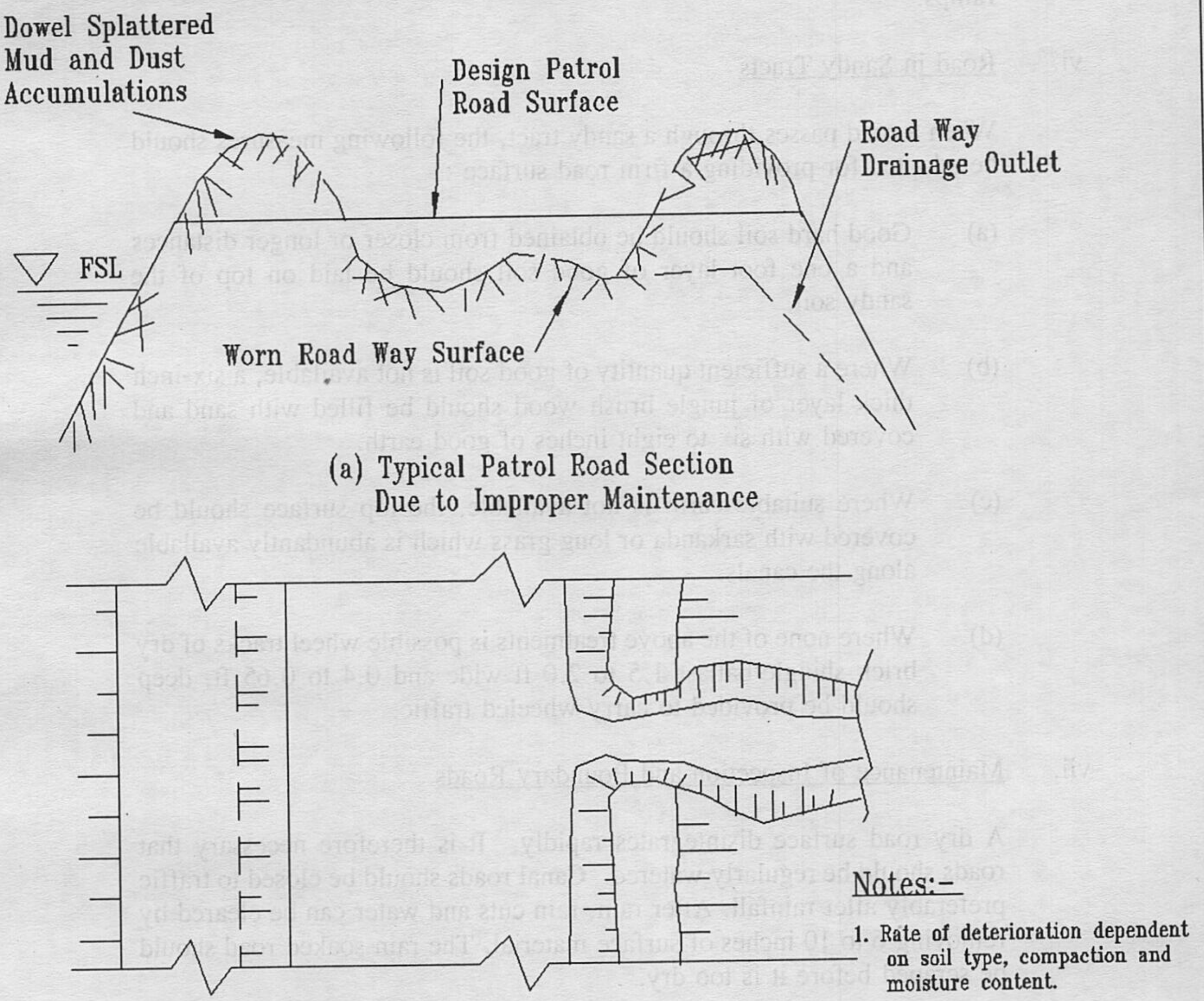
Where the road is in cutting and passes through a spoil bank, a catch water drain should be provided along the spoil to carry the rain water. Such a drain should be 12 to 18 inches wide and at least a foot deep. It should carry water towards the gaps in the spoil or discharge into the canal, through culverts.

iv. Provision of Dowel

If a dowel is to be provided along the canal, it should have the following dimensions :

Height 1.25 ft., width at top 1.25 ft
Side slopes 1:5 to 1.

Good Maintenance Retains



(a) Typical Patrol Road Section
Due to Improper Maintenance

(b) Plan View

Notes:-

1. Rate of deterioration dependent on soil type, compaction and moisture content.
2. Roadway drains cut to allow excess rainfall to flow off road.
3. Roadway drains continue to eroded embankment unless protected.

PATROL ROAD CONDITION
WITH POOR MAINTENANCE
PRACTICE

FIG.V-1

(Not to scale)

v. Ramps at Bridge Sites and Culverts

For an inspection road, ramps have to be provided at the bridge sites. Minimum slope for these ramps should be 1 in 50. For boundary roads along distributaries and minors, the ramp slope for culverts should not be less than 1 in 20. Sharp angles should be avoided at the top and foot of ramps.

vi. Road in Sandy Tracts

When a road passes through a sandy tract, the following measures should be adopted for providing a firm road surface :

(a) Good hard soil should be obtained from closer or longer distances and a one foot layer of good soil should be laid on top of the sandy soil.

(b) Where a sufficient quantity of good soil is not available, a six-inch thick layer of jungle brush wood should be filled with sand and covered with six to eight inches of good earth.

(c) Where suitable earth is not available, the top surface should be covered with sarkanda or long grass which is abundantly available along the canals.

(d) Where none of the above treatments is possible wheel tracks of dry brick shingle/ballast 1.5 to 2.0 ft wide and 0.4 to 0.65 ft. deep should be provided to carry wheeled traffic.

vii. Maintenance of Inspection and Boundary Roads

A dry road surface disintegrates rapidly. It is therefore necessary that roads should be regularly watered. Canal roads should be closed to traffic preferably after rainfall. After rain, rain cuts and water can be cleared by removing 6 to 10 inches of surface material. The rain soaked road should be scraped before it is too dry.

viii. Treatment of Kallar Reaches

Where kallar exists on the top of the road, the top one foot of earth should be removed. A six inch layer of sand on the bed of road should be laid first. It should be covered with a six-inch layer of good earth.

D. **GRAVEL ROADS**

The following tips on maintenance gravel roads can be helpful:

i. Work gravel surfaces when moist or after a rain.

ii. Most washouts occur because of improper drainage.

iii. Layers of gravel should be at least twice the thickness of the largest stone size. If you put on a six-inch gravel course, the largest stone should be 3 inches.

iv. The key to maintaining problem areas and achieving a tight, strong surface, is to use high-quality crushed/graded gravel. Also check soil quality in the base as well as the need for under drainage.

v. In the wet season use quality gravel instead of sand to correct wet problem areas.

vi. Instead of disturbing the entire roadway to correct occasional pot holes on an otherwise sound gravel surface, patch them with a 50/50 mixture of crushed gravel and calcium chloride or earth, sprinkle with water and tamp. In the same manner mud concrete can be effectively used.

vii. Establish a schedule for periodic inspection and resurfacing of all gravel roads.

E. **METALLED ROADS.**

The following tips for maintenance of metalled roads can be helpful:

i. The road berm should be kept in good condition as it would ensure the safety of the roadway. Canal roads are normally very narrow and the berms are subject to heavy traffic movement. This traffic movement causes these roads to deteriorate very quickly. Efforts should be made to put moist soil on the berms and then to compact this soil by a hand tamper.

ii. Ruts/pot holes formed in the road surface should be repaired quickly. Else they will go on expanding resulting in more damage to the road. While repairing the pot holes, the pit should be thoroughly cleaned from all dust and debris and then hot bitumen should be applied on the sides and the bottom of the pit. Then, properly graded, crushed gravel should be impregnated with bitumen and placed in the pot holes. It should be thoroughly tamped with a hand tamper. If the pot hole is deep, it would be advisable to lay the
graded impregnated gravel in two layers.

iii. Since the accumulated rain water damages the road surface, it should be ensured that there are no depressions in the road for the rain water to collect. Such depressions should be filled with bitumen impregnated material to raise the surface of the road to such a level that rain water does not collect there. The rain water which collects in the depressions can seep through the road to the formation level resulting in settlement of the road surface and deepening of the depressions.

iv. The re-surfacing program should preferably be carried out during hotter months. If this work is carried out during cold weather,the bitumen hardens very quickly and does not grip the graded material properly.

CHAPTER 6

RODENT CONTROL

6.1 GENERAL.

Rat holes are often responsible for breaches in the canals. Rat holes appear just above surface of water and may extend to the outer slopes. These holes are dangerous if the water level in the channel rises above the position of rat holes. This is particularly so if the berm is not sound. The canal bank is the only place in agricultural area that is above water and never cultivated nor disturbed. It is moist and cool in summer. It is a good source of water for succulent roots. The soil is generally soft, moist and easy to dig. The bank has a large area for extensive burrowing.

6.2 CONVENTIONAL METHODS.

The conventional methods to control rodents include destruction of burrows, flooding and release of natural enemies like cats. Catching with different types of locally made traps can also be tried. All these methods, however, are only partially successful.

6.3 ELIMINATION THROUGH POISONING PROGRAM.

A. General

When rats activity cannot be controlled by conventional methods, the alternate is to eliminate them through a poisoning program. Since rodent population may migrate and multiply rapidly, such a program must be maintained for sometime to be effective. Beldars can accomplish this task very effectively. Two species of rats are common in NWFP. These are;

i. Nesokia Indica

The Nesokia Indica, a burrowing rat, is locally referred to as the Mole Rat or Blind Rat. Approximately ninety percent of the observed activity on canal banks is caused by this rat. Evidence of its activities are small piles of soil on the inside or outside surfaces of canal banks. Its holes are often plugged near the surface by 2 to 4 inches of soil. Nesokia are plant root eaters. They burrow primarily to feed on succulent grass and plant roots. Their burrows, generally within 2 to 6 inches of the bank surface, are composed of: primary burrows running parallel to the bank, short burrows passing perpendicular to the bank to the inner or outer surface utilized for dumping soil; and occasional vertical holes which lead down and out under the adjoining fields, where they will occasionally feed on the roots of field crops such as sugarcane or wheat. Nesokia are very strong burrowers and though they prefer soft, moist soil, they can also dig in very hard soils. Nesokia like solitude and seek others only for breeding. Their gestation period is about 30 days. A Nesokia's burrow complex often extends 20 to 30 feet along a canal bank. They seldom come to the surface during the day.

ii. Bandicota Bengalensis Rat

The second most prevalent rat is a field rat commonly known as the short-tailed Bandicoot Rat and is a relatively new rodent. It feeds on sugarcane, wheat, rice and other field crops and can cause heavy crop damage. It multiplies very rapidly. It generally lives in burrows below the fields in which it is feeding. It also will store extensive grain reserves in its burrows. It moves to the canal banks primarily between crop seasons when there is no crop cover and fields are being cultivated or when the fields are flooded. It is a surface feeder and would leave its holes open.

B. **Poison Control Methods**

The following two poison-bait formula and procedures were developed by the Vertebrate Pest Control Center, P.O.Box No.8401, Karachi University Campus, Karachi-32, Pakistan. More information can be obtained from them if required.

Name and composition of poisons is as follows :

i. Phosphide Rat-cake

48% Wheat atta or flour
48% Broken rice, or wheat or maiz (cracked)
2% Zinc Phosphide
2% Cooking oil

A sample formula for field use is :

2.5 kg	Wheat flour
2.5 kg	Broken rice, wheat or maize (cracked)
100 gm	Edible oil
100 gm	Zinc phosphide
+	enough water to make a stiff dough

(a) Place the flour and grain in a clean container, bucket or mixer and mix well.

(b) Add the zinc phosphide to the mixed ingredients. Mix until an even grey color occurs. Do not over mix, because it may create a fire hazard from the zinc phosphide.

(c) Add edible oil and mix well.

(d) Slowly add the water and mix until a stiff batter is formed,

(e) Place the bait on a smooth surface and roll it flat until a thickness of one half inch is achieved. A wooden form and a piece of round wood can be used to ensure rapid rolling and uniform thickness.

(f) With using a knife, cut the flattened bait into a square size of a five paisa coin.

(g) Place it in the shade with good air circulation to dry for 2-3 days, turn it occasionally. Protect it from dew and rain.

(h) Store in a cool, dry place until used.

(i) When handling zinc phosphide or mixing a bait containing zinc phosphide, never touch the poison. Do not mix the bait, or handle the wet bait with bare hands. Use gloves or plastic bags over the hands and a wooden paddle or stick for mixing and spreading.

(j) Wash all tools, containers and hands after mixing the bait. Do not eat or smoke during mixing unless hands are washed first.

(k) Never use a container for mixing that has previously contained insecticides, or pungent chemicals. This will contaminate the bait. Also never use the mixing container for preparation of food.

The sequence for mixing the bait is very important. Zinc phosphide reacts slowly with water to release the poison gas phosphide. By adding the oil to the dry grain/zinc phosphide mix, the oil coats the zinc phosphide particles and reduces the water's contact with the poison. The amount of water used is that amount which gives a stiff, not sticky, batter suitable for easy handling and quick drying. This technique ensures the maximum amount of zinc phosphide in the bait with a minimum of deterioration. This bait can be made by using other acute poisons that do not break down when mixed with water. It can also be used as an anti-coagulant carrier, but chronic poisons do not kill insects so grains must be insect free for long storage of baits containing anti-coagulants. Zinc phosphide reacts with water in the air and gradually becomes less toxic. For this reason, when possible, make small batches of baits as needed, not one large batch. Fresh bait is more effective and attractive and kills more rats.

ii. <u>Loose Grain Zinc Phosphide Bait Poison</u>

The bait is easy to prepare and at times the best one to use :

5 kg broken rice, cracked wheat or maize.
100 gm of cooking oil.

In a dry clean container, mix the grain and oil. Then slowly add the zinc phosphide and mix till it is an even grey color. Store in a well sealed plastic bag. Precautions for handling are :

(a) When handling zinc phosphide or mixing a bait containing zinc phosphide, never touch the poison. Do not mix the bait, or handle the wet bait with bare hands. Use gloves or plastic bags over hands and a wooden paddle or stick for mixing and spreading.

(b) Wash all tools, containers and hands after mixing bait. Do not eat or smoke during mixing unless hands are washed first.

(c) Never use a container for mixing that has contained insecticides, or pungent chemicals for this will contaminate the bait. Also never use the mixing container for preparation of food.

For large scale baiting programs, it is advisable for quality control, to mix the bait at a central location under expert supervision.

iii. Recumin Bait Poison

To prepare a Recumin bait, use fairly clean broken rice, cracked wheat or cracked maize. Place 19 parts of the grain in a clean container for mixing. Add just enough edible cooking oil to lightly coat the grain. When the two are mixed, then while stirring or mixing, slowly add one part of "Recumin" master mix (a light blue powder). Mix till the grain is evenly coated. The bait is now ready for use.

C. POISON BAIT DISTRIBUTION METHODS.

i. Zinc Phosphide Baits

Distribute baits daily. Bait all open holes. Do this work early in the morning or late in evening for the Mole Rat (Nesokia Indica). It closes its holes except during the dawn and dusk hours, so baiting for this rat is best done around these hours. Its burrows can be dug open and baited but it is hard work. Since the rat holes would tend to be open at dusk and early evening, a crew (gang) would be used effectively to move rapidly along a badly infected canal bank and bait all visible holes and closed burrows. Coleman type lanterns would provide adequate light to work with. The Bandicoot Rat (Bandicota Bengalensis) leaves its holes open. Another baiting method is to carry a supply of rat cake. Bait when inspecting or working along the canal so that whenever an open burrow is seen, it can be baited. The Beldar could perform this function very effectively on his regular patrolling of the canal. After repeated use of zinc phosphide the baits rats may become "bait shy". In this case the type of poison may be changed to a chronic or anti-coagulant type.

ii. Recumine Baits

Place about 100 grams of the prepared bait per one plastic bag and seal them. Place one bag in field runs. Make a small slit in the plastic bag. The poison can also be used in the loose grain form in open burrows. Recumine is a slow acting poison so all holes should be inspected and retreated each week. At the end of the second week, close all holes. Later check for open hole and retreat them as necessary. After mechanical methods and poison methods have been employed and a few rats remain, poison gas may be used. Gassing is usually done as a "clean up" operation after baiting. It is laborious, expensive and dangerous.

iii. Gassing Control Method

Detia or phosphide tablets as well as Cymag or Cynogas maybe used. Cymag is cheapest. Three methods are used:

(a) **For tablets.** Place them on a long handled spoon and place well inside the hole. Plug the hole with weeds or grass, then soil, and pack to seal.

(b) **When using powder** one man should open the can and another man, using a long handled spoon, should dig out a spoonful of powder and seal the hole.

(c) **When using a dust pump,** insert the tube or application pump into the hole, seal the hole with grass, weeds, and dirt, then give 3-4 pumps, withdraw the tube and seal the hole completely. The dirt seal around the tube prevents blow back.

In all three methods, always work with your back to the wind so any escaping fumes are carried away from the applicator.

6.4 MENACE OF PORCUPINES FOR CANAL EMBANKEMTNS.

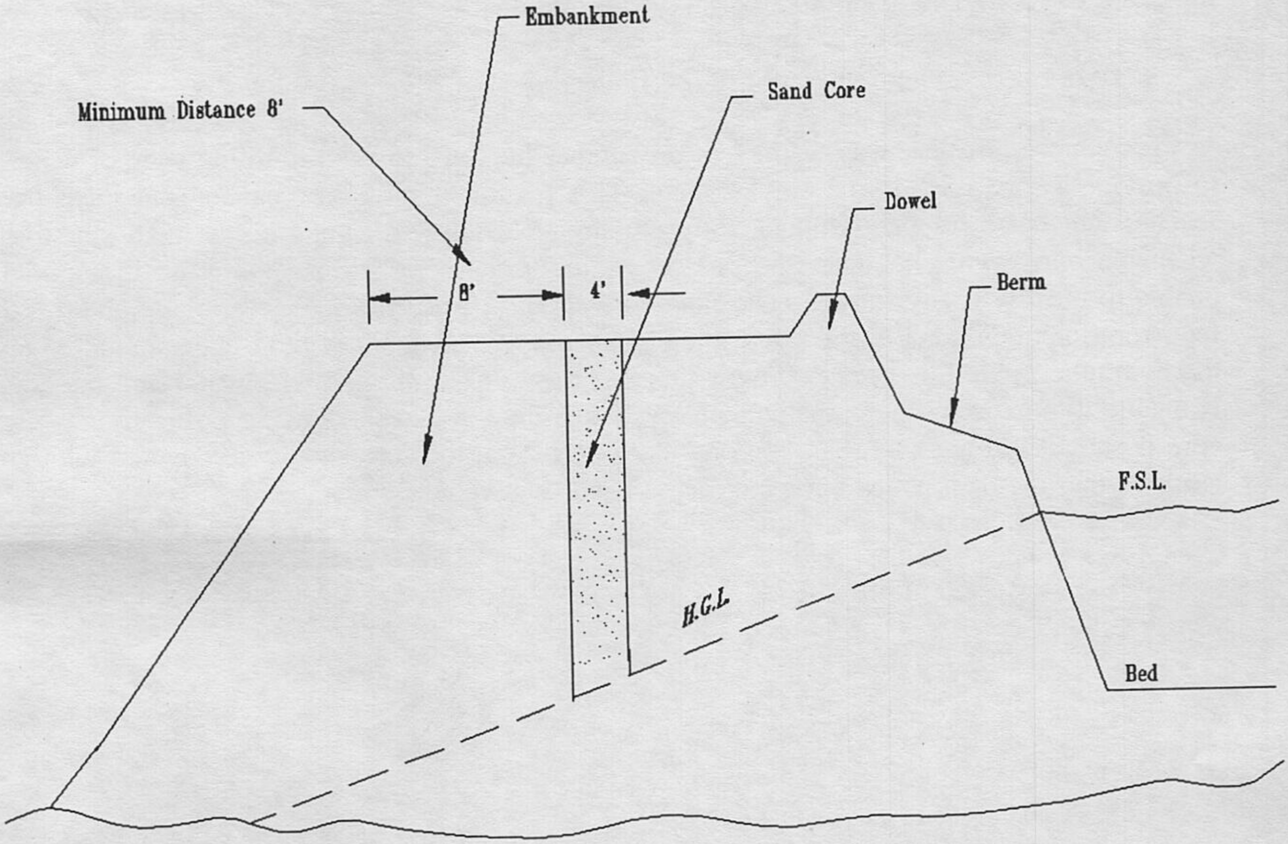
Another rodent which is very dangerous for canal embankments is the porcupine (called Shakur in Pashto). The face of this rodent is like a hare but it has very long needles on its body. It makes very wide burrows in the canal embankments in search of tender plant roots which are its favorite food. Some times the burrows go right up to the edge of the berm and cause water leakage. This leakage develops into a breach very rapidly because the burrows are very wide and water starts gushing out with great velocity. There are certain canal reaches (generally main canals and branches) which have wide banks and are infested with this type of rodent. Unless some quick action is taken, this rodent is always a source of great danger for the canal safety. Even some lined channels have collapsed due to the burrows reaching right up to the lining. The following actions are recommended to combat the menace of this rodent.

(A) Killing by Shooting Porcupines with Guns or Rifles

Porcupines remain hidden in the burrows during the day and come out at night. Gunmen should be engaged for the reaches which are habituated by porcupines. They should be provided with search lights to track down the rodents at night and shoot them as soon as they come out in search of food. This method is partially successful.

(B) Providing Sand Core in the Embankment

A more effective way to prevent porcupines burrowing right up to the edge of water, is to provide a sand core in the embankment. This treatment should be carried out in the canal reaches which are frequently attacked by porcupines. The sand should be perfectly dry so that when the burrow reaches near the sand core, the sand starts falling down and the animal is unable to burrow it any further. The sand core should be at least 4 feet wide and about 6 to 8 feet from the outer edge of the top of the embankment. The depth of the trench should be up to the hydraulic grade line because below this line the soil is saturated with water and the animal is unable to burrow in the embankment below this line. A sketch showing position of the sand core is shown in Fig. VI-1. The top one foot of the sand toe core should be covered with good earth so that the banks remain in motorable condition.



Sandcore in the Embankment to Stop Borrowing
by Porcupines
Fig. VI-1

(Not to scale)

PART 4

CANAL STRUCTURES

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CHAPTER 1

CANAL STRUCTURES

1.1 GENERAL

The maintenance of canal structures is as important as the maintenance of embankments. Any mishap with a structure, particularly on the main canal or branch, can result in an unscheduled closure of the canal. This can cause immense damage to crops. Structure repair is a time consuming process and, therefore, the closure of the canal may be a prolonged one. If the field conditions permit, the structure is often by-passed to restore supplies in the canal as early as possible.

1.2 PERFORMANCE STANDARDS FOR STRUCTURAL MAINTENANCE.

The following performance standards should be observed for the maintenance of canal structures :

A. All water control structures must meet the conditions specified on the as-built drawings and/or modified by subsequent authorized change orders and marked appropriately on the drawings. Design drawings can be substituted for as-built drawings but should be field verified and all important deviations so marked.

B. All structures must be maintained in good condition with no loose or missing bricks, rocks, open cracks or other defects. Deferred repairs period should not exceed one year.

C. All gates must be fully operational throughout the normal range of operation.

D. All cross regulators are required to have a full set of stop logs at the site at all times.

E. All mechanical equipment and miscellaneous metal work must be protected against corrosion.

F. All mechanical equipment must be lubricated in accordance with manufacturer's instructions or as otherwise specified.

G. All safety devices must be in place and in proper working condition. Bridge railing is a safety device.

H. Gate seals must be in place and complete. Leakage around seals should be minimal and not through the seal.

I. Downstream areas of all water control structures and bridges must be protected from scour; both bank erosion and bed scour should be controlled by brick/stone pitching.

J. All structures and facilities used for water measurement should have complete calibration, establishing the stage-discharge relation available. In addition, the annual re-calibration check should be made to verify the correctness of the stage-discharge relation.

