DESIGN AND CONSTRUCTION
CHASHMA RIGHT BANK CANAL PROJECT

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SYNOPSIS

Construction of the Chashma Right Bank Canal (CRBC) Project was taken in hand in June 1979 under a stage-wise construction programme. The first of the total 3 stages has been completed and commissioned in early 1987 while finalization of preparatory works for the second stage is under way so as to start actual construction in early 1988. The project on completion will provide irrigation water to a cultivable command area of 570,000 acres consisting of 350,000 acres in the D.I.Khan District of the NWFP and 220,000 acres in the D.G. Khan District of the Punjab Province. The completed first stage, commanding a cultivable area of 140,000 acres, comprises 52 miles of main cannal, five new distributaries and works for linking of the existing Paharpur Canal to the main canal, apart from a number of canal structures such as cross regulators, head regulators, cross drainage structures, bridges, falls etc. The project is being planned, designed, constructed, tested and commissioned entirely through efforts by Pakistani Engineers. The paper describes these aspects for the overal project in general and for the completed first stage in particular, highlighting the testing and commissioning operations under most difficult circumstances and numerous physical constraints.

1. INTRODUCTION

1.1 The Project aims at the development of irrigation facilities to a culturable area of about 570,000 acres situated in the NWFP and the Punjab provices on the right bank of the Indus river, through gravity flow sytem. The NWFP shares 350,000 acres including 104,000 acres under command of the existing Paharpur Canal while the remaining area of 220,000 acres is situated in the Punjab Province and includes about 20,000 acres of land under command of the existing inundation canal known as Massuwah Canal in Taunsa Tehsil of D. G. Khan District. (See Plate I for General Layout of the Project).

1.2 The principal objective of the project as enunciated in the approved project is to increasc agricultural production in the Project area by more effective use of the Indus River flows available at the existing Chashma Barrage thereby improving the general standard of living of the people in the area convering two backward districts of the country i.e. Dera Ismail Khan District in the NWFP and Dera Ghazi Khan District in the Punjab. On completion of this project, a new area of 466,000 acres shall be brought under irrigation with an irrigation intensity of 150% (90% Rabi & 60% Kharif) in addition to furnishing enhanced irrigation supplies to an area of 104,000 acres under the command of the irrigation system of the existing Paharpur Canal.

1.3 The project would create employment opportunities of over 35 million man-days during its eleven year construction period in addition to over 21 million man-days annually for increased agricultural production activities resulting from the project.

1.4 With the increased production of food grains and oilseeds in the project area, the import of food

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grains and oilseeds would be reduced. Similarly export of rice and cotton can be increased. The increase in crop production will also stimulate agro-industries development in and around the project area and with the increase in farm income and improvement in living standards it is expected that the growing trend of migration to urban areas will be reduced significantly.

1.5 A feasibility report was prepared by WAPDA in 1970 to irrigate 500,000 acres of land (350,000 acres in D. I. Khan District and 150,000 acres in D. G. Khan District) through gravity flow system at an irrigation intensity of 100% (58% Rabi & 42% Kharif). The scope of the project was later enlarged in Dec. 1977 to comprise irrigation of an area of 570,000 acres (350,000 acres in D. I. Khan and 220,000 acres in D. G. Khan Districts) at an irrigation intensity of 150% (90% Rabi and 60% Kharif). The PC-I proforma was prepared by WAPDA in December 1977 and approved by ECNEC in 1978 at a rough cost estimate of Rs.1570 millions. The ECNEC, however, directed WAPDA to prepare firm cost estimates. Detailed field investigations and studies were undertaken and the PC-I Proforma revised in May 1981. The revised PC-I Proforma was approved by ECNEC on 23-2-1982 at a cost of Rs.3477.554 millions. (See Plate III for Salient Features of the Project).

2. PROJECT COMPONENTS

2.1 Following components were constructed during construction of Chashma Barrage for future implementation of Chashma right Bank Canal:

a) Head Regulator adjacent to the barrage on the right side;

b) A three mile long Feeder Channel emerging downstream of the Head Regulator;

c) A Control Regulator at the downstream and of the Feeder Channel to form a junction between the Feeder Channel and the existing Paharpur Canal.

Rest of the major components comprising works incorporated in the approved PC-I Proforma are given below:-

a) Main Canal with a full supply discharge of 4879 cusecs. First 24 miles and last 27 miles out of a total canal length of 169 miles would be unlined while the rest of the 118 miles would be fully lined.

b) Distributaries, 48 in number and having an aggregate length of 375 miles (unlined).

c) Cross drainage structures (130 Nos.), head regulators and cross regulators (85 Nos.), bridges (206 Nos.), falls (194 Nos.) and other appurtenant works.

d) Remodelling of Paharpur Canal.

2.2 The project stands approved as a whole but, as a construction strategy it has been divided into 3 stages so that benefits start accruing from the completed stage/stages much before the overall completion of the project. Currently Stage I (from RD 0 to RD 260) has been completed (See Plate II for Layout of CRBC Stage I) and put to successful operation while preparatory works for Stage II (from RD 260 to RD 380) are in progress. Work on Stage III (from RD 380 to RD 846) is proposed to be initiated after completing Stage II in about 2 years period. The project is being designed and executed by WAPDA with concurent reviews by NESPAK, ACE and Asian Development Bank. Works under Stage-I have been

completed through competitive bidding among local contractors with a financial support of US. $ 31.5 million from the Asian Development Bank under a loan agreement signed on 23-12-1977 and revised on 16-2-1984. Going a step further, Stage II works are proposed to be executed through international competitive bidding with a probable financial aid from the Asian Development Bank under a separate loan expected to be finalized in due course of time.

2.3 Some of the salient features relating to design and construction aspects of the completed Stage-I are discussed in the following paragraphs:

Canal Alignment

2.4 The main canal is a contour channel off-taking from the river Indus running at the highest contour and irrigating areas only on the left side.

2.5 Except for the head reach from RD 0 to RD 145 where comparatively high embankments are unavoidable due to higher full supply level and lower natural surface levels, the canal has been aligned to keep the full supply level as close to the natural surface level as possible so that any possible canal damages by the excessive floods in the hill torrents can be repaired at minimum costs and shortest possible interuption of irrigation supplies. No major deviations have been made in this general scheme of cannal alignment except some minor changes at a few locations for avoiding excessive heights of canal embankments and saving costly agriculturable lands, built up property, graveyards etc.

