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GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

MINISTRY OF LOCAL GOVERNMENT, RURAL DEVELOPMENT AND COOPERATIVES

RURAL IRRIGATION WORKS STUDY
FINAL REPORT

APPENDIX C
DESIGN MANUAL

ENGINEERING CONSULTANTS, INC.
ENGLEWOOD, COLORADO, U.S.A.

PLANNERS, ENGINEERS AND CONSULTANTS LIMITED
DACCA, BANGLADESH

FEBRUARY 1980

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ABBREVIATIONS

BADC	=	Bangladesh Agricultural Development Corporation
B/C	=	Benefit-Cost Ratio
BRRI	=	Bangladesh Rice Research Institute
BSC	=	Bangladesh Shipping Corporation
BWDB	=	Bangladesh Water Development Board
CAD	=	Command Area Development
CARE	=	Cooperative of American Relief Everywhere
DEM	=	Directorate of Extension and Management
DTW	=	Deep Tube-Well
ECI	=	Engineering Consultants, Incorporated
FAO	=	Food and Agricultural Organization
GOB	=	Government of Bangladesh
HYV	=	High Yielding Variety
IRDP	=	Integrated Rural Development Program
KSS	=	Krishi Sambaya Samities (Agricultural Cooperative Society)
LLP	=	Low Lift Pump
MRD	=	Ministry of Local Government, Rural Development and Cooperatives
PEC	=	Planners, Engineers, and Consultants
RWP	=	Rural Works Program
SAE	=	Sub-Assistant Engineer, RWP
SDE	=	Sub-Divisional Engineer, RWP
STW	=	Shallow Tube-Well
TCCA	=	Thana Central Cooperative Association
TIP	=	Thana Irrigation Program
USAID	=	United States Agency for International Development
WAPDA	=	Water and Power Development Authority
WB	=	World Bank
XEN	=	Executive Engineer RWP

CURRENCY EQUIVALENTS

US $ 1 = Taka 15.00
Taka 1 = US $ .067

WEIGHTS AND MEASURES

1 acre (ac)	=	.405 hectare (ha)
1 bigha (bi)	=	.33 acre (ac)
1 sq mile	=	640 acres (ac)
1 maund (md)	=	82.28 pounds (lbs)
1 maund (md)	=	37.3 Kilograms (kg)
1 metric ton (ton)	=	26.8 maunds (md)
1 seer (sr)	=	2.06 pounds (lbs)
1 cubic foot per second (cusec)	=	0.283 cubic meters per second

GLOSSARY OF TERMS

Aman = Rice sown/planted during March to July/August and harvested in November or December.

Aus = Rice sown/planted during March and April and harvested in July and August.
T. aus = transplanted aus; B. aus = broadcasted aus.

Beel = Marsh or lake; also spelled bill or bil.

Boro = Winter rice, planted during November and December and harvested during April to June.

Char = Newly formed sandy alluvial tract.

Drain = Canal to provide drainage or irrigation water.

Khal = Narrow natural channel of water.

Kharif = Summer season or rainy season.

Kutcha = Temporary, lower grade or dirt structures.

Paddy = Unhusked or rough rice (oryza sativa).

Pucca = Permanent, good quality structures.

Rabi = Winter season or dry season.

Thana = Political sub-division of a sub-division: police station or revenue unit.

Sub-Division = Political division of a district.

APPENDIX C
DESIGN MANUAL

Section 1: Introduction

This Design Manual (Appendix C) presents standards and procedures for two distinct types of sub-projects under the Rural Irrigation Works Study. The first is for distribution systems for irrigation from deep tube-wells (DTW) or from low-lift pumps (LLP). The designs do not include the source of water. These installations are furnished and installed by BADC. The design work is simple and straightforward, consisting of dividing the area to be served into blocks and routing canals so each block can be reached. The second is for re-excavation of khals and construction of sluiceways. Many variables, both of field conditions and objectives to be attained, are involved, requiring engineering judgement in the design of these schemes.

The manual is written with the understanding that the engineers who use it for preparing sub-project designs are graduate engineers with some years of experience in the field of irrigation and water resources. Basic hydraulic flows are not stressed. The solutions of many design problems must be based on mature judgment which comes only from experience. The manual is applicable to relatively small, isolated on-farm sub-projects. The design of larger sub-projects often involves many specialists in the fields of hydrology, river morphology (sediment deposition and erosion), geology, ecology, agriculture, and economics.

All available field data, maps, river hydrograph records, and agricultural requirements are presumed to be available to the engineers at the start of design preparation.

Most calculations in engineering design are now done on electronic calculators. These devices are highly efficient in performing mathematical operations to several decimal places. Designers tend to record results of calculations to several decimal places. A number shown to decimal places indicates an accuracy of plus or minus one-half the n th decimal. The exactness of the data and observations that engineering designs are based is seldom accurate to more than three significant figures and the results of calculations should not be recorded to imply greater accuracy. For designs prepared under this manual, dimensions of structures and canal bottom grade elevations shall be to 0.01 ft. or 1/8 in. Earthwork dimensions shall be to 0.1 foot and areas, volumes, etc. to the nearest unit. Canal slopes shall be to 0.001, which is equivalent to 0.01 feet per 100 feet. Extremely accurate surveying is required to maintain this accuracy.

The design procedures include some programs for a Hewlett-Packard 97 calculator. It presumes that the calculator which has been furnished to MRD by the Consultant, will be available to the designers. All of the equations solved are shown on the program description and may be solved by hand calculation.

Section 2: Deep Tube-well and Low-lift Pump Distribution Systems

A. Data Requirements

The location of the sub-project has been determined, as well as the cropping pattern and other agricultural requirements.

A topographic map has been prepared to a scale of one inch = 165 feet. The base maps are enlarged by pantograph for one inch = 330-foot-scale mouza maps. Vertical datum is an assumed elevation of 100.00 feet at the invert of the DTW pump discharge pipe or at some clearly defined permanent location near the site for LLP sub-projects. Elevations are shown for each plot, which is assumed to be levelled. Some of the larger plots may have interior terraces, whose elevations

are shown. The locations and sections of existing kucha drains; roads, cart trails, natural drainage courses, and drainage structures under the road (with dimensions); man-made features (such as houses, cemeteries, timber plots, etc.) that may influence the distribution system; and one-foot contours are all also shown.

B. Distribution System Plan

The area of the sub-project that can be irrigated has been determined from the cropping pattern and the crop water requirements. This command area is divided into three-to-five-acre blocks, whose boundaries follow plot boundaries. The blocks should be somewhat square and should not have large elevation differences. The topography and configuration of plots necessitate frequent deviations from the optimum. The locations of the distribution canals are made at the same time as the blocks are laid out. In so far as practicable, the canals should be situated so as to serve blocks on each side.

After the blocks and canals are located, the delivery elevation and number of each block is noted on the map. The delivery elevation is 0.5 feet above the highest plot elevation in the block. The elevations are recorded to a tenth of a foot. Canals are designated by letters A, B, etc. as they take off from the pumping plant. Branch canals are designated A1, A2, etc. as they take off from a main canal. Blocks are numbered by canal, e.g., A1 is the first block served by canal A. The numbers increase along the canal. The numbers of blocks served from branch canals continue the canal number. For example: Canal A1 serves two blocks; it takes off from Canal A downstream from Block A8; the two blocks on Canal A1 are nunbered A9 and A10 and the next one downstream on canal A is numbered A11. Structures such as turnouts and road and cart crossings are shown on the canal alignment.

C. Profiles

Profiles show the vertical positions of deliveries to blocks and structures along the length of canals. The horizontal scale of the profile is the same as the plan, or one inch = 165 feet. The vertical scale is one inch = two feet. Horizontal distances are transferred

from the plan. A water surface profile is determined by trial, which will deliver water to all turnouts at or above the delivery water surface elevations. Slopes are limited to 0.002, the flattest, and to 0.001, the steepest. Where more drop occurs in elevation between turnouts than the steep slope will accommodate, drop structures are constructed. The rather flat slopes with drop structures will generally reduce high fill reaches along steeper profiles. Occasionally, a high delivery water surface, remote from the begninning of a canal, may require its relocation or may necessitate abandoning the block in question. The profile drawing includes a sketch at scale 1/8 inch = one foot of the DTW or LLP in relation to the beginning of the canal.

D. Structure List

A structure list is prepared to record governing dimensions for structures on the canals. These dimensions and elevations are used in association with the standard drawings for field staking of structures for construction. The structure list form is included with the sample sub-project drawings. Completion of the form is straightforward. Station, slope, structure, DWS elevation, and D for drop structures or culverts are taken from the profile. The bottom grade at the pump is established as the initial elevation and is taken from the profile. The starting point for a branch canal is that of the main canal at the lateral turnout. The bottom grade elevation at each structure is the initial elevation minus the distance to the structure, multiplied by the slope, the initial station being the beginning station or change in slope or drop structure. The value D for turnouts is BGEI-(DWS-1). D has a minimum value based on the height of canal walls. It is 0.25 for Sec.2521, 0.50 for Sec.2518 and 0.75 for Sec.2515. The minimum meets the requirement of a two-foot turnout pool depth while keeping the top of the turnout walls no higher than the top of the adjacent canal walls.

A program, MRD structure list for use on a Hewlett-Packard 97 calculator, has been prepared to facilitate completion of the structure list. The program appears at the end of this article and it is self-explanatory. The Consultant will deliver the calculator to MRD.

E. Quantity and Cost Summary

The quantity and cost summary is a matrix which totals the canal lengths and structure numbers, separates the totals into items of contract work, totals these items, and computes their estimated cost. To the subtotal of costs is added a contingency of 15 percent. The contingency is an item of cost in standard engineering practice; it includes minor costs not covered in major items of work, variations in quantities due to unexpected foundation conditions, and differences in costs of work items between estimated and actual contract amounts. The need for and amount of contingencies is based on extensive records of many completed works. The form is included with the sample sub-project drawings.

F. Materials Summary

The materials summary summarizes the material required for each structure on the sub-project. The structure totals, taken from the quantity and cost summary, are divided into the amounts of the various materials required. Each item of material is summed to give the sub-project totals. The form is included with the sample sub-project drawings.

G. Standard Designs

The layout and construction of distribution systems for sub-projects are based on standard designs as set forth on the drawings. Standard designs are used because the design capacity of all distribution systems is two cusecs and irrigation water is delivered to only one block at a time. Standard designs are based on the use of rectangular brick lined sections for the canals for the following reasons:

1. It is labor intensive construction.
2. Materials, except cement, are readily obtainable locally.

3. The right-of-way width is less than other sections, especially where the canal is above the ground surface, as is necessary in many places to meet the delivery water surface elevation requirements.

4. The section is resistant to damage by rodents burrowing through earth banks.

5. Unauthorized diversion of water is difficult.

6. Loss of water through seepage is minimal.

7. The operation of the system is simple. The controlling of deliveries requires only shifting of stop-checks.

Possible use of other canal sections is discussed below under "Alternative Canal Sections". Figure C-1, Distribution System Structures", shows details of the canal sections and structures used in the distribution systems. Three canal sections, differing only in the height of walls, are shown.

The wall height is dependent on the slope of the canal. Turnouts deliver water to blocks. The width of the turnout is different from the canal to preclude unauthorized use of the turnout stop-check in the canal. The bottom of the turnout stilling pool is set one foot below delivery water surface elevation to reduce erosion at the outlet. All structures are placed on concrete bases to ensure stability and permanance of the structure. The insides of the turnout walls are plastered to provide smooth surfaces for the check-stop seals. Figure C-2, "Distribution System Weir Box", shows the weir box design of the structure that will calm the flow gushing from the pump discharge pipe to a tranquil flow as it enters the canal and measure the rate of flow by means of the weir at all times. A full-size (3 ft.) print Figure C-3, "Discharge Table Suppressed Weir", should appear on the pump house wall at all times. Design of the weir gage and stop check is shown on Figure C-4.

H. Alternative Canal Sections

The distribution system layout and related estimates have been based on the use of vertical wall-brick rectangular sections. This section is deemed superior to all others for the reasons enumerated above; however, its relatively high cost indicates that a less costly alternative section should be considered. Two practicable alternatives include: (1) a round-bottom with sloping sides, brick-lined section and (2) a single-wall thickness, rectangular brick section. The latter section is considered stable only where the ground surface is above the bottom grade and below the top of the walls. A comparison of the alternatives is shown in Figure C-5, "Alternative Canal Sections". For the round-bottom section (thirteen-brick), only one height is required because the difference in depth for the range of slopes used is less than 0.3 feet. The rectangular section structures can be used. A small plaster fillet will make the transition between the sections. Of the two, the round-bottom, trapezoidal section is considered the better shape because there are no corners to check and because settlement will have minimum effect on the lining. The disadvantages of the section are the wide right-of-way required and the large amount of earthwork. The average unit cost of the round bottom brick-lined canal is approximately half of the vertical-wall brick section.

A program for the hydraulic properties of the round bottom section has been written for the Hewlett-Packard 97 calculator. The program, which is self-explanatory, appears at the end of this article.

An eleven-brick trapezoidal section was also considered. With a bottom width of fifteen inches, a water depth of 9.5 inches, a freeboard of four inches, side slopes of 1:1, and a longitudinal slope of .0005, the flow is aproximately two cusecs. Although this has a lower cost than the thirteen-brick round-bottom section because the water flows at a higher velocity, the freeboard provided is not considered sufficient. Due to the hazards of operation, this section was abandoned.

I. Final Designs

The layouts and designs in accordance with this manual are paper locations only. They must be verified in the field before construction is started. The plan must first be presented and explained to the farmers. Their suggestions may be included in the final location of block turnouts and canals. Alignment, profile, and cross-section surveys of the final location will be made, from which final structure locations and dimensions will be determined and earthwork quantities computed.

J. Sample Drawings

The drawings for Sub-Project No. 6, Rajghat DTW Pucca Drain, Savar Thana, Dacca District, are attached as an example of the design.

Section 3: Re-excavation of Khals and Construction of Sluiceways

A. Data Requirements

Accurate topographic maps, hydrologic records, detailed surveys of structure sites, and profiles and sections of khals are necesary for the initiation of designs for khal re-excavation and sluiceway construction.[1]

Topographic maps for most areas in Bangladesh are available from WAPDA Topographic Maps of scale one inch = four miles.

Hydrologic records of all river gage heights in Bangladesh are available in the annually published Hydrological Yearbook of Bangladesh "Part A, Water Level."

[1] A glossary of terms used in this section are provided at the end of this section.

Surveys will be performed by MRD surveyors under supervision of the engineer. Both horizontal and vertical control should be tied to the national control. Vertical control is especially critical and river stages must be accurately correlated with ground elevations of the structure site.

High water levels in the project area and the adjacent river and the frequency of flooding of project lands should be obtained from longtime residents. A staff gage should be established at the site and daily high and low stages recorded for at least a year prior to the start of the design.

B. Drainage Schemes

Drainage during the early monsoon runoff from a single storm is to be removed through the khal and sluiceway before inundation will damage crops. The following empirical formula has been found satisfactory for predicting runoff capacity in Bangladesh:

Q cfs = catchment area in square miles x drainage modulus x 27

The drainage modulus varies throughout the country as tabulated below.

Sub-projects that are protected from river flooding require removal of water accumulated from the monsoon rains. The amount of water to be removed is determined from area capacity curves. Area capacity curves are made by first planimetering the area at each one foot contour within the protected land using WAPDA contour maps. The area curve is the area in acres plotted for each foot of elevation. The capacity curve is the accumulated volume. The volume between two contours is the sum of their areas divided by two. The quantity of water to be removed will be determined from the capacity curve at the maximum elevation of the water surface in the protected area. Drainage will not commence until the level of the river has fallen below this elevation. From this date until the river stage has fallen below the sill of the sluiceway, the stored water will flow through the sluiceway. The length of time for the river stage to drop is determined from the hydrographs. It averages 28 days. The capacity of the sluiceway is the volume in the sub-project area divided by (28 x 2)

cubic feet per second (one cfs = two acre-feet per day) Q = Vol/(28 x 2). Where volume is in acre-feet. The number of vents in the sluiceway is Q divided by the discharge per vent.

The procedures of the Federal Highway Administration are used to determine vent capacity. When the water surface in the river is above the top of the vent, the following equation is used:

$$H = \left[\frac{1.555 + (1 + Ce)}{A^2} + \frac{287.64 \times n^2 \times L}{A^{8/3}}\right] \left(\frac{Q}{10}\right)^2$$

For the standard vent A = Cross sectional area = 5 x 6 = 30

Ce= Entrance coefficient = .5

n = Coefficient of roughness = 0.015

L = Length of vent = 20 feet

The head, H, is the difference in water surface elevation between the sub-project and the river. For design, it is assigned a value of 0.5 feet.

By substitution and simplification the equation becomes

$$Q = 168 \sqrt{H}$$
$$= 168 \sqrt{0.5}$$
$$= 120 \text{ cfs}$$

This is tailwater control and the flow remains constant until the river water surface drops to a distance

$$\frac{dc + D}{2}$$

above the sill of the vent. At this point control shifts to the entrance and the discharge remains constant until the upstream water surface reaches a depth of 1.5 dc above the sill. Irrespective of the river stage, dc is the critical depth, for a rectangular section

$$dc = 0.314 \left(\frac{Q}{B}\right)^{2/3} \text{ and } Q = 5.68B\ (dc)^{3/2}$$

$$\text{for } Q = 120,\ dc = 0.314 \left(\frac{120}{5}\right)^{2/3} = 2.6$$

The tailwater elevation at which control shifts from tailwater to entrance control is

$$\frac{dc + D}{2} = \frac{2.6 + 6}{2} = 4.3$$ above sill, and the pool elevation 5 feet

4.3 + 0.5 = 4.8 feet above sill

the minimum pool elevation for entrance control is

1.5 x 2.6 = 3.9 feet above sill

Below this point, the discharge is

$$Q = 28.4\ (dc)^{3/2}$$

The velocity head of the intake channel has been neglected because it is small in comparison to the assumed head loss through the next. Figure C-8 is a graphical representation of the flow condition.

Establishing the sluiceway sill elevation is a most important element in the design. It requires engineering judgment in balancing the many variables involved: elevation of lowest land to be drained, river stage, time, and sluiceway capacity. As a guide, the river stage should be 0.5 feet below the critical depth at the time the major part of the drainage is complete and such that the river stage will drop enough to complete the draining of al project lands. Several trials and assumptions may be required before a satisfactory solution is reached.

B. Khal Hydraulic Design

The khals that are controlled by sluiceways require hydraulic capacity equal to the uiform flow of the sluiceway at the water surface elevation determined by critical depth. For the standard structures, it is 3.9 feet above the sill elevation. The slope of the khal is governed by topography and controlling elevations. It is part of the design study for establishing sill elevations, as discussed above. For bank stability, the side slopes should preferably be 1-1/2 horizontal to 1 vertical and the ratio of depth to bottom width d/b 0.4 to 0.6. Again, these are guidelines only.

Tables C-1 and C-2 offer a convenient method for determining cross-section dimensions for given Q and S. The value 0.025 should be used for Manning's roughness factor n.