K. The staff gauge(s) located at each water measuring station or facility must be in a readable condition at all times.

L. Structures must be kept free of floating trash either manually or by mechanical means.

M. Canal freeboard standards must be observed at all structures.

N. Location of structures on all channels should be written with paint.

O. On important structures, R.L's should be written to serve as bench marks.

1.3 INSPECTIONS.

Great emphasis should be placed on periodic inspection of structures to keep them in proper state of repair. The primary function of inspections is to locate any potential problems so that timely action for preventive maintenance can be taken before it becomes more costly. A closer inspection of structures is possible during the annual closure of the canal. The following points should be particularly noted :

A. Condition of masonry: damaged, cracked or loose masonry should be noted. Repairs should be scheduled and completed prior to re-opening of canal.

B. Condition of upstream and downstream structural back fill: leakages and piping action should be noted. Repairs to piping action, if considered necessary, should not be deferred.

C. Sediment deposition in the gauge wells should be noted and cleared.

D. Check free board at the site of structure particularly where there is cattle trespass.

E. Scour in bed and on the side of falls and regulators should be checked and controlled. Well-type falls may be dewatered in every closure period to check the condition of floor.

F. Condition of gates at the regulators, and greasing of gates should be checked. Gates requiring painting should be noted. Condition of lower portion of gates which remains under water should be particularly noted. A check sheet for gates and gate hoists is shown in Exhibit-IV-1.

1.4 REASONS FOR DETERIORATION OF AND DAMAGE TO CANAL STRUCTURES.

A. The major cause of deterioration is that proper and timely attention is not paid to preventive maintenance.

B. Canal structures seldom fail except for piping and scour.

C. Dry brick/stone pitching downstream of falls and regulators can be damaged due to inadequate stilling of flow and subsequently eddy action will slowly erode the earth behind the pitching.

D. Tractor trollies passing over the bridges can bump the parapets and damage their corners.

E. Downstream portions of syphons are seldom inspected to remove any obstructions or weed growth which obstructs the flow of water.

F. Cross drainage works are mini weirs and proper attention is not paid to the maintenance of the downstream portions of these works.

CHAPTER 2

TYPES OF CANAL STRUCTURES

2.0 TUNNELS

Where a canal is in deep cut such as hills or unstable slopes, construction of a tunnel is justified on the basis of economy, low maintenance costs and safety of operation. A tunnel is also the most economical means for carrying water from one watershed to another. Such tunnels have either free flow or work as closed conduits. They are lined with concrete or stone. An example of this structure is the Benton Tunnel constructed on the Upper Swat Canal. This canal runs for 4 miles in the Swat valley and then passes through the Malakand Range of hills in a tunnel with a length of 2.25 miles. It has a cross sectional area of 216 sq.ft. and a bed slope of 1 in 215. From the south portal, i.e., the exit of the tunnel, the canal opens in Dargai Nala and runs in to the power house at Dargai.

2.1 CROSS DRAINAGE WORKS

A. Level Crossings

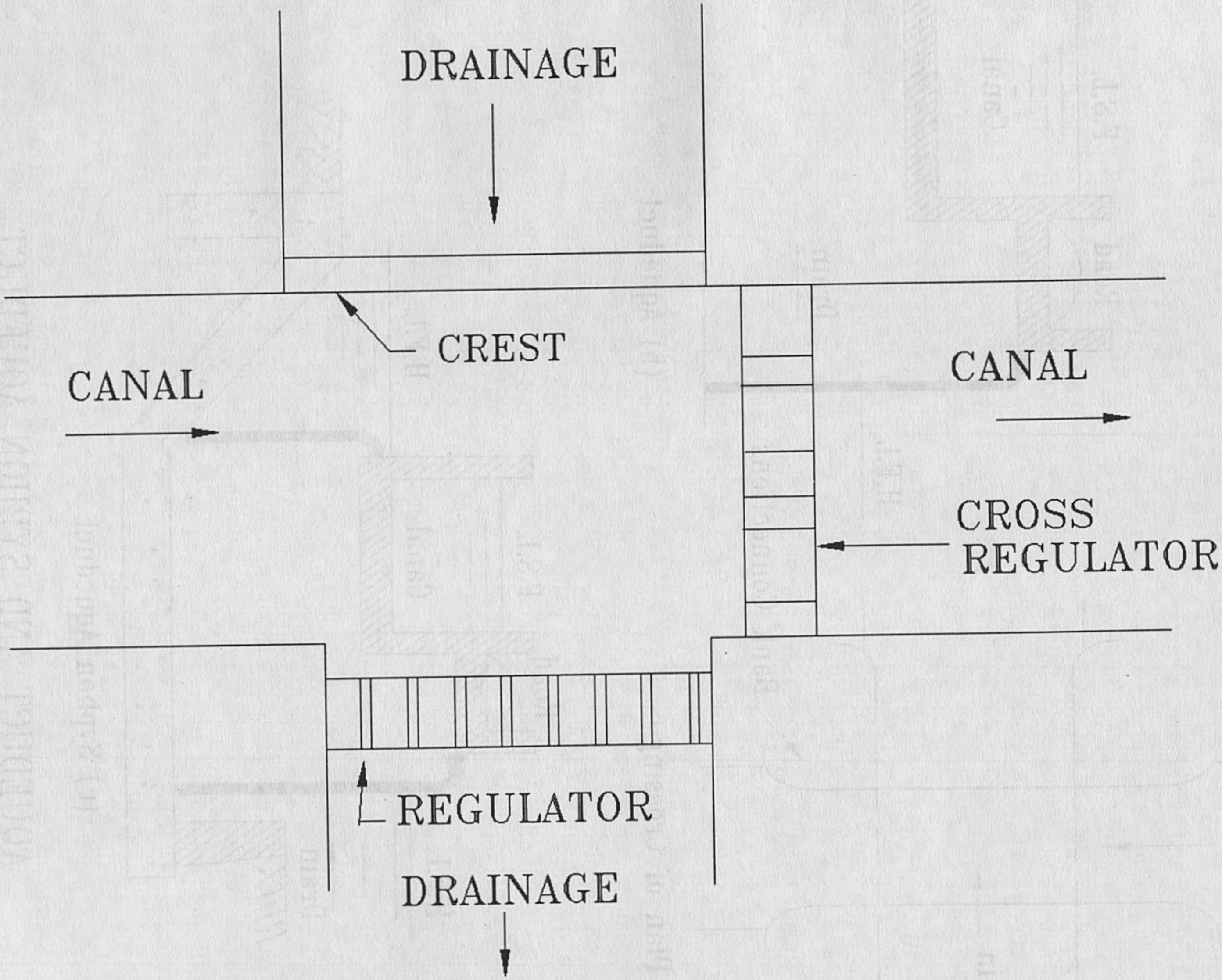
When a canal runs at the foot of hills, a number of streams coming down from the hills cross the canal. If the level of water in the stream is almost the same as of canal, a structure is constructed on the canal to cross the water of the stream. Such a structure is called a level crossing. In fact it is a mini weir which regulates the flow of the stream and canal. The canal is run with a full supply discharge and the excess water coming in the stream is passed downstream in it. A sketch of a level crossing is shown in Fig.II-1. An example of such crossings in the NWFP are in the Chashma Right Bank Canal.

B. Aqueduct

Sometimes streams or drains cross irrigation channels or water courses. Water has to be carried across such natural or artificial drainage in open rectangular concrete troughs supported on piers. Such structures are called aqueducts. With the construction of drains, a large number of water courses are crossed by them. At all such crossings, water has to be carried across the drains through aqueducts. A sketch of such an aqueduct crossing is shown in Fig II-2. Sometimes a canal is carried over a drain or stream in an aqueduct.

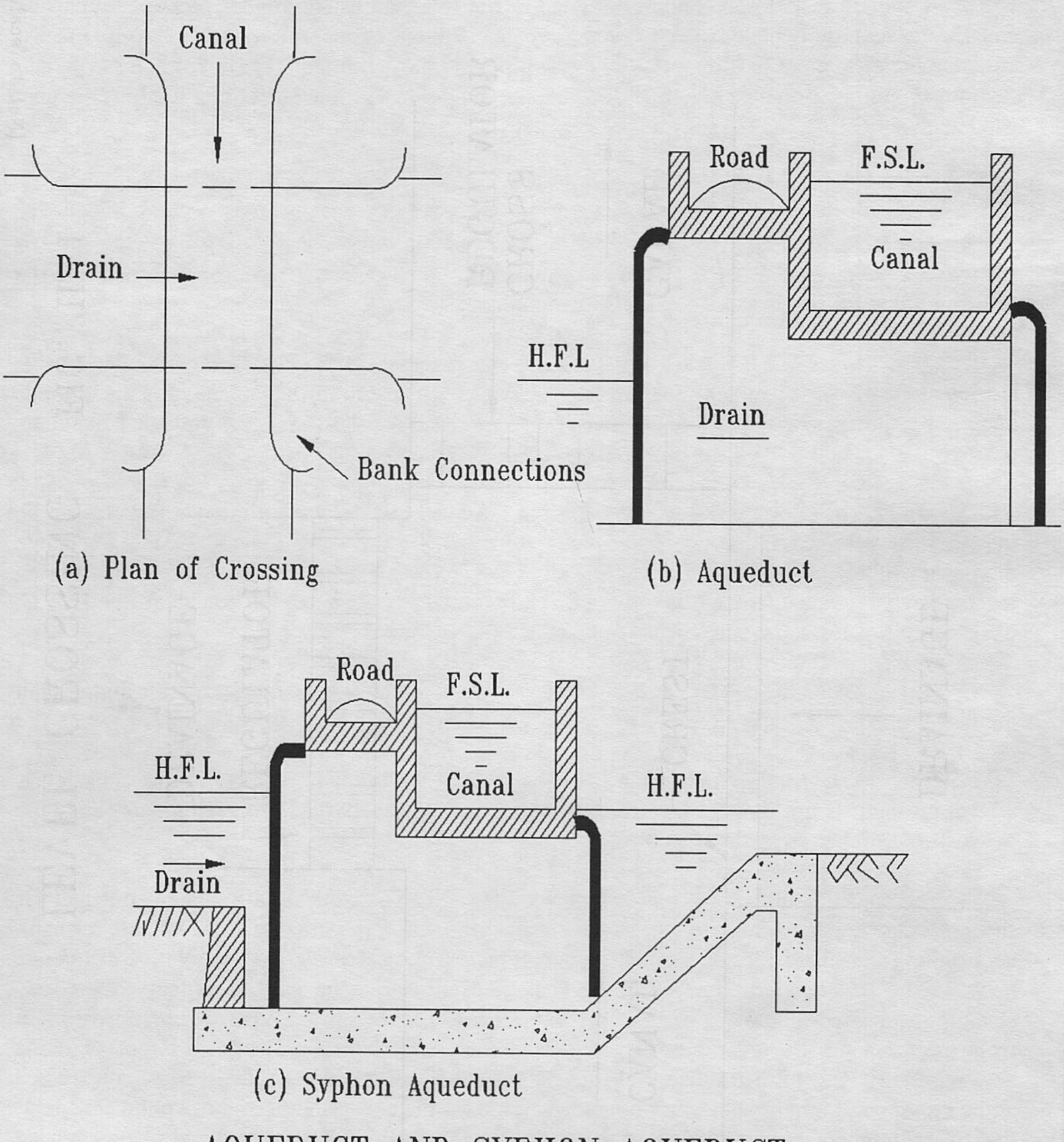
C. Super Passage

When a canal runs freely or through a syphon under a stream or a drain, the over passing structure is called a super passage. The advantage of this cross drainage work is that the canal would be in very high filling if carried as an aqueduct. Its earthwork would be liable to damage. However, in case of a syphon, the disadvantage is that inspection of a perennial canal is difficult. A sketch of this type of structure is shown in Fig II-3.



LEVEL CROSSING FIG. II-1

(Not to scale)



AQUEDUCT AND SYPHON AQUEDUCT

FIG.II-2

(Not to scale)

D. **Syphon**

A syphon is a closed conduit designed to run full, and usually under pressure. it carries canal water by gravity under rivers, drainage channels, depressions, rail roads and roads. Precast concrete pressure pipes or monolithic concrete pipes are most common types of circular syphons. A drain syphon is shown in Fig.II-3. Rectangular single or multiple barrel box sections are also used as syphons.

E. **Consideration for selection of suitable type of cross drainage work**

The factors which affect the selection of a suitable type of cross drainage work are: (i) relative bed levels and water levels of the canal and drainage, and (ii) size of the canal and the drainage. The following considerations are important :

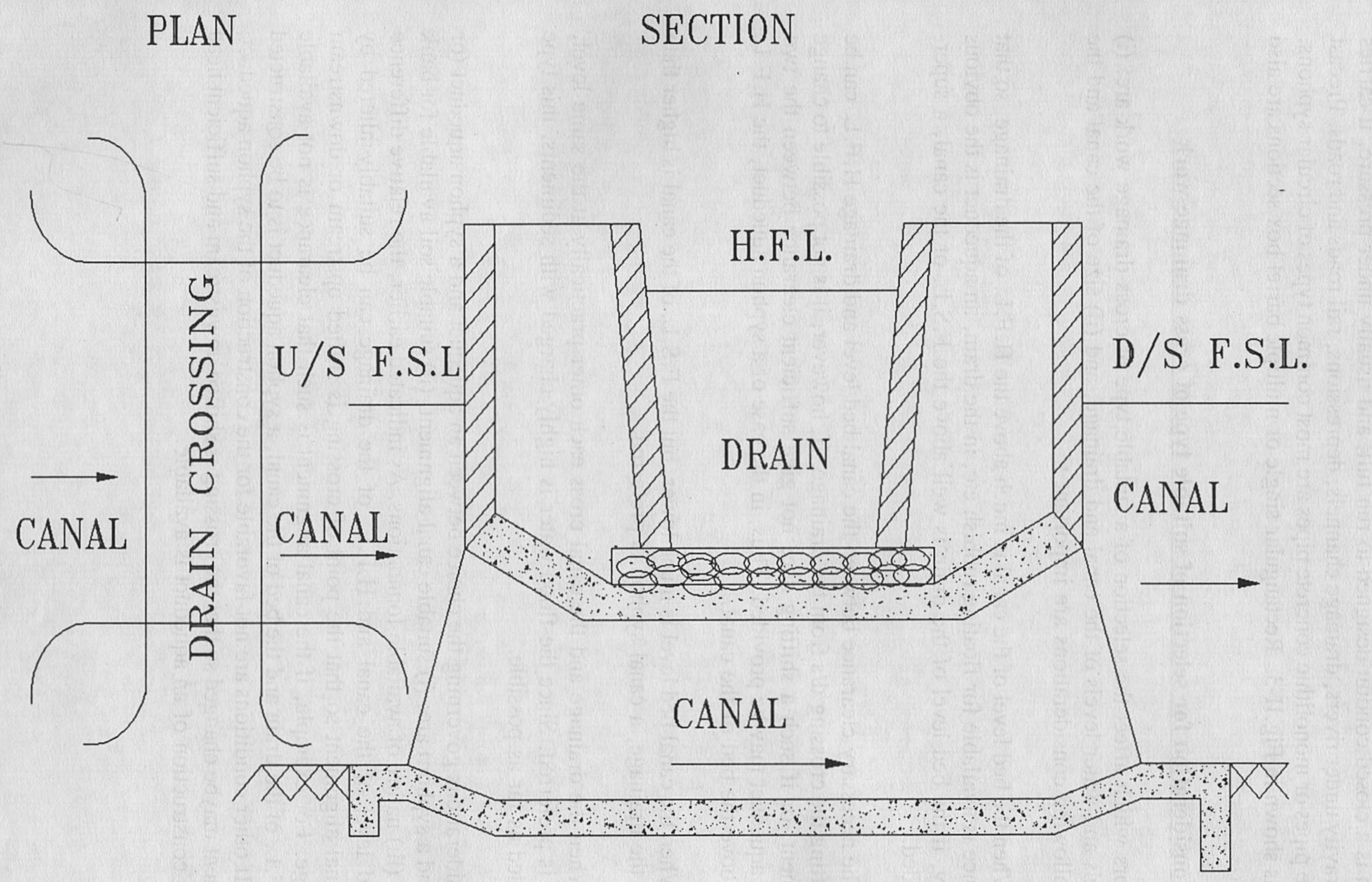
(i) When the bed level of the canal is much above the H.F.L. of the drainage, so that sufficient clearance is available for floating rubbish etc, in the drain, an aqueduct is the obvious choice. Similarly, if the bed level of the drain is well above the F.S.L. of the canal, a super-passage is provided.

(ii) The necessary clearance between the canal bed level and drainage H.F.L. can be increased by shifting the crossing d/s from the drainage. If, however, it is not possible to change the canal alignment, or if such a shifting does not give sufficient clearance between the two levels, a syphon aqueduct may be provided. Thus, in the case of a syphon aqueduct, the H.F.L. of the drain is above the bed of the canal.

(iii) When the canal bed level is much lower, but the F.S.L. of the canal is higher than the bed level of the drainage, a canal syphon is preferred.

(iv) When the drainage and the canal cross each other practically at the same level, a level crossing is preferred. Since the flood water is highly charged with sediments, this type of work is avoided as far as possible.

The considerations governing the choice between an aqueduct and a syphon aqueduct (or super-passage and a syphon) are; (i) suitable canal alignment, (ii) suitable soil available for bank connections and (iii) nature of available foundations. As indicated earlier, the relative difference between the bed level of the canal and H.F.L. of the drainage can be suitably altered by changing the canal alignment so that the point of crossing is shifted upstream or downstream from the drainage. For example, if the canal alignment is such that clearance is not available between the H.F.L. of the drain and the bed of the canal, a syphon aqueduct is to be constructed at the crossing. If other conditions are not favorable for the construction of the syphon aqueduct, the canal alignment maybe changed so that the crossing is shifted downstream and sufficient head required for the construction of an aqueduct is available.



SUPER PASSAGE AND SYPHON

FIG. II-3

(Not to scale)

2.2 FALLS.

A fall is an irrigation structure constructed across the canal to drop the water level and dissipate surplus energy liberated from the falling water which may otherwise scour the bed or erode the canal banks.

The canal water level is designed with a certain slope to overcome frictional losses. In the NWFP, the general slope of the area which is irrigated by the canal is much steeper than the water surface slope of the canal. Thus the divergence between the gentle slope of the canal water and steeper ground surface slope throws the canal in filling, although it starts at the head in cutting. To avoid heavy and uneconomical filling, falls are introduced at appropriate places. In the NWFP, most of the channels have numerous falls at short intervals. Thus the difference in water level of a channel at the head and at the tail is often very large.

In the NWFP there are generally two types of falls. One type is with the usual glacis in which the dissipation of energy takes place with hydraulic jump and standing wave. This type is shown in Fig.II-4. The other one is the well type in which the water falls into a well and energy is dissipated in the standing pool of water in the well. This type is shown in Fig.II-5.

2.3 ESCAPES.

On main canals, regulator type structures called escapes are constructed for diverting excess water. There are three types of escapes :

(A) Canal scouring escape
(B) Surplus water escape
(C) Tail escape

The scouring escape is constructed for the purpose of scouring off excess silt from the canal. Surplus escapes are used during emergencies to reduce water supplies in the downstream portion of the canal. In such cases the escape acts as a safety valve. The capacity of escape channel should not be less than half the capacity of the parent canal. A tail escape is provided at the tail end of the canal and is used for :

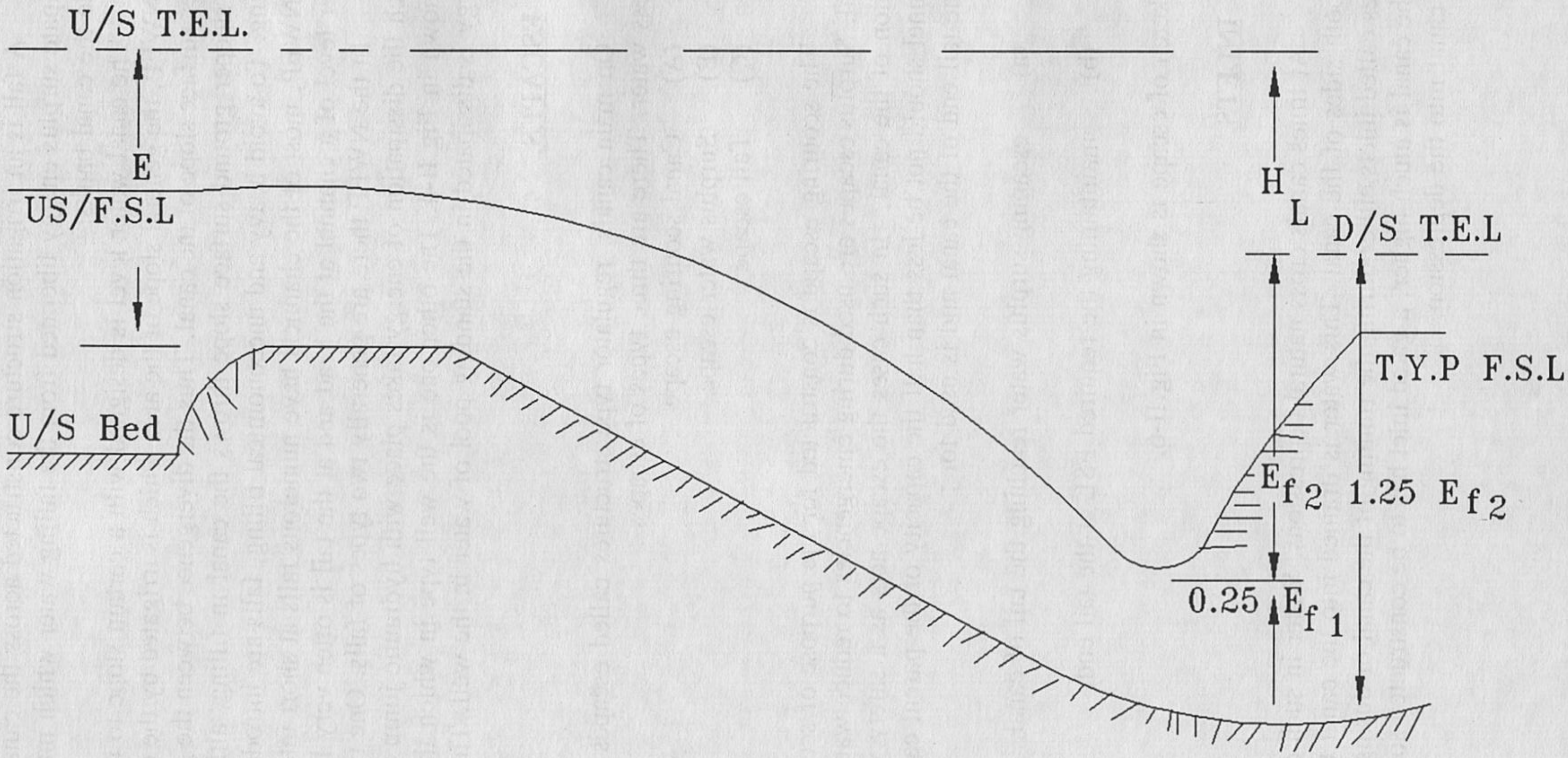
(a) escaping surplus water reaching the tail of canal.

(b) maintaining the required FSL at the tail end.

A sketch of escape is shown in Fig.II-6.