Soil Investigations

2.6 Preliminary Soil Investigations were carried out by drilling auger holes 10 ft. deep at every 4000 ft. interval along the canal alignment. Soil strata was noted and samples were tested in the laboratory for soil classification. Water table, wherever encountered, was also recorded. In the 2nd phase pits 10 ft. deep or upto water table were excavated along the canal alignment at every 4000 ft. in between the auger holes. The pits were logged and soils samples were taken and tested in the laboratory for soil classification and compaction tests. In situ moisture and density was also measured. In situ permeability tests were also under taken at a number of selected places.

2.7 Bore holes with percussion and rotary rigs were carried out at structure sites such as bridges, head regulators, cross drainage works, falls etc. The number and depth of bore holes varied with the size and type of the structure. Standard Pentration Tests were carried out at these holes. Disturbed as well as un-disturbed samples were taken and tested in the laboratory. The area being arid and water table at considerable depth in most of the area, the soil strata was generally in dry state. The SPT tests carried out in the silty strata in dry state gave quite high number of blows with a considerable reduction in this number on saturation. Therefore SPTs were considered representative for the dry strata. Some deep pits were dug out wherein the in-situ density tests were under taken and undisturbed samples were collected for laboratory tests.

2.8 In the initial reach where the canal is in filling, borrow areas were explored near the canal. From RD 0 to 50 the canal is built with the river bed silty sand material. From RD 50 to RD 135 gravely deposits in the piedomont plains were selected for constructing the canal banks. Gradation, compaction and permeability test were run on the material. The borrow areas were selected and specifications for the material and its compaction were chalked out.

Embankments

2.9 The full supply level in the head reach (from RD 0 to RD 120 is generally higher than the natural surface level, the maximum difference being of the order of 25 ft. This condition results in high fills (embankments) involving large quantities of borrow materials. However the higher water table in cultivated land adjacent to the alignment imposed restrictions on borrowing operations in such areas. Consequently, most of the material for fills had to be borrowed form gravel terraces and nullah fans in the hills of Khaisor range situated on the right side of the canal. Because of the excessive haulage distances involved and the gravelly nature of the materials, mechanical means were utilized for execution of earthwork in the head reach from RD 50 to RD 135 while the banks in the reach from RD 0 to RD 50 were made up of silty sand borrowed from the area in the immediate vicinity of the canal. In the silty clay, silty sand and sand dune areas from RD 135 onwards, where the canal runs in a cut and fill section and the height of the banks is comparatively less, local material was used.

2.10 Top width of the main canal banks has been adopted as 25 feet on the left side to accomodate service road and 15 feet on the right while top width of the banks for distributaries and minors has been kept as 6 feet, with the service road 2 feet above the natural surface level.

2.11 A side slope of 1«:1 has generally been used on either side of the embankments with 5:1 slope pushtas on outer sides to cover the hydraulic gradient lines. Compaction of the embankments has been restricted to the prism behind the inner wetted sloping surface of the canal section. Plates IV & V show L-Section and typical cross-sections of the canal respectively.

Canal Lining

2.12 Being a contour channel, the canal section is proposed to be lined in about 70% of its total length in order to maintain the flattest possible longitudinal slope to command maximum area. Out of a total length of 52 miles falling under Stage-I, a length of 28 miles has been lined leaving a stretch of 24 miles in the head reach from RD 0 to RD 120 as unlined. Double layer brick tile (12"x6"x2") lining with a sandwitch layer of «" cement/sand mortar(1:3) has generally been used except a few reaches where the contractors availed the option given by the project authorities to adopt concrete lining instead of brick tile lining for the sake of speeding up the progress which was otherwise being hampered for want of brick tiles in required numbers. Concrete lining consists of 4" thick concrete (1:3:6) slab poured in panels approximately 15'x20' in size. A 3" thick stablized layer of 1:30 cement/sand mix has been provided underneath the canal lining in certain reaches having a relatively impervious sub-grade for facilitating relief from building up of excessive pore pressures in the case of sudden draw downs and thus preventing lifting of lining panels due to uplift forces which could have otherwise developed for want of free draining facility.

Cross Drainage Works

2.13 A peculiar feature of the area traversed by the canal is the rather unpredictable onslaught of flood run offs of the hill torrents which debouch from Koh Suleiman range and fan out into numerous branches before joining the River Indus. These branches and main streams of the torrents are crossed by the main canal. Following heavy rains in the catcment, these streams and branches overflow their banks and cause sheet flow conditions which would pose a great threat to the canal embankments obstructing the flows. In order to prevent the failure of the canal embankments by erosion caused by parallel flows, adequate protection works viz spurs and guide bunds have been provided on the right bank of the canal. This sheet flow condition occurs mostly in the reach from RD 210 to RD 630 where the canal will be mainly in cut

resulting in spoil banks which, placed on the right side, would provide additional safety. The spurs will be attached to the embankment or the spoil bank.

2.14 Adequate drainage crossing structures have been provided at a number of crossings of the CRBC with the hill torrents. Capacity of these structures has been provided to pass flood flows on the basisi of 40 year return period for the lined reaches and 30 year return period for the unlined reaches. Additional protective works have been provided to protect the canal from parallel flows in the reaches afflicted with the sheet flows.

2.15 From RD O to 97 the Paharpur Canal was flowing in an old creek of the river Indus on the right bank of the CRBC. After commissioning of the CRBC, the Paharpur Canal in this reach stands abandoned and would act as an interceptor drain against the seepage from the CRBC and the storm water flows from the hills in this reach. It would discharge its flows across the CRBC through the cross drainage works under the Combined Structure at RD 97 for disposal into the river Indus through the escape channel of the Combined Structure.

2.16. Cross drainage works provided in the remaining reach from RD 97 260 comprise one super passage at RD 143 and three drainage culverts at RDs 109, 118 & 133 and thirteen drainage syphons at Rds 120, 124, 128, 129, 140, 147, 148, 152, 167, 177, 217. 219, & 232 in addition to one canal syphon and an escape structure at RD 257. The super passage has been designed to carry a nullah flow of 2100 cusecs through a reinforced cement concrete trough placed above the full supply level in the main canal. Drainage culverts and syphons essentially consist of a varying number of reinforced concrete barrels of different sizes depending on the estimated design flows of the respective nullahs. The barrels pass beneath the canal bed and are flanked by pucca transitions on each side with necessary protection and training works. Open drains have been provided where necessary to convey the flows from these cross drainage works to the river Indus. An aggregate capacity of about 130,000 cusecs of nullah flows has been provided through the cross drainage works falling in the Stage I.