C. Tide Storage Schemes

In tidal areas where the river water remains suitable for irrigation the water entering khals during rising tide can be stored to provide a stable and continuous supply for LLP irrigation. A sluice gate at the mouth of the khal with flap gates on the upstream side provides the storage. The sluice gate may also be used for flood protection. The khal to be used for storage must have volume enough at the design tide height to supply the irrigation demand. The ebb tide elevation and amplitude of the design tide are determined from the river hydrograph. The sill of the sluiceway is set one to, preferably two feet below ebb tide. Higher setting of the sill impedes inflow. The number of vents required in the sluiceway is a function of tide, khal cross-section and length, setting of sill, and the khal bottom grade elevation. Figure C-9 is a schematic sketch of tidal water storage.

Hewlett-Packard 97 Calculator Program "Tidal storage" provides aproximate values of water surface elevations vs. time, and total storage as an aid in determining the number of vents needed. Use of the program is self-explanatory.

D. Glossary of Terms

Khal: A small interior, natural or man-made, waterway draining adjacent land into a river. It may be either perennial or ephemenal.

Sluiceway: A structure located near the mouth of a khal for regulation of flow into and from the khal. For the designs included in this manual, sluiceways are constructed of brick masonry and metal control gates. A sluiceway may contain one or more vents or openings.

Vent: The standard-size (5 feet wide by 6 feet high) opening in the sluiceway through which water flows and is regulated.

Flapgate: A steel gate placed at one end of a sluiceway to permit flow in only one direction. A flapgate is hinged at the top and opened by water pressure on the upstream side. The flapgate may be fastened in a wide-open position for the time of year the predominant flow of water is in the opposite direction. Flap gates are used primarily to store tide inflow to a khal and/or to prevent river flood waters from entering the khal.

Vertical Slide Gates: A steel gate that is operated manually by a hoist at the top of the roadway across the sluiceway. Slide gates are used to control the rate of flow of water through the sluiceway, generally to maintain a certain water surface level in the khal. A slidegate can regulate flow in one direction only. When being operated to regulate flow, vertical slide gates must be continually attended to prevent flooding caused by clogging of the opening by debris or from storm runoff.

Stoplogs or Wooden Shutters: Rectangular timbers that are placed by hand in slots at the ends of sluiceway vents. Stoplogs are used primarily to isolate a vent of a sluiceway for maintenance or repair. They may also be used to regulate the minimum water surface elevation in a khal.

Section 4: Structural Design of Sluiceways

Sluiceways will be constructed of brick walls and arch culverts on plain concrete slab foundations. Each sluiceway will have one or more 5'0" x 6'0" bays, as required to meet hydraulic conditions. The design of the culvert section is in accordance with standard practice.

For multiple bays, the intermediate walls are 2'6" thick. Applicable equations and dimensions are given in Figure C-10. Retaining walls are designed as gravity sections with vertical exposed face and sloping earth face. Standard designs for retaining walls are given on Figure C-10. Weep holes, at six-foot centers each way, and pervious backfill will be provided in retaining walls to eliminate unequal water pressure on the walls during fast draw-down on the khal or river.

Flow through the sluice is controlled by vertical lift gates and/or flap gates. Design drawings of steel gates and gate hoists are in Figures C-11 through C-16. These gate designs are in accordance with Bangladesh standards. The sluiceways are provided with stoplog (shuttering) grooves at each end of each vent so dewatering can be done to facilitate maintenance and repair of gates and brick work. Gate seats and stoplog grooves are embedded in concrete to provide firm support and smooth operation for the gates.

The sluiceway transitions will be provided with cut-off walls at each end to increase the length of percolation path under the structure and to protect against undermining the structure by scour. The thickness of the floor will be determined from the uplift from the upward pressure of water of water seeping under the structure. The exit gradient of seepage under the floor is the difference in water surfaces upstream and downstream, H, divided by the percolatin path, Li. The percolation path length may be computed by Lane's weighted creep theory which is

$Li = 1/3L + 2\ E\ cd$

where L is the length of structure

and E cd is the sum of the depths of all cut-offs

The slope of the exit gradient is taken as 1:7. Other procedures for determining the exit gradient may be used; however, the assumptions made for the difference in water surface elevtions and transmissivity of the foundation material do not justify elegant mathematical solutions. The occurrence of the highest water on one side and lowest on the other at the same time for a protracted period of time is very remote. The uplift pressure to be resisted in the concrete floor is the difference between the depth of water on the slab and the gradient

on the seepage pressure. A one-foot depth of concrete is equal to 2.25 feet of water. For structures not more than three vents wide, the slab, for a distance equal to the width between walls, may be taken as 1.5 times the actual thickness for resisting uplift.

At the ends of all structures where the floor changes from a fixed to a moveable bed, (that is, concrete to earth), hydraulic action tends to carry the erodable material away, creating a scour hole. To protect the structure from being undermined, a cut-off wall is provided and the channel is protected for some distance downstream by heavy material. The depth of the cutoff wall is determined from the following equation.

$$R = 0.9 \left(\frac{q^2}{F} \right)^{1/3}$$

for F = 1

$$R = 0.9^{2/3} q$$

R = depth of scour

q = discharge, cfs per foot of width at end of concrete.

F = scour factor, 1.0 for sand, use for sluiceways.

The floor of the channel will be protected by two-foot, cube brick blocks and the side slopes by brick pitching for a distance of twenty feet.

Flap gates allow uncontrolled flow in one direction only. When flow is desired in the opposite direction, the flap gate is connected open by ropes tied to the top of the structure walls. Slide gates also control flow in one direction only. The rate of flow may be regulated by a slide gate. They require an operator to be on duty at all times when the gate is not fully opened.

The sluiceways designed under this program are located near the mouths of khals that require re-excavation or control. Wherever possible, the sluiceways are located outside the existing khal. This location allows construction to be done in the dry and does not disrupt natural flow in the khal. After the structure is completed, the khal is relocated through the structure. When it is not possible

to locate the sluiceway outside the existing khal, the contractors will be required to construct a dike around the structure site and bypass the existing flow.

The sluices will be located so they may be incorporated in a future embankment. Each sluiceway will accommodate a twelve-foot-wide pucca road across its fourteen-foot width, with a 3:1 slope on the river side and a 2:1 slope on the country side.

Section 5: Cropping Patterns

A. Factors Influencing Cropping Patterns

Crop suitability and cropping patterns are influenced both by physical and socio-economic factors. Physical factors include land, soil, and climatic conditions and can be classified according to types of land, floods, drainage, soil permeability, soil moisture holding capacity, and soil properties.

1. Land types are based upon the land position as related to the depth of flooding during the rainy season. Brammer defines five land types: highland, medium highland, medium lowland, lowland, and bottomland.

a) Highland is normally above flood level. During years of very high flood, fields may be flooded for a short period of time.

b) Medium Highland is normally shallowly flooded to a maximum depth of less than 3 feet. If the soils are suitable, this land type may be used for aus or transplanted aman.

c) Medium Lowland is normally moderately deeply flooded to a maximum depth of 3 to 5 feet. This is too deep for growing ordinary transplanted aman varieties. It is possible to grow mixed aus and broadcast aman if the soils are suitable.

d) Lowland is normally flooded to a depth greater than 5 feet. Usually, this land type is used for growing boro during the winter season and for broadcast aman during the summer. The flood level is too great for ordinary aus and transplanted aman varieties.

e) Bottomland is usually in a depression, where flooding is greatest, and remains wet for most or all of the dry season. Boro and transplanted deepwater aman varieties are the usual crop grown in these areas.

2. Flood types assist in determining whether or not it is safe to grow boro, aus or broadcast aman. Three types of flooding are defined by Brammer: early flooding, normal flooding, and flash-flooding.

a) Early flooded land may be flooded during early heavy rainfalls prior to the onset of monsoon rains. Lands in this category are not well suited to aus, aman, or boro because flood damage is likely to occur once in every two-to-three years.

b) Normally flooded land are normally not flooded before June or July. Damage seldom occurs more than once in three-to-five years when the rains may begin very early, resulting in high river levels. In most cases, boro, aus, broadcast aman, and jute are not severely damaged by flooding.

c) Flash-flooded land generally consists of lands located near the foothills, near rivers flowing from the hills, in valleys within the hill acreas, or in the Madhupur and Barind tracts and result from unusually heavy rainfall. These floods can occur at any time and may cause damage to boro, aus, broadcast aman, transplanted aman, and early winter crops.

3. Drainage types are based upon the times at which floodwaters normally drain off. This timing determines when the rabi (winter) crops can be grown. Brammer defines three drainage classes: early draining, normal draining, and late draining.

a) Early draining land is normally free of floodwater by September or October, thus allowing early rabi crops to be grown where soils are suitable. These crops could include early vegetables, tobacco, sweet potatoes, and mustard.

b) Normally draining land normally becomes free of floodwater sometime during the period between the end of October and mid-December. In areas with suitable soils, middle rabi crops can be grown; these include wheat, barley, potatoes, lentil, gram, oilseeds, and spices.

c) Late draining land normally remains wet after mid-December. In areas where the land drains by the end of January, late rabi crops such as sesame, kaon, sorghum, chili, cowpea, khira, and melon may be grown. Boro may also be grown, where soils are suitable, both with and without irrigation, depending upon when the soils dry out.

4. Soil permeability indicates the rate at which water passes through the soil. It significantly influences the types of crops suitable for certain areas. Permeability is related directly to soil texture, which is determined by the amounts of sand, silt, and clay and the size and number of pores in the soil. Three types of soil permeability can be identified: permeable, moderately permeable, and impermeable.

a) Permeable soils do not hold water on the surface more than a few hours after a heavy rain or a heavy irrigation. Normally, these soils are not suitable for boro or transplanted aman unless the area is naturally flooded or wet throughout the growing season.

b) Moderately permeable soils usually retain water on the surface for two-to-three days after a heavy irrigation or rain. This may make these areas unsuitable for crops, such as wheat, maize, and vegetables, that cannot tolerate wet conditions during their seedling stage. Normally, these soils are unsuitable for boro or transplanted rice. In areas of high rainfall, it may be possible to grow transplanted aman on medium highland sites.

c) Impermeable soils will normally retain water on the surface for one week or more following heavy rainfall or irrigation. Most floodplain clay soils are naturally impermeable. The puddling process used in preparing land for transplanted rice changes the naturally permeable silt loam and clay loam soils to impermeable soils suitable for rice cultivation. It should be noted that this puddling process may make naturally permeable soils unsuitable for dry land rabi crops unless the topsoil is thoroughly broken up before seeding.

5. The moisture-holding capacity of a soil determines how well the soil holds moisture for the plant's use. The moisture-holding capacity is directly related to soil texture and soil porosity. Organic matter content also affects this capacity. Brammer classifies soil moisture-holding capacities as good, moderate, or poor.

a) Good moisture-holding capacity is usually characteristic of deep, loamy or have a water table relatively close to the surface during the dry season. These soils will normally hold sufficient water after the rainy season to grow a dryland rabi crop (such as wheat, pulses, or oilseeds) without irrigation or to receive sown aus, jute, or broadcast aman in February and March without waiting for the first rain showers to occur.

b) Moderate moisture-holding capacity is characteristic of deep sandy loams, moderately deep silt loams, clays, or clay loams. These soils normally hold sufficient water after the rainy season to grow an early rabi crop (such as mustard) or a quick-maturing middle rabi crop (such as wheat, pulses, or oilseeds) without irrigation; however, yields may be low without favorable winter rains or irrigation.

c) Poor moisture-holding capacity is characteristic of various soils: loose sands; heavy clays that quickly dry and crack; some areas that have been puddled for transplanted aman, resulting in a strong ploughpan or a compacted layer; red and brown soils in the Madhupur and Barind tracts; and most hill soils. These soils do not hold sufficient moisture for rabi

crops unless irrigation is available or unless very favorable winter rains occur. Highland and medium highland areas suffer from drought during the rainy season if there is a one-to-two week period without rainfall. Frequent irrigation is required for sandy and shallow, loamy soils.

6. Several soil properties significantly influence cropping patterns and management practices. Properties listed by Brammer include: subsoil texture; organic matter content; chemical properties, such as salinity; soil parent material; soil moisture properties determined by flooding, drainage, permeability and moisture-holding capacity; and soil disturbance resulting from man's activities.

Several sources of information are available to determine the soil properties of a specific site. Very important to these determinations are field observations and questioning of farmers regarding existing cropping patterns, crop rotation, crop conditions, flooding, and drainage characteristics. Field observations should consider the texture of the subsoil and substratum, particularly where there appear to be changes in land and drainage type. Also important to these determinations are reviews of the District reconnaissance soil survey reports prepared by the Soil Survey Department of Bangladesh, which provides essential information on soil associations and land use. By combining all of these sources of information, general soil types can be defined and their influence on cropping patterns and management practices determined.

B. Main Existing Cropping Patterns

Brammer (1978) outlines nine traditional cropping patterns used by farmers in Bangladesh: aus-rabi crops, aus-transplanted aman-fallow, transplanted aman-fallow, mixed aus and broadcast aman-rabi crops, broadcast aman-fallow, boro-fallow, boro-transplanted aman, jhum cultivation, and perennial crops.

1. Aus-rabi cropping constitutes the main pattern practiced on permeable highland and medium highland soils, particularly in the central and western districts. These areas are usually located on higher floodplain ridges, on raised soil platforms, or on the red soils of the Madhupur and Barind tracts. Perhaps ten-to-thirty percent of the aus acreage may be planted to jute, particularly on loamy soils in medium highland areas. Mesta and kharif groundnuts may replace small portions of the aus acreage on soils having a poor moisture-holding capacity. Rabi crops are generally determined by soil moisture-holding capacity. Soils having a moderate-to-good moisture-holding capacity are suitable for wheat, barley, mustard, lentils, gram, sweet potatoes, rabi groundnuts, and vegetables. Soils having a poor moisture-holding capacity are best suited for early rabi crops, such as mustard.

2. Aus-transplanted aman-fallow constitutes a major cropping pattern practiced on moderately impermeable or impermeable soils in highland and medium highland positions on the Teesta floodplain, on higher portions of the Brahmaputra floodplain, in Bhola, in northeastern parts of the Barisal mainland, on some grey soils of the Madhupur and Barind tracts, and on some foothill land. The amount of aus acreage being transplanted rather than broadcasted, and the use of high yielding varieties are increasing. Portions of the aus acreage may be replaced by jute, especially on the Teesta and Brahmaputra floodplains. Most of the transplanted aman varieties following aus or jute are local or locally improved varieties; however, where aus and jute can be sown early, HYV transplanted aman can be grown. In areas where the topsoil has been puddled for the transplanted aman crop, the planting of a rabi crop may be limited and in some cases may result in the lands staying fallow during the winter.

3. Transplanted aman-fallow constitutes a pattern practiced mainly on impermeable loams and clays in highland and medium highland positions. It is practiced mainly in the Rajshahi District, along coastal areas in Khulna Division, on the Noakhali

charland, in northern Dinajpur, and in western portions of Jessore. This practice of single-cropping may result from low rainfall, but it is more often due to larger land owners' satisfaction with one crop; however, the amount of double-cropping does appear to be increasing in all of these areas.

4. Mixed aus and broadcast aman-rabi cropping occurs on medium lowlands of the Brahmaputra, the Jamuna, the Ganges, and the old Meghna floodplains in the Districts of Bogra, Pabna, Rajshahi, Faridpur, Dacca, Tangail, Mymensingh, and Comilla. The soils are usually moderately permeable and have a good moisture storage capacity, and the lands normally drain by October or November. This is the major triple-cropping area found in the country. Mixed aus and aman constitute the double-cropping and are followed by a rabi crop. Therefore, the land is used throughout the year. Jute may be substituted for mixed rice in areas, such as the main river channels, where there is a greater risk of early or high floods. Many different rabi crops are found in this pattern. Some farmers broadcast mustard, mashkalai, and lentil in the aman crop two-to-three weeks before harvest. In some areas, such as the western portion of Comilla District, the early rabi crop may be followed by a late rabi crop (such as sesame, kaon, or chili). In other cases, farmers plough the land after aman is harvested and then sow wheat, barley, potatoes, mustard, gram, lentil, onions, or spices.

5. Broadcast aman-fallow constitutes the main cropping pattern practiced in the lowland areas of the Brahmaputra, the Jamuna, the Ganges, and the Meghna floodplains in the Pabna, Rajshahi, Faridpur, portions of Jessore, northern Barisal, Dacca, Tangail, Mymensingh, Kishorganj, Comilla, and Sylhet Districts. Normally, flooding is too deep in July and August to mix aus with the aman crop, and much of the land is too wet in December and January for a rabi crop. Jute is sometimes substituted for the aman where the topsoils are loamy. In years of low flood levels, it is possible to broadcast khesari and mustard in the standing aman

crop prior to its harvest.

6. Boro-fallow constitutes the usual cropping pattern in lowland and bottomland areas where the soil is wet most or all of the dry season or where irrigation is available. These lands are common in all of the major floodplains, in Noakhali north of the char areas, in deep valleys of the Madhupur tract, and in some hill areas. Some farmers, especially in the Dacca and Comilla Districts, follow the boro crop with a transplanted deep-water aman crop.

7. Boro-transplanted aman constitutes the main rotation practiced on impermeable highland and medium highland areas where irrigation is available. Typical areas for this pattern are the Brahmaputra, the Teesta, and the Ganges floodplains; parts of the tidal clay areas in the Khulna Division; and the gray soil areas of the Madhupur and Barind tracts.

8. Jhum cultivation is used in the Chittagong Hill Tracts. It involves clearing and burning the natural vegetation during the dry season and then sowing a mixture of summer crops (such as aus-type rice, sesame, beans, gourds, and hill cotton). After one or two years, the land is abandoned to remain idle for several years.

9. Perennial crops include tree crops (such as mango) or field crops occupying the land most or all of the year (such as sugarcane, ginger, and pineapple). This type of cropping is practiced on the permeable highland soils: on the high floodplain ridges in the western portion of the Ganges floodplain, in parts of Rangpur and Dinajpur, on the deep red soils of the Madhupur and Barind tracts, on the hill soils, and in homestead areas. At times, farmers practice this cropping on lands normally used for aus-rabi crop rotation. Sometimes intercropping of perennial crops with quick maturing field crops occurs.

C. Recommended Cropping Patterns With Irrigation

When irrigation water becomes available to the farmers, such as through DTW's and LLP's, their traditional cropping patterns must be examined and carefully modified where appropriate. Table III-1 outlines improvements that could be made to each of the nine traditional croppings patterns upon introduction of available irrigation water (Brammer, 1978).