2.4 INLETS.

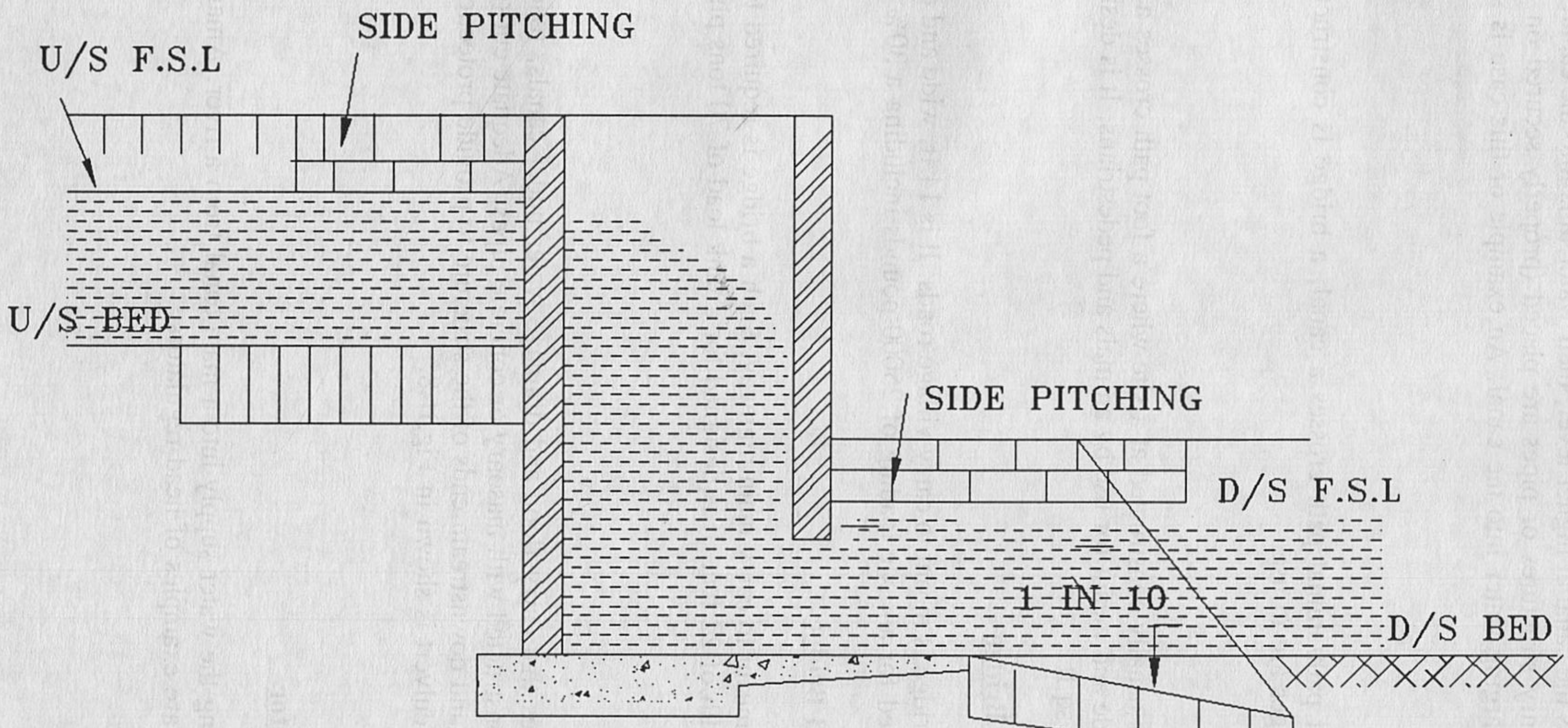
At times canals cross natural depressions. Water in such depressions gets stored on one or both sides of the canal. This water is drained into the canal through masonry structures or pipes called inlets either during the running of the canal or during its closure. If the water level in the canal is much higher, a gated inlet has to be constructed so that water does not flow from the canal into the depression.



TYPICAL SECTION OF FALL

FIG.II-4

(Not to scale)



WELL FALL

FIG.II–5

(Not to scale)

Inlets into a canal are also provided for another situation. If a canal runs at the foot of a hill (such a canal provides irrigation on one side only and is called contour channel) and number of small streams cross the canal at higher level, their water falls into the canal. In order to avoid bank erosion, masonry structures or pipes are placed (properly secured on masonry walls) at such sites for discharging water into the canal. An example of this case is shown in Fig.II-7.

2.5 BRIDGES.

Where a road or foot path/animal path crosses a canal, a bridge is constructed. The following three types of bridges are in use.

A. Foot Bridge

This type of Bridge is usually constructed at a site where a foot path crosses a canal. It is a narrow bridge, 4 feet wide and meant for use by animals and pedestrians. It is designed for a loading of 100 pounds per sq.ft.

B. Village Road Bridge

This type of bridge is meant to carry village roads. It is 14 ft. wide and can carry vehicular traffic. It is designed for an axle loading of 25000 pounds including a 30% impact.

C. Arterial Road Bridge

An arterial bridge is meant to carry main highway. Such a bridge is required to carry a two lane highway with a width of 22 feet. It is designed for a tank load of 70 tons plus a 30% impact.

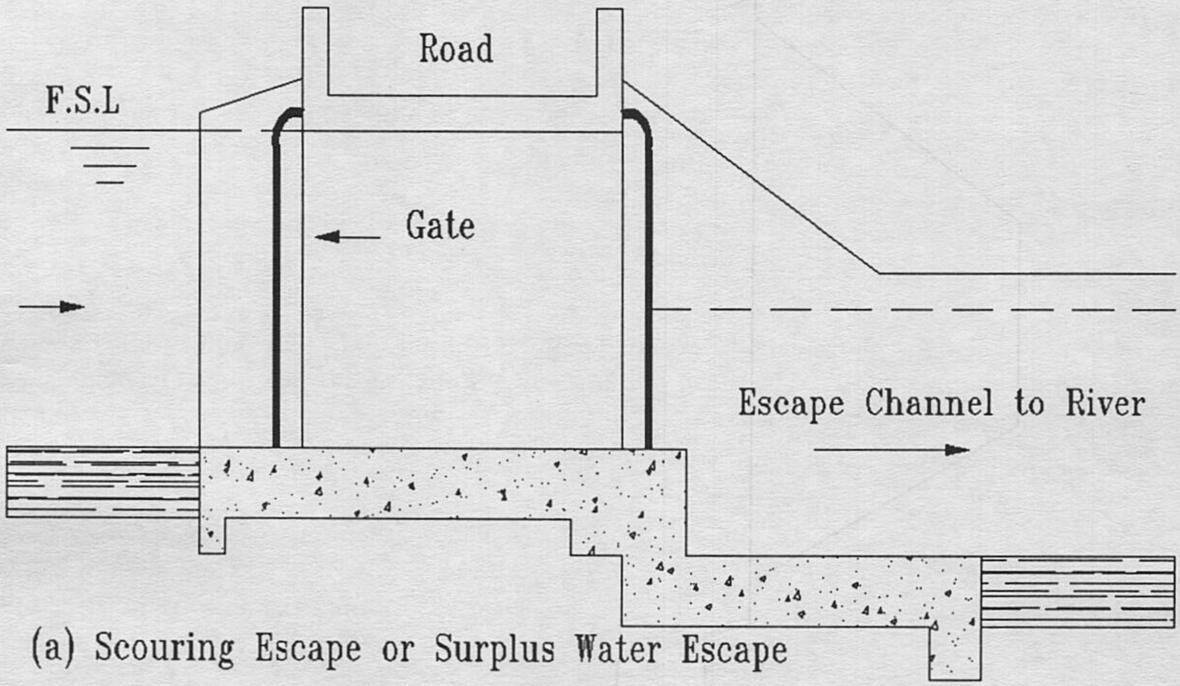
2.6 CULVERTS.

Culverts are structures that carry flood and drainage water under canals, roads or rail roads. They are generally constructed with masonry or concrete pipes. Adequate cut-off should be provided at the upstream and downstream ends of the structure to provide protection against scour. A plan for a railway culvert is shown in Fig.II-8.

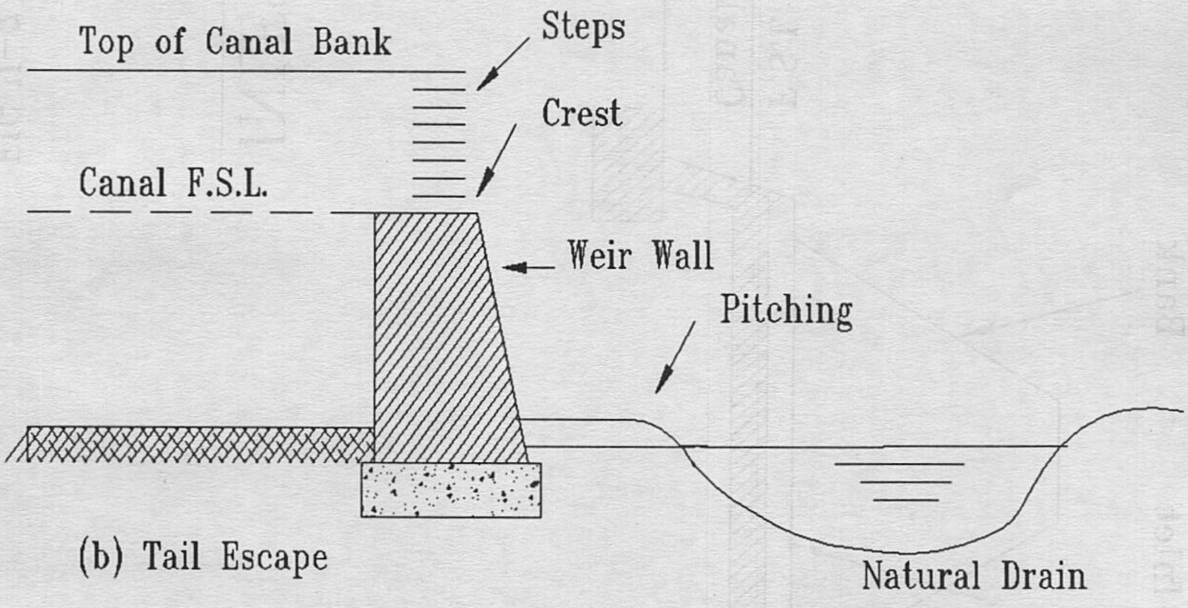
2.7 REGULATORS.

A. Head Regulator

A regulator controlling the water supply into a main canal from a river. Amandara and Munda Headworks in Swat are examples of head regulators.



(a) Scouring Escape or Surplus Water Escape

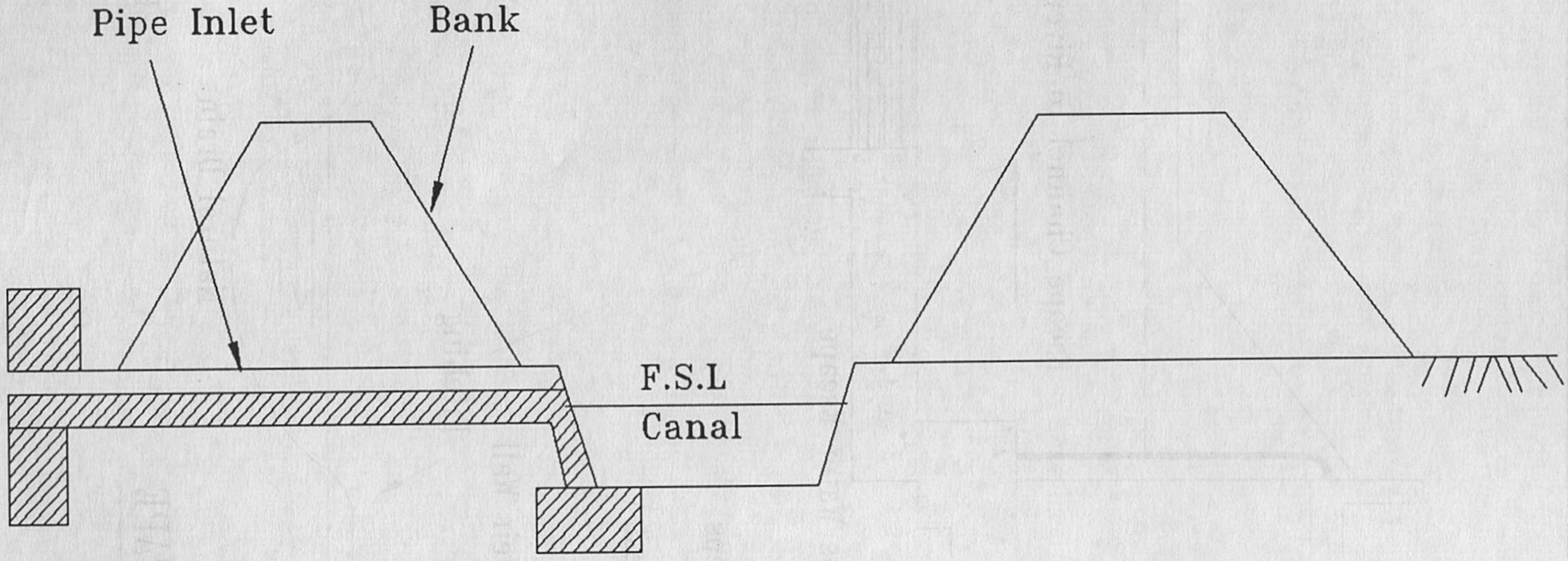


(b) Tail Escape

CANAL ESCAPE

Fig.II-6

(Not to scale)



INLET

FIG.II-7

(Not to scale)

B. **Cross-Regulator**

A regulator on a main canal where heading up of the water level is accomplished by gates, karries or needles to feed off-taking channels is called a cross-regulator.

C. **Proportionate Regulator**

This regulator is an unmanned regulator. At this structure, the crest of the parent and off-taking channel is at the same level. The incoming flow is distributed in proportion to the cross section of the channel. Such a regulator is used for feeding distributaries and minors.

2.8 SILT CONTROL STRUCTURES.

A. **Silt Excluder**

This structure is a device by which silt is excluded from water entering a canal. It is constructed in the river bed in front of canal head regulator. An example of this structure is shown in Fig.II-9.

B. **Silt Ejector**

With this type of structure, silt (which has already entered the canal) is extracted and thrown back into the river. It is constructed on the canal at some distance away from the head regulator. An example of this structure is shown in Fig.II-10. The structure consists of a horizontal diaphragm placed slightly above the canal bed. The canal bed is slightly depressed below the diaphragm so that the height of the silt tunnel below the diaphragm is about 2.5 ft. The diaphragm thus separates top layer of canal water from the bottom layer (containing a heavier silt charge). The escape channel from the silt ejector is given a steeper slope so that the silt is discharged back into the river.

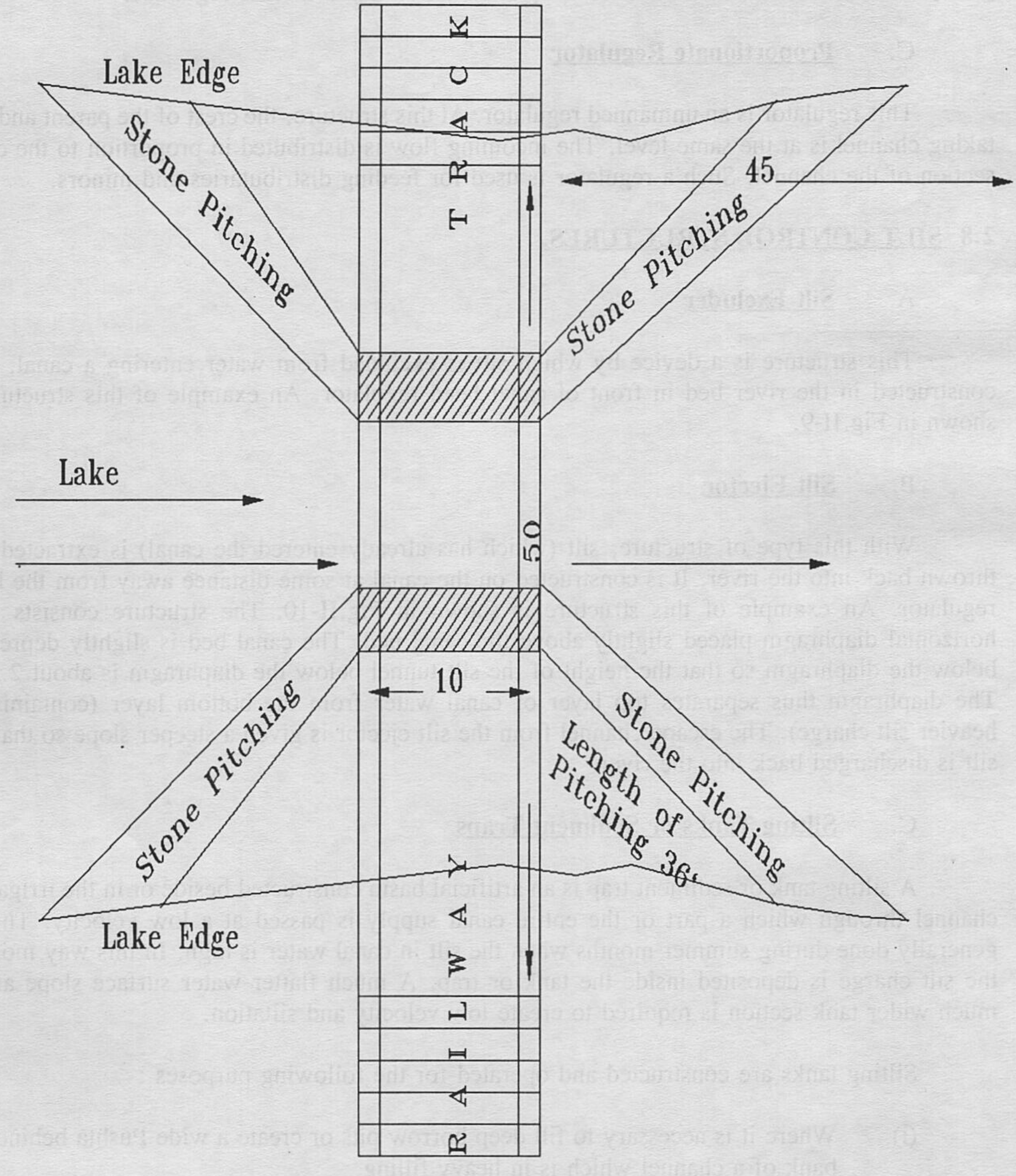
C. **Silting Tanks or Sediment Traps**

A silting tank or sediment trap is an artificial basin constructed beside or in the irrigation channel through which a part or the entire canal supply is passed at a low velocity. This is generally done during summer months when the silt in canal water is high. In this way most of the silt charge is deposited inside the tank or trap. A much flatter water surface slope and a much wider tank section is required to create low velocity and siltation.

Silting tanks are constructed and operated for the following purposes :

(i) Where it is necessary to fill deep borrow pits or create a wide Pushta behind the bank of a channel which is in heavy filling.

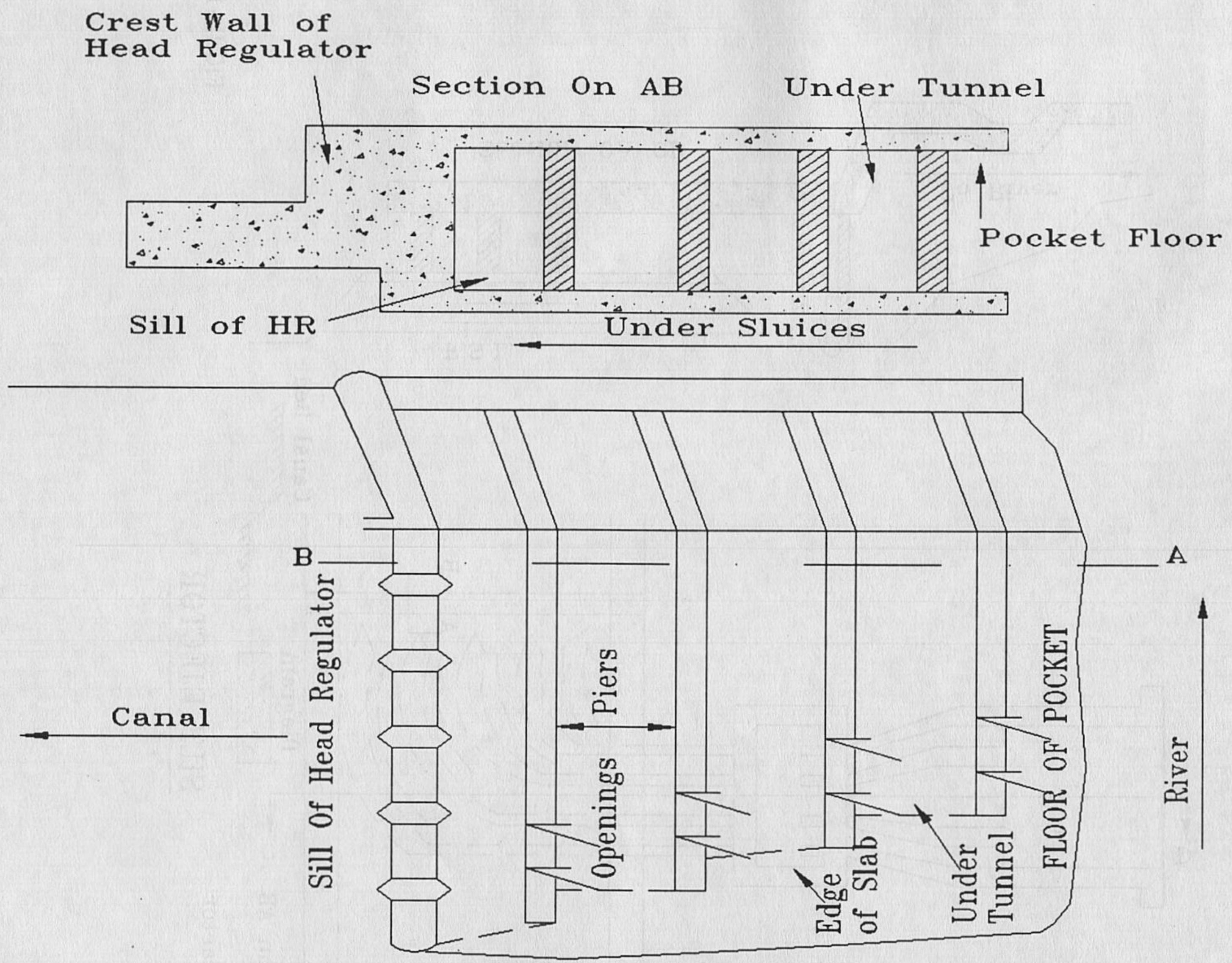
(ii) For desilting of canals, i.e., removing injurious silt charge from the irrigation channels.



PLAN OF RAILWAY CULVERT

FIG.II-8

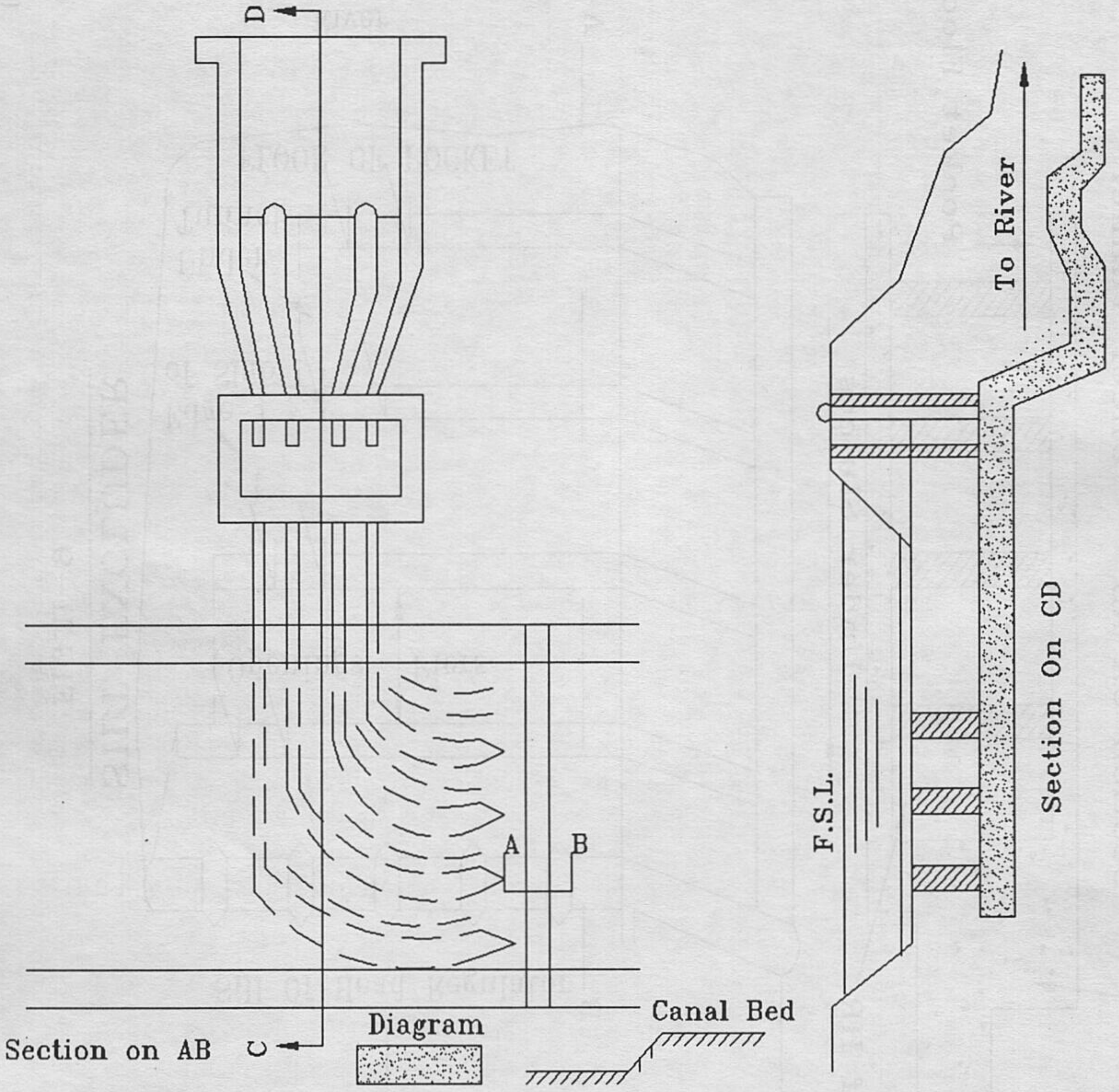
(Not to scale)



SILT EXCLUDER

FIG.II–9

(Not to scale)



SILT EJECTOR

FIG.II-10

(Not to scale)

(iii) Reclamation of low lying and water logged areas situated along the canals in order to make the area fit for cultivation.