Combined Structure

2.17 A massive structure known as Combined Structure has been provided at RD 97. It combines 6 functions at one place and serves as cross regulator, escape, silt excluder, cross drainage work, A.A. bridge and D.R. bridge simultaneously. It has 12 gates (11'x10') for the cross regulator, 6 gates (13«'x11') for the escape and 2 gates (13«'x2«') for the silt excluder. Cross drainage work consists of 14 reinforced concrete barrels (6'x9') to pass an estimated design flow of 11,000 cusecs. The whole structure is supported on 138, cast in situ and 60 feet deep, reinforced concrete piles. (Plate VI shows photograph of the combined structure).

Bridges

2.18 Bridges have been provided on the main canal and the distributaries at all such locations where the canal alignment happened to cross the existing roads and foot paths as identified during actual ground surveys. In all, one Arterial Road (A.R.) bridge, 18 Village Road (V.R.) bridges and 15 Foot bridges have been provided on the main canal whereas distributaries have been provided with 16 V.R. bridges and 7 Foot bridges in Stage I. The above number of bridges takes care of uninterrpted flow of traffic just like it used to be before the consturction of CRBC.

Cross Regulators and Head Regulators

2.19 Two cross regulators at RD 97 & RD 257 have been constructed apart from 8 head regulators for feeding the required supplies of irrigation water to the 2 existing distributaries, one existing minor and 5 new distributaries. Mechanical components comprising gates and gate hoist mechanisms have been designed, fabricated and installed by the Mechanical Circle of the Punjab Irrigation Department. (Plate VI shows photograph of the cross regulator at RD 257.

3. CONSTRUCTION ACTIVITIES

3.1 The civil works contracts were awarded on the basis of competitive bidding among prequalified local contractors. Works under Stage I were divided into 15 main contracts, 7 for earthwork and lining and 8 for structures apart from the mechanical works entrusted to the Mechanical Circle of the Punjab Irrigation Department. In the lined reach, earthwork and lining was done by the same contractor. Structures covered under the 8 contracts for the main canal and distributaries comprised bridges, cross drainage works, head regulators, cross regulators, escapes and falls.

3.2 Conventional means of manual/donkey labour supported with suitable compaction equipment has generally been deployed for the earthwork on the main canal and distributaries except in a reach of 17 miles from RD 50 to RD 135 where deployment of heavey earth moving and compaction equipment was essential due to large earthwork quantities, greater haulage distances and gravelly nature of material. The work was split up in two contracts and awarded to M/s MCPL from RD 50 to RD 96 and to M/s HAKAS Ltd. from RD 96 to RD 135 after open competitive bidding. Each of the contractors had adequate suitable earthmoving machinery which was further supplemented by procurement of machinery through financial assistance from WAPDA in the form of Special Plant Advance as per provisions of their contract agreements. Basically loader-dumper combination supplemented with heavy vibratory rollers was deployed to achieve the desired results.

3.3 Regarding lining and the related canal structures, conventional means of placement of concrete and construction of brick masonry were deployed. As already stated the job of design, fabrication and installation of gates has been carried out by the Mechanical Circle of Punjab Irrigation Department who had all the requisite resources and technical through the State Cement Corporation and supplying knowhow. WAPDA had made arrangements for procuring cement to the various contractors. Cost of cement supplied to the contractors was recovered from their bills as per provisions of the respective contract agreements.

4. CONSTRUCTION MATERIALS

4.1 In the initial reach RD O to 50 the canal was constructed with silty sand borrowed from the immediate vicinity of the canal. This material, associated as it is with somewhat high permeability, had to be used for economic reasons because the comparatively impervious clayey material was not available within economic haulage distances. The inner prism was compacted to 95% Proctor density. The fill material for construction of embankments in the reach from RD 50 to RD 135, where comparatively high embankments were involved, was borrowed from gravel terraces on the nullah fans located on the downhills on the right of the main canal. Borrow areas were selected following extensive topographic and soil testing investigations. Material to be accepted for filling was specified to have a minimum of 15% passing # 200 sieve and with a maximum stone size of 12". The material was compacted by means of vibratory rollers in horizontal layers not more than 15 inches thick after being compacted. Embankments for the rest of the canal from RD 135 to RD 260 were made of local material excavated from the canal

sections which was partly in cut and partly in fill. For compaction, vibratory rollers were deployed in case of granular (silty sand) material while sheep foot rollers were used for silty clayey materials.

5. TESTING AND STAUNCHING OF CANAL

5.1 Before describing the various operations adopted for testing and staunching operations of this canal, it is pertinent to highlight some of the constraints which posed a real challenge to the project authorities entrusted with the task of testing and staunching of the newly constructed canal especially the unlined reach of 24 miles from RD O t RD 120:-

(i) Available time duration of only one month for completing numerous and difficult testing and stauching operations (essentially associated with newly built unlined canals) was extremely inadequate as against normally required duration of 6 to 9 months under similar circumstances. The limiting factor was the absolutely essential requirement of maintaining uninterrupted irrigation supplies to the existing Pharpur Canal which ran in and out of the CRBC through a number of gaps left in the latter during its construction. Closing of these gaps was a necessary pre-requisite for letting water into the CRBC for its testing and the gaps could only be closed in the one month closure period of the Pharpur Canal in January during which the CRBC was to be completely tested and staunched so as to be able to feed the Paharpur Canal immediately after the closure period. This constraint dictated an undesirable compulsion to raise the supplies in the CRBC at rates much faster than the minimum recommended during testing and stauching of the newly built unlined canals.

(ii) Apart from the limited period available for testing and staunching, the month of January is, unfortunately, perhapse the most undesirable period for such purposes as the river water is almost silt free during this period.

Use of silt free water for tesing purposes is liable to cause bed and banks erosion resulting in breaches. Apprehensions of countless breaches were vehemently expressed by certain quarters for the same reason.

(iii) The material constituting the canal bed in the untire unlined reach and that used in the construction of the canal embankments in the 10 mile reach from RD O to RD 50 was silty sandy, because the canal alignment traverses a reclaimed area abandoned by the river following construction of the Chashma Barrage. As such, seepage loss during initial period was bound to be on the exeessive side. The seepage situation in fact furned to be quite so during limited initial period but it was drastically reduced in a short period following silt inducing measures to be described later.

(iv) The canal in the unlined reach runs in high fill with designed bed level falling about 3 to 17 feet above the existing land level. The intervening space of 3 to 17 feet is to be filled by sediment deposit over the next 15 year or so. Fairly high depth of water in the main canal had to be attained in a limited time for feeding certain distributaries with head regulators having silt levels higher than the ultimate designed bed levels.

