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Sub Surface Pipe Drainage Construction Methodology.

By

Javed Saleem Qamar

Chief Engineer(Water)WAPDA,Faisalabad.

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1. Introduction.

To sustain perpetual agriculture, drainage of agricultural land is a necessity. This is true for humid, sub-humid, arid and semi-arid regions where agriculture is practised. The drainage required may be both surface and sub-surface. An important objective of a drainage system in irrigated agriculture is to keep water table below root zone and maintain salinity in the root zone within acceptable limits for maximum production. Agriculture land in the Indus basin requires surface and sub-surface drainage. Surface drainage is achieved through open drains which outfall into the rivers. The problem of sub-surface drainage is being countered on a large scale since early sixties. Many areas have been provided with sub-surface drainage and there is still lot of agriculture land which requires drainage. Indus basin is an alluvial plain having good aquifer. In majority of the areas sub-surface drainage has been achieved through installation of tubewells. In useable ground water area the tubewell effluent is used for supplemental irrigation. In the saline ground water area the tubewell effluent is disposed in the drainage system or mixed with irrigation water. In certain areas either the aquifer is not available or ground water quality is too hazardous for disposal in the drainage system. In such areas sub-surface pipe drainage is technically more feasible. In Faisalabad Salinity Control and Reclamation Project (SCARP) sub-surface drainage is planned to be achieved through horizontal pipe drainage, commonly called tile drainage.

2. Project area

Faisalabad SCARP is located in Faisalabad, Jaranwala and Samundri Tehsils of Faisalabad District. The Project covers about 355,000 acres of which 295,000 are canal commanded. About 77 percent of the Project area has water-table within five feet from land surface. Due to high water-table about 33 percent of the area has developed salinity and sodicity. Ground water quality is marginal to hazardous.Although the area is underlain by reasonably good aquifer yet poor ground water quality makes it undesirable to pump saline effluent and polute river flows down-stream.

The problem of water logging and salinity is proposed to be controlled by installing sub-surface horizontal pipe drains apart from improving surface drainage and adopting on-farm water management practices. Sub-surface pipe drains are proposed to be installed in disastrous area, i.e. 130,000 acres. The sub-surface drains are of perforated corrugated PVC pipe of 4 to 15 inches

*Chief Engineer (Water) WAPDA, Faisalabad.

dia. The drains are placed at 6 to 11 feet below land surface with the help of trenching machines. Four inches thick gravel envelope is placed around the pipes to prevent fine soil particles entering the pipe and improve flow conditions in the close vicinity of the pipes. Sub-surface pipe drainage area is shown in Figure-1 and lay-out plan of a pipe drainage unit of which there are 79 Nos, on basis of design completed for 75,000 acres, is shown in Figure-2.

3. Project investigations.

For successful design of a drainage system it is imperative to have comprehensive surveys and investigations such that values of the basic parameters of a design model are adequately assessed. First requirement is to have good quality maps. Topographic survey was carried out in the Project area and survey was plotted on 1:6000 scale with one foot contour interval. One topo sheet covers 9000 x 6000 feet area i.e. about 1240 acres.

To determine the capability of top soil to drain surplus water under gravity to pipe drains hydraulic conductivity of the area requiring sub-surface drainage was investigaged. A 2000 feet grid with 27 nodal points in each topo-sheet was established to conduct the survey. About 2603 hydraulic conductivity tests covering 122,712 acres were performed. Hydraulic conductivity was determined through auger hole method. Due to sloughing conditions majority of the holes were cased. Soil texture was also determined at each auger hole. Project lithology is such that top soil (approximately 6 to 30 feet depth) is underlain by highly permeable lower zone over 300 feet thick. Impermeable layer or barrier closer to pipe location is non-existent. As flow model applicable is of two-layer condition, depth to sand layer information is important for correct design of drain spacing. Six holes, each 50 feet deep were made through hand percussion for each topo-sheet area. About 660 holes were bored to determine depth to sand.

4. Project design.

The primary function of a drainage equation is the computation of drain spacing. In alluvial plains the soils are layered and the hydraulic conductivity varies considerably in both horizontal and vertical directions. The drainage equation applicable to Project conditions is one which is based on two layered model and takes into account the anisotropic condition of the soil. Anisotropy is accounted for through transformation. However the drainage equations are looked upon as over simplified models of a very complex reality. The design of individual drain in a sump system is site specific. The system of design adopted is extended lateral which is typical for an arid, semi-arid irrigated area having relatively high hydraulic conductivity. The average design

parameters are given in the following:

Water table depth	4 (ft)
Saturated hudraulic conductivity	0.5to5.0(ft/day)
Drainage coefficient	.008 (ft/day)
Drain spacing	300 - 2000 feet
Gravel shrouding	4" All around drain pipe
Size of plastic perforated corrugated pipes.	4",6",8",10",12",and 15".
Slot size	1/8" x 1 3/4" Maximum
Open area	1 Sq.in per foot length.