There are three types of silting tanks as discussed below :

a. <u>Outside Silting Tanks</u>

In this type a silting tank is constructed outside the channel and along one of its sides. A typical layout of this type is shown in Fig II-11. The advantage of this tank type is that its construction and subsequently its silt clearance is independent of the canal operation. In this type, part or the entire channel discharge can be passed through the silting tank.

b. <u>Ditch Type Silting Tank</u>

In this tank type, a deep ditch is excavated in the canal bed. The width of the ditch is equal to the width of the channel and its length is determined by the amount of sediment to be deposited each year. This type of tank is shown in Fig II-12. Channel closure is required for construction and silt clearance of ditch type tank. In this type of tank the channel water level and the discharge of any outlet located in the silting tank is adversely effected. No inlets and outlets are required for this tank type.

c. <u>Wide Channel Silting Tank</u>

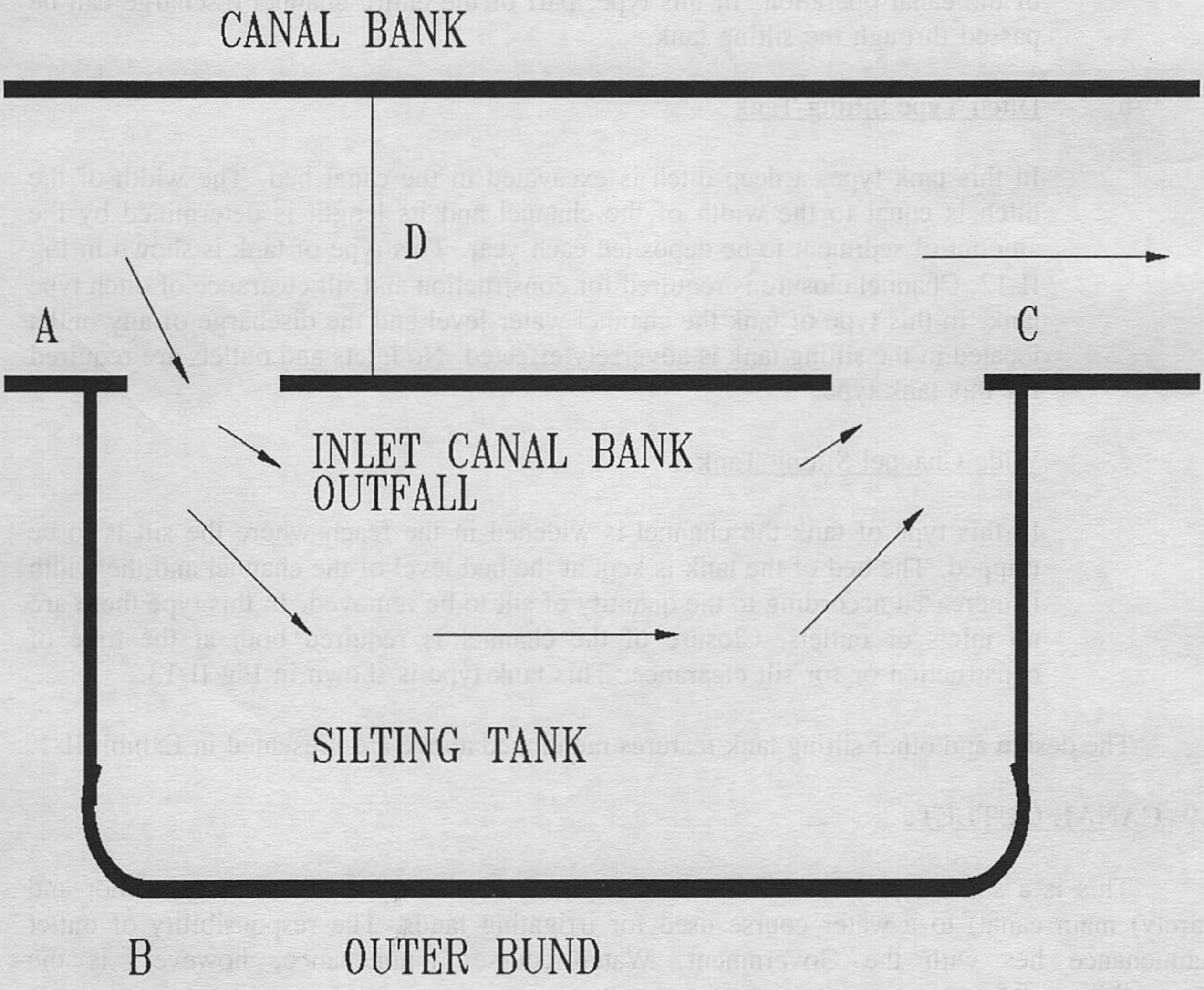
In this type of tank the channel is widened in the reach where the silt is to be trapped. The bed of the tank is kept at the bed level of the channel and the width is increased according to the quantity of silt to be removed. In this type there are no inlets or outlets. Closure of the channel is required both at the time of construction or for silt clearance. This tank type is shown in Fig II-13.

The design and other silting tank features mentioned above are presented in Exhibit II-1.

2.9 CANAL OUTLET.

This is a small structure which diverts water from the canal (distributary, minor and (rarely) main canal) to a water course used for irrigating lands. The responsibility of outlet maintenance lies with the Government. Water courses maintenance, however, is the responsibility of farmers.

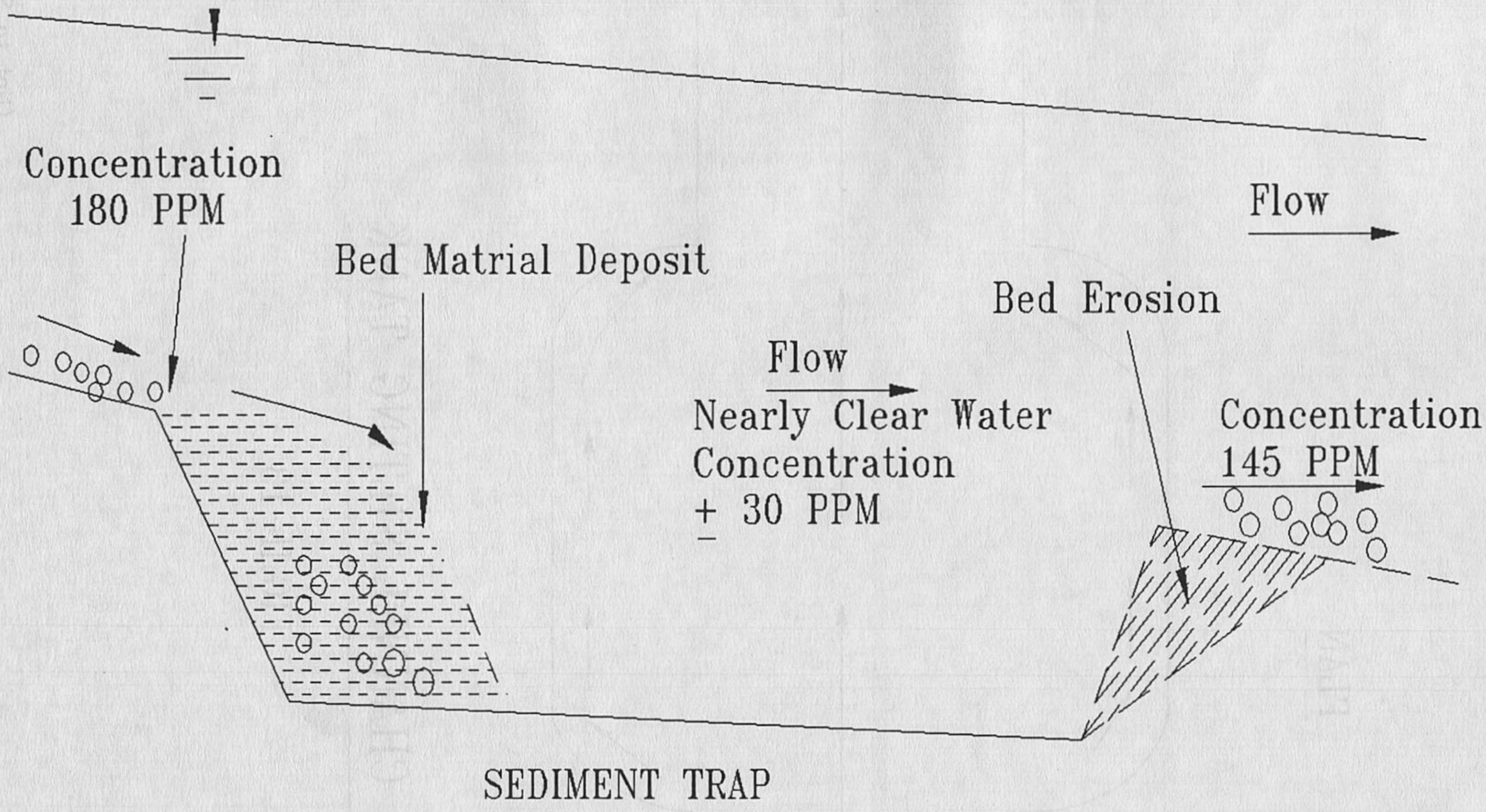
COMPONENT PARTS OF A SILTING TANK



NOTE:- BUND OR REGULATOR (D) ACROSS THE CANAL MAY OR MAY NOT BE NECESSARY

FIG. II-11

(Not to Scale)

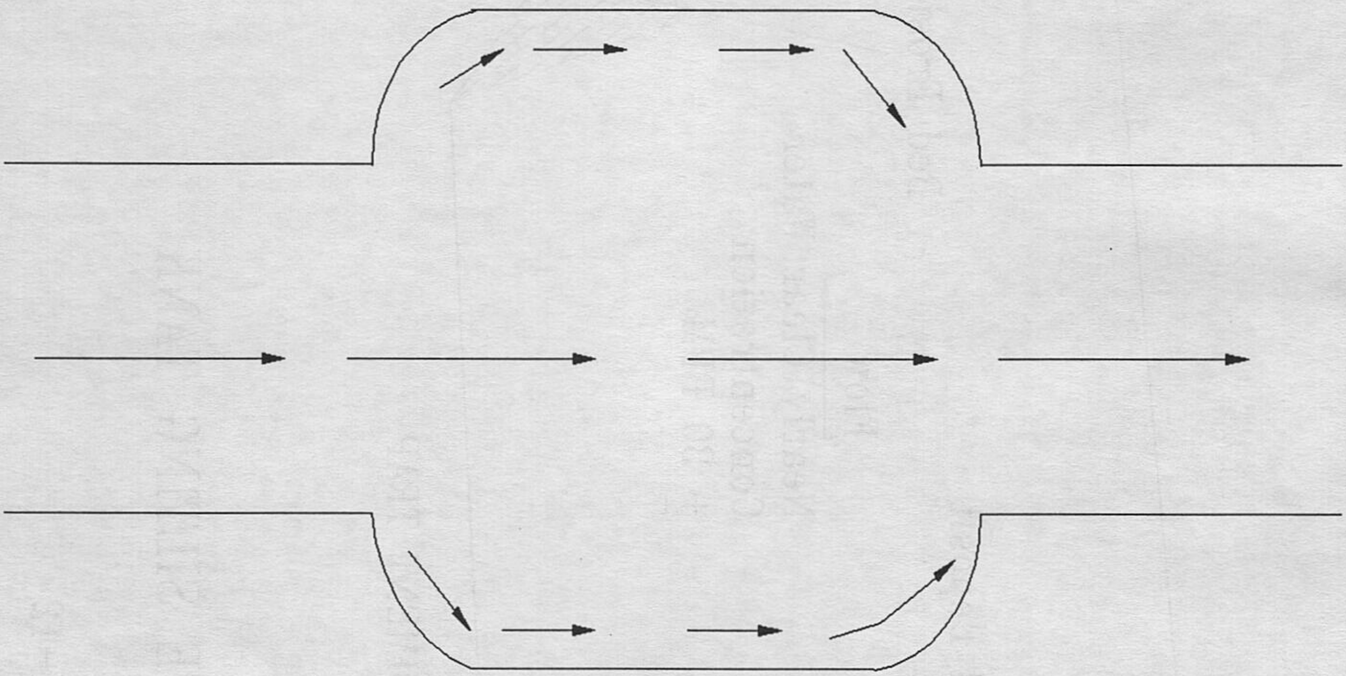


DITCH TYPE SILTING TANK

FIG.II-12

(Not to Scale)

PLAN



WIDE CHANNEL SILTING TANK

FIG.II-13

(Not to Scale)

EXHIBIT II-1

DESIGN FEATURES OF SILTING TANKS

These design features relate to the silting tanks constructed outside the channel. Design features of this silting tank type are discussed below :

1. Head Across Inlet

The inlet head for a silting tank in the case of a canal or branch should not be less than 0.5 ft under a full supply condition. If the water surface slope in the canal from inlet to outlet is not sufficient, water may have to be headed up by putting a bund or a regulator across the canal downstream from the inlet site. A head regulator or a canal fall may be used for this purpose.

2. Water Surface in the Tank

The water surface slope in the silting tank is usually flat on the order of 0.05 feet per thousand. This slope should be measured along the outer bund ABC (in Fig. II-11) and not directly from A to C.

3. Angle of Inlets and Outlets

For small channels, inlets and outlets are generally kachha. The openings for inlets and outlets should be placed at an angle of 45 degrees to the center line of the channel because square openings are likely to silt up easily. The position of an inlet in the case of silting tanks works on an "in and out" system and must be moved periodically, because the deposit of silt in such silting tanks reaches a certain maximum level at the inlet end, gradually diminishing towards the out fall end; no further silting up can take place unless the position of the inlet is moved downstream. It is necessary to close an inlet after working it for a period of a few weeks depending upon the silt charge in the water, and to open up another inlet a few feet downstream until the silting operations are completed.

4. Outer Bund

All possible care should be exercised in designing and constructing the outer bund of a silting tank, as a breach in it is bound to be disastrous on account of the large volume of water impounded in the silting tank. The inner slope of such bunds is usually made 1 to 2 to 1 to 3 to withstand wave action, and the bund section is designed to provide a cover of at least two feet over a hydraulic gradient of 1 to 5 to 1 to 8 depending upon the nature of the soil. The service road should be carried on top of the bund. Earthwork of the outer bund should closely follow the standard specifications for such works. When opening the silting tank for the first time, water should be let into the tank very slowly, and the inner slope of the bund should be thoroughly puddled from its toe upwards as the water level in the tank rises.

5. <u>Laying of Borrow Pits</u>

Before drawing up an estimate for earthwork in connection with a silting tank, a careful examination should be made of the area from which earth for the outer bund has to be borrowed in order to
ascertain the actual quantity of earthwork involved. Generally such areas are already waterlogged, and deep borrow pits are not feasible. If proper care is not exercised in framing the estimate, large quantities may have to be moved later. In fact, in some cases, it maybe advantageous to dig seepage drains in order to lower the water table of the area to be covered by borrow pits. This permits placement of deep borrow pits, thus reducing the lead and cost of earthwork. Borrow pits should be placed inside a silting tank. Outside borrow pits should be avoided.

6. <u>Types of Inlets</u>

Inlets are usually of the following types:

a. A kacha open cut in the canal bank having its flanks suitably protected.

b. A barrel or a large pipe placed at bed level. This is of use only in the case of small channels and small silting tanks.

c. A needle regulator without any cross regulator (D in Fig. II-11) in the canal, i.e., without control of the water surface levels in the canal. A pacca inlet has an advantage over a kacha inlet; the former can be closed immediately in an emergency.

d. A second type is the needle regulator combined with a cross regulator in the canal thus ensuring proper control of water surface levels under all conditions of canal water supply.

e. <u>Design of Pacca Inlets</u>

In designing a pacca inlet, care should be taken to provide a smooth, eddy-free "approach" and to keep the crest level of the inlet as low as possible, provided that the length of the regulator needles is not so long as to become unwieldy for manipulation. A pacca inlet is sometimes combined with silt vanes in the canal bed for greater silt induction into the silting tank.

7. <u>Types of Out falls</u>

Out falls of silting tanks are of the following two types:

(a) A <u>Katcha</u> open cut in the canal bank having its flanges suitably protected.

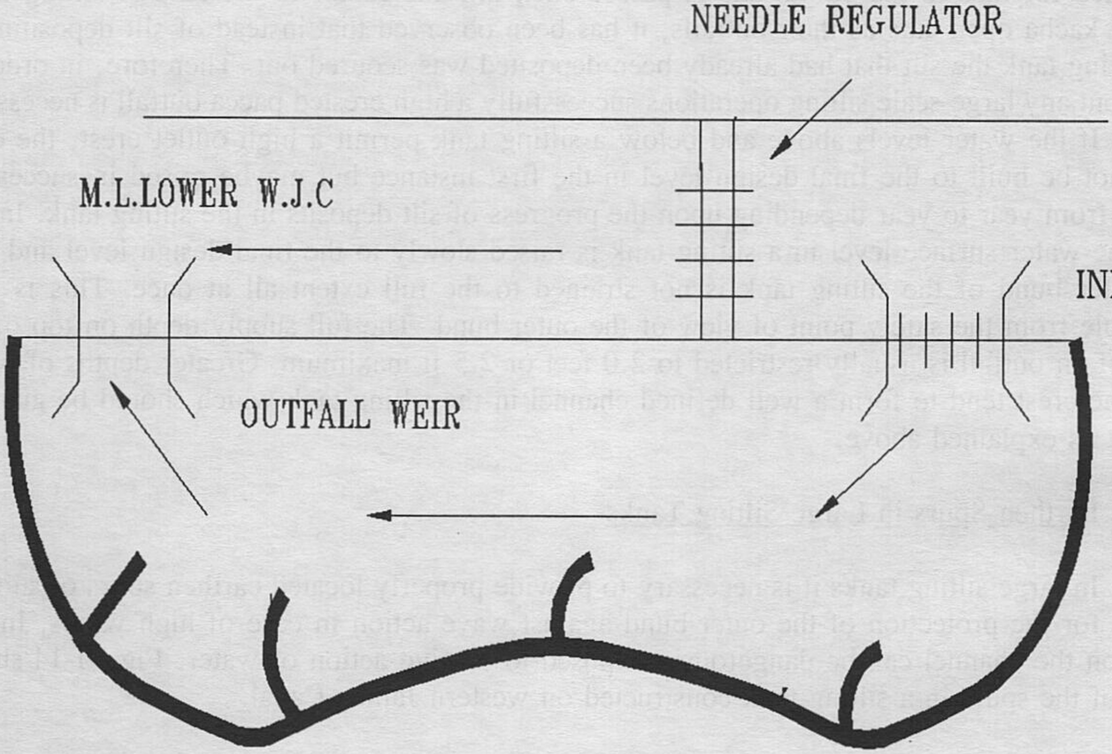
(b) A Pacca high crested weir.

A high crest is essential in order to prevent the development of a well defined and comparatively deep channel inside the silting tank from inlet to outfall which is the usual feature of the silting tanks with " kacha" open outfalls. Such a well defined channel carries a major portion of the discharge into the silting tank with the result that most of the silt in suspension is carried forward to the outfall and is passed back into the canal. In the case of silting tanks having kacha open cuts as their outfalls, it has been observed that instead of silt depositing in the silting tank the silt that had already been deposited was scoured out. Therefore, in order to carry out any large scale silting operations successfully a high crested pacca outfall is necessary.

If the water levels above and below a silting tank permit a high outlet crest, the crest need not be built to the final design level in the first instance but maybe raised in successive stages from year to year depending upon the progress of silt deposits in the silting tank. In this way the water surface level in a silting tank is raised slowly to the final design level and thus the outer bund of the silting tank is not strained to the full extent all at once. This is very desirable from the safety point of view of the outer bund. The full supply depth on top of the crest of an outfall is usually restricted to 2.0 feet or 2.5 ft maximum. Greater depths of water over the crest tend to form a well defined channel in the silting tank which should be guarded against as explained above.

8. Earthen Spurs in Large Silting Tanks

In large silting tanks it is necessary to provide properly located earthen spurs of suitable design for the protection of the outer bund against wave action in case of high winds, In this situation the channel can be dangerously exposed to erosive action of water. Fig.III-14 shows some of the spurs in a silting tank constructed on western Jamna Canal.



DIAGRAMMATIC SKETCH OF A SILTING TANK ON A CANAL

FIG.II-14

(Not to Scale)

CHAPTER 3

MAINTENANCE OF STRUCTURES

(CIVIL WORKS)

3.1 TUNNELS

The tunnel design should be such that when it is not running full, negative pressures do not develop inside the tunnel and cause damage to the concrete lining. If this aspect is observed tunnel operation will be trouble free and maintenance will be minimized. If possible, the tunnel should be inspected during the closure period. Some attention should be given to the tunnel exit. If the water coming out of the tunnel falls on natural rock, as in the case of the Benton Tunnel in the NWFP, there will be little danger of erosion.