(v) An undue and unfounded alarm about grossly excessive and over estimated seepage losses was in the circulation even before the testing and staunching operations were taken in hand. To begin with, a Harza Consultant came out with an average permeability value of 1.7×10^{-2} cm/sec. (24.6 in. hour) through the so called in-situpermeability tests. Using these values an ADB Mission which visited the project site from 28-11-1986 to 4-12-1986 estimated a seepage loss of 2100 cusecs in the reach from RD O to RD 50 (which would roughly be equivalent to a loss of 5100 cusecs in the full

unlined reach from RD O to RD 120). The ADB Mission went to the extent of postponing the commissioning of the canal by one year till an impervious blanket with an estimated cost of US.$ 5 million was laid in the canal section in the reach from RD O to 50. The reach beyond RD 50 was considered to be trouble free by the Mission though the actual canal operation has shown that both the reaches have behaved equally well and in the normal manner. Later, a ponding test was performed under guidance of the same Harza Consultant in a 300 feet length of the canal at RD 45 from 25-12-1986 to 27-12-1986. As a result of this test, the seepage rate was estimated at 48 cusecs per million square feet of wetted perimeter which gave a loss of 1150 cusecs in the unlined reach from RD O to RD 120 and 620 cusecs from RD O to RD 50. A seepage rate of 8 cusecs per million square feet of wetted perimeter was provided for at the design stage which is equivalent to a loss of about 200 cusecs from RD O to RD 120. Actual running of the canal has, however, shown a seepage rate of less than 5 cusecs per million square feet of wetted perimeter. The rather low rate of seepage has been brought about due to timely remedial measures taken by the project authorities.

5.2 The above is a very brief picture of the abnormal constraints and limitations posing serious threats to the testing and staunching of the CRBC. The alarm thus raised was generally discouraging but the concerned authorites, being confident about the design and construction aspects, decided to go ahead with testing, staunching and commissioning of the canal with a pre-planned programme of the requisite remedial and precautionary measures. Accordingly, testing and staunching operations were started on 6th January by cutting off supplies to the Paharpur Canal and letting water into the CRBC. Initially 100 cusecs of water was released which was progressively increased to 700 cusecs. First the canal was tested upto RD 97 wherefrom the water was escaped at the combined structure to the escape channel leading to a creek of the river. Staunching operations such as killa bushing and puddling were continued. Water depth was about 18 feet at RD 97, while at RD O it was only a couple of feet. Since the canal was opened in the month of January when water was almost silt free, efforts were made to induce silt by artificial means. The source of silt utilized for this purpose is the 15000 feet long Paharpur Feeder located just upstream of the CRBC and constructed as a part of the Chashma Barrage to feed the existing Paharpur Canal initially and the CRBC ultimately. This Feeder had been designed and constructed for a discharge of 5000 cusecs while it has been passing a discharge of 480 to 600 cusecs only. The water level was, however, maintained at the FSL corresponding to the design discharge of 5000 cusecs by ponding in the Feeder through a Control Regulator at its downstream end in view of the head across restrictions prescribed for the various Barrage components. These operation conditions have caused a substantial amount of silt deposit inside the Feeder which proved to be a blessing in disguise for the CRBC. This silt was carried by the flows into the CRBC following effective agitation operations which comprised cutting and throwing the silt into the running water and stirring it with compressed air.

5.3 In the first fifty RDs specially from RD 30 to 50 the permeability of the bed material was comparatively high as the top cover had been borrowed and used in the banks and thus initial rate of seepage was somewhat on the excessive side. The water appeared in the borrow areas a day after it was let into the canal. Even small sand boils were seen near RD 30. The ground water table which was about 2 to 3 feet from the NSL in this reach rose to surface and all the borrow areas were filled with water.

5.4 Although the exist gradient at the toe of the banks was within safe limits, yet in order to strengthen the banks, pit-run gravel about 1« ft. thick was laid on the pushtas. The free draining gravel would provide the weighted berm, free flow of seepage water and filter against migration of fines and piping condition. Animal burrows or any preferential passages which were transmiting water freely in initial days were closed due to collapse of the sandy strata or saturation and the puddling action from inside. The induced silt had a marked effect in choking the pores and the seepage loss descreased drastically over the passage of time.

5.5 Canal embankments in the reach from RD 50 to 97 are made up of silty sand gravels borrowed from the piedomont plains. It was specified that the gravels should contain minimum of 15% of fines passing No. 200 sieve with maximum stone size of 12", should be well graded and compacted to atleast 80% relative density by vibratory rollers. The inner prism of the banks was compacted while the outer bank and the pushtas were to be of loosely dumped material. At a few points in this reach also, the seepage was initially high because of less fines in the gravels due to segregation during handling and placing. Even at places gap graded material had been used. Impervious material was dumped inside the canal and free draining gravels were placed on the pushtas at places where excessive seepage was observed. This helped in reducing the seepage and strengthening the banks. Longitudinal cracks appeared on the banks at a few places. The cracks were mostly in the middle of the banks or near the outer edge. Sloughing was also observed on the inner banks. The cracks were filled with sand and kept under observation. After some time when they did not open out further they were capped with impervious material to avoid entry of rain water. Any crack cutting the bank across was opened above the water level and refilled with compacted impervious fill. At one location, excessive seepage was oberved along an abandoned pipe outlet crossing the embankment during construction. The pipe was removed after excavating a trench and refilling it properly. In a small reach just upstream of the combined structure at RD 97, the contractor had built the banks of sandy material instead of gravel material. The inner prism was remade by compacted gravels choked with fines.

5.6 From RD 97 to 120 the canal banks are made up of predominantly fine to medium sand with a 3 ft. cover of silty sandy gravels. In this reach the banks are relatively high with a height ranging from 20 to 30 ft. and the contractor used uniformly graded sand or skip graded gravels instead of prescribed well graded gravels choked with fines. Water was let in this reach on 1.2.1987 and it filled up in a couple of days in view of the fact that the closure period of the Paharpur Canal was already over and this canal had to be fed then from the CRBC.