The following information on four of the recommended irrigated cropping patterns should be considered when determining the most appropriate cropping system for an irrigation sub-project:

1. Aus (HYV)/Jute - T. aman (HYV) - Rabi crops (wheat/mustard/potatoes): Wheat and similar rabi crops are most ideally suited for rotations not having transplanted rice. In cases where transplanted rice is a part of the rotation, as it is in this cropping pattern, certain techniques should be used to obtain maximum crop production. Wheat and other rabi crops that are to be grown on naturally impermeable soils or on puddled lands should be sown on ridges or raised beds to prevent water logging damage (Brammer, 1978). Also necessary, is the careful control of water in order to prevent over-irrigation, which results in damage to the seedlings. It is important to ensure that any plough pan created for the transplanted rice be broken up to allow penetration of both roots and irrigation water. This means that the fields must be re-puddled for subsequent transplanted rice crops. These operations increase the labor required for land preparation for both types of crops.

2. Boro (HYV): When boro (HYV) is introduced under irrigated conditions to replace the traditional mixed aus and broadcast aman-rabi crop pattern, it is important to determine which cropping pattern gives the farmer the greatest financial return for each specific sub-project area. The mixed aus and broadcast aman-rabi crop pattern is the major triple-crop pattern practiced in Bangladesh and it seems likely that, in some applications, the single boro crop has given lower financial returns than the

triple-crop system (Hobbs, Clay, and Hogue, 1979).

3. Boro (HYV)-Transplanted deep water aman: Some farmers are experimenting with transplanting deep water aman following the boro crop. The yields of transplanted aman are somewhat reduced, but the farmer still receives the boro crop, plus the "bonus" aman production (Hobbs, Clay, and Hogue, 1979). This practice needs further experimentation before its widespread use is recommended.

4. Boro (HYV) - Transplanted aus (HYV/LIV) - Transplanted aman (LIV): This triple-rice-crop pattern is possible using an early maturing boro (HYV), harvested by April or May, followed by a quickly maturing transplanted aus (HYV/LIV/LOCAL) harvested in August, and followed by transplanted aman (LIV or Local). However, this cropping pattern requires a high degree of management, proper irrigation, and high levels of fertilizer and labor (Brammer, 1978). The BRRI reports two problems with triple-cropping of rice in some areas: First, soils kept in a continuously wet condition may have increasing amounts of iron, which can be harmful to the rice plants. Second, continuously flooded, heavy silt and clay soils may lose their capability to support the weight of animals and people and must be periodically allowed to fallow and dry. Due to high input requirements and other problems experienced by BRRI, extensive triple-cropping of rice is not recommended without careful consideration and experimentation to determine which parts of the country are suitable for this intensive system.

D. Procedure for Evaluating and Recommending Improved Cropping Patterns

The following procedure is suggested for use in evaluating and recommending improved cropping patterns for existing and proposed irrigation sites. These steps should be followed for each specific sub-project and must be accomplished through interviews with farmers,

village, and project leaders; through on-site inspections; through crop-cut surveys; and through farm management studies.

1. Determine and evaluate existing cropping patterns, including:

   a) cropping patterns presently used;

   b) the extent of each crop and time grown;

   c) the amount and kind of intercropping and mixed cropping;

   d) cropping intensities;

   e) crop inputs and yields;

   f) productivity of total system;

   g) the gross and net returns from entire systems; and

   h) the crop production problems encountered by farmers.

2. Collect and evaluate socio-economic information, including:

   a) farm sizes;

   b) land tenure system;

   c) family sizes;

   d) the labor situation;

   e) the availability of credit;

   f) the input supply system;

   g) marketing arrangements; and

   h) the farmers' other socio-economic problems.

3. Collect information on soil and water resources and climate:

   a) Prior to field observations, review available literature on soil and water resources and climate and discuss this literature with the appropriate Government agencies. For example, in collecting information on soil resources, review the District reconnaissance soil survey reports prepared by the Soil Survey Department of Bangladesh:

   a-1) Review general district geology, soils, and land use;

a-2) Locate sub-project on the soil and land-use association maps;

a-3) Review the soil and land-use association in which the sub-project is located to determine soil series and appropriate land use;

a-4) Review the soil series description, noting soil texture, drainage, permeability, moisture holding, chemical properties, relief, flooding, etc;

b) Supplement the literature with field observations and survey questions regarding physical resources.

4. Determine the land types as defined in "Factors Influencing Cropping Patterns", from field observations and interviews.

a) These land types should then be plotted onto a detailed map having a scale such as that used on the mouza maps.

b) Each land type should be denoted by color on the map. For example: Highland, red; Medium Highland, brown; etc.

5. Determine the flood types, as defined in "Factors Influencing Cropping Patterns" from field observations and interviews. Delineate the different flood types on the map.

6. Determine the drainage types, as defined in "Factors Influencing Cropping Patterns", from field observations and interviews. Delineate the different drainage types on the map.

7. Determine the soil permeability types, as defined in "Factors Influencing Cropping Patterns", from field observations and interviews. Delineate the different permeability types on the map.

8. Examine the soils in those areas having different land and drainage types and in those areas exhibiting significant relief changes.

a) Especially important are the subsoil and substratum textures and the soil structure. To determine these, holes must be dug three-to-four feet deep and the soil examined.

b) Subsoil and substratum textures are generally determined in the field by dividing them into four broad, textural classes: sand, loam, clayey loam, or clay. The following criteria are used for classification (Brammer, 1970):

b-1) Sand: This includes sand, loamy sand, and loose sandy loams that, when moist, can be squeezed into a cone or rolled into a ball but cannot be rolled into a cylinder.

b-2) Loam: This includes loam, silt loam, and sandy loam that, when moist, can easily be rolled into a cylinder but cannot then be bent into a ring.

b-3) Clayey Loam: This includes clay loam, silty clay loam, and sandy clay loam that, when moist, can easily be rolled into a cylinder and then bent into a ring. It is also characterized by the fact that a small fragment can be squeezed out to form a "tongue", although it breaks easily.

b-4) Clay: This includes clay, silty clay, and sandy clay that, when moist, can easily be made into a ring. It is also characterized by the fact that a small piece can be squeezed into a strong "tongue".

c) Delineate the soil texture classes on the map.

9. Determine the soil moisture-holding capacities, as defined in "Factors Influencing Cropping Patterns," from field observations and interviews.

a) The soil textural and structural characteristics of the soil (determined in Step 8) are the main determinants of that soil's moisture-holding capacity.

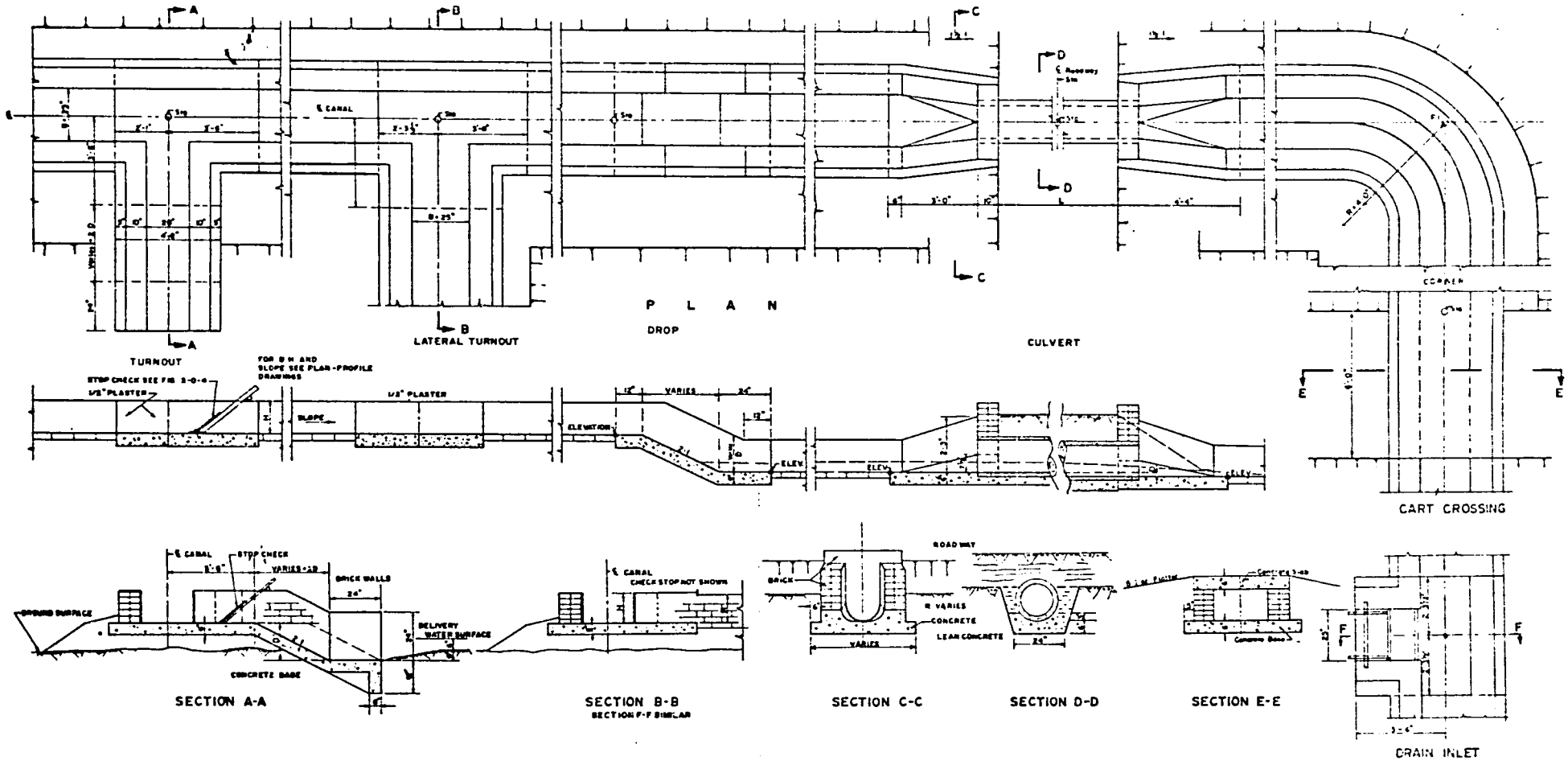
b) Observation of the types and condition of crops growing in an area provides other important information.

c) Areas having different moisture-holding characteristics should be denoted on the map.

10. Recommend cropping patterns for the irrigated sub-projects.

a) Evaluate the existing cropping patterns, the socio-economic situation, physical resources, land types, flood types, drainage types, soil permeability, soil types, and moisture-holding capacities (determined in Steps 1 through 9).

b) Using Table 3-1 as a guide and by inserting the information gained from Steps 1 through 9, determine the most appropriate irrigated cropping pattern for each sub-project.



SECTION	B	H	SLOPE
2521	25	21	0·0003
2518	25	18	0·0003
2015	25	15	0·0015
			0·0010

PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER -

DISTRIBUTION SYSTEM STRUCTURES

PRC ENGINEERING CONSULTANTS INC (PRC ECI) DENVER, COLORADO, USA

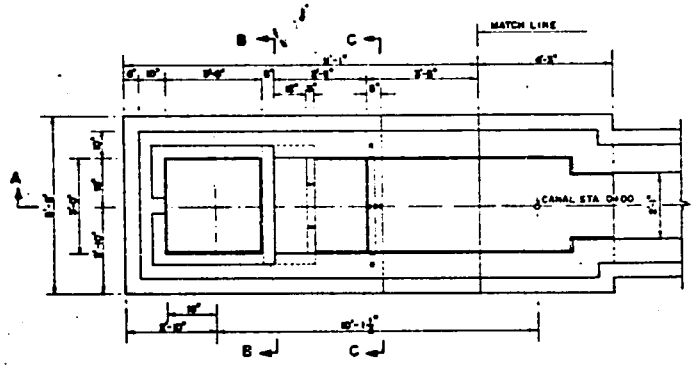
PLANNERS ENGINEERS & CONSULTANTS LTD (PECI) DACCA, BANGLADESH

SUBMITTED BY

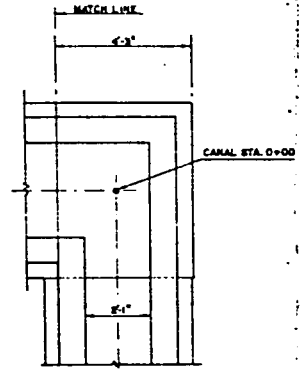
APPROVED (PRC ECI PROJECT MANAGER)

DATE

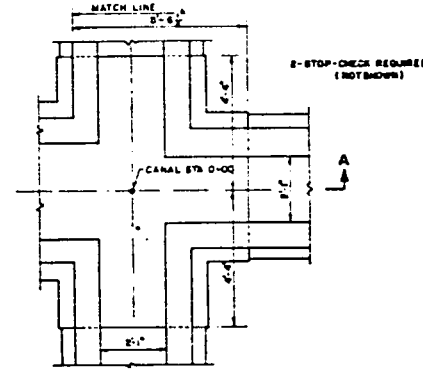
FIGURE – C – 1



DELIVERY AHEAD

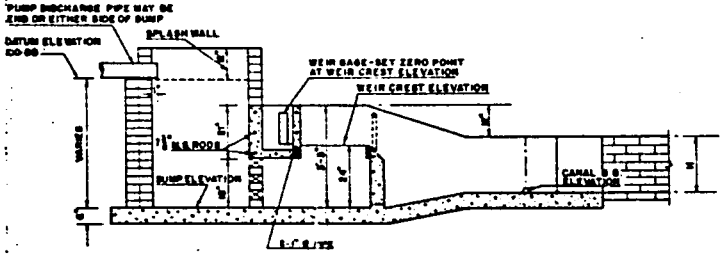


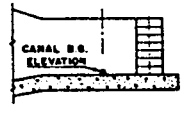
DELIVERY RIGHT
DEL. LEFT OPPOSITE HAND

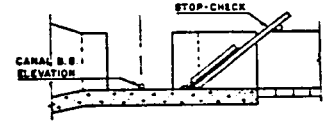


MULTIPLE DELIVERY
ANY ONE DELIVERY MAY BE OMITTED

P L A N



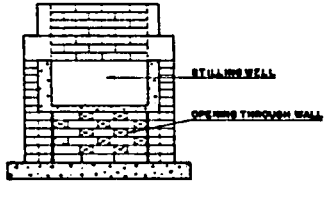




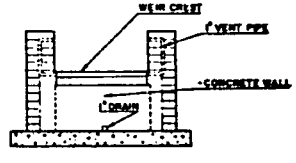
S E C T I O N - A-A

REFERENCE FIGURE

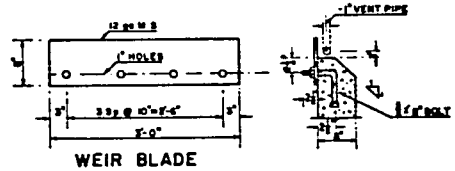
CANAL STRUCTURES ..... FIG.
WEIR BLADE STOP CHECK ..... FIG
FOR CANAL BOTTOM GRADE ELEVATION AND
SUMP ELEVATION SEE SUB PROJECT
PROFILE DRAWINGS



SECTION ON B-B



SECTION ON C-C



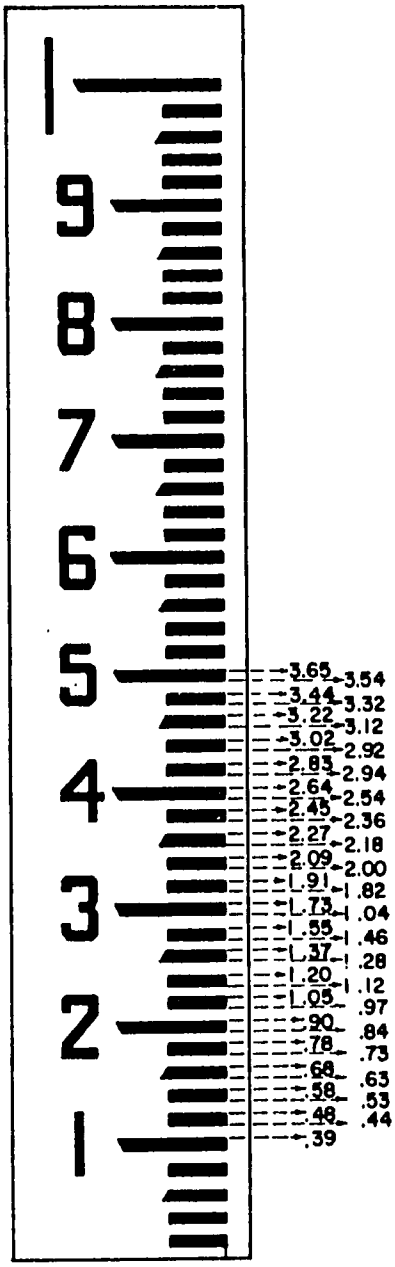
WEIR BLADE
NOT TO SCALE

1 0 1 2 3 4 5 FEET
SCALE

PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT, RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER—

DISTRIBUTION SYSTEM WEIR BOX

PRC ENGINEERING CONSULTANTS INC (PRC ECI) DENVER, COLORADO, U.S.A.	PLANNERS ENGINEERS & CONSULTANTS LTD. (PECL) DACCA, BANGLADESH
SUBMITTED	FIGURE-C-2
APPROVED (PRC ECI) PROJECT MANAGER	
DATE	



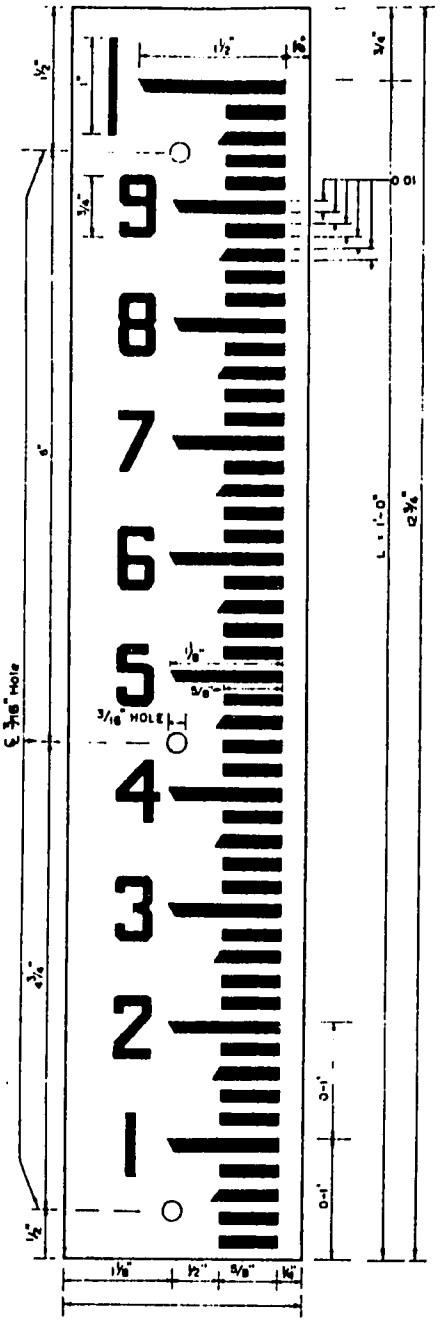
DISCHARGE TABLE
3'-0" SUPPRESSED WEIR

PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES

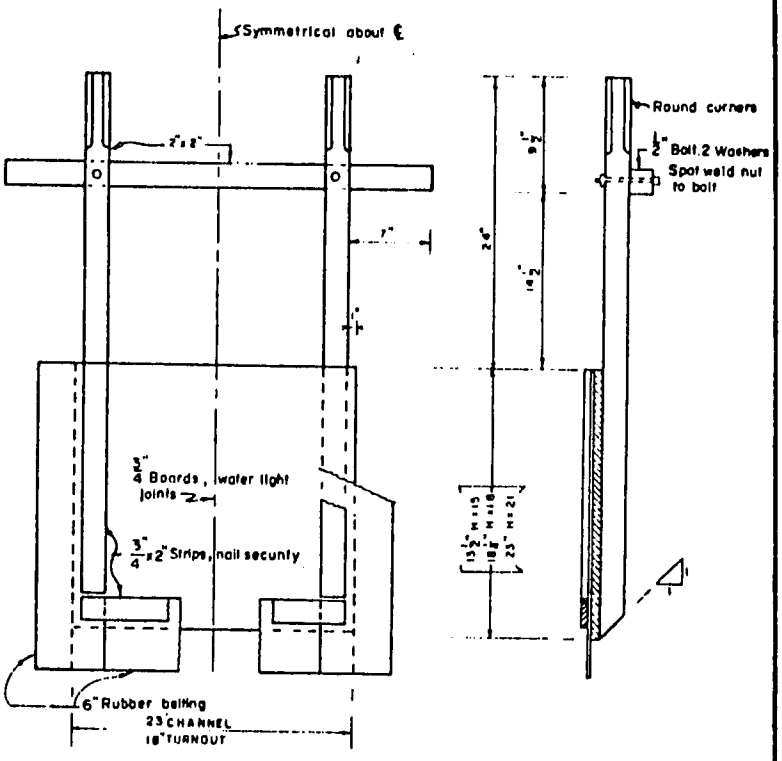
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER

DISCHARGE TABLE
3'-0" SUPPRESSED WEIR

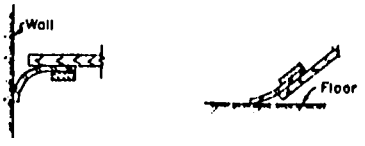
PRC ENGINEERING CONSULTANTS INC. (PRC ECI) DENVER, COLORADO, U.S.A.	PLANNERS ENGINEERS & CONSULTANTS LTD. (PEC) DACCA, BANGLADESH
SUBMITTED	FIGURE – C-3
APPROVED (PRC ECI) PROJECT MANAGER	
DATE	



WEIR GATE
FULL SIZE



STOP CHECK



INSTALATION DETAIL

FOOT 1/2 0 FOOT

SCALE OF FEET

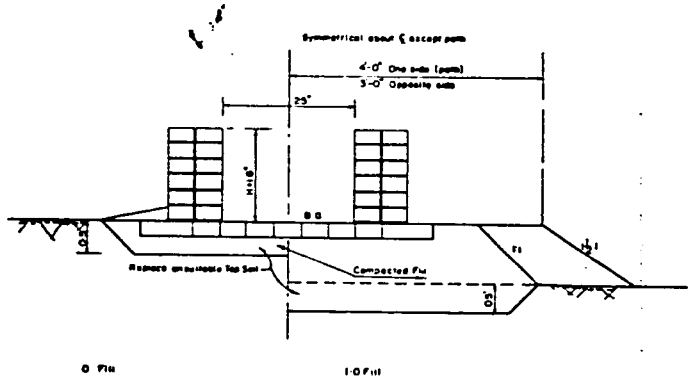
NOTES:—

Weir gage shall be made of No. 189090 (U.S. std) mild steel plate and shall be corner with Vitreous enamel.

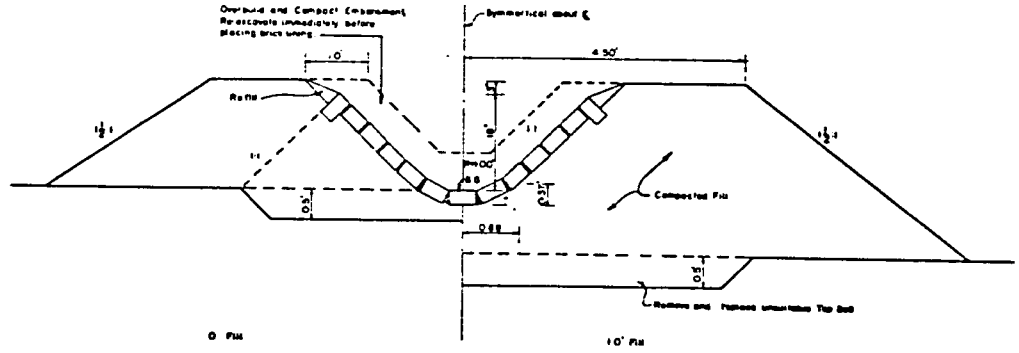
The face of the gage shall be white and the numerals and graduation black.

Graduations shall be sharp and accurate to the dimensions shown

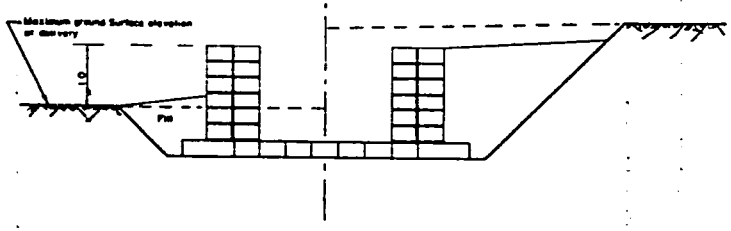
PEOPLE'S REPUBLIC OF BANGLADESH MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES	
RURAL IRRIGATION WORKS PROJECT SUB PROJECT NUMBER —	
WEIR GAGE — STOP CHECK	
PRC ENGINEERING CONSULTANTS INC. (PRC ECI) DENVER, COLORADO, U.S.A.	PLANNERS ENGINEERS & CONSULTANTS LTD. (PEC) DACCA, BANGLADESH
SUBMITTED B. G. Hoge	FIGURE — C-4
APPROVED Paul H. Kirkham (PRC ECI) PROJECT MANAGER	
DATE	



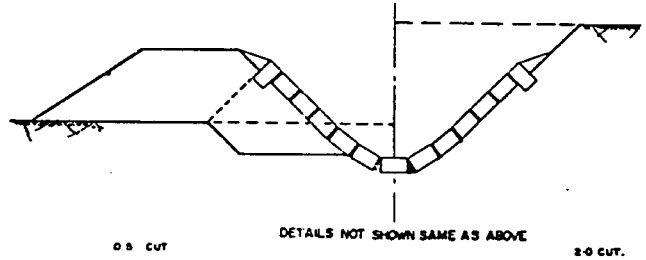
VERTICAL WALL BRICK SECTION



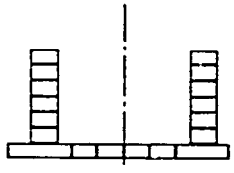
CIRCULAR BOTTOM BRICK LINING



DETAILS NOT SHOWN SAME AS ABOVE



DETAILS NOT SHOWN SAME AS ABOVE



THIN WALL BRICK SECTION
DETAILS NOT SHOWN SIMILAR TO
VERTICAL WALL BRICK SECTION

SUITABLE FOR USE ONLY FOR CUT
FROM 0.0' TO 1.5'

COST COMPARISON

Section	Item	Unit Cost	2.0 Cut Amount	2.0 Cut Cost	0.5 Cut Amount	0.5 Cut Cost	0 Fill Amount	0 Fill Cost	1.0 Fill Amount	1.0 Fill Cost
Vert. wall Brick Section	Brick masonry	2400	2.5	6000	2.5	6000	2.5	6000	2.5	6000
	Brick lining	750	4.7	3625	4.7	3625	4.7	3625	4.7	3625
	Excavation	20	32.6	652	4.3	86	2.7	54	14.3	286
	Compacting Emb	18	11.0	198	1.5	27	2.7	49	11.0	198
	Cost/% Foot	—	—	10460	—	9740		9730	—	10110
Circular bottom Brick lining	Brick lining	750	5.0	3750	5.0	3750	5.0	3750	5.0	3750
	Excavation	20	8.6	172	12.6	252	25.0	500	43.0	860
	Compacting Emb	18	0	—	10.0	180	20.0	360	33.7	842
	Cost/% Foot			3930		4180		4610		5250
Thin wall Brick section	Brick masonry	2400					1.3	3120	1.3	3120
	Brick lining	750					3.5	2625	3.5	2625
	Excavation	20					2.7	54	14.3	286
	Compacting Emb	18					2.7	49	11.0	198
	Cost/% Foot							5850		6230

PEOPLES REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT

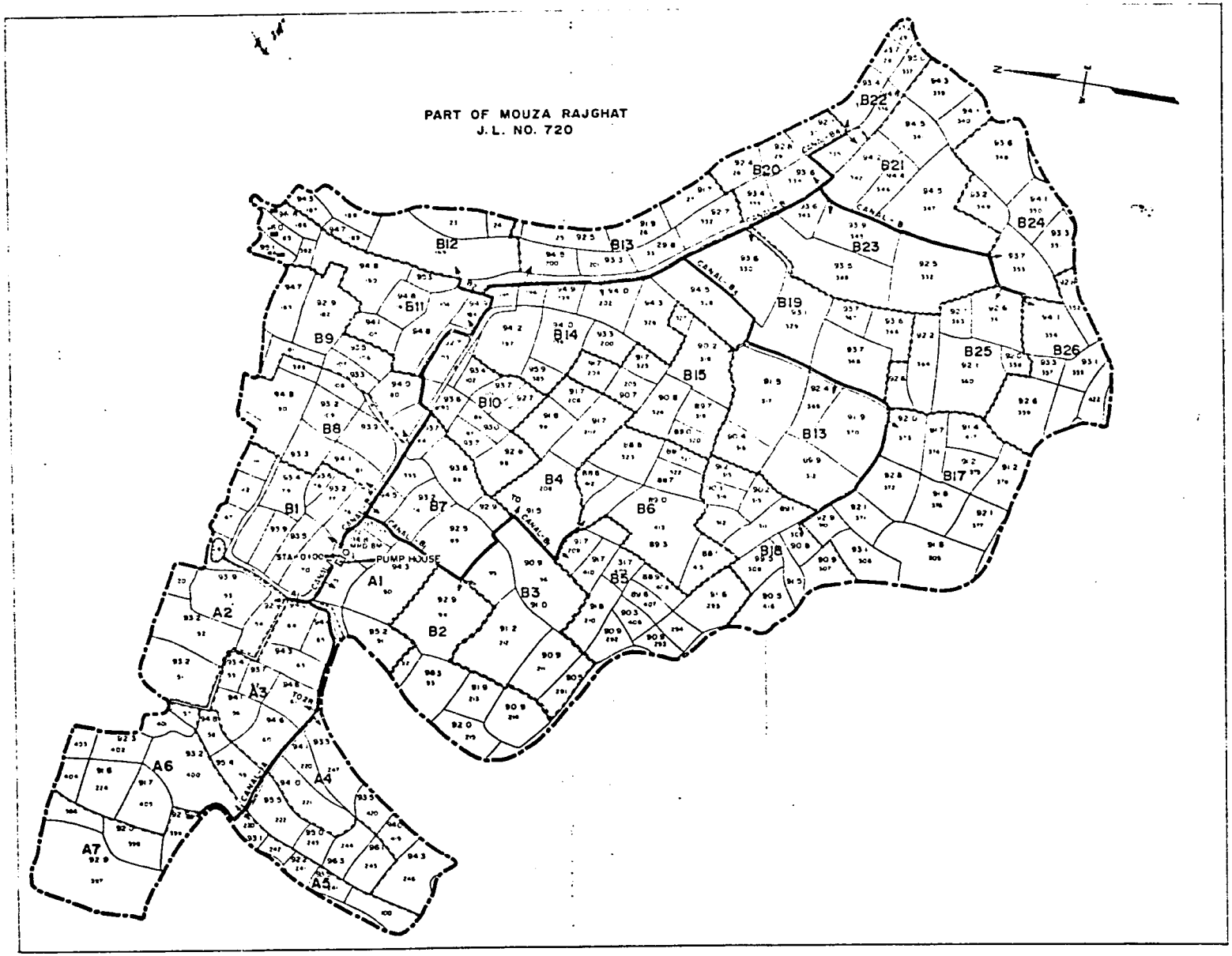
ALTERNATIVE CANAL SECTIONS

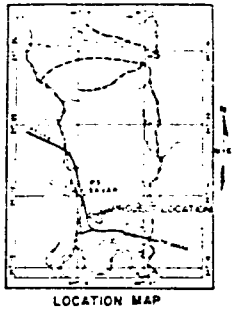
PRC ENGINEERING CONSULTANTS INC
(PRC WILDBANKER COLORADO USA)

PLANNERS ENGINEERS & CONSULTANTS LTD
(PELT DACCA, BANGLADESH)

SUBMITTED
APPROVED
DATE

FIGURE-C-5





LOCATION MAP
THANA SAVAR
SCALE 1=8 Miles

LEGEND

- Plot Boundary
- Elevation & Plot No.
- Distribution Canal
- Turnout
- Proposed Irrigation Boundary
- DTW Location
- Home Stead
- Low Land
- Foot path
- Existing Drain
- Irrigation Blocks

REFERENCE DRAWINGS

Profiles Weir box	FIG
Standard Structures	FIG
Weir Block Step check	FIG
Discharge Table	FIG

NOTE

SCALE

PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NO MSFR-8
DACCA DISTRICT
SAVAR THANA

RAJGHAT DTW. PUCCA DRAIN

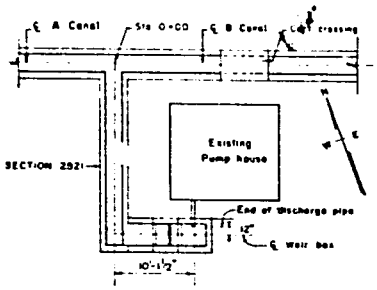
DISTRIBUTION SYSTEM
PLAN

PRC ENGINEERING CONSULTANTS INC
(PRC EC) DENVER COLORADO USA

PLANNERS ENGINEERS & CONSULTANTS LTD.
(PECL) DACCA BANGLADESH

SUBMITTED
APPROVED
PRC EC PROJECT MANAGER
DATE

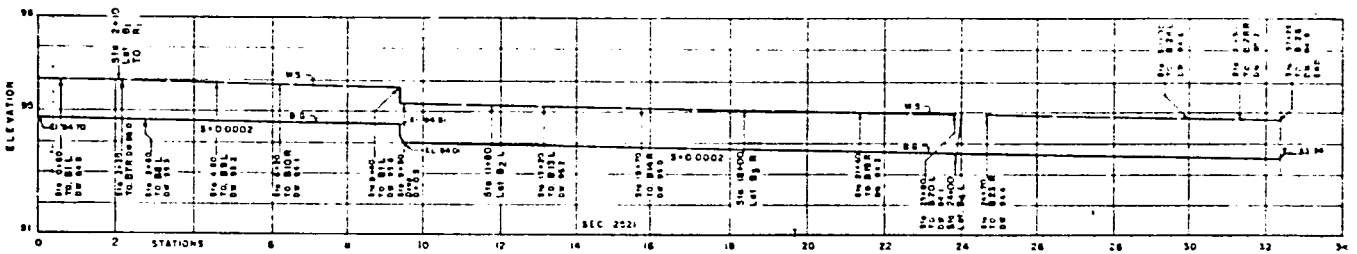
FIGURE-C-6



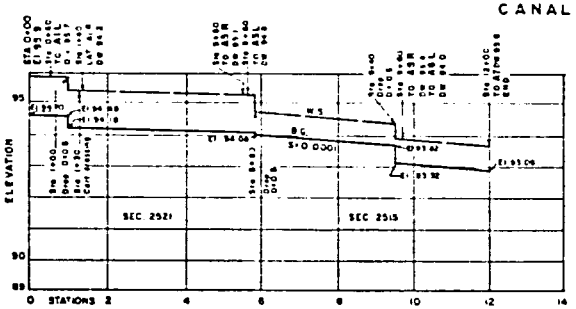
SITE PLAN

DISCHARGE TABLE

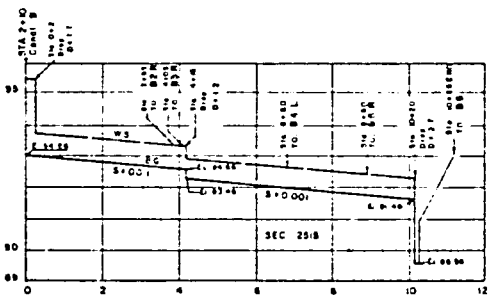
h Feet	Q C.F.S.
.10	.00
.15	.00
.20	.00
.25	.00
.30	.70
.35	.80
.40	1.00
.45	1.20
.50	1.40
.55	1.60
.60	1.80
.65	2.00
.70	2.20
.75	2.40
.80	2.60
.85	2.80
.90	3.00
.95	3.20
1.00	3.40
1.05	3.60
1.10	3.80
1.15	4.00
1.20	4.20
1.25	4.40
1.30	4.60
1.35	4.80
1.40	5.00
1.45	5.20
1.50	5.40



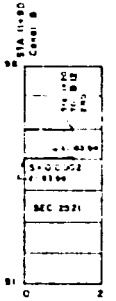
CANAL B



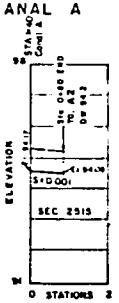
CANAL A



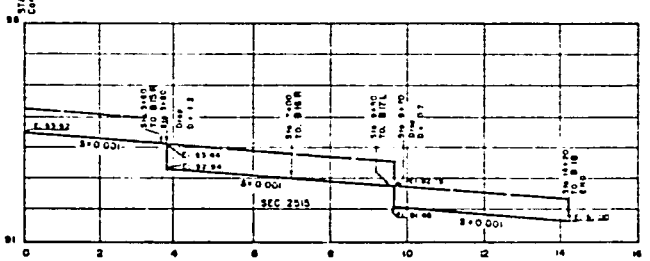
CANAL B_1



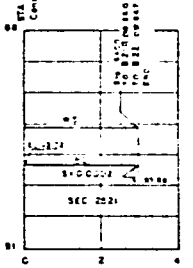
CANAL B_2



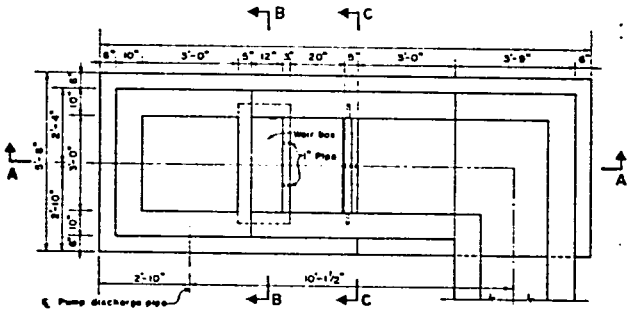
CANAL A_1



CANAL B_3

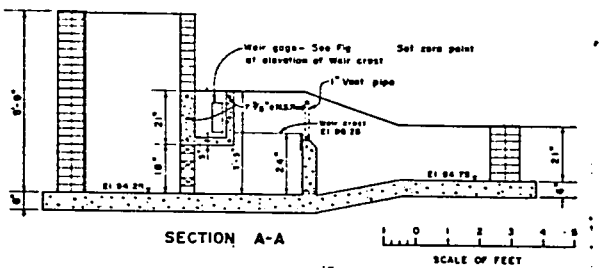


CANAL B_4

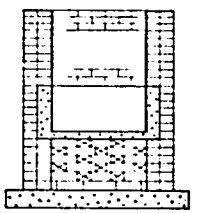


PLAN OF WEIR BOX

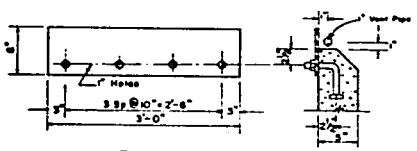
NOTE
Interior & top of brick walls to be plastered with 1:3 cement mortar.