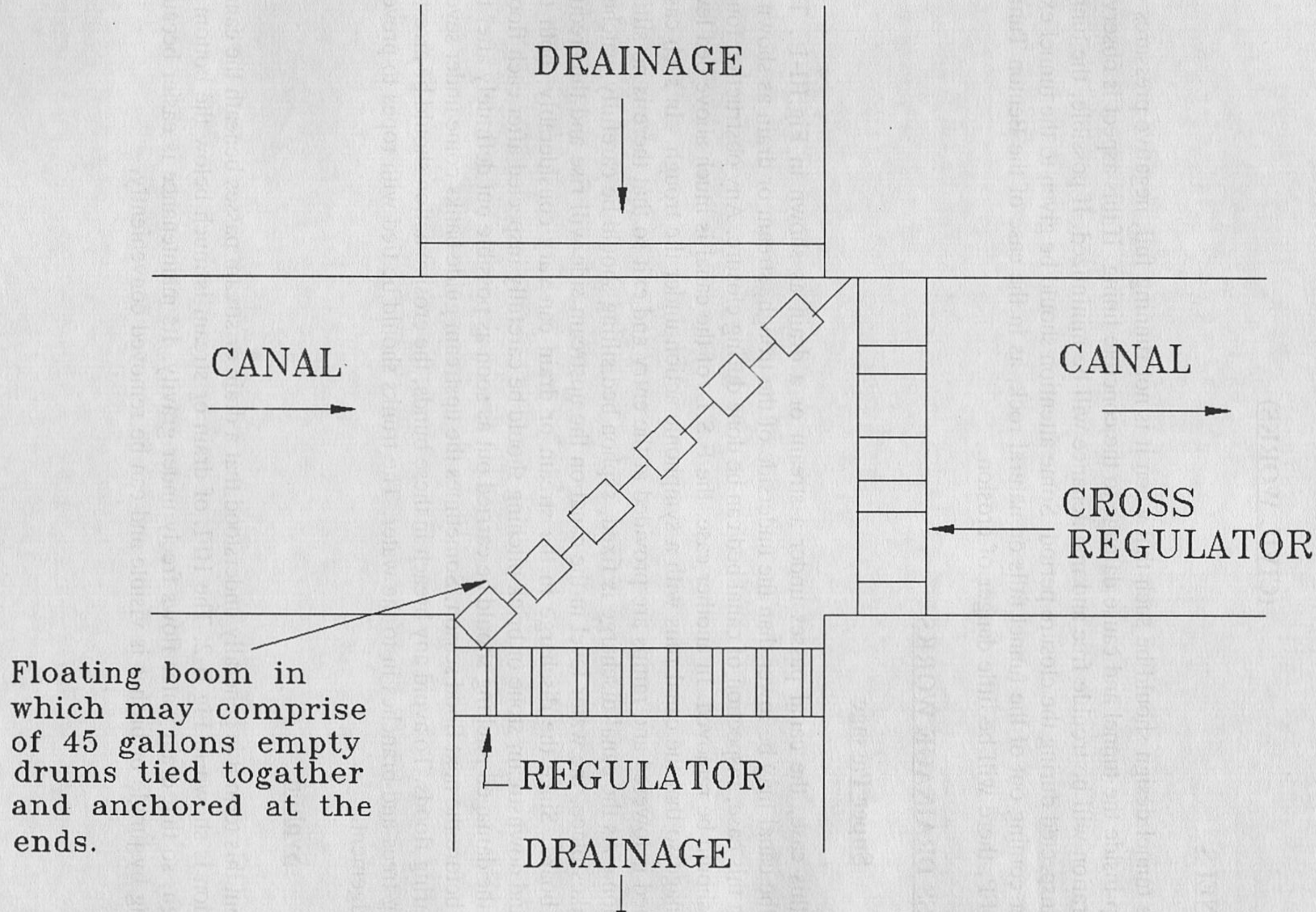
3.2 CROSS DRAINAGE WORKS

A. Super Passage

In this case, the canal passes under a stream or a drain as shown in Fig.III-1 . The F.S.L. of the canal may be lower than the underside of the trough, stream or drain as shown in Fig.II-3. In this case, inspection of canal bed can be done during closure. Any obstruction found in the bed should be removed. In another case, the F.S.L. of the canal is much above bed level of the drainage so that the canal runs with a symphonic action under the trough. In such cases the canal bed is lowered and ramps are provided at the entry and exit so that there is no silting in the syphon. As the canal discharge is fixed, syphon bed silting should be carefully watched. If silting takes place, the water level in the canal on the upstream side will rise and thus reduce canal free board. Since the discharge in the stream or drain can vary considerably, both the upstream and downstream stone or brick pitching should be carefully inspected after each flood. Repairs to the damaged pitching should be carried out as soon as possible but definitely after the floods and before the next flood season. Sometimes the upstream guide banks come under severe pressure during floods. To avoid any breach in these bunds, the erosive action should be arrested by dumping trees and branches in to the water. The trunks should be tied with ropes to prevent their dislodgement.

B. Syphon

From this term it is generally understood that a drain or stream passes beneath the canal. This situation is shown in Fig.II-2. The HFL of drain or stream is much below the bottom of canal trough, so that drain water flows freely under gravity. Its maintenance is easier because any choking by jungle or bushes is visible and can be removed conveniently.



LEVEL CROSSING

FIG.III–1

(Not to Scale)

In Fig.II-3 the HFL of drain is much higher than the canal bed and the drain water runs with symphonic action. In this case the damage done to the canal by floods is rare. During a heavy flood, however, the foundation is subjected to scouring action and may get damaged. Also the drainage water way may get choked with trees. Such a situation may increase the scouring action. Upstream pitching may also get damaged. Thus close observation of drain bay's choking is necessary. Any damage done must be rectified soon after the flood season.

C. **Aqueduct**

In Fig.II-2(a) and (b) the canal is passing over stream or drain in a trough which is called an aqueduct. Its maintenance is simple. Any leakage from the aqueduct is visible and should be repaired during the closure period.

D. **Level Crossing**

This type of cross drainage work is chosen when the bed level of the canal is practically at the bed level of the drainage. The drainage water is taken into the canal and surplus water is reintroduced at the other side of drain. The following works are required :

(i) A head regulator placed across the drainage channel at its downstream junction with the canal.

(ii) A cross regulator located in the drainage channel at its downstream junction with the canal.

When the drain does not carry any water, its regulator is kept closed while the canal cross regulator is kept fully open so that the incoming flow of the canal passes down into the canal. During floods the drainage regulator is opened so that the flood water, after mixing with canal water, passes through it downstream. The required supplies in the canal are maintained by the cross regulator. This structure has the following disadvantages which have to be taken care of in its maintenance :

(i) The drainage water velocity is much greater than the canal velocity. It carries a much greater quantity of silt and trash. During floods when mixing of water takes place, silt and trash laden water enters the canal.

(ii) Regulation has to be done very carefully, particularly, if the drainage carries flood water at night. Faulty or negligent regulation may damage the canal.

(iii) If excessive silt enters the canal, silt clearance may be required. The following measures should be taken during the canal operation.

(iv) The floods in the stream are of a flashy nature. The water supply in the canal should be gradually reduced when there is a flood in the stream. It should be kept reduced till the flood passes away.

(v) Floating booms in a slanting position should be installed in front of the canal cross regulator so that trash coming into the stream collects in one corner and can be easily removed by manual labour using rakes as shown in Fig.III-1.

Canal maintenance at a level crossing is not a difficult problem. The drainage regulator is a mini weir and it must be thoroughly inspected after each flood. Sometimes downstream stone pitching settles or is washed away. It must be repaired after floods because winter freshet may aggravate the problem. Due to higher level of canal water, there is sufficient water head on the downstream side of drainage regulator. This sometimes causes appearance of springs in the loose apron or unprotected downstream drainage bed. These springs should be observed. If clear water is coming out, there is no reason for any alarm. If sand is coming out with water, it may cause damage to the downstream floor. In such a case construction of a cut-off below the downstream floor is required.

3.3 Escape

Escapes are generally used to release water in case of emergencies so that water supplies in the channel downstream from the escape can be reduced. These are located close to river channel or natural depression. This channel should not be less than 50% of the capacity of parent channel. If it is connected to the river, the back water from the river comes into it and channel silting takes place. When an escape is operated on a silted channel, the water over flows its banks and may damage the crops in the adjoining fields. A silted escape channel is also a source of temptation to the farmers whose lands are located along the escape channel. During periods of high demand, they try to induce the gauge reader to open the escape for irrigating their fields. It is therefore very necessary that escape channels be inspected by the XEN frequently. If the channel has silted up, it should be desilted to restore the designed section.

3.4 SILT CONTROL STRUCTURES

A. Silt Excluder

Since this structure is located in the river upstream from the under sluices, no special maintenance is required for it. During the headwork's closure period it should be ensured that the inlets of the silt excluder are not choked with bushes or jungle so that silt laden water layers pass it freely.

B. Silt Ejector

Since it is located in the bank of a canal and there is a good deal of water fall at its exit point, frequent inspections of the tail end are required to see that the downstream cut off is safe against the erosive action of falling water or piping action due to high head across the ejector.If any damage is noticed it can be repaired either during canal operation or during the closure period.

C. **Silt Traps**

(i) Use of Silting Tanks in Winter

This situation is applicable to silting tanks which are constructed outside the channel. Where conditions permit, water supply to such silting tanks should be closed in winter season and the area thrown open to the owners to cultivate for the following reasons:

- Silt charge in canal is usually low in winter.
- Water is specially valuable in the Rabi season (winter) and the high absorption losses from the silting tanks can be avoided.
- Cultivation in the silted bed of the tank produces excellent crops and tends to check the growth of weeds.
- Annual compensation to the cultivators can be reduced by leasing the silted area for cultivation.

(ii) Protection Against Wave Action

In the outside silting tanks and wide channel silting tanks great attention should be given to the maintenance of the inner slopes of the outer bunds which are subject to wave action. This is dangerous due to high winds. Construction of earthen spurs along the inner side of the outer bunds is necessary to check wave action. Sometimes " pilchhi pitching " has to be done along the inner slope to protect the banks.

(iii) Monitoring of Silting Tanks

Sediment monitoring is necessary to watch the efficiency of the silting tanks. If efficiency decreases, it shows that scouring action has started in the tank and therefore it should be silt cleared. Too much clear water in the silting tank may induce weed growth. Cross sections of the silting tanks should be taken every year to find out the quantity of silt deposition.

3.5 INLETS

The canal inlet as shown in Fig.II-7 is constructed when cross drainage flow is small and its water can be absorbed into the canal without causing an appreciable channel water level rise. Usually pipe inlets are installed. Generally the land on canal side is higher than the canal F.S.L. so that there is a free fall of water into the canal from the inlet.

At certain locations the water level in the canal is higher than the adjoining fields. During heavy downpours, the rain water collects in the fields and there is no drainage for that area. After such a heavy rainfall, the demand for irrigation water is slack. The farmers close outlets to prevent further flooding of their fields. Water supplies in the canals must be reduced to avoid breaches. Due to lower water level in the canal, water from the adjoining fields can be drained into the canal. The farmers therefore cut the canal banks to drain water from their fields and save their crops. It is desirable to construct gated inlets on the canals at such sites.

Very little inlets maintenance is required. Sometimes due to heavy traffic, the inlet pipe gets damaged. In such cases the pipe should be replaced. A cover of 2 feet of earth should be provided to avoid damage to the pipe by the vehicular traffic such as tractor trollies.

3.6 FALLS

A. Maintenance of Falls on Distributaries & Minors

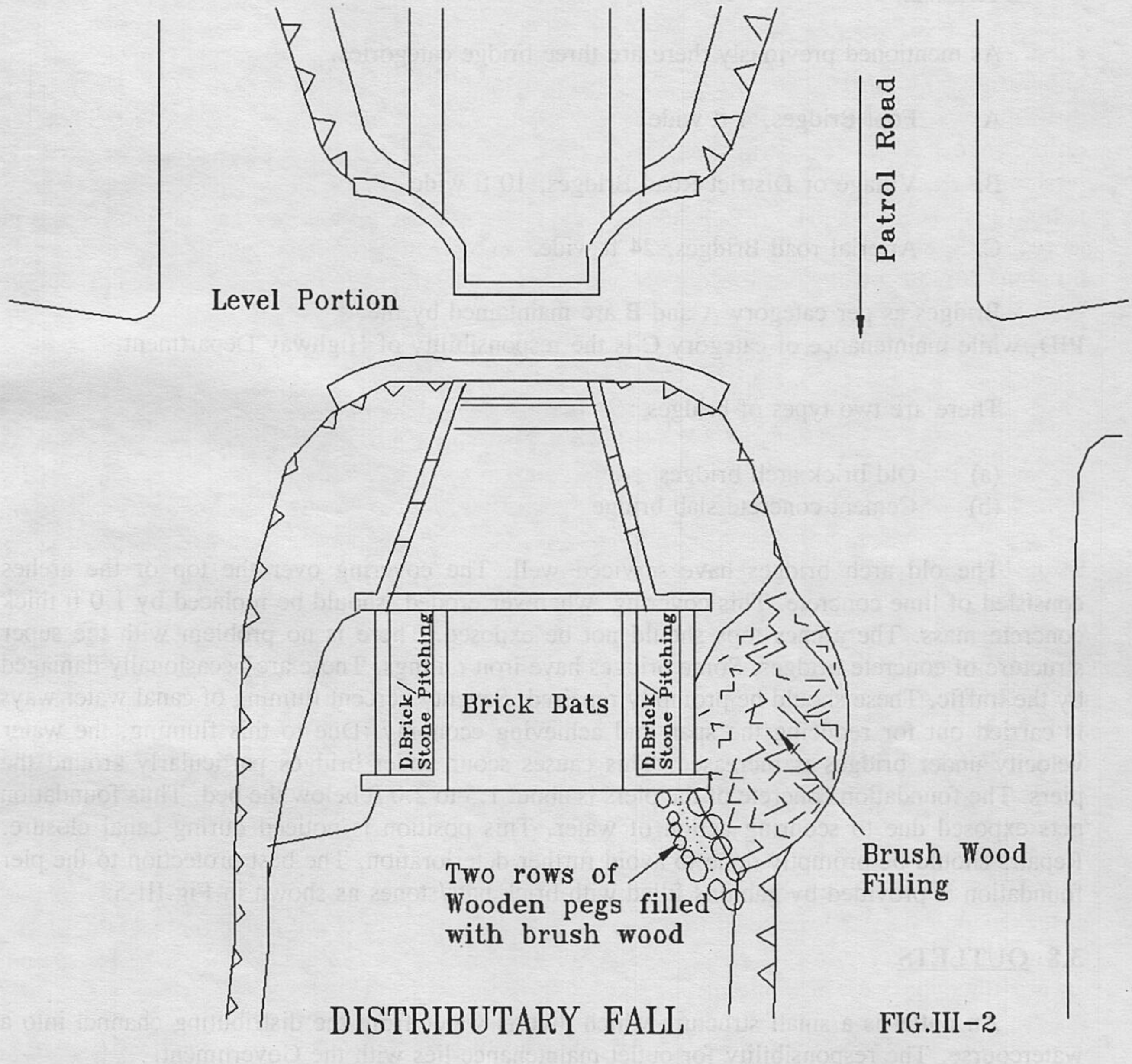
Falls on distributaries and minors are usually small. Therefore, there is no problem with either bed scour or side erosion. In the NWFP, the ground slope is steep. Therefore large number of falls must be provided. Falls are provided at intervals of 500 to 1000 ft. Buxaly distributary is an example. It has numerous falls in a length of 10 miles and has a total water drop of about 60 ft. A general problem on most of the falls is that the downstream brick/stone pitching is damaged by water action. These falls are old and their design is deficient. Energy is not fully dissipated. At most of the falls, the conditions have stabilized and no further action is required. On some falls where the problem of damage to pitching and side erosion is pronounced, the existing pitching should be repaired and extended. The pitching backside should be filled with earth. Sometimes the side erosion can be checked with staking and bushing as shown in Fig.III-2.

B. Maintenance of falls on Main Canals and Branches

On the main canals and branches, in addition to simple falls, there are regulating falls from which distributaries offtake. The problems for both falls type are similar. The problem of bed scour can be minimized by the provision of adequate upstream and downstream cut offs. Even if some bed scour takes place on the downstream side of the fall, it will not endanger the structure. If the apron is damaged,it can be replaced during canal closure. Side erosion, however, causes damage both to the dry stone pitching and the banks if the energy of falling water is not dissipated. This can result in soil erosion at the back of pitching and causes erosion of the banks. A breach may take place on the non patrol bank side if the free board is inadequate and the bank settlement occurs. This erratic functioning of a fall is attributable to its faulty design. Before taking remedial measures at big falls, model studies should be carried out at a research station. If model studies are not proposed,the following action can control bank erosion.

If water rollers are being formed on both sides below the fall, the embankment is under water attack. In order to prevent formation of water rollers, walls should be built on the glacis in line with the piers so that water falling from the central portion of the fall does not spread towards the sides. An example of pier extension is shown in Fig.III-3.

Often when a main canal is running with full supply discharge, the roller action is very severe and embankment safety is endangered. The water depth near the bank is very high. In such case the following action should be taken to save the side embankment.



DISTRIBUTARY FALL

FIG.III-2

(Not to Scale)

Such a condition is shown in Fig.III-4. A good deal of bank has been eroded. Reduction in canal supplies cannot be achieved rapidly. Therefore, to stop erosive action, trees of suitable size should be cut and dragged to the site by tractors. Gabions filled with stone or brick bats can be tied to bigger branches of trees to prevent floating. Trees should then be dumped into the eroded spot as shown in Fig.III-4. By this method, bank erosion can be controlled during canal operation. Repairs can be carried out later during canal closure.

3.7 BRIDGES

As mentioned previously there are three bridge categories.

A. Foot Bridges, 4 ft wide

B. Village or District Road Bridges, 10 ft wide

C. Arterial road Bridges, 24 ft wide.

Bridges as per category A and B are maintained by the PID, while maintenance of category C is the responsibility of Highway Department.

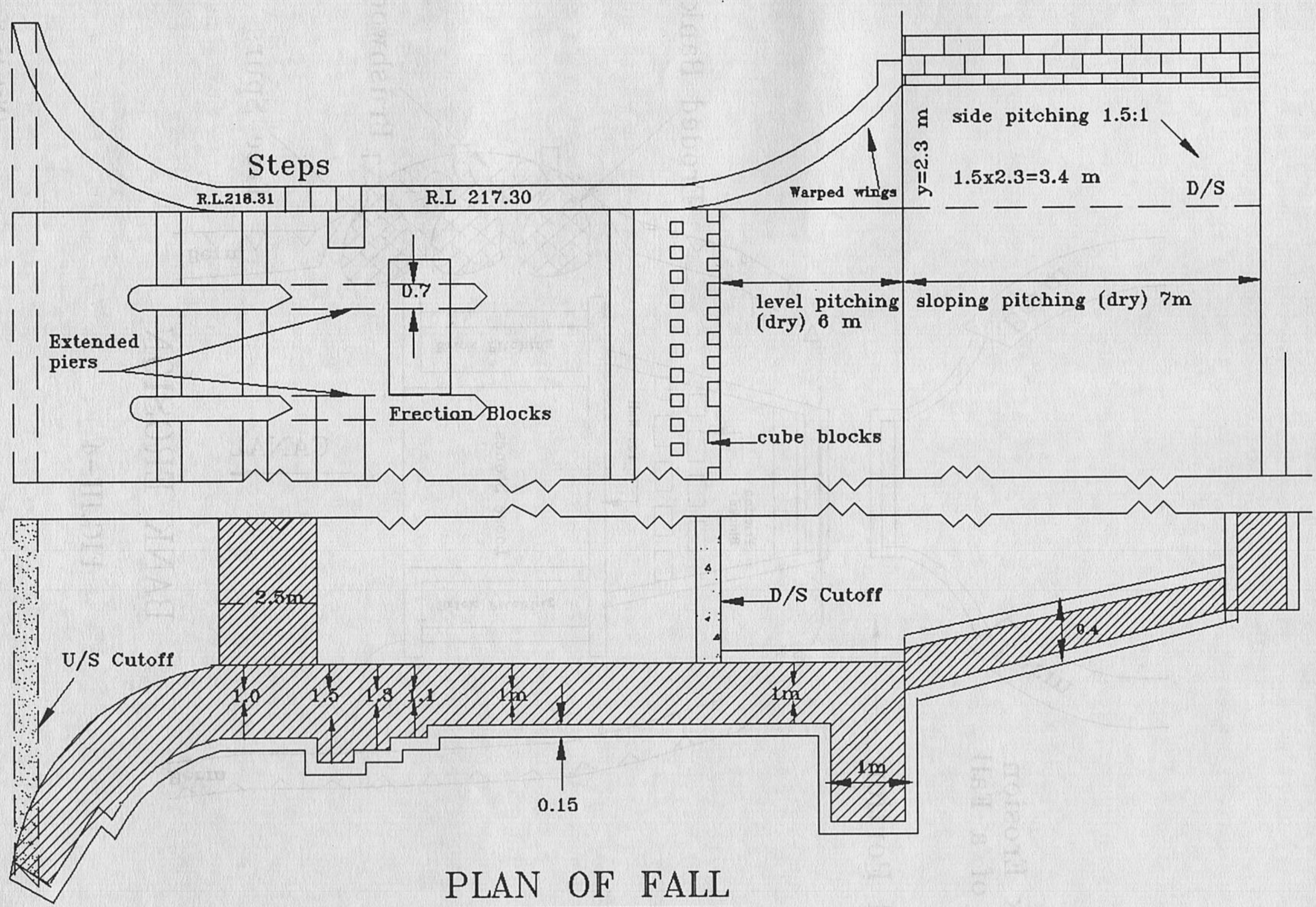
There are two types of bridges :

(a) Old brick arch bridges
(b) Cement concrete slab bridge

The old arch bridges have serviced well. The covering over the top of the arches consisted of lime concrete. This covering, wherever eroded, should be replaced by 1.0 ft thick concrete mass. The arches tops should not be exposed. There is no problem with the super structure of concrete bridges. Some bridges have iron railings. These are occasionally damaged by the traffic. These should be promptly repaired. Seventy percent fluming of canal water ways is carried out for reducing the span and achieving economy. Due to this fluming, the water velocity under bridges is increased. This causes scour under bridges particularly around the piers. The foundation concrete of the piers is about 1.5 to 2.0 ft below the bed. Thus foundation gets exposed due to scouring action of water. This position is noticed during canal closure. Repairs should be promptly done to avoid further deterioration. The best protection to the pier foundation is provided by gabions filled with brick bats/stones as shown in Fig.III-5.

3.8 OUTLETS

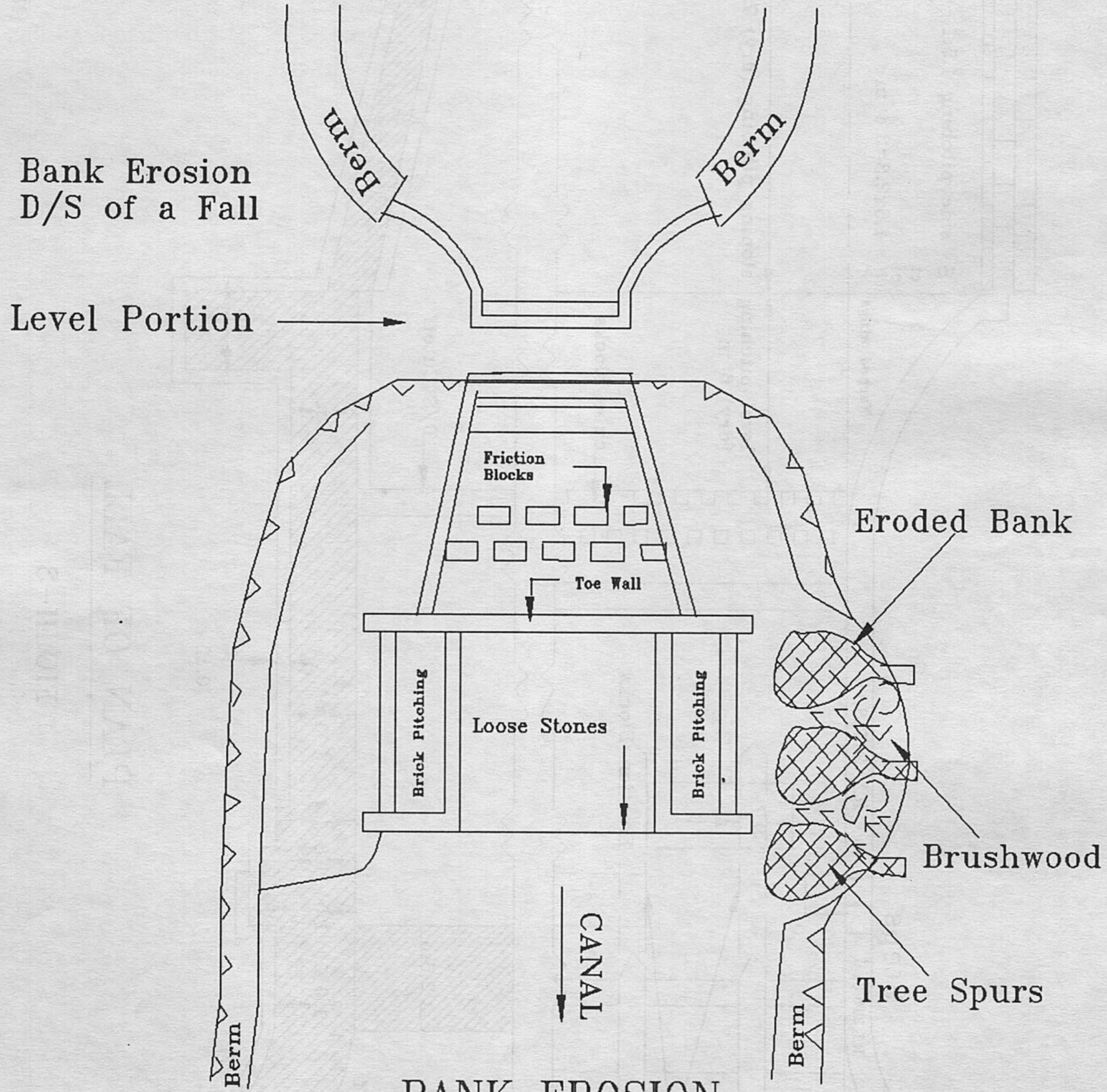
An outlet is a small structure which diverts water from the distributing channel into a watercourse. The responsibility for outlet maintenance lies with the Government.