5.7 As the two head regulators at RD 99 and RD 114 feeding respectively the Takkarwah and Kot Hafiz distributaries of the Paharpur Canal were designed with respect to the ultimate bed level of the CRBC, the canal had to be brought to nearly full supply level in order to feed these outlets. A gabion weir was built at RD 120 (start of the lined reach) to raise the water level in the main canal. Consequently this reach was subjected to about 20 ft. head of water. The banks being pervious soon got saturated and seepage started appearing outside. On saturation, the uniformly graded loosely dumped sand on outer slopes are known to slump and liquefy and flow away with the build up of pressure. The first two slides appeared on right bank from RD 117 to 118. Then a major slide involving about 550 feet width occured at RD 117 on the left bank. The material, starting from outer edge of the bank, flowed away leaving an almost vertical bank of sand. Immediately dumpers and dozers were brought into action and within 10 hours a gravel bench was added to buttress the bank. There was sloughing of inner bank into the canal. Silty material was dumped into the canal in order to seal it from inside. The entire reach from RD 100 to 120 on the left bank and vulnerable points on the right bank were protected with gravel buttresses. (Plate VII shows the strengthening of banks with gravel benches).

5.8 Had there been sufficient time available for raising the water level gradually at desirable rates and for providing effective staunching measures, the above described slides could have been avoided. In order to cope with the situation, the gabion weir at RD 120 was removed and two temporary bypass arrangements provided at the sites of the two head regulators at RD 99 and RD 114 to feed the two distributaries at low water levels in the CRBC. These arrangements have proved very successful with the result that the full demand of the Paharpur Canal is being met from the CRBC as per indents received from the Irrigation Department of the NWFP. Overall performance of the CRBC is fairly satisfactory with drastically reduced seepage losses. The current seepage rate has been found to be less than 5 cusecs per

million square feet of wetted perimeter as against 8 cusecs acceptable for unlined canals under similar conditions. The canal is currently carrying a discharge of 2000 cusecs which could be increased further as and when required.

6. PROBLEMS ENCOUNTERED DURING CONSTRUCTION

Collapsible Soils

6.1 One of the problems encountered at the CRBC project was the discovery of collapsible soil in a 10 mile reach from RD 210 to RD 260.

6.2 Excavation of the canal section in the above reach was started in June, 1979. By August, 1981, lining consisting of double layer of brick tiles had been placed in a length of about 2 miles when some cracks appeared in the lining on side slopes at RD 249. The lining was opened at this location and samples of sub-grade taken and tested to find out the reasons for appearance of the cracks. The sub-grade soil was found to contain excessive moisture. The cracks were repaired. Additional cracks of the same type appeared in the side slopes at other places in the reach from RD 242 to RD 252 which called for immediate action to fully investigate the possible causes for the continued appearance of cracks in the lining on slopes. These cracks were appearing in most of cases at 1/3rd of the depth of the canal above the bed.

6.3 A comprehensive programme of site investigations for ascertaining the causes for cracks was launched in January, 1982. The investigations comprised gradation, insitu density, moisture content and compaction tests; double odeometer tests on undisturbed samples, insitu collapse tests etc.

6.4 After a careful evaluation of the results of these investigations, it was concluded that most of the tests indicated presence of collapsible soil which is defined as an unsaturated soil that is subjected to a radical re-arrangement of particles and great loss of volume upon wetting with or without additional loading. The resulting collapse of the soil had been the cause of cracks in the lining.

6.5 After a comparative study of all the possible remedial measures to tackle the problem caused by the presence of collapsible soil, it was decided to pre-collapse these soils by over-excavating the canal section and refilling and compacting the soil to the desired level and grades. It was also decided to provide a 3" thick filter layer beneath the lining and drill 9" drameter boreholes at the toe of the lined slopes inside the canal section at 50 feet interval on each side.

Alignment Constraints

6.6 The canal between RD 97 & RD 120 was known from very early stages to be inflicted with serious alignment constraints. The alignment in this reach had to run winding through village abadis, graveyards, shrines and the existing Paharpur Canal. By-passing all these restrictions would have either resulted into deep cutting of the order of 60 to 70 feet or it would have required fills of 40 to 50 feet high. The finalized alignment still ran through cultivated lands of Chura, Dhakki, Kotla and Saiduwali villages. During progress of the work, inhabitants of these villages supported by local administration made numerous representations to the Government and WAPDA for shifting the alignment to save their properties. A number of alternatives were examined to save the inhabitants from hardship as well as high cost of construction.

Accordingly some final adjustment in the canal alignment had to be made during construction stage

so as to cause least disruption to the existing irrigation system, village abadis, graveyards etc.

Land Acquisition

6.7 The local inhabitants stopped work on a few occasions due to land acquisition problems which were solved by taking timely actions regarding payments of compensations and with active support of the local administration.

7. CONSULTANCY SERVICES

7.1 As per loan agreement with the Asian Development Bank, services of consultants are being utilized only in assisting WAPDA in setting up and implementing a monitoring programme on irrigation delivery system in order to measure water losses. Being fully convinced about the capabilities of WAPDA engineers for handling all the planning and design aspects of the project, the Bank did not insist on the appointment of consultants for these purposes. In fact, CRBC is one of the very few foreign aided projects which is being planned and designed by WAPdA engineers themselves.