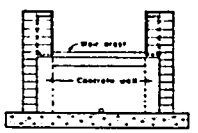
SECTION A-A



SECTION B-B



WEIR BLADE DETAILS



SECTION C-C

NOTE
Elevations based on an assumed datum of El 100.00 at invert of pump discharge pipe

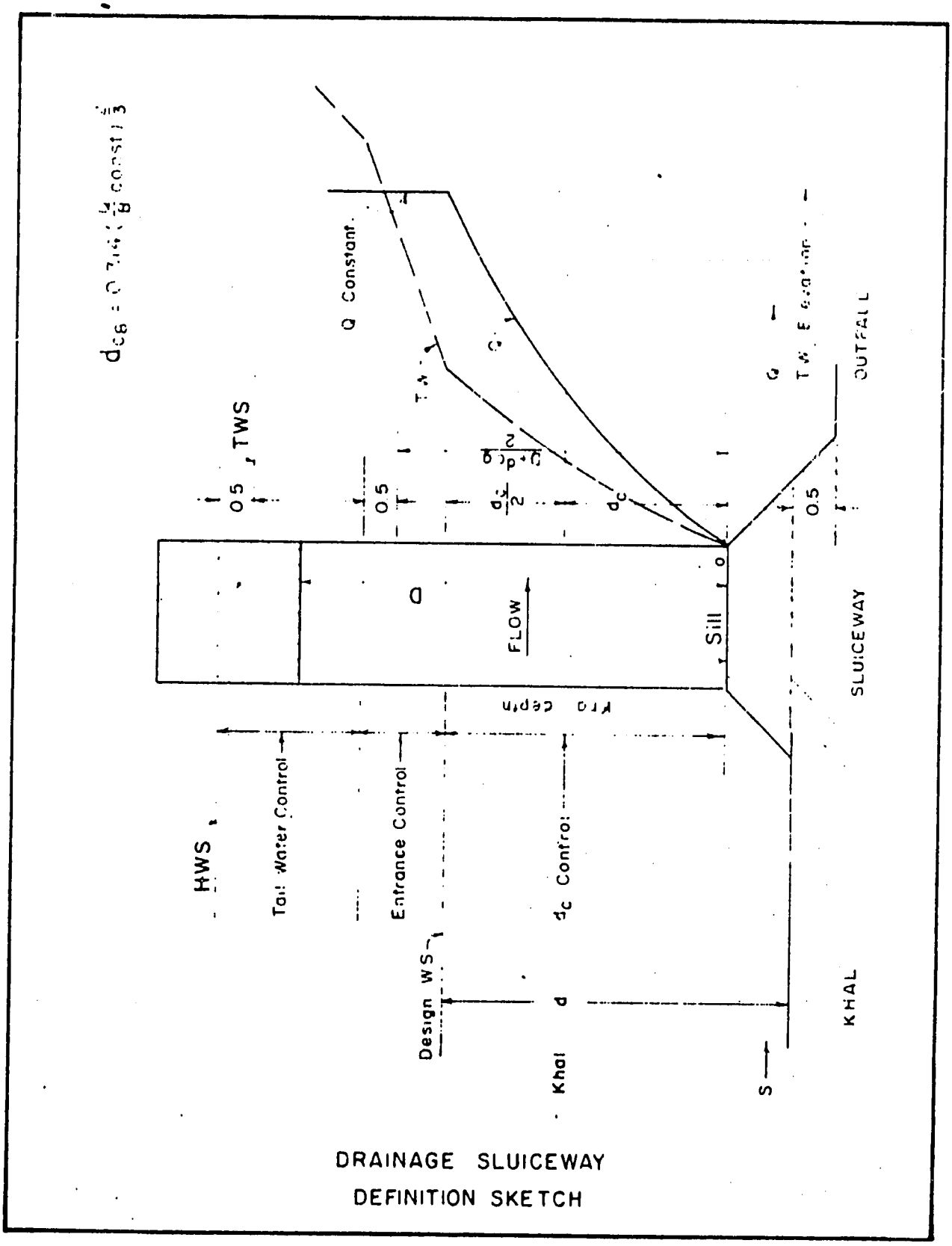
PEOPLES REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER - 6
DACCA DISTRICT
SAVAR THANA

RAJGHAT DTW. PUCCA DRAIN

PROFILES - WEIR BOX

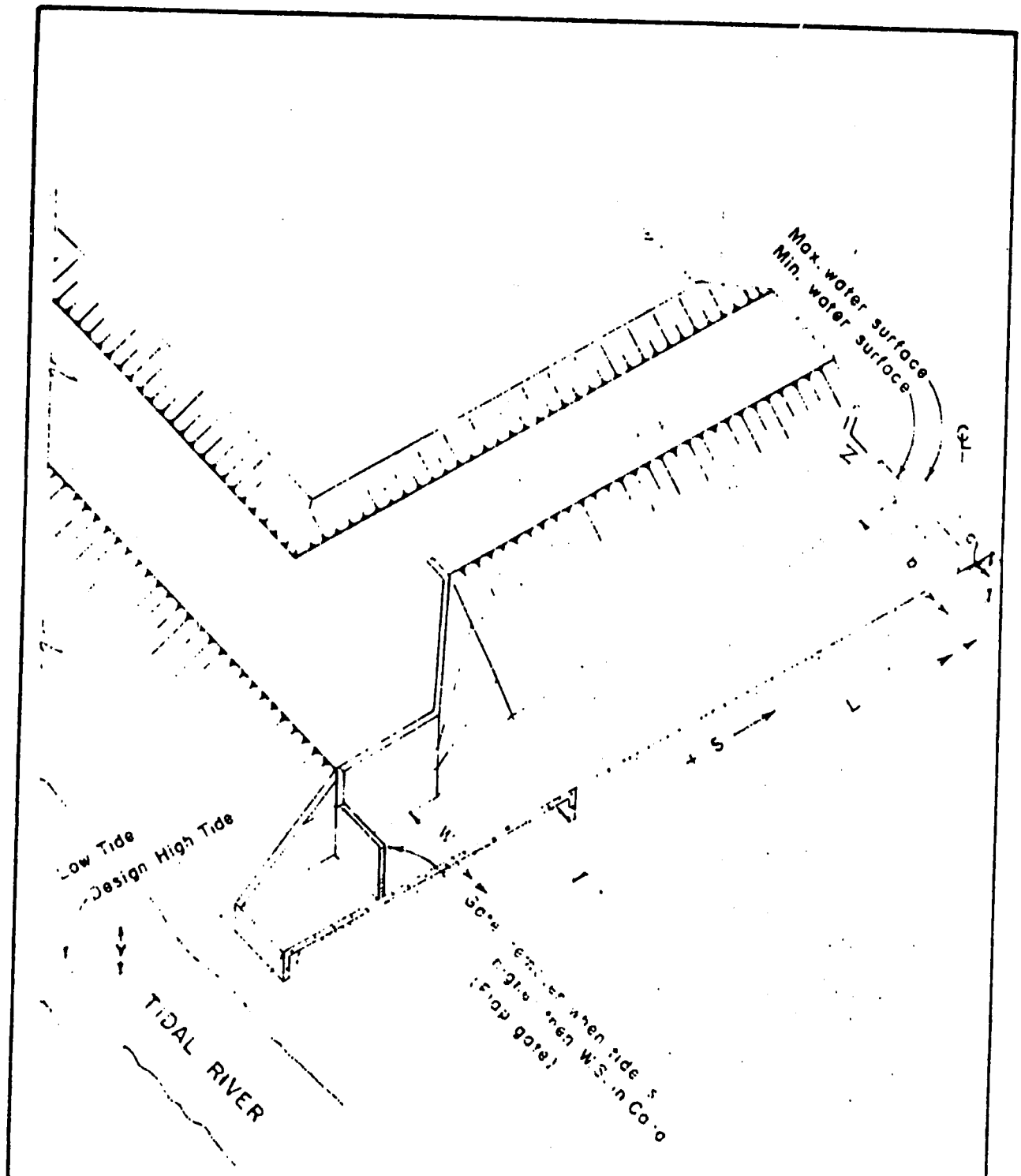
PRC ENGINEERING CONSULTANTS INC (PRC EC) DENVER, COLORADO U.S.A.
PLANNERS ENGINEERS & CONSULTANTS LTD (PECL) DACCA, BANGLADESH
SUBMITTED
APPROVED (PRC EC) PROJECT MANAGER
DATE

FIGURE - C-7



DRAINAGE SLUICEWAY
DEFINITION SKETCH

FIGURE- C-8



SCHEMATIC
OF
CANAL USED TO STORE TIDAL WATER

FIGURE - C-9

Abut Ø Arch

$a = \frac{Span}{2}$

$r = \frac{Span}{4} = \frac{a}{2}$

$R = \frac{a^2 + r^2}{2\left(\frac{a}{2}\right)} = \frac{a + \left(\frac{a}{2}\right)^2}{2\left(\frac{a}{2}\right)} = \frac{5}{4}a$

$t = \sqrt{\frac{R + a}{4}} + 0.2 = \frac{3}{8}\sqrt{a} + 0.2$ Min

$E = \frac{R}{5} + \frac{r}{10} + 2 = \frac{9}{4} + \frac{a}{20} + 2 = \frac{3a}{10} + 2$

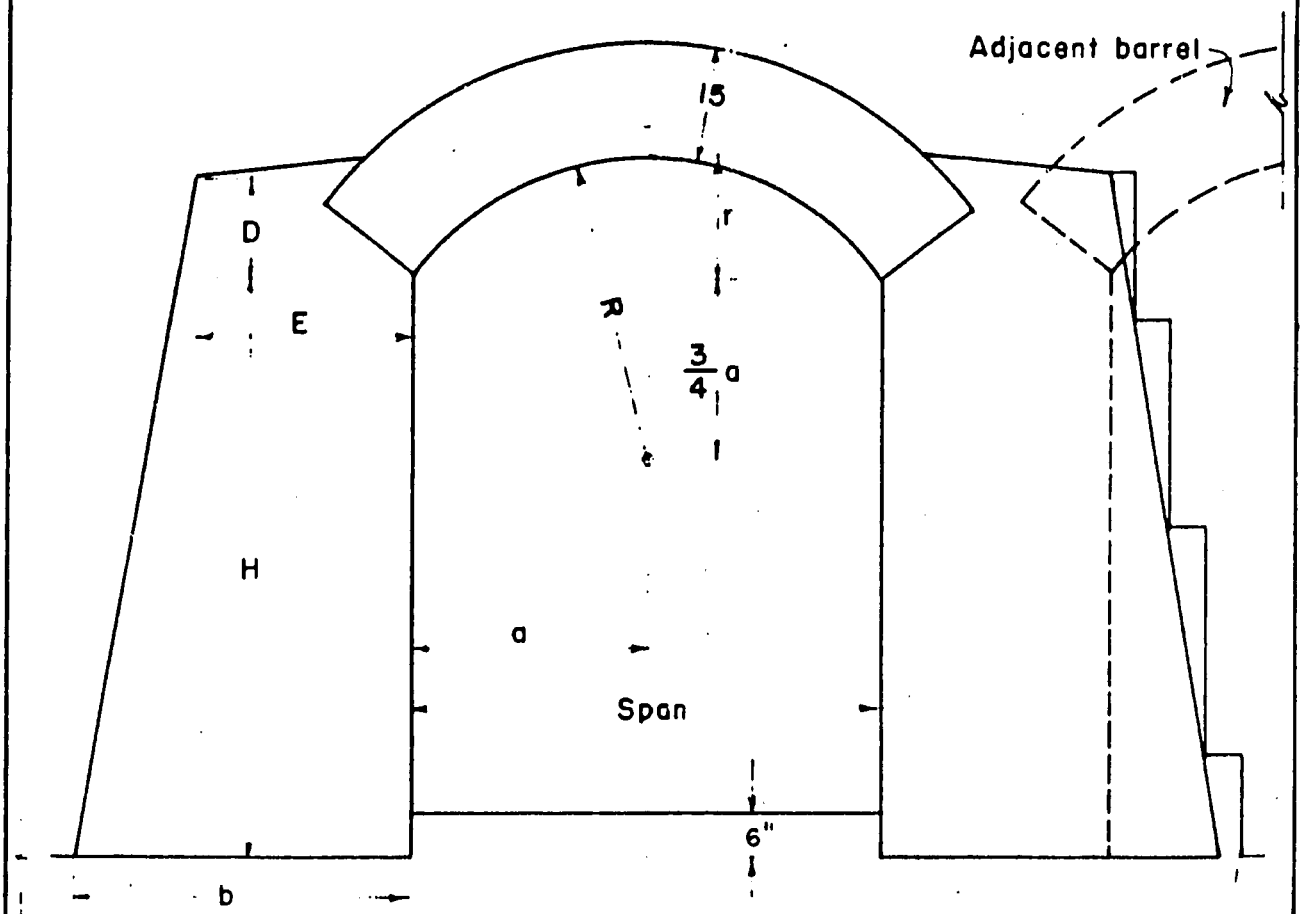
$D = \frac{r + t}{2}$

$N = \frac{24H}{5} = \frac{12a}{5} = 2.4a$

$b = E + \frac{H}{N}$

Span = 5', H = 6.5'

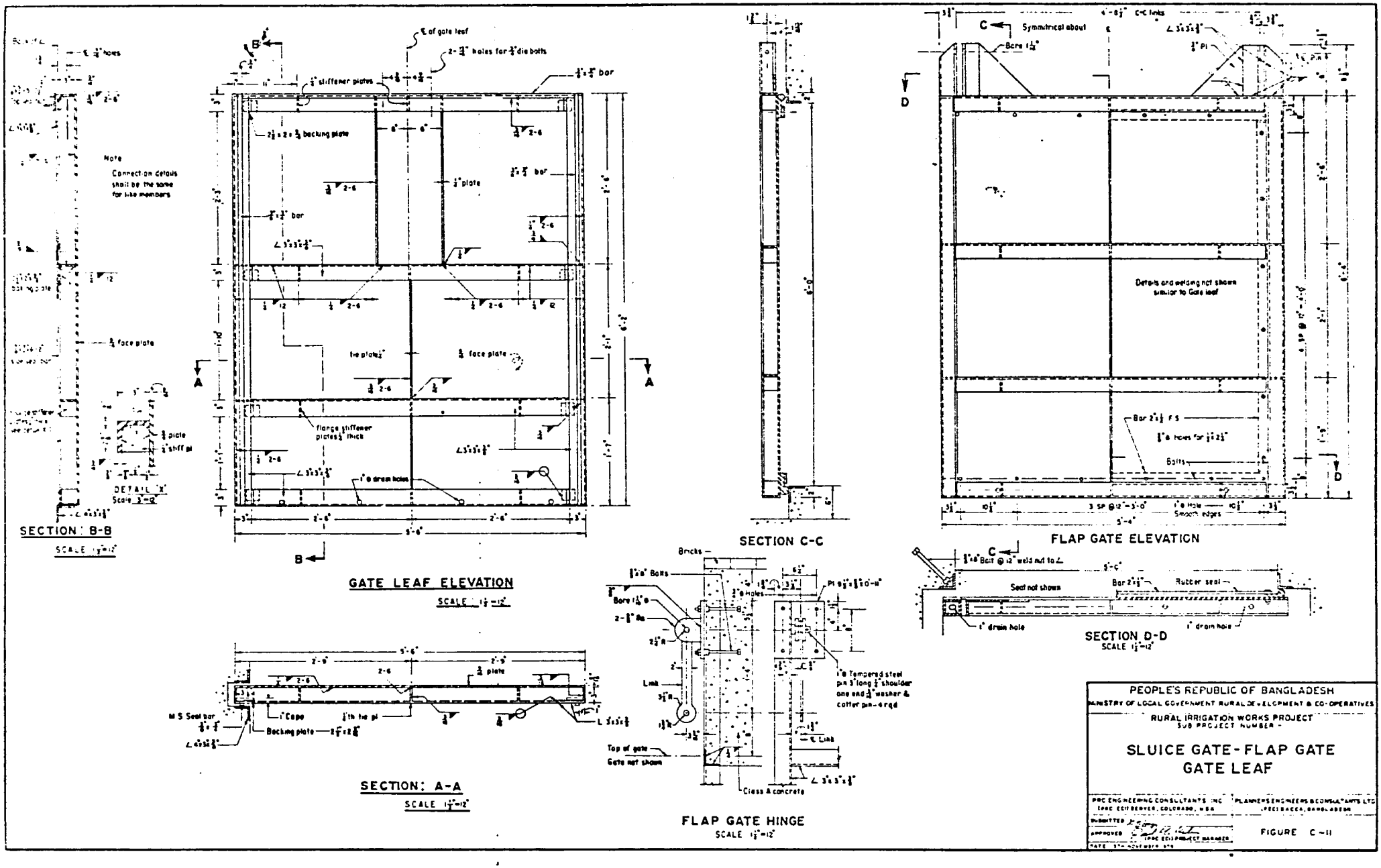
a =	2.5	
r =	1.25	
R =	3.125	3 - 1½
t =	0.80 = 9.5"	Use 15
E =	0.3x2.5+2=2.75	2 - 9
D =	1.25	1 - 3
N =	6.0	
b =	3.56 = 43"	3 - 9

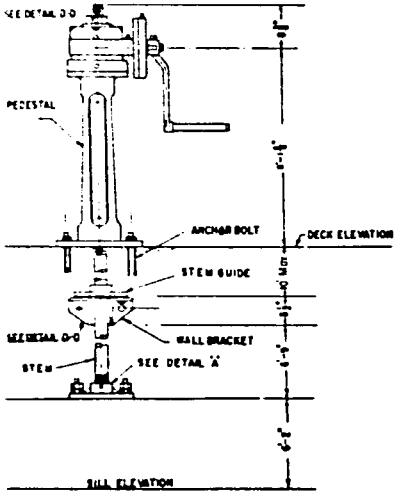


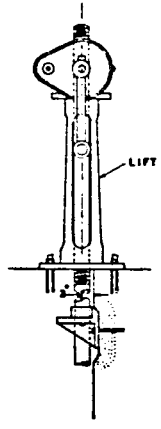
Plain Concrete Foundation

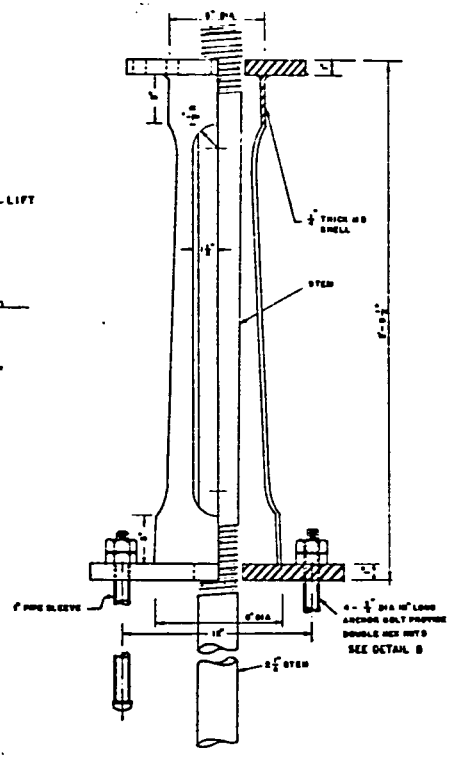
BRICK ARCH CULVERT

FIGURE - C-10

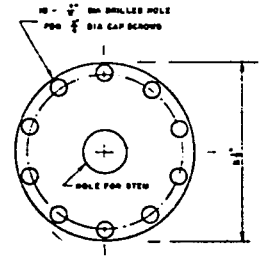

SECTION : B-B
GATE LEAF ELEVATION
SECTION C-C
FLAP GATE ELEVATION
SECTION : A-A
FLAP GATE HINGE
SECTION D-D
PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER -
SLUICE GATE - FLAP GATE
GATE LEAF
FIGURE C-11



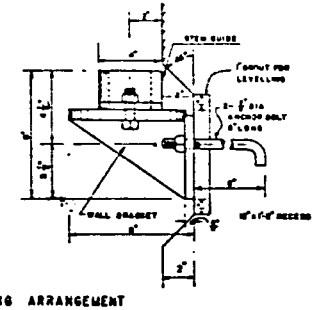




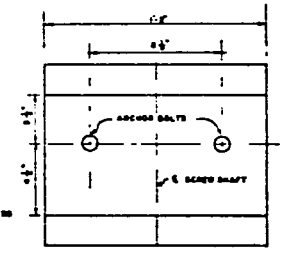
PEDESTAL
PARTS NO. 2
MAT M.S.