PLAN OF FALL

FIG.III-3

(Not to Scale)



BANK EROSION

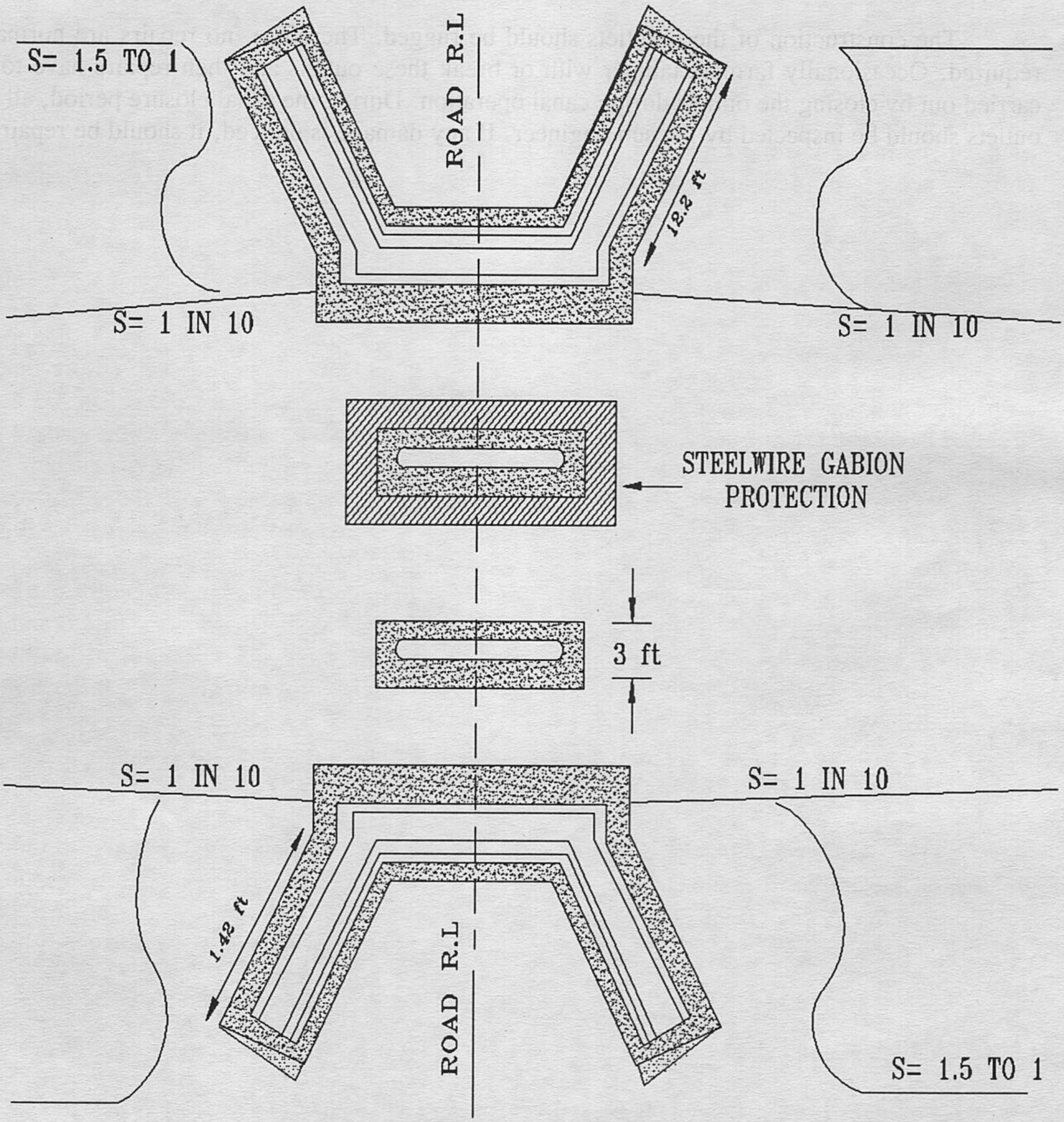
FIG.III-4

(Not to Scale)

There are three general types of outlets in use.

- pipe outlets
- open flume (O.F.)
- adjustable proportionate module (A.P.M.)

The construction of these outlets should be rugged. Therefore, no repairs are normally required. Occasionally farmers tamper with or break these outlets and then repairs have to be carried out by closing the outlets during canal operation. During the canal closure period, all the outlets should be inspected by the sub-engineer. If any damage is noticed, it should be repaired.



DISTRIBUTARY BRIDGE

FIG.III-5

(Not to Scale)

CHAPTER 4

MAINTENANCE OF STRUCTURES

(Mechanical Equipment)

4.1 GENERAL

The maintenance of gates and gate guides, gate hoists, gears and other mechanical parts of the irrigation control structures is very important. Periodic inspection of these mechanical parts is a part of preventive maintenance. Presented in Exhibit IV-1 is a check sheet for inspections.

4.2 PREVENTIVE MAINTENANCE (PM)

Preventive maintenance consists of simple method of scheduling works at specific intervals and keeping records of inspections and repairs by using a check list to ensure that the inspection and work meet certain standards. Prepared check sheets as mentioned in 4.1 above are used to conduct the inspection. These check sheets give pertinent instructions on what to look for and what to do. The detailed check sheet may indicate amount of gate leakage, poor readability of staff gauge and slack in gear drives. Key equipment that is required to receive periodic PM inspections includes gates, gate hoists, and miscellaneous metal works located within the irrigation system.

To facilitate the inspections and control, individual maintenance record cards are maintained which list when repairs were made and what was repaired. Materials used and time spent in making the repair are also listed to add to the data base or the information system needed to assist in preparation of the annual maintenance work program and budget. Exhibit IV-2 is an example of maintenance record card.

4.3 ROUTINE MAINTENANCE (RM)

The routine maintenance of gates, guides and hoist mechanisms is assigned to the Sub-engineer whose area of responsibility includes the structures. The gauge reader is responsible for the day-to-day operation of gates including the removal of floating trash from in front of structures. He is responsible for greasing the moving parts of the hoist mechanisms and lubricating guides.

A. Lubrication

The gate hoist mechanism must be properly lubricated. There are two types of gate hoists. The crank type with an oil reservoir that keep the gears lubricated and a wheel type that directly turns the gate shaft. With the crank type, the oil level in the gate hoist housing should be checked at the beginning of each irrigation season; 15 April and 15 October. If the level is low, the correct (specified) lubricant must be added, (Normally ASAE 90 or 140). The wheel type requires periodic greasing to keep the stem well lubricated. The large wire type hoists have grease fittings or caps that have to be filled up with special grease. Lubrication charts or guides should be prepared for all gates and gate hoists. The location of all grease fittings are known to gauge reader. The fittings on the threaded stem may require greasing once a month, whereas the other fittings should be greased at the beginning of each season. The grease type should be stated. Fig.IV-1(a) shows a typical hand wheel gate hoist with the grease fitting location indicate. Fig IV-1(b) shows the entire pedestal type gate hoist. Another type of gate cable-gear hoist is shown in Fig. IV-2. Fig. IV-3 shows two pedestal hoists modified to operate as a double lift on a roller gate. A lubrication chart shows the details for each gate roller and any other lubrication point or surfaces to be protected with a coating of grease. Fig. IV-4 shows a single-screw, winch-type DC gate hoist. This type of gate hoist is dust proof and self lubricated. Self lubrication means that on an annual PM check sheet the gear lubricating oil level should be checked. In this type of gear housing, either ASAE 90 or 140 weight oil is used. This type of housing would normally have a check plug to see the oil level.

B. **Protective Coating**

The appropriate paint should be used to protect the metal parts from rust and deterioration. Care must be exercised that all rust and other loose material is carefully removed prior to painting.

4.4 GATE SLOTS

Gate slots should be cleaned during closure and the gate checked to see that it seats properly.

4.5 GATE OPENING INDICATORS

Two types of gate opening indicators are in general use in Pakistan:

(A) A slotted steel stem covered with an indicator visible through the slot.

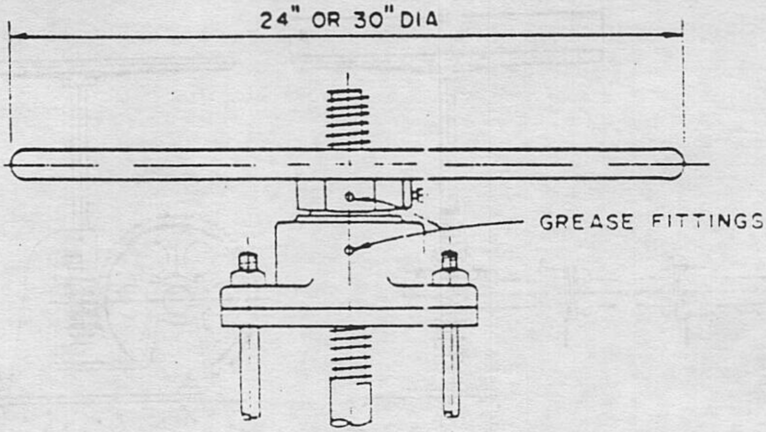
(B) Counter type indicator graduated to show opening.

The Type A indicator has a mounted fully graduated scale. Care must be taken to keep the scale clean and have it replaced when it becomes difficult to read. During the closure period, the actual gate opening should be checked with the indicator and adjusted as necessary. The indicator should be checked for a series of openings covering the full range of operation. The Type B indicator consists of a special counter mounted on top of the hoisting mechanism. The face of the counter shows through a recessed window in the housing. This type is used on the pedestal type gate hoist where the stem is not raised.

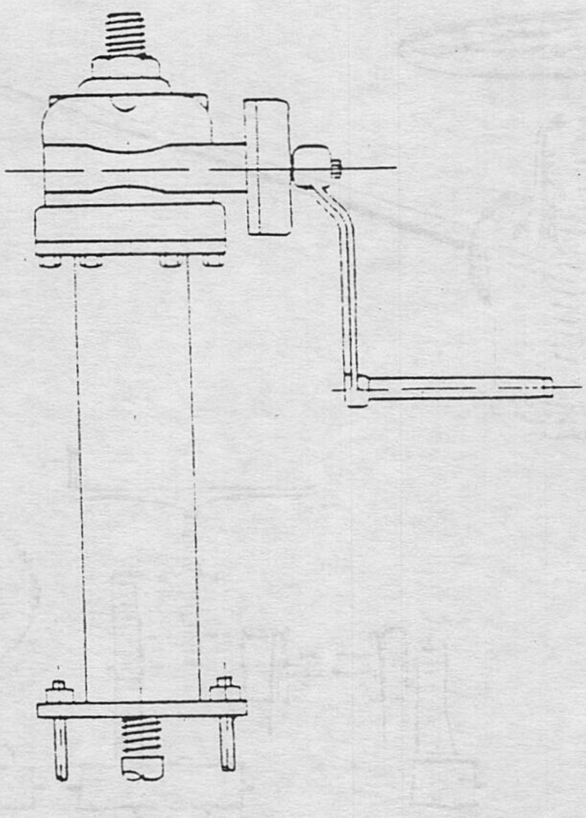
4.6 EXERCISING GATES.

The gates should be exercised once a year, but more frequently if the situation permits. This can be done at the end of the rabi season when discharges are reduced. This will ensure the operation of the gates during the kharif season. Exhibit IV-3 contains typical instructions.

FIG. IV-1 (a+b)



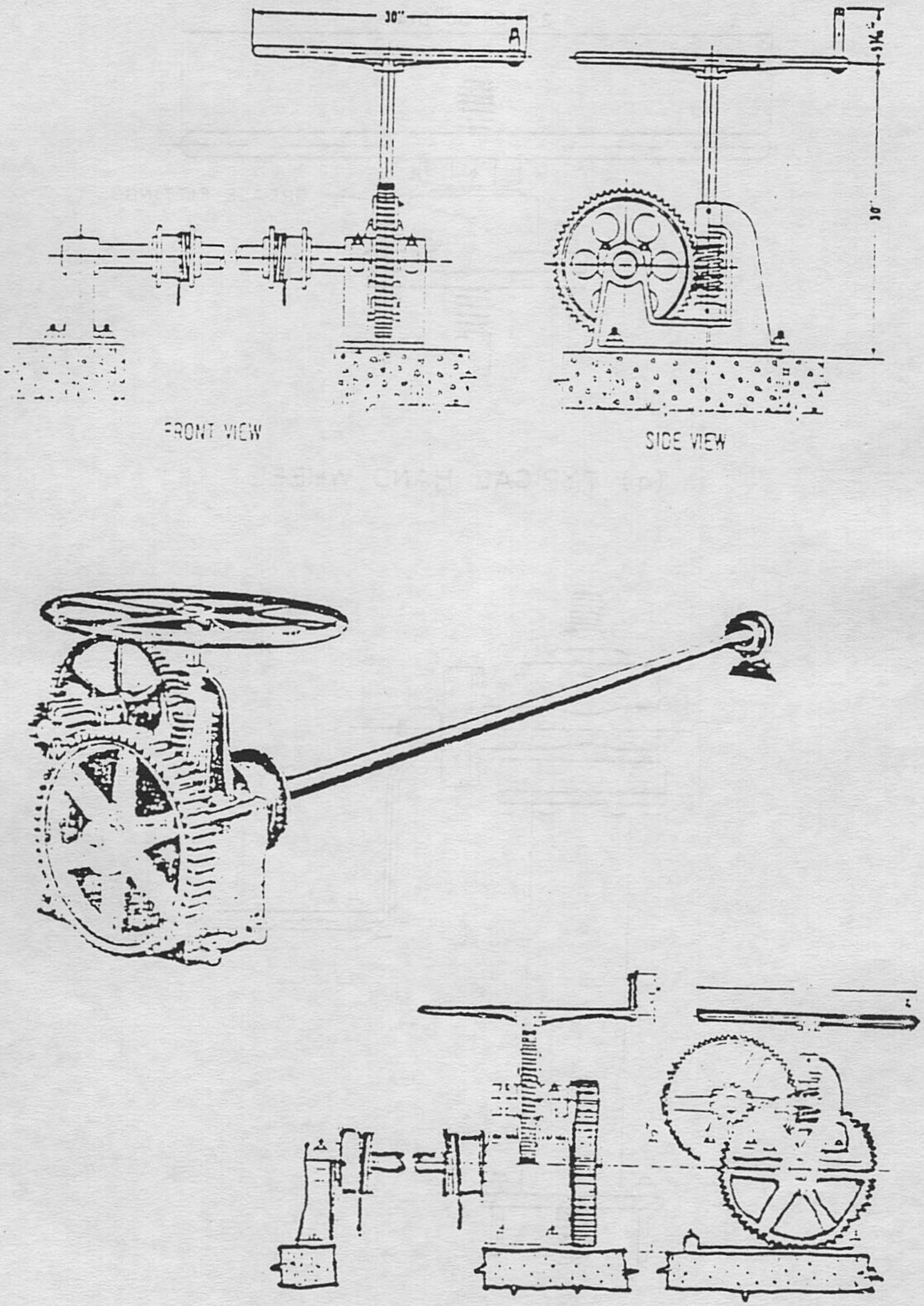
(a) TYPICAL HAND WHEEL



(b) PEDESTAL TYPE LIFT

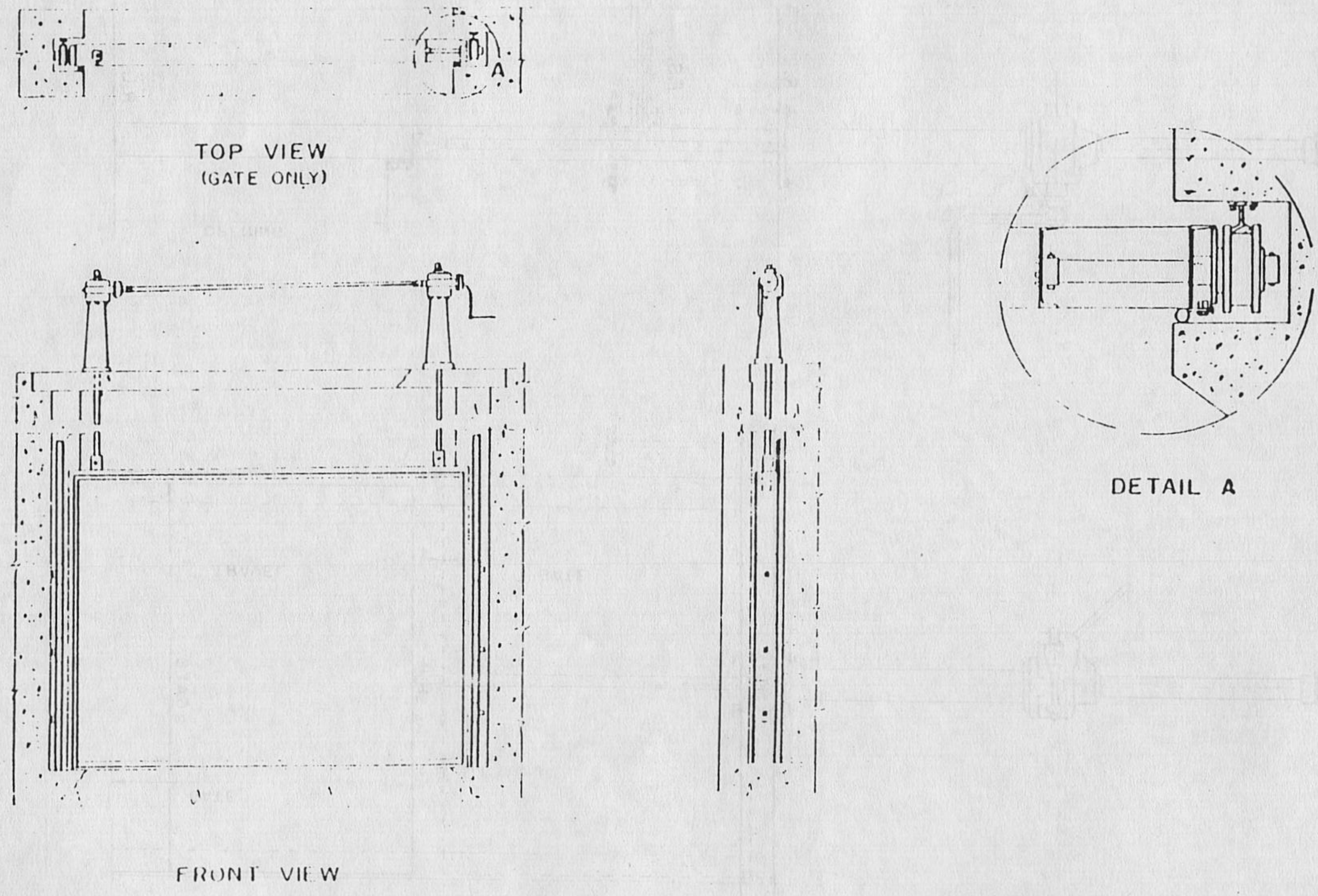
HAND WHEEL AND
PEDESTAL TYPE GATE HOIST

-FIG. IV-2



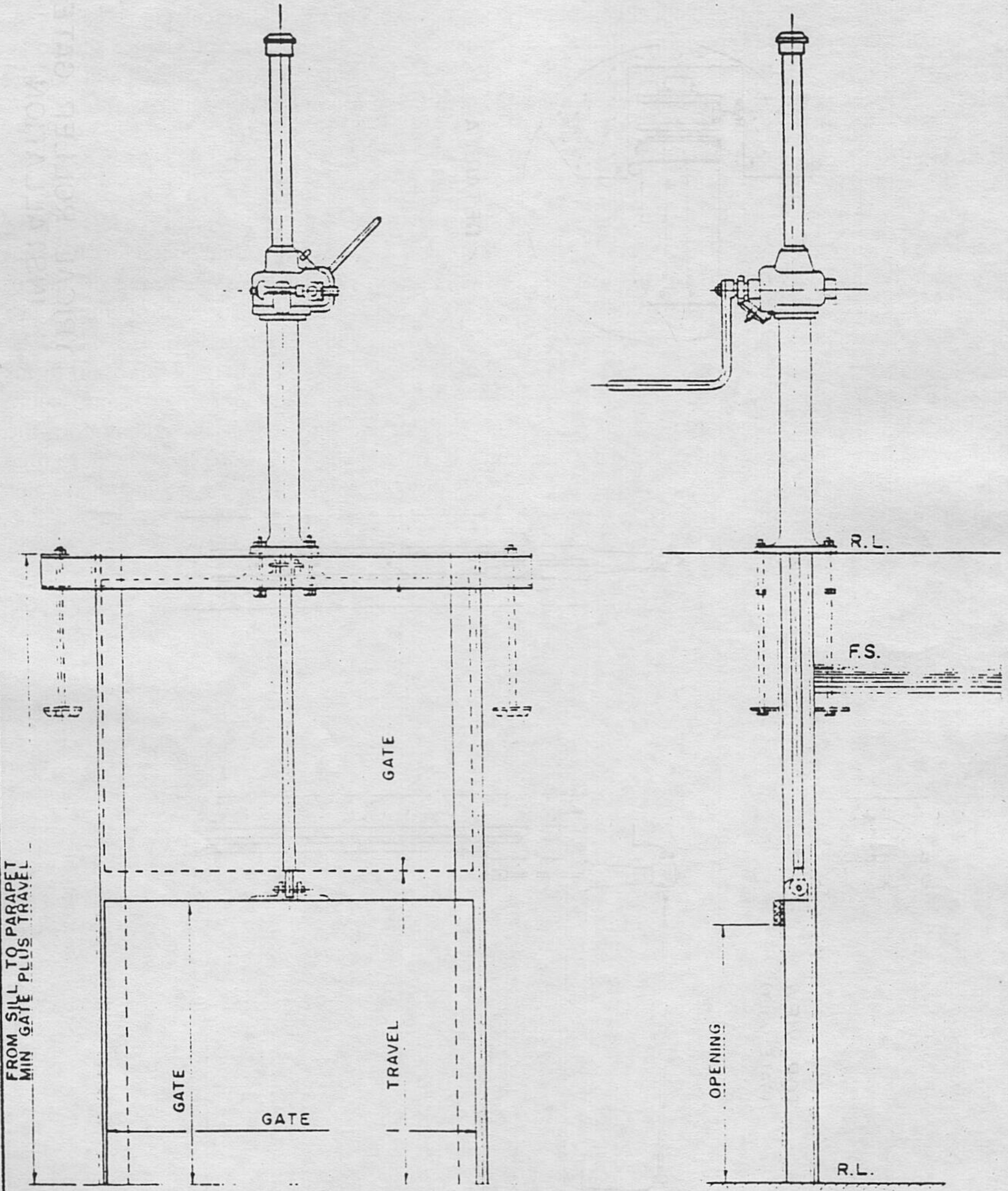
TYPICAL
CABLE - GEAR GATE HOISTS

-FIG.IV-3



TYPICAL ROLLER GATE INSTALLATION

FIG. IV-4



SINGLE SCREW TYPE WINCH
TYPE DC GATE HOIST

4.7 REPAIR OF EQUIPMENT

When a piece of mechanical equipment becomes inoperative or the leakage is excessive, the condition should be reported by the SDO. The necessary repairs to the structure should be carried out during the next closure period. Emergency repairs should be carried out by the Mechanical Division. A gang should be dispatched to make repairs as soon as possible.

4.8 OPERATING INSTRUCTIONS

Generalized operating instructions should be prepared and given to gauge readers. These will cover most situations. In some cases, older equipment may have different characteristics that will require the SDO or XEN to modify the instructions for a given site. Where the off taking canal is aligned at an angle of diversion less than 90 degrees, the procedure for opening gates may be modified slightly. Where there is more than one gate, the upstream gate should be opened more than the downstream gate. This should be considered where a sand bar forms downstream in the diversion channel. Opening the upstream gate more will cause more turbulence along the adjacent area in the diversion channel and thus reduce the potential for the bar and it may also reduce the amount of incoming sediments slightly. Since there is more time for the lower moving water at the canal bed to enter the diversion canal, the downstream gates will tend to draw more sediments.