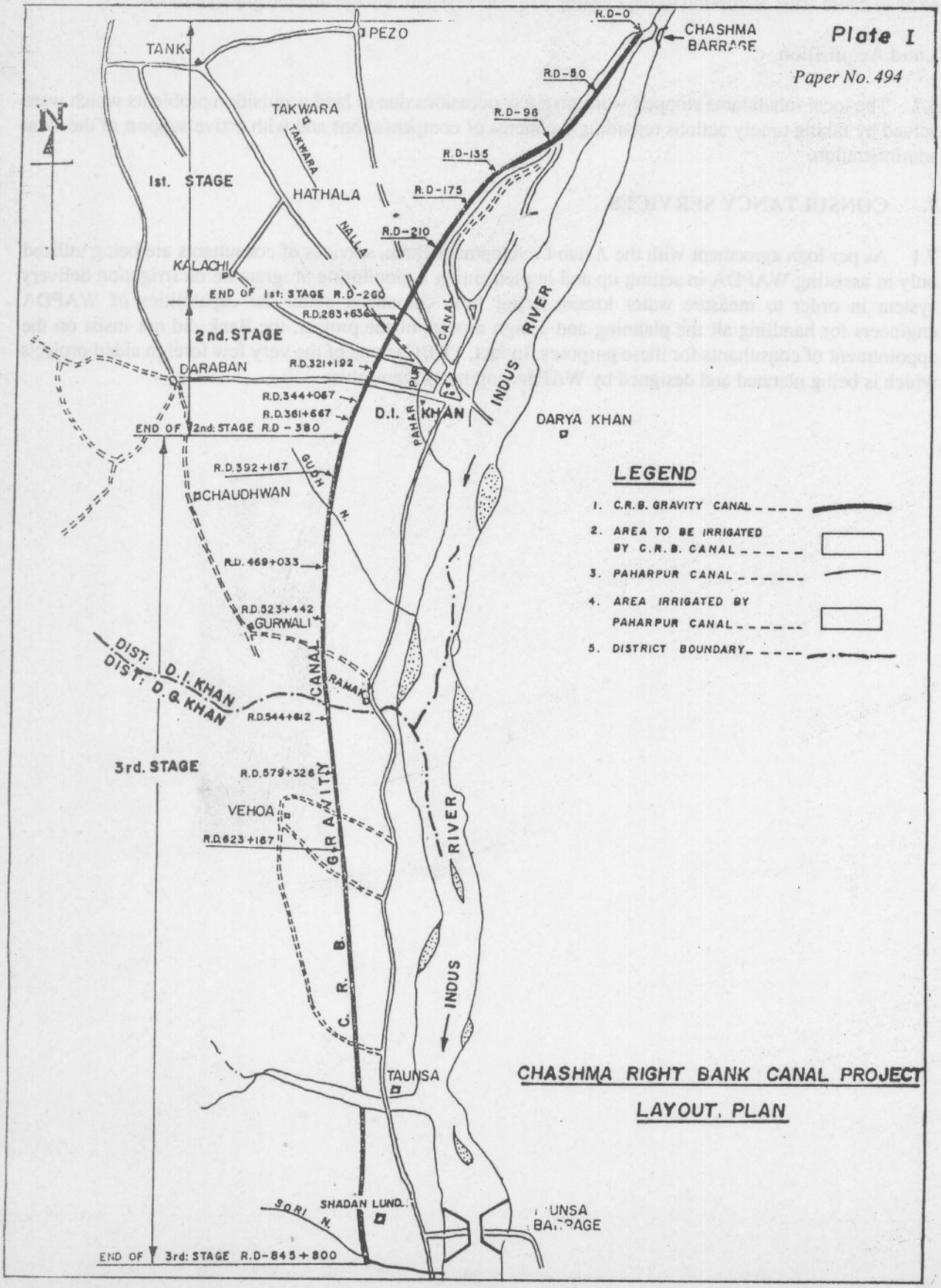
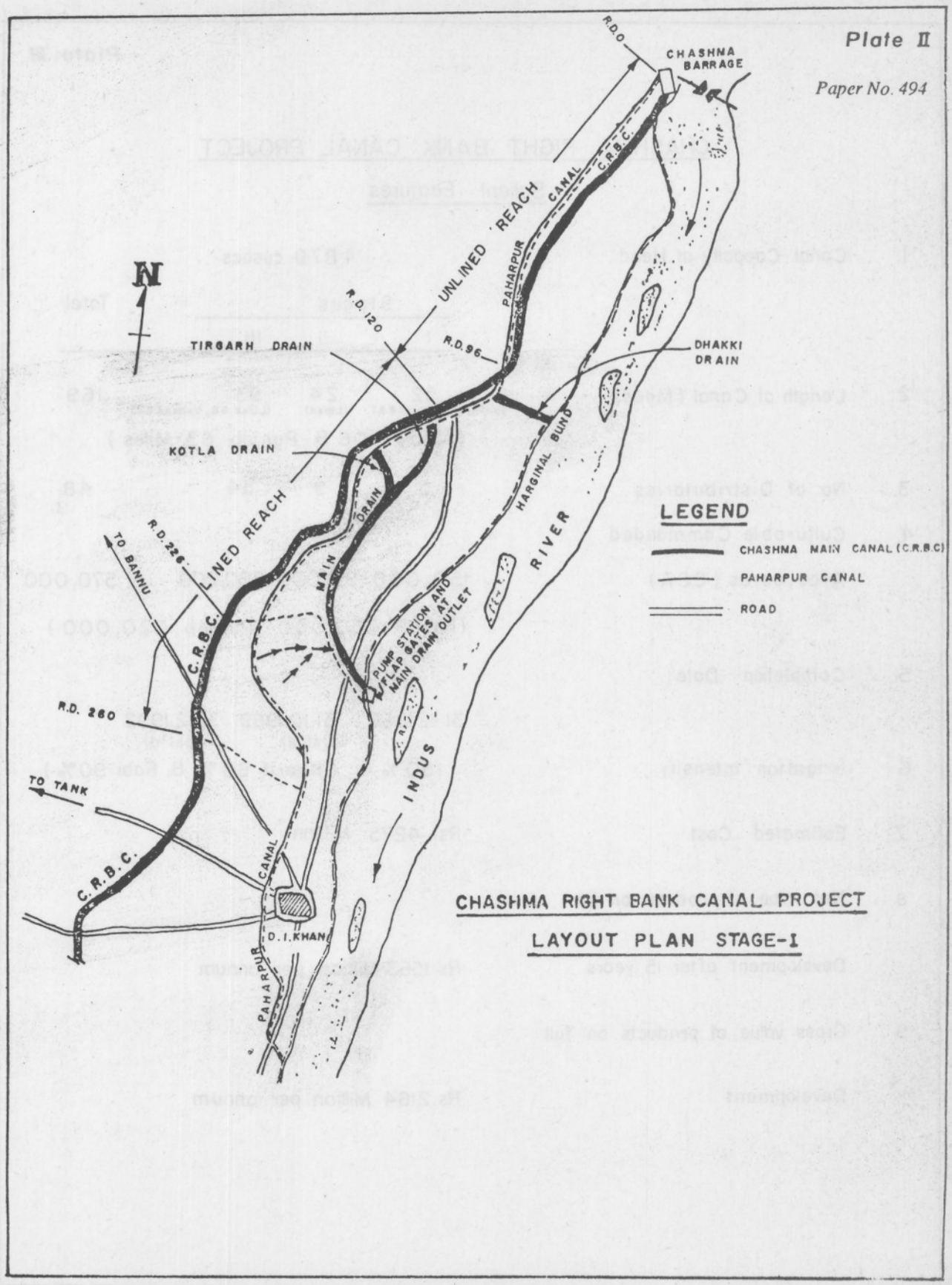