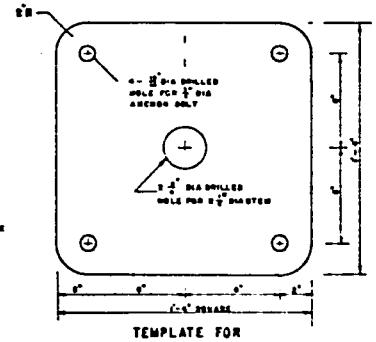
PLAN OF TOP



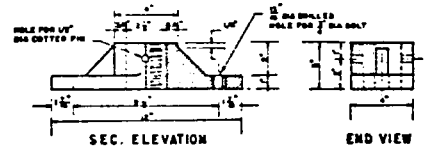
FIXING ARRANGEMENT
OF WALL BRACKET
SCALE: 3"=12"



FRONT VIEW OF RECESS

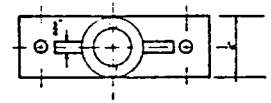


TEMPLATE FOR
PEDESTAL
SCALE 3"=12"



SEC. ELEVATION

END VIEW



PLAN
DETAIL-A

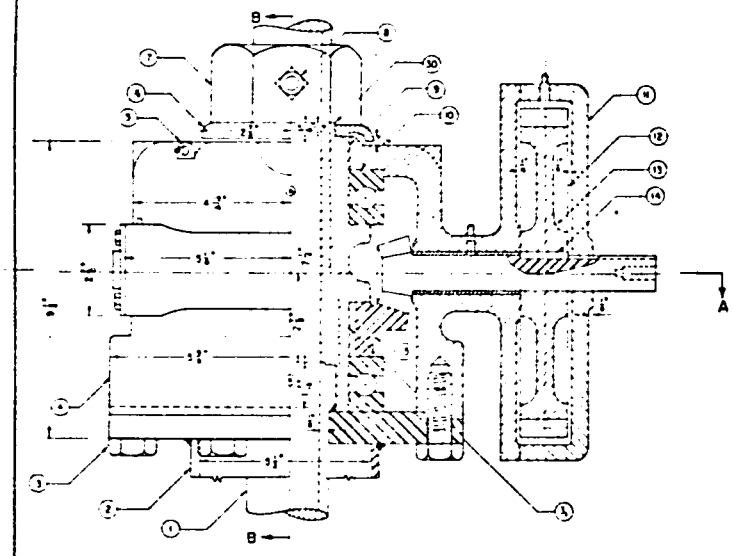
STEM ATTACHMENT
SCALE: 3"=12"

PEOPLES REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES

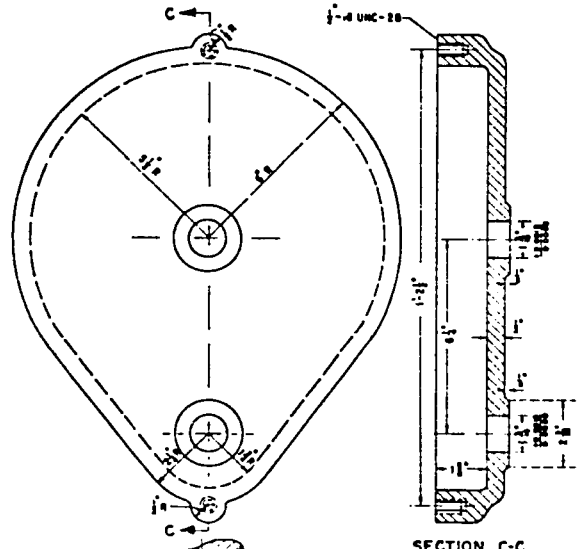
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER

GEAR LIFT PADESTAL & DETAILS

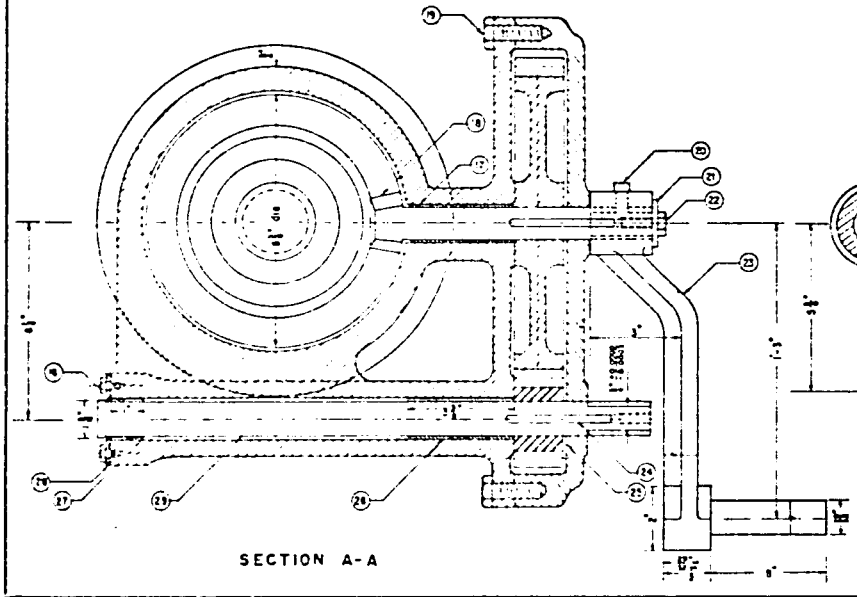
PRC ENGINEERING CONSULTANTS INC (PRC, ECHIDENVER COLORADO, USA	PLANNERS ENGINEERS & CONSULTANTS LTD PEC DACCA, BANGLADESH
SUBMITTED	FIGURE C-12
APPROVED (PRC ECI PROJECT MANAGER)	
DATE 13TH NOVEMBER 1979	



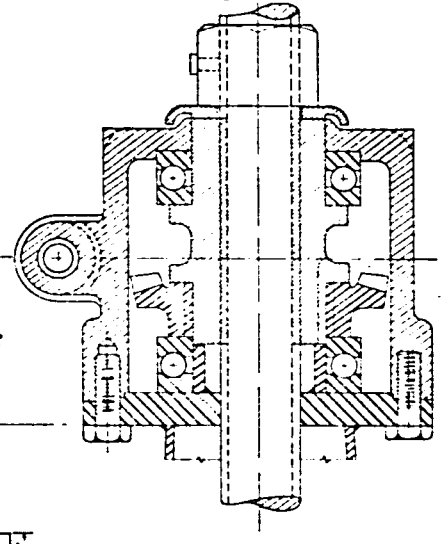
HALF ELEVATION



SECTION C-C
GEAR COVER
PARTS No 11
MAT-C I



SECTION A-A



SECTION B-B

PARTS LIST					
PC No	NAME	QTY	MAT	P/W	REMARKS
1	THREADED STEM	1	M S	M	
* 2	PEDESTAL	1	M S	M	
3	3/4" HEX HD CAP SCREW	10	M S	P	
4	BOWL	1	C I	M	
5	GREASE FITTINGS	9	—	P	
6	RAIN SHIELD	1	C I	M	
7	2 1/2" HEX STOP NUT	1	M S	M	
8	3/4" SQUARE HEAD SET SCREW	1	M S	M	
9	LIFT NUT	1	BRONZE	M	
* 10	THRUST BALL BEARINGS	2	—	P	
11	GEAR COVER	1	C I	M	
12	SPUR GEAR	1	C I	M	
13	3/8" ALLEN HEAD SET SCREW	1	M S	M	
14	KEY	1	M S	M	
15	BEVEL GEAR	1	M S	M	
16	3/4" HEX HD CAP SCREW	4	M S	P	
17	BRONZE BRUSHINS	1	BRONZE	M	
18	PINION AND SHAFT	1	M S	M	
19	3/4" HEX HD CAP SCREW	2	M S	P	
20	1/2" SQ HD SET SCREW	1	M S	M	
21	LOCK WASHER	1	M S	M	
22	5/8" CAP SCREW	1	M S	P	
23	CRANK	1	M S	M	
24	KEY	1	M S	M	
25	PINION	1	M S	M	
26	BRONZE BRUSHINGS	1	BRONZE	M	
27	BRONZE BRUSHING	1	BRONZE	M	
28	LOCK WASHER	1	BRONZE	M	
29	PINION SHAFT	1	M S	M	
30	3/8" FLAT HEAD CAP SCREW	2	M S	M	
31	KEY	1	M S	M	

* Std. thrust bearings of nearest dimension may be used but necessary alterations of other members for this shall have to be approved of before manufacture
* Cast iron pedestal parts No 2A, Fig may be used

PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES

RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER -

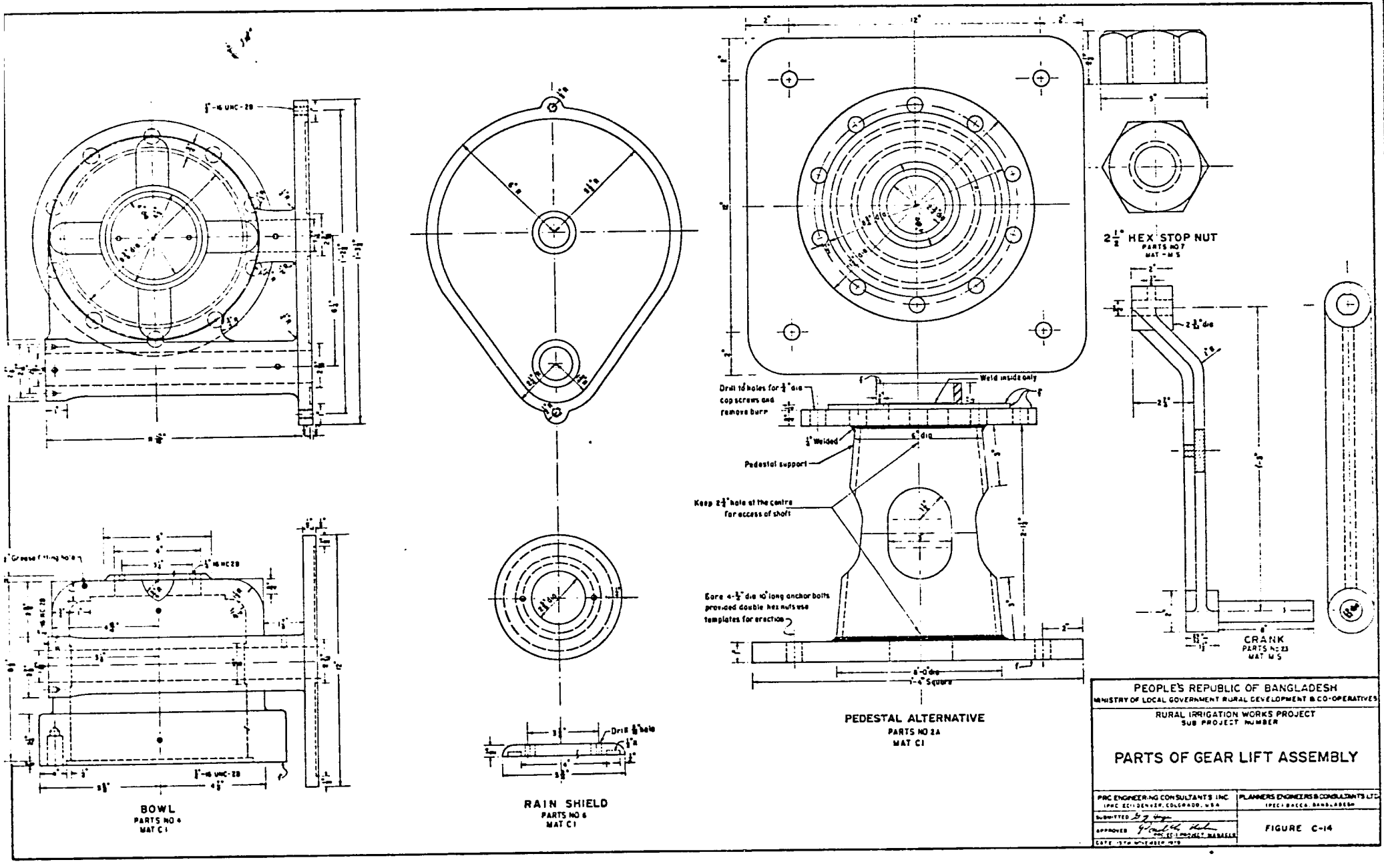
GEAR LIFT ASSEMBLY

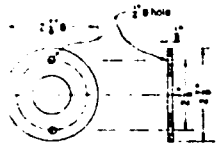
PRC ENGINEERING CONSULTANTS INC (PRC ECI) DENVER, COLORADO, USA

PLANNERS ENGINEERS & CONSULTANTS LTD (PEC) DACCA, BANGLADESH

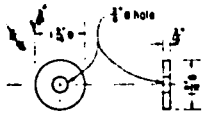
SUBMITTED
APPROVED (PRC ECI PROJECT MANAGER)
DATE

FIGURE C-13

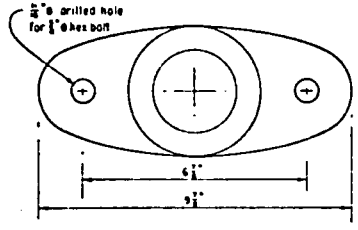

BOWL
PARTS NO 4
MAT C I
RAIN SHIELD
PARTS NO 6
MAT C I
PEDESTAL ALTERNATIVE
PARTS NO 2A
MAT C I
Drill 10 holes for 1/2" dia cap screws and remove burr
Weld inside only
Pedestal support
Keep 2 1/2" hole at the centre for access of shaft
Bore 4-1/2" dia 10" long anchor bolts provided double hex nuts use templates for erection
2 1/2" HEX STOP NUT
PARTS NO 7
MAT - M S
CRANK
PARTS NO 23
MAT M S
PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER
PARTS OF GEAR LIFT ASSEMBLY
PRC ENGINEERING CONSULTANTS INC
PLANNERS ENGINEERS & CONSULTANTS LTD
SUBMITTED
APPROVED
FIGURE C-14



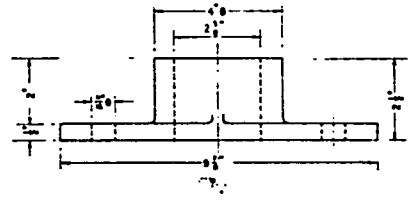
LOCK WASHER
PART NO 20
MATERIAL - BRONZE



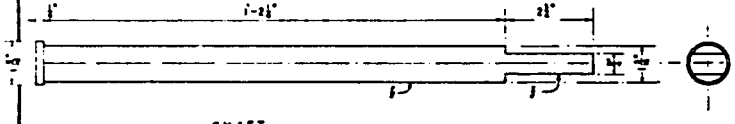
LOCK WASHER
PART NO 21
MATERIAL - MILD STEEL



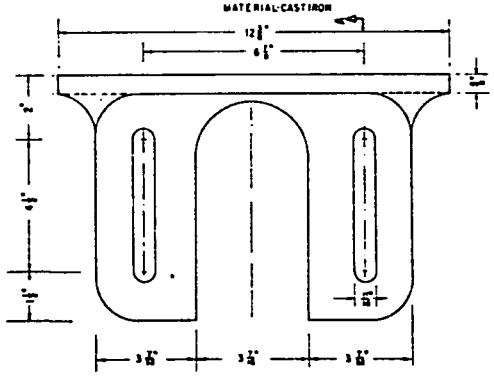
PLAN OF STEM GUIDE
PART NO 1
MATERIAL-CAST IRON



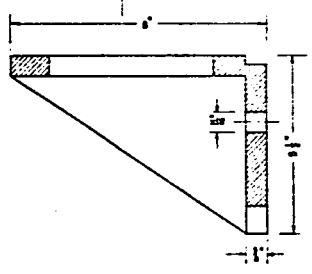
ELEVATION



SHAFT
PART NO 22
MATERIAL-MILD STEEL



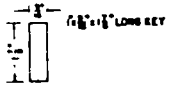
WALL BRACKET
PART NO 2
MATERIAL-CAST IRON



SECTION-A-A

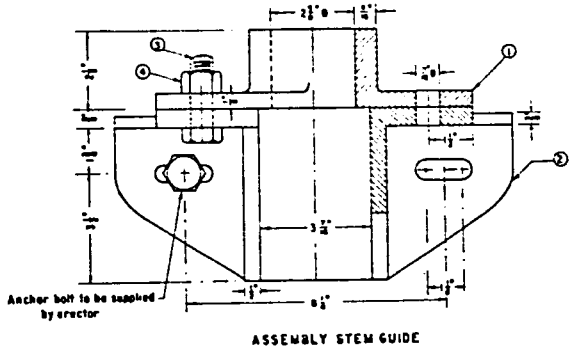
Hex cap screw
PART NO 16
MATERIAL - MILD STEEL