EXHIBIT IV-1

GATE & GATE HOIST CHECK SHEET

System:----------------- Date:--------------

Canal :----------------- Facility: -------------------

Identification:--

Reference Drawings:	Condition Code	
Manufacturer-------------	A	Adjustment Reqd
Type-------------------	R	Repairs Reqd
Size--------------------	P	Parts Needed
Model No.---------------	X	See Remarks

Mechanical Checks:		Code
1.	Check with Gauge Reader	-----
2.	Note operation and condition	-----
3.	Is gate lubricated	-----
4.	Check for loose or stuck gate opening indicator	-----
5.	Check graduated indicator strip for readability	-----
6.	Inspect all seals for leaks	-----
7.	Estimate gate leakage (enter in notes)	-----
8.	Check gate leaf for corrosion and leaks	-----
9.	Check hoist for excessive end play and alignment (1/8 turn is normal)	-----
10.	Check mechanical freeness of moving parts	-----
11.	Check gate frame for rigid mounting	-----
12.	Check that all keys, set screws and bolts are tight	-----
13.	Check if lock is being used	-----
14.	Check structural soundness and unsafe conditions	-----
15.	During closure, check gate opening with scale and compare with indicator. If any difference, adjust as required.	-----
16.	Does gauge reader have supply of proper lubricants for gate and hoist and tools or grease gun to lubricate fittings	-----

Additional work, recommendations, and notes: -----------------------------

----

Inspection by:--------------------------- Date:---

EXHIBIT IV-2

GATE & HOIST MAINTENANCE RECORD

Equipment______________________ File No.___________________________

Facility ______________________Location________________Inspection Frequency_______

____

EQUIPMENT DATA

Specification______________________ Date Furnished______________________

Reference Drawing____

Manufacturer_____________________Size_________________Type____________________

Type of gate opening indicator____

Model or Style No.____

____

____

____

____

INSPECTION AND MAINTENANCE RECORD

Date	Inspected by	Condition found or description of work done

CHAPTER 5

PROTECTION OF SURFACES

5.1 GENERAL

A. Purpose

Provision of protective coating on exterior wood work, concrete work and iron work is very important to provide protection against weathering action. If such coatings are not provided the deterioration of the above mentioned materials is very rapid due to weathering agents. This shortens the life of certain parts and leads to their replacement much earlier than expected. For this purpose proper selection of protective coatings must be carried out. There are conventional methods for applying such coatings. The following three companies in Pakistan are now preparing products for protection of surfaces of wood, concrete and iron. These are ready made products and can be easily used:-

i. Berger Paints Pakistan Limited
ii. Buxly Paints Limited
iii. ICI Pakistan Limited

Information from these companies has been collected. Existing treatments and company recommendations for various types of surfaces are discussed in the following section.

5.2 LAYING SPECIFICATIONS.

In order to help manufacturers in recommending a suitable product for a particular type of surface,it is necessary to provide specifications for the required covering. The following points will serve as guidelines:

(A) objective of covering the surface of structure.

(B) weather and other conditions under which the structure has to operate, i.e. maximum & minimum temperature and relative humidity during application of paint.

(C) existing condition of surface and what treatment has been done in the past.

(D) facilities available at site for surface preparation i.e. pumice stone, sand papering, sand blasting and burning of surface.

(E) thickness of paint required.

(F) color of final coat and inter coat color contrasts.

(G) facilities for application of paint at site i.e. brush, sprayer etc.

EXERCISING AND TESTING GATES

1. Safety of the structure, the canal system, and good operation and maintenance practices require that each gate be tested to confirm that it will operate as designed.

2. All gates not subject to normal operations (periodic raising and lowering) must be tested once a year, or more frequently if the situation permits. This applies primarily to escapes, which are occasionally operated.

3. Exercising and testing should be done by using the normal power sources (nominally by assigned operator) to ensure the operation of each.

4. All exercising and testing results should be recorded and dated in the "opening log" or with the Sub-engineer. Copies should be forwarded to the SDO.

5. A differential head test should be performed while subjected to the maximum normal head expected for the season. Testing confirms that the gates will open and close satisfactorily. Testing should be conducted in the following sequence:

(a) Barely open (crack) the gate so that it will produce additional leakage; then close.

(b) Open the gate 1 inch; then close.

(c) Open the gate 3 inches; then close.

(d) Open gate 10 percent; then close.

Note: Percentage of gate opening refers to the percentage of normal, full range of height the gate would be operated in.

6. **Caution:** If, during any test, the gate will not close from any position or otherwise malfunctions, stop the test and determine the cause of the malfunction and correct it. If the malfunction cannot be immediately corrected, testing should be stopped and should not be resumed until the malfunction is corrected.

(H) paint application and inspection condition i.e. during closure of canal systems and during their period of operation.

(I) use of expensive and sophisticated paints should be avoided.

5.3 SURFACE PREPARATION.

The performance of any protective coating is greatly influenced by surface preparation before paint application. For higher paint durability and longer structure life, it is essential to remove contamination. The following guidelines are provided for preparing wood, concrete and iron surfaces.

A. Wood Work.

(i) Rubbing of Surface

Surface rubbing with a pumice stone or medium and fine grade sand paper is good for smoothening of surface.

(ii) Knot Treatment

Deodar or other resinous woods are painted with hot lime and scraped off after 24 hours. The knots are then primed with red lead and hot glue is laid on it. A coat of knotting varnish is then applied and the surface is rubbed smooth with pumice stone or sand paper.

(iii) Priming Coat

A priming coat of red lead or red and white lead mixed in double boiled linseed oil in the quantities shown below should be applied :

Red lead	-	7 lbs.
White lead	-	7 lbs.
Linseed oil	-	0.75 gallon

(iv) Stopping (putty) application

Putty applications to a wooden surface are required to fill nail holes, cracks and other inequalities. This is done as soon as the priming coat dries up. The following materials are required for preparing putty :

1.	Powdered chalk	-	2 parts
2.	White lead	-	1 part
3.	Linseed oil	-	3 oz to 1 lb of chalk

These materials are mixed and applied when the surface dries up. Then sand paper should be applied to the surface.

B. **Concrete Work.**

For concrete painting, the following instructions should be followed for surface preparation :

i. Concrete work should be allowed to dry for 12 months before painting. Concrete work should be white washed. If it is necessary to paint it earlier then instructions given (in item V) below should be followed. All loose flaking, dusty and greasy material should be removed by scraping or wire brushing.

ii. A priming coat of boiled linseed oil or glue mixed with water should be applied. White washing should not be done when using glue water.

iii. The first two coats normally consist of white lead and boiled linseed oil.

iv. The finishing coat should consist of a large quantity of turpentine oil with a little varnish to serve as binder.

v. If concrete work is to be painted much earlier than 12 months, then acid etching should be done. This is carried out with dilute hydrochloric acid (10-15% concentration) or phosphoric acid/zinc phosphate mixture. After this treatment when the surface is dry, it should be washed with water. The painting should be done according to the instructions given above.

C. **Iron Work.**

Following are commonly accepted methods for preparing Iron Work surfaces:

(i) **By Steel Brush or Wood Fibre**

Loose dust is removed by steel brush or wood fibre.

(ii) Sand Blasting

Air mixed sand is impinged on the steel surface to a standard Sek of 2.5. This will remove mill scale and rust.

(iii)

Rust scale and old paint can be burnt off by an oxy-acetylene flame and then rubbed off with wire brushes and scrapers.

(iv) Oil and grease can be removed by petrol or benzine.

(v) Old paint can be loosened by applying a solution of country soda (sodium carbonate) and fresh slaked lime.

5.4 THICKNESS MEASURING INSTRUMENT

In order to combine economy with durability, measurement of the paint coating thickness is important. For this purpose an electronic instrument called Elcometer or Positector is used. It measures the thickness in microns. Twenty-five microns are equivalent to one thousandth of an inch.

5.5 PAINTING EXTERIOR WOOD WORK

A. Conventional Method

(i) Preparation of Surfaces

As already discussed above.

(ii) Preparation of Coal Tar Paint

Coal tar should be heated and thinned with kerosine oil or common country spirit in the following proportions :

4 parts tar to 1 part kerosine oil or
1 gallon tar to 1/2 pint country spirit
2 lbs unslaked lime shall be mixed with
1 gallon of tar to prevent its running.

The mixture shall be heated to near the boiling point.

(iii) Application of Coal Tar Paint

(a) The mixture should be applied to wood work with a stiff flat brush or a spraying machine.

(b) The mixture should be kept hot and stirred occasionally while applying.

(c) The ends of wooden planks shall be liberally coated.

(d) The thickness of the first coat should not be less than 50 micron dry.

(e) A second coat of the same thickness, if required, shall be applied, when the first coat has dried up.

B. Ready Made Paints

(i) Berger Paints Ltd

Berger has recommended their paint "Epilux 4 Enamel". Before applying it, however, wooden surfaces should be sand papered, dusted down and holes/cracks filled with putty. One coat of primer "Epilux 4 primer white" should be applied to a thickness of 40 microns dry. Then three coats of "Epilux 4 Enamel" should be applied to a total thickness of 100 microns. Application should be done either by airless or conventional sprayers, brush or rollers. When using Berger paint, complete instructions should be obtained from the dealer for surface preparation and application of primer and paint coats.

(ii) BUXLY PAINTS LTD

After preparing the surface, Buxly Paints Ltd. recommend no primecoat and recommend three coats of Synthetic Enamel 413.

(iii) ICI Paints Ltd

After preparing the surface two coats of "Red and White Lead Priming" are recommended. After drying, two coats of "Dulux Synthetic Enamel" are recommended.

5.6 PAINTING CONCRETE WORK

A. Conventional Method

The following instructions should be followed for painting concrete after preparing surface as described below:

(i) Two coats of boiled linseed oil and white lead should be applied.

(ii) The finishing coat should contain a large proportion of turpentine with a little varnish to serve as a binder and applied when the previous coat is still sticky. This will give a flat finish.

For painting concrete before expiry of 12 months, the surface should be prepared as explained under section 5.32 for concrete work. Then two coats of ready made paint, such as ICI, Dulux Synthetic Enamel, should be applied.

B. **Ready Made Paints**

(i) **Berger Paints Ltd.**

Their recommendations are the same as for wood work, i.e.,

(a) Preparation of surface
(b) Application of one priming coat of Epilux 66
(c) Two coats of Epilux 4 Enamel

(ii) **Buxly Paints Ltd.**

Two coats of Buxly's Corroguard EP-2 paint are recommended.

(iii) **ICI Paints Ltd.**

The surface should be prepared as described before them.

Two coats of "Dulux Synthetic Enamel" should be applied.

Allow 12-16 hours for drying between coats.

Allow 5-7 days for full curing.

5.7 PAINTING IRON WORK NOT UNDER WATER

A. **Conventional Methods**

(i) Preparing Surface

As already discussed.

(ii) Priming Coat

The priming coat consists of a mixture of pure linseed oil and dry red lead in the proportions of 1 gallon of oil to 33 lbs. of red lead. It is applied by brush or spraying machine immediately after cleaning the surface of dry metal.

(iii) Second and subsequent Coats

The second coat is applied when the priming coat has dried and set i.e., after about four days. The second coat consists of red oxide paint or paint with aluminum or graphite base (red oxide paint may consist of 6 lbs of red oxide, 1 lb of lamp black and 1 gallon of boiled linseed oil), The third coat is applied when the second coat is dried completely. This coat consists of 7 lbs of red oxide paint and 1 gallon of boiled linseed.

B. **Ready Made Preparations**

(1) Berger Paints Ltd.

"Epilux 4 Enamel" is applied in the following way:

a) Preparation of Surface

As already discussed.

b) Priming Coat

Blast-cleaned steel should be primed within 4 hours with either Epilux 66 or Epilux 610 primer with a thickness of 25 micron dry.

c) Application of Paint

When the primer dries then apply three coats of Epilux 4 Enamel of the desired color, grey or black. Allow time for drying after each coat.

(2) Buxly Paints Ltd.

Epoxy Coal Tar Paint - EP-TAR-10, is recommended. Application is carried out as described below :

a) Preparation of Surface

As per instructions already described.

b) Priming Coat

One coat of Buxly's Epoxy Primer EP-R-10 should be applied before applying paint.

c) Mixing of Paint

This paint comes in two components, component A and hardener component B. The mixing ratio of these components by volume is component A, two parts and components B, one part. The pot life of mixture is 3 to 4 hours. Therefore, paint should be applied as soon as possible after mixing. The mixed quantity should be such as can be applied within 3-4 hours. Thinner E-T-10 should be used. It takes 18-24 Hours for hard drying and 7 days for complete curing.

d) Application of Paint

Two coats of Buxly's Epoxy Coal Tar Paint EP-TAR-10 should be applied by brush or roller. The first coat should be allowed to dry and then roughened before applying the second coat to ensure proper inter coat adhesion.

(3) ICI Paints Ltd.

Permeable Epoxy Finish is recommended by them.

a) Surface Preparation

As already described.

b) Priming Coat

A priming coat of permeable protective primer should be applied to the prepared surface. Nine parts of component A and one part of component B of primer are mixed and applied to the surface, 20 microns dry. This should be allowed to stand for ten minutes before applying. The mixture should be used within 36 hours.

c) Application of Paint

The paint" Permeable Epoxy Finish" should be applied by brush two to three coats each coat being 20-25 microns thick. The paint has two components. The components should be mixed in equal parts. Each coat should be allowed to dry overnight.

5.8 IRON WORK UNDER WATER

A. Conventional Method

(1) Preparing Surface

As already discussed.

(2) Paint Preparation

The usual paint applied for iron work under water is Khanki Mixture. It is made at the site before application in the following manner:

Two lbs of unslaked lime are added to a gallon of tar and the mixture is heated until it begins to boil. Then the mixture should be taken off the fire and the Kerosine oil in the following proposition should be added slowly :

Kerosine oil	-	1 part
Tar	-	4 parts

(3) Application of Paint

The paint prepared in the manner presented above should be applied with a flat brush while it is as hot as possible. Rags wrapped on wooden sticks should not be used for application of paint.

B. **Ready Made Preparation**

(1) Berger Paints Pakistan Ltd.

EPILUX 5 (Coal Tar Epoxy) is recommended. It is a high performance product with outstanding resistance to fresh and salt waters. It is particularly recommended for the protection of steel/concrete under water.

(a) Surface Preparation

As already described.

(b) Priming Coat

Although Epilux 5 can be directly applied to sand blasted surfaces, it is preferable to have a priming coat of Epilux 66 or Epilux 610 with a thickness of 25 micron dry.

(c) Preparing Paint

Epilux 5 consists of two components: part A base and part B hardener. To prepare the paint, stir part A vigorously and then add part B. The ratio for preparing the mixture should be 3:1 (base to hardener). The pot life of the mixture is about 6 hours. Therefore, the prepared paint should be applied with in this period.

(d) Application of Paint

Two coats of paint are to be applied with an airless sprayer. The first coat on metal should be thinned with 180/15 thinner and it should be chocolate color. The second coat has black color. The total thickness of two coats should be 250 microns dry.

For full curing 5 days are required.

(2) Buxly Paints Ltd.

Epoxy Coaltar Paint-EP-Tar-10, is recommended. This paint is resistant to acids, alkalies, fresh and sea water and sewage water.

(i) Preparing Surface

As already described.

(ii) Priming Coat

Two coats of Buxly's Epoxy primer EP-R-10 should be applied before applying paint.

(iii) Preparing Paint

The paint has two components: Part A base and part B hardener. In preparing paint for application, mix the two parts thoroughly for 3 to 5 minutes in the ratio of 2 part of component A (base) and one part of Component B (Hardener). The pot life of mixture is 3 to 4 hours. Therefore only that much quantity should be mixed which can be used within this period.

(iv) Application of Paint

To obtain the required film thickness (75 microns each coat) and smooth paint film, the paint should be applied by brush or roller. To achieve maximum adhesion between the two successive coats, the surface of first coat must be roughened to ensure adhesion. For full curing seven days are required.

(3) ICI Paints Ltd.

For iron work under water "Paintex Coaltar Epoxy" is recommended. It provides protection to iron work of barrages and regulators against the corrosive action of fresh and salt water.

(i) Surface Preparation

As already described.

(ii) Priming Coat

It is satisfactory to apply one coat of "Permeable Protective Primer" before applying the Paint.

(iii) Preparation of Paint

Printex Coaltar Epoxy is a two pack material in two separate containers marked component A and component B. The contents of two containers are mixed in the ratio 1:1 before use. The mixed paint will remain usable for 4 to 12 hours depending on temperature.

(iv) Application of paint

The mixed material should be applied by brush or airless spray and normally requires no thinning. If thinning is required, 5% thinner should be added. Three coats of mixture should be applied, each coat being 65-75 microns. The drying time between successive coats should not be more than 24 hours under any circumstances. A Longer drying period will impair inter coat adhesion. For full paint curing, seven days are required.

Annex-I

Glossary of Terms

Aeration ..	(1)	The process of mixing air or other gases with water sewage, etc.
	(2)	The process of relieving the effects of cavitation by admitting air to the section affected.
Acre foot ..		A unit of volume used in irrigation practice. It means the volume of water required to cover an area of one acre, to a depth of one foot. It amounts to 43,560 cubic feet. It will be noticed that a cusec day is equal to 1.98 acre feet ordinarily taken = 2. This equals 4049 cubic meters.
Accretion of levels ..		It is rise of bed levels in river channels or canal, particulary downstream of headwork or canal regulator.
After Bay ..		The tail-race of water power plant, a pond, or reservoir at the outlet of the turbines.
Afflux ..		It is the rise of water in its natural surface caused by an obstruction in the water way.
Apron ..		A floor or lining of concrete stone, etc. to protect a surface from erosion, such as the pavement below weirs, falls or at the toe of a bund.
Aqueduct ..		A channel, in which water flows with "free", surface, constructed to carry water above the natural surface level.
Area, Assessed ..		The area irrigated, on which water rates are levied (generally the same as area matured).
Area, Culturable commanded ..		That portion of culturable irrigable area which is commanded by flow irrigation.
Area, Cultureable Lift ..		That portion of culturable irrigable area which can be irrigated by lift.

Area, Discharge Section ..	The area of the water-way of a channel at the discharge section line, this is expressed in square feet or square meters.
Area, Gross ..	The total area within the extreme limits set for irrigation by a project, system or channel.
Area, Gross Commanded ..	That portion of the gross irrigable area which is commanded by flow irrigation.
Area, Matured..	The area irrigated upon which crops have matured.
Area, Non-perennial ..	The area served by a non-perennial canal.
Area, Outlet ..	The unit of area, in irrigation practice, for final distribution. It is the area served by the individual outlet. The village area may be divided into several outlet areas or alternatively an outlet area may consist of portions of several villages. Its boundaries are, or should be, defined by the configuration of the ground, whereas village boundaries are not so limited.
Area, Perennial..	The area served by a perennial canal.
Area, Remitted ..	The area irrigated for which water rates are remitted owing to failure of crops to mature or for other reasons.
Arid ..	A term applied to lands or climates that lack sufficient water for agriculture without irrigation or rainfall.
Back Water Curve ..	The shape of the water caused by an obstruction in the channel such as a weir.
Baffle Wall ..	A cross wall or a set of vanes or some other device placed in a channel to effect a uniform distribution of velocities across the section.
Barrage ..	A weir equipped with series of sluice gates, over the entire width of a river, to regulate the water surfaces level above them.
Base Period ..	The number of days in a crop. In NWFP, there are 183 days for kharif and 182 days for rabi.

Bed Load ..	Silt, sand, gravel or other detritus rolling along the bed of a stream.
Berm ..	A horizontal strip or shelf built into an embankment along the edge of a canal.
Blocks ..	Obstructions in the path of high velocity water to dissipate energy and prevent scour.
Branch ..	This term is applied to a large channel taking its supply from the main canal but whose functions are the same, viz., the supply of water to distributaries.
Bucket Wheel ..	The revolving portion of a current meter driven by the force of the current and whose rate of revolution is an indication of the velocity of that current.

C.

Caisson ..	A chamber, usually sunk by excavating within it, for the purpose of gaining access to the bed of a stream or other body of water. If the chamber is closed on top and the water excluded by air pressure, it is called pneumatic caisson.
Canal, Inundation ..	This term is ordinarily applied to a canal with or without some form of head regulator, dependent upon the surface level of the water in the river for its supplies. It follows that inundation canals will only run when the supply in the river rises to a level which permits of feeding the canal.
Canal, Navigation ..	A canal whose primary object is transport by water. In a purely navigation canal the flow of water is reduced to a minimum.
Canal, Prism ..	It comprises of the inner slopes and the bed of a canal.
Canal, Weir Controlled ..	A canal taking its supply from a river at whose head the works are of a nature which permit control of the water level of the source of supply.
Capacity .. (A)	When applied to a channel, the authorized full supply discharge.

(B) When applied to a reservoir or tank the gross capacity is the quantity of water stored between bed level and the level of the cill of the waste weir.

(C) When applied to an outlet the outlet capacity is the discharge passed by the out let when the channel is running at authorized full supply discharge.

Capacity Curve .. The graph of the volume of reservoir tank, etc., as function of elevations.

Capacity Factor.. The ratio of the mean supply to the authorized full supply or capacity.

Capacity Flood Absorption .. Is the capacity of a reservoir between flood level and the normal reservoir level, provided for the temporary storage of flood water.

Capillarity .. In a soil, water arises from the fine in terstices between the particles and results in the raising of the contained water above the free water level.

Capillary Water.. Water held above the water-table in soil by capillary force.

Caving .. Falling of river or canal banks by the undermining action of water.

Cavitation .. A condition wherein a vacuum to any degree exists as a result of flowing water; complete cavitation obtains when the pressure within the affected part is reduced to that of the vapor pressure of the water.

Channel Non Perennial .. A channel which is designed to irrigate during only part of the year usually the "kharif" or summer season.

Channel Perennial .. A channel which is designed to irrigate all the year round.

Cistern .. A pool of water maintained to take the impact of water overflowing a dam, chute, drop or other spillway structure.

Civil Canal .. A canal dug by farmers on self help basis and its water is distributed according to customs (Riwaj) of the farmers.

Clay ..	According to the American standard this represents soil particles under .005 mm. diameter. The standard adopted by the International Society of Soil Science, however, lays down the limit as particles under .002 mm. diameter.
Co-efficient Of Discharge ..	Ratio of observed (actual) to theoretical discharge.
Co-efficient Of Roughness ..	A factor in the Kuttar, Manning, Bazin and other formulae expressing the character of a channel as effecting the friction slope of water flowing therein.
Coffer Dam ..	A barrier built in water so as to form an enclosure from which water is pumped to permit free access to the area within.
Cohesion ..	It is the resistance of soil particles against motion because of their stickiness. Cohesion is high in clays, but may be very low in silt and is entirely lacking in sand.
Colloids ..	Soil particles smaller than .001 mm. diameter.
Commutator ..	The portion of a current meter containing the electrical contacting device for indicating single revolutions of the bucket wheel.
Compaction ..	Compaction is one of the methods used in the consolidation of stabilized earth-work and consists in the application of load at the top of an unconsolidated or partially consolidated layer of a graded mixture, which contains enough granular material to provide for mechanical interlocking. The load is readily transmitted vertically and causes consolidation throughout the thickness of the layer. The soil is rolled in relatively thin layers and, as a rule, in a moistened state, but neither thickness of layers nor the moisture content is critical. (See Densification).
Contraction ..	The extent to which the cross sectional area of a jet or nappe is decreased after passing an orifice, weir or notch.
Control Point ..	A "free" fall, so designed that the water surface level above it bears a fixed relation to the discharge passing. The level is usually fixed with reference to the authorized full supply discharge.
Crest .. (A)	The top of a dam, dike, spillway or weir, frequently restricted to the overflow portion:

(B) The summit of a wave, peak a flood.

Crop Ratio .. The crop ratio, or kharif: rabi ratio is defined as the ratio between the areas anticipated to be irrigated in these two crops.

Current Meter.. The device for determining the velocity of flowing water by ascertaining the speed at which a stream of a water rotates a vane or a wheel.

Cusec .. The unit of discharge used in irrigation practice and means a rate of flow of one cubic feet per second.