Plate I
Paper No. 494
R.D-0
CHASHMA BARRAGE
PEZO
TANK
R.D-50
TAKWARA
R.D-96
TAKWARA
R.D-135
1st. STAGE
HATHALA
R.D-175
NALLA
R.D-210
KALACHI
END OF 1st: STAGE R.D-260
R.D.283+636
2nd. STAGE
CANAL
INDUS RIVER
DARABAN
R.D.321+192
PAHARPUR
R.D.344+067
R.D.361+667
D.I. KHAN
DARYA KHAN
END OF 2nd: STAGE R.D - 380
R.D.392+167
GUDH N.
CHAUDHWAN
R.D. 469+033
R.D.523+442
GURWALI
DIST: D.I.KHAN
DIST: D.G.KHAN
CANAL
RAMAK
R.D.544+612
3rd. STAGE
R.D.579+326
GRAVITY
VEHOA
R.D.623+167
RIVER
C. R. B.
INDUS
TAUNSA
SORI N.
SHADAN LUND
TAUNSA BARRAGE
END OF 3rd: STAGE R.D-845+800
LEGEND
1. C.R.B. GRAVITY CANAL
2. AREA TO BE IRRIGATED BY C.R.B. CANAL
3. PAHARPUR CANAL
4. AREA IRRIGATED BY PAHARPUR CANAL
5. DISTRICT BOUNDARY
CHASHMA RIGHT BANK CANAL PROJECT
LAYOUT PLAN

Plate II

Paper No. 494



CHASHMA RIGHT BANK CANAL PROJECT

LAYOUT PLAN STAGE-I

Plate III

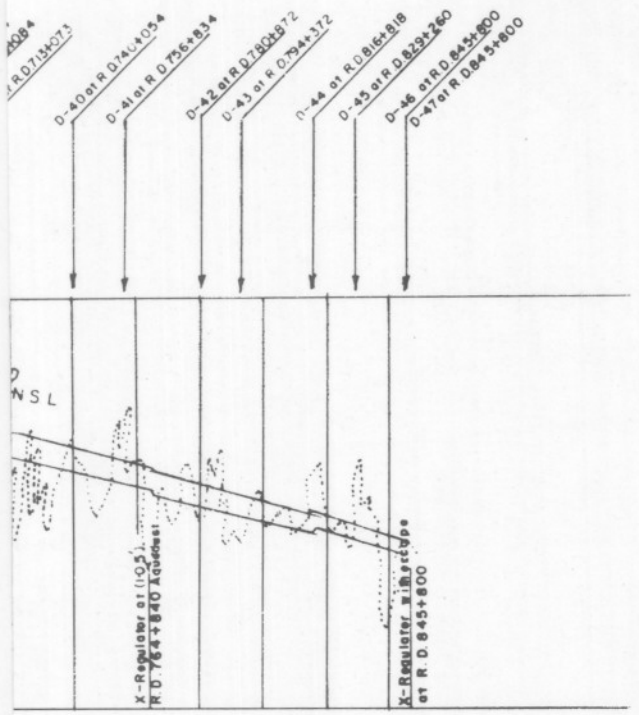
CHASHMA RIGHT BANK CANAL PROJECT

Salient Features

1.	Canal Capacity at Head	4879 cusecs			
		Stages			Total
		I	II	III	
2.	Length of Canal (Miles)	52 (Unlined 24, Lined 28)	24 (Lined)	93 (Lined 66, Unlined 27)	169
		(NWFP 106 & Punjab 63 Miles)			
3.	No. of Distributaries	5	9	34	48
4.	Culturable Commanded Area, acres (CCA)	150,000	90,000	330,000	570,000
		(NWFP 350,000 Punjab 220,000)			
5.	Completion Date.	31.12.1986	31.10.1989 (Est'd)	31.12.1992 (Est'd)	
6.	Irrigation Intensity	150 % (Kharif 60 % & Rabi 90 %)			
7.	Estimated Cost	Rs:- 4275 Million			
8.	Net value of products on full Development after 15 years	Rs. 1563 Million per annum			
9.	Gross value of products on full Development	Rs. 2164 Million per annum			

PLATE - IV

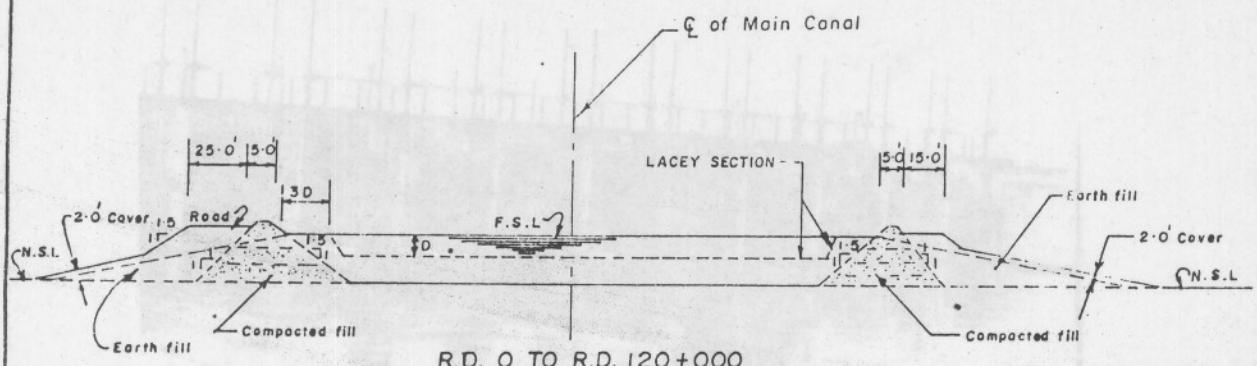
Paper No. 494



DATUM				
VELOCITY	2·28 ft/Sec	2·28/Sec	2·05 ft/Sec	1·89/Sec
TYPE	Unlined	Unlined	Unlined	Unlined
VALUE	0·88	0·88	0·88	0·87
F.S. D	753 Cs	753 Cs	384 Cs	234 Cs
F.S.	4·59′	4·59′	3·75′	3·24′
BED	67·07′	67·07′	47·20′	36·40′
N.S		569·12	563·22	
R.	764+840	780+384	800+488	816+818	845+800