Allen Hd set screw
PART NO 13
MATERIAL-MILD STEEL



LONG KEY

KEY
PARTS NO 31
MATERIAL-MILD STEEL



ASSEMBLY STEM GUIDE

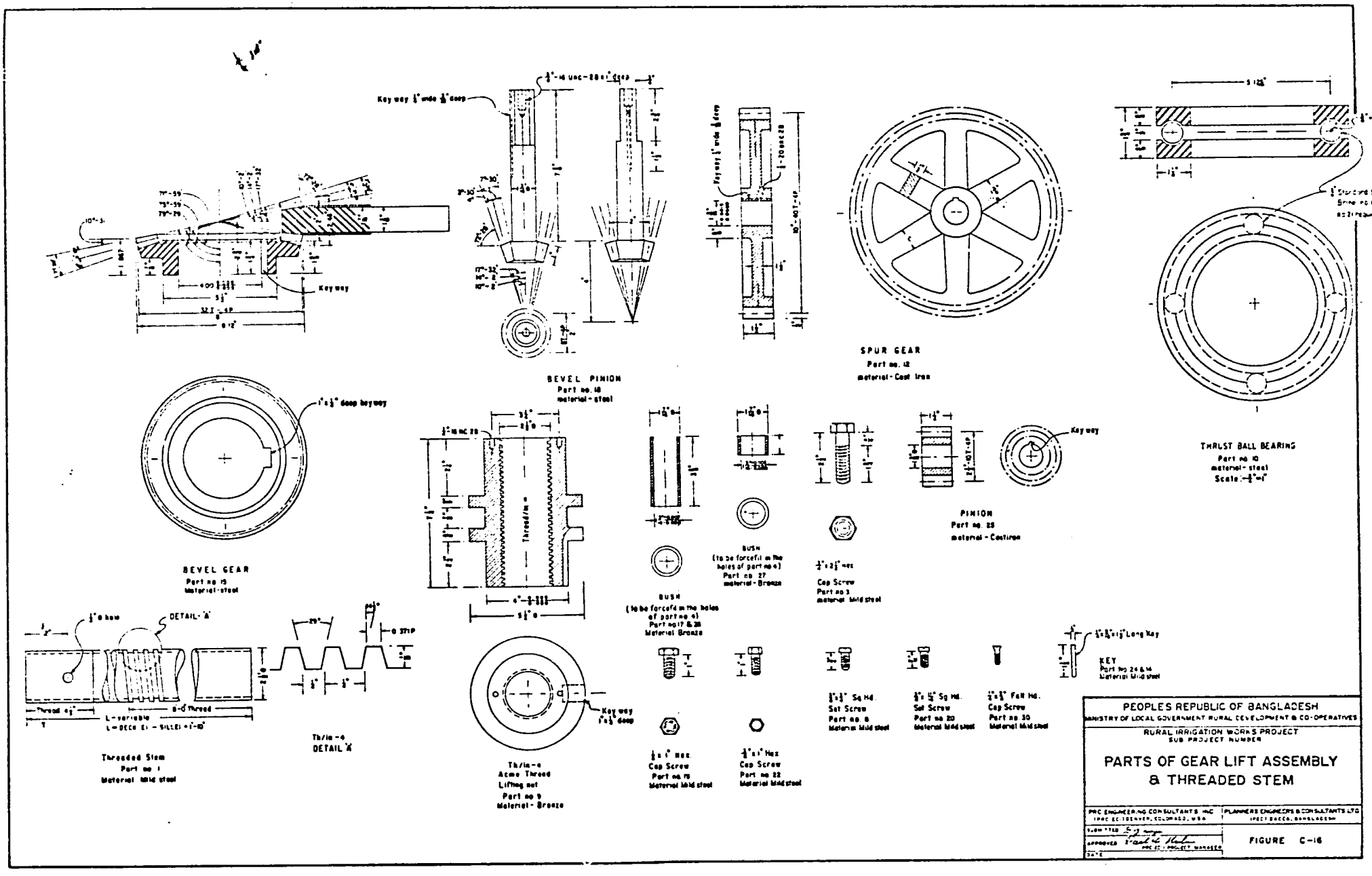
PARTS LIST					
PT NO	NAME	QTY	MAT	P/M	REMARKS
1	GUIDE SLEEVE	1	C.I	M	
2	WALL BRACKET	1	C I	M	
3	HEX BOLT	2	M S	P	
4	HEX NUT	2	M.S	P	

PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER -

PARTS OF GEAR LIFTS & STEM GUIDE

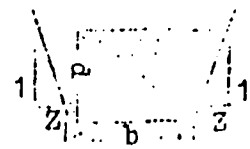
PRC ENGINEERING CONSULTANTS INC (PRC ED) DENVER, COLORADO, USA
PL BANNERS ENGINEERS & CONSULTANTS LTD (PEC) BACCA, BANGLADESH
SUBMITTED
APPROVED (PRC ED) PROJECT MANAGER
DATE

FIGURE C-15


Key way
BEVEL PINION
Part no. 18
material - steel
SPUR GEAR
Part no. 12
material - Cast Iron
THRUST BALL BEARING
Part no. 10
material - steel
BEVEL GEAR
Part no. 19
Material - steel
PINION
Part no. 25
material - Castiron
BUSH
(to be forcefit in the holes of part no 4)
Part no. 27
material - Bronze
Cap Screw
Part no 3
material Mild steel
BUSH
(to be forcefit in the holes of part no 4)
Part no 17 & 28
Material Bronze
KEY
Part No 24 & 14
Material Mild steel
Threaded Stem
Part no 1
Material Mild steel
DETAIL 'A'
Th/in-4
Acme Thread
Lifting nut
Part no 9
Material - Bronze
Cap Screw
Part no 15
Material Mild steel
Cap Screw
Part no 22
Material Mild steel
Sq Hd.
Set Screw
Part no. 6
Material Mild steel
Sq Hd.
Set Screw
Part no 20
Material Mild steel
Fat Hd.
Cap Screw
Part no 30
Material Mild steel
PEOPLES REPUBLIC OF BANGLADESH
MINISTRY OF LOCAL GOVERNMENT RURAL DEVELOPMENT & CO-OPERATIVES
RURAL IRRIGATION WORKS PROJECT
SUB PROJECT NUMBER
PARTS OF GEAR LIFT ASSEMBLY
& THREADED STEM
PRC ENGINEERING CONSULTANTS INC
PLANNERS ENGINEERS & CONSULTANTS LTD
FIGURE C-16

Uniform Flow Coefficients. Mannina's Furmula - English Units

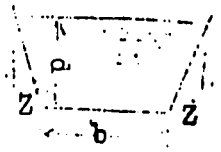
Values of $\frac{Qn}{b^{8/3} S^{1/2}}$



d/b	z = 1	z=1-1/2	d/b	z=1	z=1-1/2	d/b	z=1	z=1-1/2
.02	.00218	.00220	.39	.326	.371	1.05	2.13	2.75
.03	.00429	.00433	.40	.341	.389	1.10	2.34	3.04
.04	.00690	.00700	.41	.357	.408	1.15	2.56	3.34
.05	.0100	.0102	.42	.373	.427	1.20	2.79	3.68
.06	.0136	.0138	.43	.389	.447	1.25	3.04	4.03
.07	.0176	.0180	.44	.405	.467	1.30	3.30	4.39
.08	.0219	.0225	.45	.422	.487	1.35	3.57	4.76
.09	.0267	.0275	.46	.439	.509	1.40	3.85	5.18
.10	.0318	.0329	.47	.457	.530	1.45	4.15	5.60
.11	.0373	.0387	.48	.475	.552	1.50	4.46	6.04
.12	.431	.0450	.49	.492	.575	1.55	4.78	6.50
.13	.0493	.0516	.50	.512	.599	1.60	5.12	6.99
.14	.0559	.0587	.52	.548	.646	1.65	5.47	7.50
.15	.0628	.0662	.54	.590	.696	1.70	5.83	8.02
.16	.0699	.0740	.56	.631	.748	1.75	6.21	8.57
.17	.0775	.0823	.58	.671	.802	1.80	6.60	9.13
.18	.0854	.0910	.60	.717	.858	1.85	7.01	9.75
.19	.0936	.100	.62	.763	.917	1.90	7.43	10.4
.20	.102	.110	.64	.809	.976	1.95	7.87	11.0
.21	.111	.120	.66	.858	1.04	2.00	8.32	11.7
.22	.120	.130	.68	.908	1.10	2.10	9.27	13.1
.23	.130	.141	.70	.958	1.17	2.20	10.3	14.6
.24	.139	.152	.72	1.01	1.24	2.30	11.3	16.2
.25	.150	.163	.74	1.07	1.31	2.40	12.5	17.9
.26	.160	.175	.76	1.12	1.39	2.50	13.7	19.8
.27	.171	.188	.78	1.18	1.46	2.60	15.0	21.7
.28	.182	.201	.80	1.24	1.54	2.70	16.3	23.8
.29	.193	.214	.82	1.30	1.63	2.80	17.8	25.9
.30	.205	.227	.84	1.36	1.71	2.90	19.3	28.2
.31	.217	.242	.86	1.43	1.79	3.00	20.9	30.6
.32	.230	.256	.88	1.49	1.88	3.20	24.2	35.8
.33	.243	.271	.90	1.56	1.98	3.40	27.9	41.5
.34	.256	.287	.92	1.63	2.07	3.60	32.0	47.8
.35	.270	.303	.94	1.70	2.16	3.80	36.3	54.6
.36	.283	.319	.96	1.78	2.27	4.00	41.1	61.9
.37	.297	.336	.98	1.85	2.37	4.50	54.5	82.9
.38	.311	.354	1.00	1.93	2.47	5.00	70.3	108

Uniform Flow Coefficients. Mannina's Furmula - English Units

Values of $\frac{Qn}{d^{8/3} S^{1/2}}$



d/b	z=1	z=1-1/2	d/b	z=1	z=1-1/2	d/b	z=1	z=1-1/2
.01	148.3	148.8	.39	4.02	4.57	1.05	1.871	2.41
.02	74.0	74.5	.40	3.93	4.48	1.10	1.813	2.36
.03	49.3	49.8	.41	3.85	4.40	1.15	1.763	2.30
.04	36.9	37.4	.42	3.77	4.32	1.20	1.717	2.26
.05	29.5	30.0	.43	3.69	4.24	1.25	1.676	2.22
.06	24.6	25.1	.44	3.62	4.17	1.30	1.638	2.18
.07	21.1	21.6	.45	3.55	4.10	1.35	1.603	2.14
.08	18.43	18.95	.46	3.48	4.04	1.40	1.570	2.11
.09	16.39	16.91	.47	3.42	3.97	1.45	1.540	2.08
.10	14.75	15.28	.48	3.36	3.91	1.50	1.512	2.05
.11	13.42	13.94	.49	3.30	3.85	1.55	1.486	2.02
.12	12.31	12.87	.50	3.25	3.80	1.60	1.461	1.995
.13	11.37	11.90	.52	3.14	3.70	1.65	1.438	1.972
.14	10.57	11.10	.54	3.05	3.60	1.70	1.416	1.949
.15	9.88	10.42	.56	2.96	3.51	1.75	1.396	1.928
.16	9.27	9.81	.58	2.87	3.43	1.80	1.377	1.905
.17	8.74	9.28	.60	2.80	3.35	1.85	1.359	1.890
.18	8.27	8.81	.62	2.73	3.28	1.90	1.342	1.872
.19	7.85	8.39	.64	2.66	3.21	1.95	1.326	1.856
.20	7.47	8.01	.66	2.60	3.15	2.00	1.310	1.840
.21	7.13	7.67	.68	2.54	3.09	2.10	1.282	1.811
.22	6.82	7.36	.70	2.48	3.03	2.20	1.256	1.784
.23	6.53	7.08	.72	2.43	2.98	2.30	1.233	1.760
.24	6.27	6.82	.74	2.38	2.93	2.40	1.212	1.737
.25	6.04	6.58	.76	2.33	2.88	2.50	1.192	1.717
.26	5.82	6.37	.78	2.29	2.84	2.60	1.174	1.698
.27	5.62	6.16	.80	2.25	2.80	2.70	1.157	1.681
.28	5.43	5.98	.82	2.21	2.76	2.80	1.142	1.665
.29	5.25	5.81	.84	2.17	2.72	2.90	1.128	1.650
.30	5.09	5.64	.86	2.14	2.68	3.00	1.114	1.636
.31	4.94	5.49	.88	2.10	2.65	3.20	1.090	1.611
.32	4.80	5.35	.90	2.07	2.62	3.40	1.069	1.589
.33	4.67	5.22	.92	2.04	2.58	3.60	1.050	1.569
.34	4.54	5.09	.94	2.01	2.55	3.80	1.033	1.552
.35	4.43	4.98	.96	1.981	2.53	4.00	1.019	1.536
.36	4.32	4.87	.98	1.954	2.50	4.50	.987	1.502
.37	4.21	4.76	1.00	1.928	2.47	5.00	.962	1.476
.38	4.11	4.67						

User Instructions

TIDAL STORAGE

1 Data A | Data B | run C 2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load Program 2 sides				
2.	Store data				
	Canal bottom width	B	ENT		
	Canal side slope horiz = 1 vert	Z	ENT		
	Canal length	L	ENT		
	Canal bottom grade to low tide	do	A		
	Canal bottom grade to sluice sill	ys	ENT		
	Number of hours in sluiceway	j	ENT		
	Number of half hour intervals	N	ENT		
	Height of tide	Y	B		
3.	Start program		C		
4.	Printout				
	time interval				n
	height of tide above canal BG				do+y
	depth of water in canal				d
	total storage in canal acre ft				S

PROGRAM LISTING

STEP	KEY ENTRY	KEY CODE	COMMENTS
13	X	-35	
14	TX	54	
15	STCC	35 13	
16	RCL0	36 14	Compute Ks
17	RCLC	36 13	
18	X>Y?	16-34	
19	GTCO	22 16 13	
120	RCL3	36 13	
21	X	-35	
22	STO8	35 08	
23	STO1	35 01	
24	GTC	21 16 13	
25	RCB	36 12	
26	STO	35 12	
27	X	-35	
28	STO2	35 02	
29	LBL1	21 01	Compute Kq
130	P<S	16-51	
31	GTO7	22 07	
32	GTO	22 00	
33	P<S	16-51	
34	RCL1	36 01	
35	X=Y?	16-33	
36	-	-45	
37	X	-35	
38	3	03	
39	0	00	
140	X	-35	
41	STO7	35 07	
42	LBL4	21 16 14	Compute S
43	RCL9	36 09	
44	RCLA	36 11	
45	-	-45	
46	X<0?	16-45	
47	GTO3	22 15	
48	GTO	22 00	
49	X	-35	
150	STC	35 13	
51	RCLA	36 11	Compute Q
52	TX	54	
53	RCL7	36 07	
54	X	-35	
55	RCLD	36 13	
56	X<Y?	16-35	S Q
57	GTCE	22 15	
58	RCLA	36 11	
59	RCLE	36 15	
160	+	-55	
61	STCA	35 11	
62	GTCd	22 16 14	
63	LBLE	21 15	Itemation for h
64	RCLA	36 11	
65	RCLE	36 15	
66	-	-45	
67	STOA	35 11	
68	.	-62	

STEP	KEY ENTRY	KEY CODE	COMMENTS
69	1	01	
170	RCL5	36 15	
71	X	-35	
72	STCE	35 15	
73	RCL1	36 11	
74	+	-55	
75	STCA	35 11	
76	RTZ	16 25 46	
77	GTCd	22 16 14	Point d
78	STO9	35 09	
79	RCL1	36 01	
180	RTX	-14	
81	+	-55	
82	RCL1	36 11	
83	-	-45	
84	STO1	35 01	
85	STO	35 00	
86	RPC	-12 00	
87	RTX	-14	Point n
88	DSP2	-63 02	Loop n
89	P<S	16-51	
190	RCL6	36 06	
91	P<S	16-51	
92	X=Y?	16-33	
93	GTOD	22 14	
94	1	01	
95	ST+0	35-55 00	
96	STOA	35 11	
97	GTOa	22 16 11	
98	RTN	24	
99	R/S	51	
200			
210			
220			

LABELS

A data	B data	C start	D Storage S	E itemation
a comp Y	b comp T	c Comp ks	d comp S	e
0	1 comp kq	2	3	4
5	6	7	8	9

FLAGS

0, 1, 2, 3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☒	FIX	☒
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n	

Program Description

Program Title CANAL TIDAL STORAGE

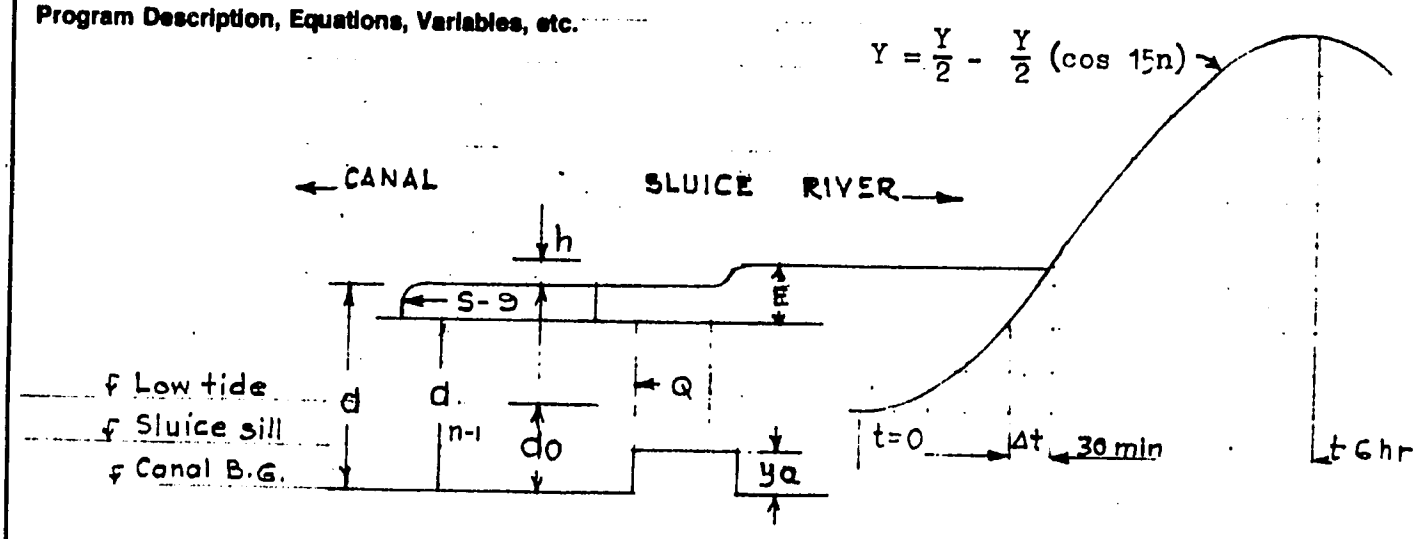
Name ~~G. L. Hoge~~

Address

City **State** **Zip Code**

Date ~~October 1979~~

Program Description, Equations, Variables, etc.