Cusec Day .. The unit of volume used in irrigation practice and means the volume of water resulting from a discharge of one cusec for one day (24 hours). It amounts to 86,400 cubic feet of water and is equal to nearly two acre-feet.

Cut-off .. A wall, collar, or other structure intended to reduce percolation of water along otherwise smooth surfaces or through porous strata.

[illegible]f Trench .. An excavation in the base of a dam or other structure filled with relatively impervious material to reduce percolation.

D.

Dam .. A structure created to impound water in a reservoir or to create hydraulic head.

Dam, Arched .. A curved dam, convex upstream that depends on arch, or arch and cantilever action for its stability. The load is transferred by the arch to the canyon walls or other abutments.

Dam, Debris .. A barrier built across a stream or channel, to collect debris such as sand, gravel, silt, drift wood.

Dam, Gravity .. A dam which depends for its stability, entirely on its weight. It may be straight or slightly curved in plan.

Dam, Gravel Fill .. An embankment composed of gravel or shingle with the down stream part made of relatively coarse material, and the upstream, or water side part made of finer gravel and sand.

Dam, Hydraulic Fill .. A dam composed of earth, sand gravel, etc., sluiced into place generally the fine materials are washed towards the centre for greater imperviousness.

Dam, Over-Flow.. A dam designed to be over topped in floods.

Dam, Rock Filled .. A modified form of the earth dam using rock of all sizes to provide stability and an impervious membrane on the upstream side to provide water tightness.

Datum .. The reference point from which levels or distances are measured.

Dead Storage Level .. See Level, Dead Storage.

Delta .. An expression used in irrigation practice to mean the depth of water that would result over a given area from a given discharge for length of time. Alternatively, delta may be as the total volume o delivered divided by the area over which it has been spread.

Demand .. (A) At the outlet, the cultivators' water requirements.

(B) At the head of channel, the sum of all useful discharges required plus total losses.

Densification .. Is one of the methods used in consolidation of stabilized earth work and consists in the application of such a load as penetrates the unconsolidated material and compacts the layer from the bottom upwards in order that the material shall be consolidated uniformly throughout its thickness without stratification. For densification the soil is deposited in layers of specified thickness and at a particular moisture content (see compaction).

Density Soil .. The density of a soil is its weight per unit volume. A soil which consists of solids and pores has two densities that of the mass termed "bulk" density and that of the solids termed "absolute" density.

Discharge .. The rate of flow at a stated site, i.e., the quantity of water passing in unit time.

Discharge Section Line .. The line along which depths and velocities of water are measured between two points located one on each bank of a channel.

Distributary, Major .. (Commonly known as a distributary). A Government channel taking its supply from a main line or branch, the function of which is to supply water to minor discharge distributries and outlets.

Distributary, Minor .. (Commonly known as minor). A small Government channel, usually taking its supply from a major distributary, the function of which is to supply water to outlets.

Distributary, Sub-Minor .. (Commonly known as sub-minor). A Government channel off-taking from one already defined as a minor.

Divide Wall .. A long wall which separates the weir proper from the undersluices.

Drainage .. The natural lines of depression in an area, through which storm water escapes to the river.

[illegible]age Cut .. An artificial channel, deliberately excavated on a line which is not naturally a drainage, for the disposal of storm water.

Drowning Ratio.. The ratio of the tail water elevation to the head water elevation, when both are higher than the crest, the overflow, crest of the structure being the datum of reference. The distance upstream or downstream from the crest at which head-water and tail-water elevations are measured have not been standardized but should be such that the levels are not in the influence of the work.

Duty .. When applied to a channel, the area irrigated during a base period divided by the mean supply utilized in cusecs.

Duty On Capacity .. The full supply factor obtained by a canal system or channel after it has been opened for irrigation.

E.

Energy Gradient.. The slope of energy line with reference to any plane.

Energy Head .. The elevation of the hydraulic grade line at any section plus the velocity head of the mean velocity of the water in that section. The energy head may be referred to any datum or to an inclined plane such as the bed of a conduit.

Escape	..	The channel through which surplus or excess water may be removed from a canal to a drainage cut.

F.

Fall	..	A work designed to secure the lowering of the water surface in a channel and the safe destruction of the surplus energy.
Feeder	..	A channel constructed primarily to convey water from one source of supply or system to another.
Float Run	..	The fixed distance over which surface float is timed.
Floatation	..	The floating action caused by the residual force of water flowing through the subsoil, which acts in the direction of flow and is proportional to pressure gradient.
Flow, Critical	..	Is that state of a stream, either momentary or sustained in whi[ch] energy or flow per unit mass of the stream is a minimum for t[he] discharge passing and the channel section through which the discharge passes.
Flow, Hyper Critical	..	Flow at velocities greater than the critical.
Flow, Sub-Critical	..	Flow at velocities less than the critical.
Flow, Uniform	..	A constant flow or discharge, the mean velocity of which is also constant. Uniform flow is also referred to as 'steady uniform flow'. It is an ideal condition that can only be approximated. If the velocity of the constant discharge varies, the flow is defined as 'steady non-uniform'.
Flow, Turbulent	..	That type of flow in which any particle may move in any direction with respect to any other particle and in which the head loss is approximately proportional to the second power of the velocity (Sometimes designed as 'sinuous flow or tortuous flow'). Flow in natural streams and artificial open channels is almost always turbulent.
Flume	..	A constricted water way used to measure the quantity of flow.

Free Board ..	(A)	The distance between the designed full supply level and the top of the sides of an open channel or masonry work left to allow for wave action, floating debris, or any other condition or emergency without over-toping the banks of the channel sides of the structure.
	(B)	When applied to a dam, it is the distance from the top of the dam to the water surface in the reservoir during maximum flood conditions.
Fore Bay ..		A reservoir or pond at the head of a penstock or pipe line.
Full Supply Factor ..		The area proposed to be irrigated in project during the base period divided by the authorized full supply discharge of the channel.
		Note-(i) The full supply factor is assessed for project purposes in these light of experience.
		Note-(ii) Once a project commences irrigation, the full supply factor is usually known as the duty.

G.

Gauge, Discharge Curve..	The curve resulting from plotting of discharges against equivalent gauges elevations.
Glacis ..	The sloping floor below and in continuation of the raised crest of a weir.
Government Channel ..	A canal or channel which is owned maintained and operated exclusively by Government.
Gravel ..	Soil particles retained on a 10 mesh sieve, which has opening 2 mms. in diameter.
Groyne ..	A spur constructed with more permanent materials.
Guide Bank ..	The embankments forming the upstream and downstream approaches of a weir. The nose of a guide bank is heavily armored to withstand river action.

H.

Head ..	(A)	The height of water above any point or plane of reference. Used also in various compound terms such as energy head, entrance head, friction head, static head pressure head, lost head, etc.
	(B)	The term is usually applied to the control work constructed at the off-take of a channel subsidiary to main canal.
Head, Available Working ..		The minimum difference between supply and delivery water levels available.
Head, Gross ..		When applied to a dam, the gross head is the total fall or difference between the elevation of water surface in a reservoir and that of the lower end of the tail race.
Head, Minimum Modular ..		The difference of the water level or pressure difference between s[illegible] and delivery sides, which is the minimum necessary to enable a mod[illegible] or semi module to work as designed.
Head, Net ..		When applied to a dam- Net head is the gross head less all losses in the conduit and tail race. (Losses within the turbine casings the turbines and the draft tube are not included in the conduit losses, being accounted for in the turbine efficiency).
Head Race ..		A channel leading water to a water-wheel, a fore-bay.
Headwork ..		The works constructed at off-taking of a main canal. It includes the weir or barrage on a river.
Hydraulic Gradient ..		The slope of hydraulic grade line. The slope of the surface of water flowing in an open conduit.
Hydrograph ..		The curve resulting from the plotting of discharges against time.
Hydraulic Jump ..		The sudden and usually turbulent passage of water from low stage below critical depth to high stage above critical depth during which the velocity passes from hyper-critical to sub-critical. It represents the limiting condition of the surface curve wherein it tends to become perpendicular to the stream bed.

Hydraulic Mean Depth ..		The cross sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit the ratio of area to wetted perimeter.
Hydraulic Mean Radius ..		The cross sectional area of a stream of water divided by the total length of its periphery.

I.

Indent ..		Is the total requirements of discharge at any place. It includes the discharges actually used for irrigation as well as absorption losses in between the indenting site and the place where irrigation is actually done.
Infiltration ..		The percolating flow of ground water into a drain, gallery, or other underground conduit.
Inlet ..	(A)	A surface connection to a drain.
	(B)	A structure at the diversion end of a conduit.
	(C)	The upstream end of any structure through which water may flow.
Intensity, Annual ..		The term is applied to the percentage of the culturable irrigable area irrigated during a year to the total area. The project intensity is the annual intensity aimed at in the project.
Invert ..		The floor, bottom or lowest part of the internal cross-section of a conduit.
Irrigation Requirements ..		The quantity of water, exclusive of precipitation that is required for crop production. It includes economically unavoidable wastes.
Irrigation, Subsoil ..		Watering plants by applying the water below the ground surface.

L.

Leach .. To remove salinity and/ or sodicity from soils by abundant irrigation combined with drainage if possible).

Level, Dead Storage .. The water level below which a reservoir is not depleted in order that the minimum designed head for hydro-electric generation is not reduced. The capacity below this level is reserved for silt deposit.

Levels, Degradation of.. A reduction of specific bed levels at any site which has originated at that site or has worked downstream from a site higher up.

Lining .. A protective covering over all or over portion of the perimeter of a conduit, or reservoir or canal to prevent seepage losses and / or to improve hydraulic conditions.

Liquid Limit .. Moisture content expressed as percentage of the weight of ove soil at which the soil will just begin to flow when lightly jarred. At stage cohesion and internal friction are practically zero.

Long Line .. The weight and cord attached to it used for determining depths at observation points where it is impossible to use a sounding rod, (sounding line).

Losses, Absorption .. Losses from a canal or reservoir on account of evaporation and percolation or seepage.

Losses, Total .. The sum total of losses of water by absorption, percolation and evaporation. The total loss in a channel may be defined as be difference between the discharge at head of a channel reach and the total actual outflow from the channel reach, i.e., the sum of outlet discharge.

M.

Main Line .. This term is applied to the principal channel of a canal system off-taking from a river or other source of supply.

Mean Velocity Position ..	The point lying between water surface and the bed of a channel at which the velocity is equal to the mean velocity.
Meter Flume ..	A device used for measuring water discharge by the direct measurement of the depth of water flowing over the flume.
Module ..	Device for ensuring a constant discharge of water from one channel to another irrespective of the water level in each within specified limits; this word is sometimes applied to what are really rateable modules which instead of ensuring a constant discharge aim at passing a discharge into the smaller channel which is in proportion to the supply in the parent channel.
Modular Limits ..	The extreme value of any factors at which a module or semi-module ceases to be capable of acting as such.
Modular Range ..	The range of conditions between the said limits, within which a module or semi-module works as designed.
MMH Ratio ..	The ratio between the MMH, (Min Modular Head), and the depth of upstream water level on the crest of an outlet.
Marginal Bund ..	An embankment constructed along the river at a short distance from the margin with the object of preventing inundation the area behind the embankment.
Meander ..	Consists of two consecutive loops one flowing clockwise, the other anti clock wise.
Meander Belt ..	The distance between lines drawn tangential to the extreme points of successive fully developed meanders.
Meander Length..	The tangential distance between corresponding points at extreme limits of successive fully developed meanders.
Meander Ratio..	The ratio 'meander width' to 'meander length'.
Meandering River ..	River flowing in a sinuous path due to natural physical causes not imposed by external restraint; condition occurs where varying discharges and slit loads lead to curved flow and erosion of the banks.

Meander Width..	The amplitude of swing of a fully developed meander from midstream to midstream.

N.

Nappe ..	A sheet or curtain of water flowing over a weir dam, etc. The nappe has an upper and a lower surface. A nappe is said to adhere if its lower surface is in contact with the face of the work.
Notch ..	A narrow fall whose crest is usually at or near the bed level usually without a glacis. In irrigation practice, notches are designed primarily to maintain the depth discharge relation of the canal at all stages of discharge.

O.

Observation Points ..	The points at segmented intervals along a discharge section line which the velocities and depths are measured.
Optimum Moisture Content ..	The moisture content at which the maximum density is produced by a specific degree of compaction.
Out Fall ..	The point where water flows from a conduit, the mouth of drains and sewers.
Outlet ..	The term used to designate the work which passes water from Government channel to a water course.
Outlet, Direct ..	An outlet constructed in a main line or branch canal.
Outlet, Semi Modular ..	An outlet of which the discharge is independent of the level in the water course, within working limits.

P.

Pendant ..	A sheet metal disc bearing the current meter observation point number and carried by the pendant wire.

Pendant Wire	..	The wire exactly marking section line and carrying pendants upon it to indicate the exact position of current meter observation points, (tag line).
Percolation	..	Movement of water through the interstices of a substance as through soil.
Permeability	..	The rate at which water flows through the soil under the action of unit hydraulic gradient
Pile Line	..	A long line of inter-locked piles driven into the soil to from an impermeable cut off.
Piping	..	The flow of water with high velocities under or around structure built on permeable foundation which, if not prevented will remove the material from beneath the structure and cause it to fail.
Pivot Point	..	The point at a fixed distance from the discharge section line on to which rays from the observation points converge.
Pivot Point Layout	..	A geometrical layout of points on one or both banks for the purpose of locating observation points in a river without direct measurement along the discharge section line.
Pivot Point Line	..	The line from the zero point of the discharge section line, passing through the pivot point.
Plastic Limit	..	The lowest moisture content expressed as a percentage of the weight of the oven dried soil, at which the soil can be rolled into thread 1/8" in diameter without showing sings of crumbling.
Plasticity Index	..	The numerical difference between the liquid and the plastic limit. This shows the percentage in moisture content through which soil remains plastic.
Pocket, Undersluice	..	The undersluice pocket may be defined as the area adjacent to the head regulator bounded on one side by the flank and on the other by the divide wall.

Porosity	..		The ratio of the volume of voids in given soil mass to the total volume soil mass.
Precipitation	..		The total measurable supply of water received directly from clouds, as rain, snow and hail usually expressed as depth in inches/millimeter in a day, month or year, and designated as daily, monthly or annual precipitation.
Priming	..	(A)	The first filling of a canal reservoir or other structure, that is, either the absolutely first or the seasonally first.
		(B)	Starting the flow, as in a pump or syphon.
Pressure	..		Total load or force upon a surface, also appropriately used to indicate intensity of pressure or force per unit area.
Pressure Sounder.			The device for determining depths of water from the cubical measurement of water trapped within the device due to the pressure created at various depths.
Proportional Moduling	..		The fitting of the semi-modules on a supply channel in such a manner that when supply fluctuates each off-take draws always a constant proportion of the supply.
Puddle	..	(A)	Earthy material as a mixture of clay, sand, and gravel, placed with water to form a compact mass to reduce percolation.
		(B)	To place such material.
Penstock	..		A closed conduit for supplying water under pressure to a water wheel or turbine.
Power, Primary or Firm	..		(When applied to hydro-electric installation). Is the minimum power that can be generated under the worst working conditions.
Power, Secondary..			(When applied to hydro-electric installation). Any power generated over and above firm power due to variation of flow and head is called secondary power.

R.

Rack and Pinion..		The machine incorporating a toothed wheel and a toothed rod to the bottom of which the swivel and current meter are attached.
Rapids ..	(A)	A term used by some writers for "chute"
	(B)	Swift and turbulent flow, without pronounced fall.
Referring Bench Mark ..		A masonry or other fixed point whose level above sea level is known and by reference to which the levels of gauges, etc., may be determined and thereby the water surface levels above see level as read from those gauges.
Regulation ..		The process of distribution of supplies available in river between different canals taking off it or between channels on a canals.
[illegible]or ..		A structure through which the discharge can be varied at will, also applied to a structure provided with means of varying the water surface level above it.
Reservoir ..		The lake impounded by dam.
Riparian ..		Pertains to the banks of a body of water; a riparian owner is one who owns the banks, a riparian right is the right to control and use water by virtue of the ownership of the bank or banks.
Rotational Working ..		When the demand exceeds the available supply, recourse is given to a system known as Rotational Working. In sound irrigation practice every endeavour is made to run the distributary channels at the authorized full supply discharge or to close them entirely. This is possible in the case of some branches and most distributaries. Each channel takes a turn of full supply for a certain number of days, other channels being closed to admit of this. The unit period for which the channels run or are closed is known as Rotational Turn.
Run-off ..		The part of precipitation that appears as flow in streams.

S.

Sand .. According to American standard, it is taken as particles of soil 0.05 mms. to 1 mm.diameter. The standard adopted by the International Society of Soil Science is, however .02 to 2 mm diameter.

Segment .. A specified length of total discharge section line.

Sliding Factor .. Is the ratio of net horizontal force to net vertical load acting on a structure.

Sluice .. (A) A conduit for carrying water at high velocity;

(B) an opening in a structure for passing debris;

(C) to cause water to flow at high velocities for wastage for purpose of excavation, ejecting debris, etc.

Shear Friction, Factor Of Safety. The terms is used to denote the factor of safety of a structure against failure by sliding, taking into consideration the shearing strength of material of which the structure constructed.

Shrinkage Limit.. The moisture content expressed as a percentage of dry weight of the sample at which the removal of additional water produces no further change in the volume of the sample. In other words, the amount of water required to fill the pores of a soil sample which has been dried to consent weight from a wet condition.

Shutter .. When applied to a weir, a plate of steel or wood construction hinged to the crest. Shutters are used to regulate the level of river above crest. The size is limited by that which can be raised against to modest head by manual labor.

Side Slope .. The slope of sides of a canal, dam, or embankment; custom has sanctioned the naming of the horizontal distance first as 1.5 to 1 (or, frequently, 1.5:1) meaning horizontal distance of 1.5 to 1 feet vertical.

Silt .. (A) Water-borne sediment. The terms is generally confined to fine earth, sand, or mud, but is some times broadened to include all materials carried, including both suspended and bed load;

(B) deposits of water-borne material in a canal or a reservoir.

Slope Gauges ..	Gauge fixed on a slope upstream and downstream from a discharge section line for the purpose of determining the discharge based on the water surface elevation
Soil, Alkali ..	Soil that contains harmful concentration of mineral salts.
Soil Evaporation.	Evaporation of water from moist soil.
Sounding Rod ..	The graduated pole with which depths of water are measured in feet/centimeters at observation points.
Spill Way ..	A passage for spilling surplus water, a wasteway.
Spur ..	In irrigation practice, a projection into a stream, provided with an armored head; the head may be of various shapes.
Stability ..	In a soil, this may be defined as the resistance to natural flow, when loaded, denoting the structural shear strength representing the combined effect of internal friction of the soil particles.
tanding Wave ..	A term used in Pakistani practice identical with hydraulic jump.
Static Head ..	The total head without deduction for velocity head or losses; for example, the difference in elevation of head-water and tail-water of a power plant.
Submerged Orifice ..	An orifice which in use is drowned by having the tail-water higher than all parts of the opening.
Supply, Authorized Full or Designed Full Supply or Full Supply Discharge.	Is the maximum discharge for which a channel or work is designed.
Supply, Average ..	The average supply in a channel during a certain period is the sum of the daily discharges run at the head of the channel in that period divided by the number of days when the channel is in flow.
Supply,Mean ..	The mean supply in a channel is the sum of the daily discharges at the channel head divided by the number of days in the base period.
Surface Float ..	A wooden disc or other floating matter used for timing over a fixed distance in order to determine surface velocity.

Suspension Rod ..	The hand operated rod used in shallow water instead of rack and pinion.
Swivel ..	The device fixed between current meter and its means of suspension, so that it may be free to swing in horizontal plane.
Syphon ..	A term applied in irrigation practice to an "inverted syphon" a tube or "scaled" channel constructed to carry water at a level lower than at which the open channel normally flows.
Syphon, Inverted..	A pipe line crossing over depression or under a highway, rail road, canal, etc. The term is common but inappropriate, as no symphonic action is involved. The suggested term, "sag pipe", is very expressive and appropriate.
Storage, Dead ..	The volume of a reservoir below dead storage level.
Storage, Live ..	The volume of the reservoir above Dead Storage Level.

T.

Time Factor ..	The ratio of the number of days the channel is in flow to the base days.
Time Lag ..	Is the allowance that has to be made for time required for the effect of change in indent at one site reaching another indenting site.
Toe-Wall ..	A shallow wall constructed below the foundation level to provide a footing for the pitching of the face of an embankment. When the sub-soil water level is high, the toe-wall takes the form of a series of shallow wells.
Trash Rack ..	A grating, usually made up of mild steel flats, provided at the entrance of submerged outlet to prevent entry of debris, jungle, etc.
Tail Race ..	The channel that leads water away from a turbine or water wheel.

U.

Under Sluices ..	Under shot gates-in irrigation practice generally confined to the openings in the weir, adjacent to the canal head regulator.
Uplift ..	The upward water pressure exerted on the base of a structure.

V.

Velocity ..	The rate at which movement occurs and usually expressed in feet per second.
Velocity, Central Surface ..	The rate at which the surface layer of water moves in the centre of a channel.
Velocity, Mean ..	The average rate at which all the layers of water move between water surface and the bed of a channel.
Velocity, Modified ..	The velocity as observed after correcting for drift and angularity.
Velocity, Overall Mean ..	The average velocity of the discharge through a discharge sectional area i.e. $Q/A = V$.
Velocity of Approach ..	The mean velocity in a channel immediately upstream of a weir dam, venturi throat, orifice, or other structure.
Velocity Rod ..	A rod loaded with metal at one end so that it floats in a vertical position and on being timed through a float-run, gives the mean velocity of the water between water surface and the bottom of the velocity rod.
Velocity Rod Correction ..	The correction to be applied to a velocity rod velocity in order to convert it into mean velocity.
Velocity, Surface.	The rate at which the surface layer of water moves.
Vena Contracta ..	the section at which the boundaries of a jet passing through an orifice or over a weir become parallel.

W.

Wall, Breast or Face ..	When applied to irrigation practice, a wall generally of reinforced concrete or brickwork, immediately above the face of a submerged orifice.

Wall,Curtain ..		A cross wall built under the floor of a hydraulic structure with the object of dividing the work into suitable compartments, or to provide cut-offs
Wall, Core ..		A wall of masonry, sheet-piling, or puddled clay built inside a dam or embankment to reduce percolation.
Water Account ..		Is an account maintained of distribution of supplies between units of interlinked canals or different channels of one canal.
Water Allowance..		The outcome of all considerations of the duty of water, intensity proposed crop ratio, water available, etc. is the fixing of the water allowance. Water allowance may be defined as the number of cusecs of outlet capacity, authorized per 1,000 acres of culturable irrigable area. The water allowance, therefore, not only defines the size of outlet for each outlet area but also forms the basis for the design of the distributing channels in successive stages.
Water Course ..		The term applied to an irrigators channel takin[illegible] Government channel, from which fields are irrigated directly.
Water Logged ..		A condition of land where the ground water stands at a level that is detrimental to plants. It may result from over-irrigation, or seepage with inadequate drainage.
Water Right ..		A legal right to the use of water.
Water Shed ..	(A)	The area drained by stream or stream system.
	(B)	The divide between drainage basins.
Water Table ..		The upper surface of a zone of saturation in soil or in preamble strata or beds.
Weep Holes ..		Opening left in retaining walls, aprons, linings, foundations etc. to permit drainage, reduce pressure, etc.
Weir ..		A fall structure extending across a river or canal, usually provided with a raised crest and a downstream apron.
Weir, Waste ..		The escape provided for the passage of surplus water from a reservoir or tank.

Weir, Drowned ..	A weir which in use has the tail water level higher than the highest level with which a hydraulic jump is formed and by which the discharge is affected.
Weir, Broadcrested ..	An overflow structure on which the nappe is supported for an appreciable length; a weir with a significant dimension in the direction of the stream.
Weir, Sharpcrested ..	A measuring weir with its crest at the upstream edge or corner of relatively thin plate, generally of metal.
Wetted Perimeter.	The length of the wetted contact between a stream of water and its containing conduct, measured along a plane at right angles to the direction of flow; that part of the periphery of a cross sectional area of a stream in contact with its container.

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