L - SECTION OF C.R.B.C.
C.R.D. 0+000 TO 845+800

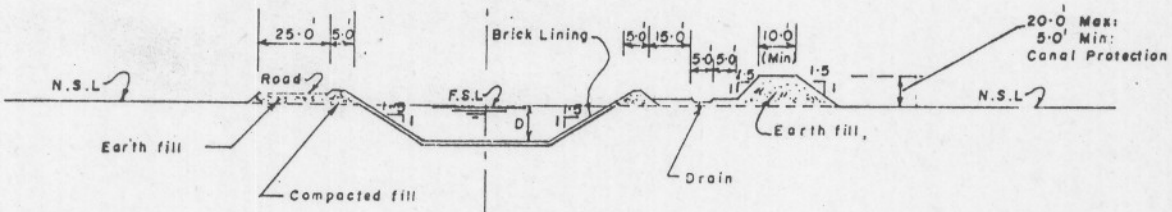
Plate V



R.D. 0 TO R.D. 120+000

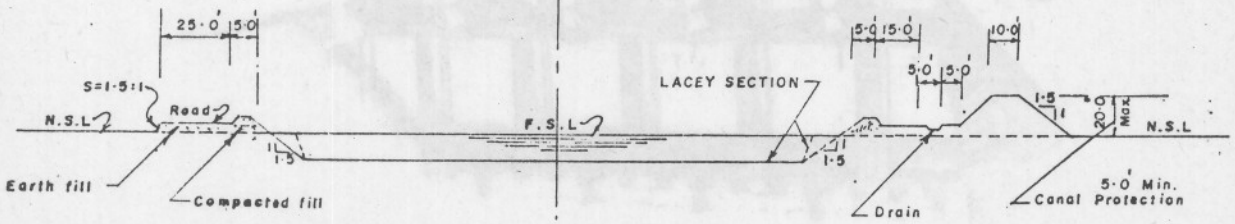
(UNLINED)

CANAL SECTION IS 1:20 FOR SPECIFIC SECTIONS ONLY IN REACH.



R.D.120+000 TO R.D.713+000

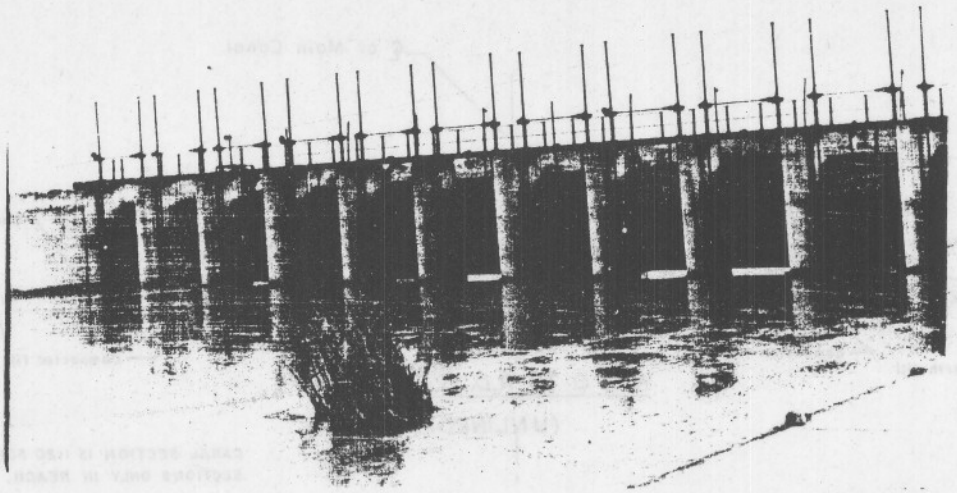
(LINED)



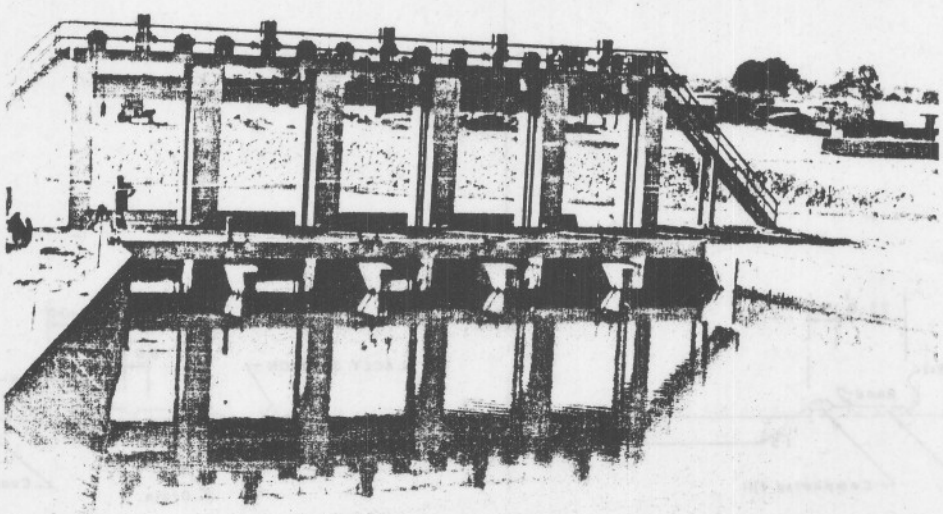
R.D. 713+000 TO R.D. 845+000

(UNLINED)

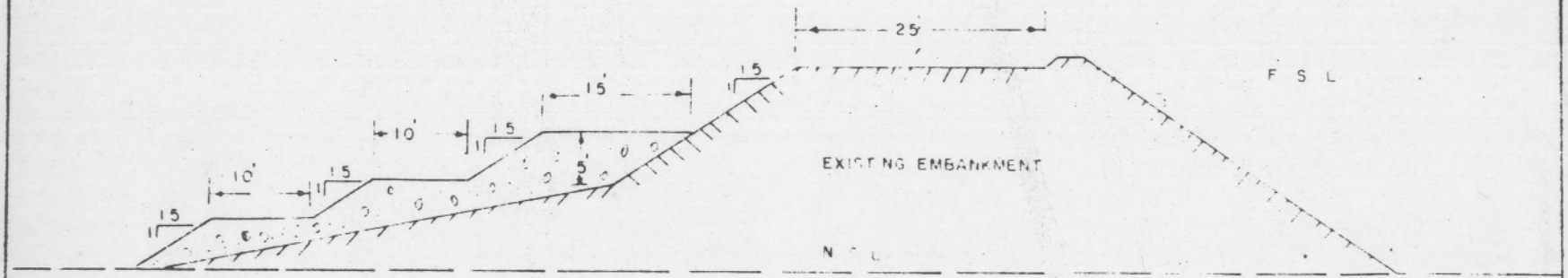
MAIN CANAL
TYPICAL SECTION
C.R.B.C



Upstream view of Cross Regulator at
the Combined Structure at R.D. 97



Upstream view of the Cross Regulator
at R.D. 257



C.R.B.C

LEFT BANK (R.D116) REINFORCEMENT WITH PIT RUN GRAVEL

PLATE-VII

Paper No. 494