Natural or excavated channels extending inland from tidal rivers are used to store water entering during rising tide for irrigation. Reverse flow is prevented by self operating flap gates in the sluiceway at the mouth of the channel. This program provides a guide for selecting the canal and sluiceway dimensions

$S = T_{(n-1)} (E-h)C$

T = top width of canal

C = celerity of standing wave

$= \sqrt{g D}$

$D = A + T$

$A =$?

$S = Q$

Solve for h

$Q = (d_{n-1}) - Ya)\, k_a \sqrt{h}$ Ka

$ka = b.c. \sqrt{2g}$

$= 5.c. \sqrt{2 \times 32.2}$

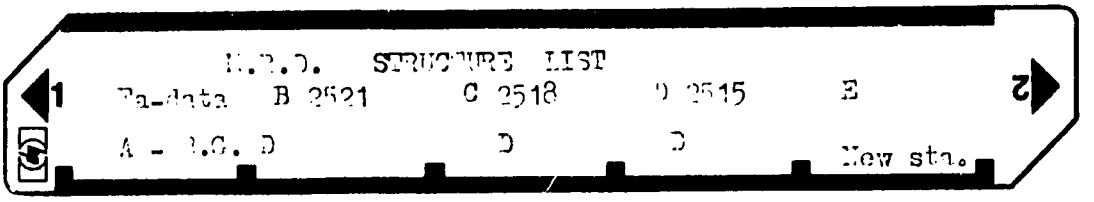
$= 30$

Define E, h, A

Operating Limits and Warnings This program is set to use in Bangladesh for sluiceways with multiple barrels of standard 5ft wide by 6ft high bays. The discharge Q thru the sluiceway is based on freeflow conditions. Other sluiceway dimensions may be used by changing the coefficient C (step 138 - 9) Accuracy beyond a unit value is not justified. Low tide is considered to be above sluice way sill. The canal water surface falls below the tide so water will continue to flow after high tide. N = 14 or 15 is suggested.

DO NOT USE THIS SPACE

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load side				
2.	Input initial station elevation and				
	bottom grade				
	Station, if 0 omit	Sta	Sto	0	
	Bottom grade	Bg	Sto	1	
	Slope	S	Sto	I	
3.	Input structure station	Sta	NT		
4.	For turnout input delivery water surface	DWS	F	a	
	For drop structures	D	F	a	
5.	Compute bottom grade at sta pause will flash		A		B.G.
6.	For turnout, for sec 2521		B		D
	for sec 2518		C		D
	for sec 2515		D		D
	If D is negative, DWS is above water				
	surface and grade must be adjusted				
7.	Compute new BG and initial station at drop				
	structure change in grade or Road crossing		E		B.G.
8.	Report 3 at seg.				
	9				
	Note : For structures with no DWS or D -				
	lateral turnout, cart crossing, or				
	change in slope often for step 4		F	a	

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBLa		
2	STO5		
3	R↓		
4	STO2		
5	RTN		
6	LBLA		
7	REL2		
8	RCL0		
9	-		
010	RCL1		
11	X		
12	RCL1		
13	-		
14	CHS		
15	STO3		
16	PSE		
17	RTN		
18	LBLB		
19	1		
020	.		
21	2		
22	5		
23	STO6		
24	GSB8		
25	.		
26	2		
27	5		
28	STO4		
29	GTO1		
030	RTN		
31	LBLC		
32	1		
33	STO6		
34	GSB8		
35	.		
36	5		
37	STO4		
38	GTO1		
39	RTN		
040	LBLD		
41	.		
42	7		
43	5		
44	STO4		
45	STO6		
46	GSB8		
47	GTO1		
48	RTN		
49	LBL1		
050	RCL2		
51	RCL5		
52	-		
53	1		
54	+		
55	RCL4		
56	X⇄Y		
57	X≤Y?		
58	GTO9		
59	PSE		
060	CLX		
61	GTOA		
62	RTN		
63	LBLE		
64	RCL5		
65	RCL3		
66	X⇄Y		
67	-		
68	STO1		
69	RCL2		
070	STO0		
71	RCL1		
72	PSE		
73	RTN		
74	LBL9		
75	RCL4		
76	PSE		
77	CLX		
78	LBL8		
79	RCL3		
080	RCL6		
81	+		
82	RCL5		
83	-		
84	X>0?		
85	RTN		
86	PSE		
87	R/S		
88	RTN		
89	R/S		
090			
100			
110			

REGISTERS

0	1	2	3	4	5	6	7	8	9
Initial Station	Initial B.G.	Sta.	B.G.	Min D	D.DTS	d			
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
					Slape

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBLA	21 11	
2	PAD	16-16-22	
3	DSP5	-63 05	
4	STOA	35 11	d
5	R	-31	
6	STOB	35 12	Z
7	PRTX	-14	print Z
8	1/X	52	
9	TAN-1	16 43	θ1
010	STO3	35 03	
11	ENT	-21	
12	1	01	
13	R	44	
14	STO4	35 04	D1
15	X Y	-41	
16	2	02	
17	X	-35	
18	STO5	35 05	T
19	1	01	
020	RCL4	36 04	
21	-	-45	d1
22	PRTX	-14	print d1
23	RCL5	36 05	
24	PRTX	-14	print T1
25	GPC	16-11	
26	RCL4	36 11	
27	PRTX	-14	d
28	1	01	
29	-	-45	
030	TAN	-22	
31	STO6	35 06	D
32	RCL4	36 04	
33	X Y	-41	
34	X Y?	16-34	is D1 D1
35	GTO0	22 12	- yes
36	RCL4	36 04	no
37	[illegible]	[illegible]	for dual comp.
38	[illegible]	22 11	
39	[illegible]	[illegible]	D D1
040	[illegible]	[illegible]	
41	[illegible]	[illegible]	for dual comp.
42	[illegible]	22 11	
43	[illegible]	[illegible]	D or D1
44	[illegible]-1	[illegible]	θ
45	[illegible]	35 07	
46	2	02	
47	X	-35	
48	[illegible]	35 02	P or P1
49	RCL7	36 07	
050	[illegible]	-[illegible]	
51	[illegible]	41	
52	[illegible]	36 06	
53	X	-35	
54	-	-45	
55	[illegible]K1	35 01	A or A1
56	RCL4	36 04	

STEP	KEY ENTRY	KEY CODE	COMMENTS
57	RCL6	36 06	
58	X Y?	16-34	
59	GTO0	22 13	Yes D D1
060	RCL4	36 04	No D D1
61	RCL6	36 06	
62	-	-45	
63	STO8	35 08	D2
64	RCL5	36 05	
65	X	-35	
66	ST+1	35-55 01	add area
67	RCL8	36 08	
68	X²	53	
69	RCL[illegible]	36 12	
070	X	-35	= A
71	ST+1	35-55 01	add area
72	RCL1	36 01	
73	PRTX	-14	print A
74	RCL3	36 12	
75	TAN-1	16 43	
76	SIN	41	
77	1/X	52	
78	2	02	
79	X	-35	
080	RCL8	36 08	
81	X	-35	
82	ST+2	35-55 02	Per. for d d1
83	LBL0	21 13	
84	RCL1	36 01	
85	RCL2	36 02	
86	PRTX	-14	
87	+	-24	
88	PRTX	-14	Print r
89	[illegible]	-21	
090	1	01	
91	.	-62	
92	5	05	
93	1/X	52	
94	[illegible]	21	
95	RCL1	36 01	
96	X	-35	
97	[illegible]	-14	Print Km
98	1	01	
99	.	-62	
100	[illegible]	04	
1	8	08	
2	6	06	
3	X	-35	
4	[illegible]	-14	Print Ke
5	[illegible]	16-11	
6	[illegible]	16-11	
7	[illegible]	[illegible]	
8	[illegible]	[illegible]	
110			

REGISTERS

0	1	2	3	4	5	6	7	8	9
D or D1	Area	Perimeter	θ1	D1	T	D	θ	D2	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
d	Z				

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBLA	21 11	Data storage
2	STO1	35 01	
3	R↓	-31	
4	STO2	35 02	
5	P⇄S	16-51	
6	STO2	35 02	
7	P⇄S	16-51	
8	R	-31	
9	STO3	35 03	
010	R↓	-31	
11	STO4	35 04	
12	RTN	24	
13	LBLB	21 12	
14	STO6	35 06	
15	R↓	-31	
16	P⇄S	16-51	
17	STO6	35 06	
18	R↓	-31	
19	STO7	35 07	
020	R↓	-31	
21	STO8	35 08	
22	P⇄S	16-51	
23	RTN	24	
24	LBLC	21 13	Start Comp
25	RCL6	36 06	constant storage
26	2	02	
27	STO6	35-24 06	
28	1	01	
29	STO6	35 06	
030	STOA	35 11	
31	RCL2	36 02	
32	1	01	
33	8	08	
34	0	00	
35	0	00	
36	+	-24	
37	STOD	35 14	
38	RCL1	36 01	
39	STO2	35 02	
040	GTOa	22 16 11	
41	LBLD	21 14	Compute
42	RCL4	36 04	storage in
43	RCL1	36 01	acre feet
44	X	-35	
45	LSTX	16-63	
46	X²	53	
47	RCL2	36 02	
48	X²	53	
49	-	-45	
050	RCL3	36 03	
51	X	-35	
52	+	-55	
53	RCL4	36 04	
54	RCL2	36 02	
55	X	-35	
56	-	-45	

STEP	KEY ENTRY	KEY CODE	COMMENTS
57	P⇄S	16-51	
58	RCL2	36 02	
59	P⇄S	16-51	
060	X	-35	
61	4	-35	
62	3	04	
63	5	05	
64	6	06	
65	0	00	
66	÷	-24	
67	PRTX	-14	
68	RTN	24	
69	LBLa	21 16 11	compute Y
070	1	01	
71	5	05	
72	RCL0	36 00	
73	X	-35	
74	COS	42	
75	RCL6	36 06	
76	X	-35	
77	LSTX	16-63	
78	X⇄Y	-41	
79	-	-45	
080	RCL2	36 02	
81	+	-55	
82	PRTX	-14	Print duty
83	RCL1	36 01	Compute E
84	-	-45	
85	STO9	35 09	
86	3	03	Decimals in
87	STO1	35 46	solution for h
88	1	01	
89	STOE	35 15	
090	LBLb	21 16 12	Compute T
91	RCL4	36 04	
92	RCL1	36 01	
93	RCL3	36 03	
94	X	-35	
95	2	02	
96	X	-35	
97	+	-55	
98	STOB	35 12	
99	RCL4	36 04	Compute A
100	RCL1	36 01	
1	X	-35	
2	LSTX	16-63	
3	X²	53	
4	RCL3	36 03	
5	X	-35	
6	+	-55	
7	RCLB	36 12	Compute C
8	÷	-24	
9	3	03	
110	2	02	
11	.	-62	
12	2	02	

REGISTERS

0 n	1 do, d	2 I, do	3 Z	4 B	5	6 YY, $\frac{Y}{2}$	J, kq	8 Yaks	9 E
S0	S1	S2 L	S3	S4	S5	S6 N	S7	S8	S9
A h	B T	C S	D C max	E Δh	I i				

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
				170			
120							
				180			
130							
				190			
140							
				200			
150							
				210			
160							
				220			

LABELS

A B G	B D,2529	C D 2518	D 2515 sta	E Drop Sta	0
a	b	c	d	e	1
0 [illegible]	1 solve D	2	3	4	2
5	6	7	8 W.S.Check	9 deep Drain	3

FLAGS

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☒	FIX	☒
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n 2	

Program Description

Program Title M. R. D. Structure List

Name

Date

Address

City **State** **Zip Code**

Program Description, Equations, Variables, etc. For given initial station, bottom grade elevation, section properties and slope plus delivery water surface elevations and change in bottom grade elevations and slope this program computes elevations and controlling structure dimensions for construction layout. The dimensions are in in accordance with Fig C-1 Standard Structures.

The program solves the following equations :

For Key A -

$$BG_n = BG_o - (Sta_n - Sta_o)S$$

For keys B.C.D corresponsing to sections 2521, 2518 and 2515:

a - test for W.S. elevation being at or above delivery water surface.

BG + d - DWS 0 yes, grade ok, no-negative number flashes and grade or slope must be adjusted.

b. - D = BG + 1 - DWS, with minimum of 0.25 for sec 2521

0.50 for sec 2518 and 0.75 for sec 2515. The minimum is determined by the structural dimension of 2' from the turnout floor to top of wall with the top of wall the same as the adjacent canal wall.

For key E

The program moves the initial station and bottom grade to the location of the changed properties.

Operating Limits and Warnings This program is applicable for canals conforming to Fig_____ The bottom grade computations, Key A can be applied to any canal.

This program is for a Hewlett - Packard HP 97 calculator it may also be used on a HP 67 calculator.

User Instructions

Hydraulic Properties for Round Bottom Canal

1 2

A

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load side 1				
2.	Key in data				
	Z - Side slope - (Z horiz to 1 vert)	Z	ENT		
3.	d - ratio of water depth to radius				
	of curved bottom	d	A		
	Out put - Coefficients (R = 1)				
	Z Side slope				Z
	d_1 - depth to tangent point				d1
	Multiply by R				T1
	T_1 - Width at Tangent points				
	Multiply R				
	A - Area of section				A
	Multiply by R^2				
	r - Hydraulic radius Multiply by R				r
	p - Perimeter				p
	K_m - Coefficient of discharge for				
	Metric Units				km
	$km = Qn/b^{8/3} S^{\frac{1}{2}}$				
	n = Manning's roughness factor				
	K_e - Same as K_m only in English units				ke

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBLA	21 11	
2	RAD	16-22	
3	DSP5	-63 05	
4	STOA	35 11	d
5	R	-31	
6	STOB	35 12	Z
7	PRTX	-14	print Z
8	1/X	52	
9	TAN-1	16 43	θ1
010	STO3	35 03	
11	ENT	-21	
12	1	01	
13	R	44	
14	STO4	35 04	D1
15	X Y	-41	
16	2	02	
17	X	-35	
18	STO5	35 05	T
19	1	01	
020	RCL4	36 04	
21	-	-45	d1
22	PRTX	-14	print d1
23	RCL5	36 05	
24	PRTX	-14	print T1
25	SPC	16-11	
26	RCLA	36 11	
27	PRTX	-14	d
28	1	01	
29	-	-45	
030	ZIS	-22	
31	STO6	35 06	D
32	RCL4	36 04	
33	X Y	-41	
34	X Y?	16-34	is D1 D1
35	GTOB	22 12	- was
36	RCL4	36 04	no
37	STO[illegible]	35 03	for dual comp.
38	GTO[illegible]	22 1[illegible] 11	
39	LBL[illegible]	21 1[illegible]	D D1
040	[illegible]	36 0[illegible]	
41	STO[illegible]	35 0[illegible]	for dual comp.
42	GTO[illegible]	22 1[illegible] 11	
43	[illegible]	36 0[illegible]	D or D1
44	COS-1	1[illegible] 4[illegible]	θ
45	STO7	35 07	
46	2	02	
47	X	-35	
48	STO2	35 02	P or P1
49	RCL7	36 07	
050	[illegible]	-21	
51	[illegible]	41	
52	RCL6	36 06	
53	X	-35	
54	-	-45	
55	STO1	35 01	A or A1
56	RCL4	36 04	

STEP	KEY ENTRY	KEY CODE	COMMENTS
57	RCL6	36 06	
58	X Y?	16-34	
59	GTO0	22 13	Yes D D1
060	RCL4	36 04	No D D1
61	RCL6	36 06	
62	-	-45	
63	STO8	35 08	D2
64	RCL5	36 05	
65	X	-35	
66	ST+1	35-55 01	add area
67	RCL8	36 08	
68	X²	53	
69	RCLP	36 12	
070	X	-35	= A
71	ST+1	35-55 01	add area
72	RCL1	36 01	
73	PRTX	-14	print A
74	RCLB	36 12	
75	TAN-1	16 43	
76	SIN	41	
77	1/X	52	
78	2	02	
79	X	-35	
080	RCL8	36 08	
81	X	-35	
82	ST+2	35-55 02	Per. for d d1
83	LBL0	21 13	
84	RCL1	36 01	
85	RCL2	36 02	
86	PRTX	-14	
87	+	-24	
88	PRTX	-14	Print r
89	ENT	-21	
090	1	01	
91	.	-62	
92	5	05	
93	1/X	52	
94	Y^X	31	
95	RCL1	36 01	
96	X	-35	
97	PRTX	-14	Print Km
98	1	01	
99	.	-62	
100	4	04	
1	8	08	
2	6	06	
3	X	-35	
4	PRTX	-14	Print Ke
5	SPC	16-11	
6	SPC	16-11	
7	ENT	-21	
8	R/S	51	
110			

REGISTERS

0	1	2	3	4	5	6	7	8	9
D or D1	Area	Perimeter	θ1	D1	T	D	θ	D2	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
d	Z				

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
				170			
120				180			
130				190			
140				200			
150				210			
160				220			

LABELS

A Iniate	B Segment	C Hyd.pump	D	E	0
a D or D1=D	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

FLAGS

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☐	FIX	☐
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☒	ENG	☐
3	☐	☐			n 5	

Program Description

Program Title	Hydraulic property coefficients for round bottom canal		
Name	G. J. Hoge		**Date**
Address			
City		**State**	**Zip Code**

Program Description, Equations, Variables, etc.

For the section shown with $R = 1$

when $d \leq d1$ the section is a segment of a circle

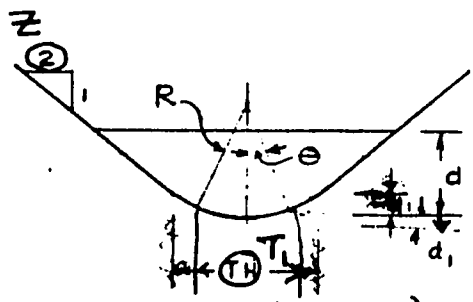
$\theta = \cos^{-1}(1-d)$

Perimeter $= 2\,\theta$

Top width $T = (1-d)\tan\theta)2$

Area = Segment - tringle

$= \theta - (\frac{T}{2} \cdot (1-d)$



For $d > d1$

$Per = per(\theta) + (d-d1).\ 2.\ CSC\theta = 2\,(Per\ \theta + (d-d_1)\csc\theta)$

Area = Area $(\theta) + T1.\ (d-d1) + z\ (d-d1)^2$

$r = A/P$

$K_m = A.\ r^{\frac{2}{3}}$

$K_s = K_m.\ 1.486$

Operating Limits and Warnings

Program will not operate for Z = 0, semicircle

For semicircle let z = 0.00001

DO NOT USE THIS SPACE