5. Project preparation.

The area requiring sub-surface drainage is divided into units and sub-units. Area served by one sump to which a specified length of system of drain pipes discharge the effluent, is one sub-unit. The design in form of plan and profile is adjusted through office lay-out on a topo-sheet. This office lay-out is checked in the field. The plan and profile of drains are revised in the light of field staking. The process involves rechecking of soil texture and hydraulic conductivity on the proposed drain line, verification of drain spacing, fixing of location of sump and man-holes, fixing of size, length and elevations of drain pipes and noting of angles of individual drains taking off from a sump. On the basis of field staking final construction drawings are prepared. Plan and profile lay-out of a drainage sub-unit are shown in Figures - 2 and 3.

6. Drainage materials.

Major construction materials in sub-surface pipe drainage are pipe and filter. Pipe is manufactured from polyvenyle chloride (PVC) or polyethylene (PE) compounds. Corrugations are made to make the pipe flexible, light in weight but strong enough to with-hold stresses during laying operation. Perforations are provided to facilitate entry of water. Filter is required in silty soils to prevent entry of soil particles in the drain, thus choking it. Filter is either graded gravel or nylon sock wrapped around the pipe. Gravel filter is commonly used but utility of nylon sock in silty soils in arid zones is yet to be established. Gravel shrouding serves the purpose of filter and permeable surround in addition to providing stability to the pipe in un-stable silty soils in water-logged areas.

7. Construction equipment.

The major construction equipment for sub-surface drainage in the Project area is trenching machines. Plastic corrugated perforated pipe of sizes 4-6-8-10-12 & 15 inches is required to be placed at 6 to 11 feet below ground surface with concurrent placement of gravel shrouding of 4 inches uniform thickness all around the pipe. This is envisaged to be achieved through 4 Nos BSS-350 Steenbergen, 4 Nos D-30 Barth Hollanddrain and 2 Nos GSS-288 Steenbergen trenching machines. There is a large fleet of other support equipment to make tranching machines operative.

8. Drainage units.

Project design and preparation is complete for 75000 acres. The area is divided in 7 units SIA, SIB,SIC,SID,SIIA, SIIB and SIIC. There are 79 sump sub-units in the seven units. Each sump is an independent drainage unit. Within a sump service area which ranges between 600 - 1000 acres, the design and location of pipe drains is site specific. Lay-out plan of a sump sub-unit is given in Figure-2.

9. Components of a drainage unit and their construction.

(i) Pipe drains: The laying of pipe drains is either singular, composite or extended lateral system. The lay-out of sub-surface drain in the Project area is based on extended lateral system. An individual drain strarts at a shallow depth with small size pipe 4 or 6 inches dia-meter. The size of pipe is increased according to requirement of discharge to be carried. The progressive sizes used are 4,6,8,10,12 and 15 inches. Ultimately larger size pipe leads to the sump discharging the effluent. Some time 2 or 3 laterals join to a larger size collector at different locations. The drains are constructed with PVC corrugated perforated pipes. The pipe is placed at pre-determined grade with the help of trenching machine. Normally 4 inch thick gravel pack is placed around the pipes. The process of excavation, placing of pipe at proper grade and placing of gravel around the pipe is simultaneously carried out by the trenching machine. Trenching is started from the sump with the larger size dia-meter pipe. As trenching progresses drainage starts taking place and the effluent is pumped from the sump through temporary arrangements.

(ii) Man-holes: Man-holes are located at junction of laterals or change of pipe size. If length of pipe is too long then a man-whole is placed.The basic purpose of man-hole is inspection and facility for cleaning operation of the pipe drain. The man-hole is constructed with pre-cast concrete slabs and

pipes which are fixed to each-other and sealed with mortar. The top of the man-hole is covered with lid. Access is provided through ring ladder. Discharge of individual lateral can also be measured at the man-hole. Design of a man-hole is shown in Figure-4.

(iii)Sump: Sump is a masonry well which is sunk through conventional system. Sump is plugged at the bottom with RCC slab placed under dry condition which is achieved through de-watering. Pump house is built on the top of the sump. Automatic electric pumps are installed in the sump. These pumps operate at specific interval to keep the drainage effluent being collected in the sump below invert level of the lowest drain pipe. The size of sump is 10 feet inside dia-meter with 13 1/2 inch brick wall and is about 22 feet below NSL. Design of a sump is shown in Figure-5.

(iv) Discharge box: Discharge box is a masonry structure constructed close to sump well. The discharge pipes of the pumps empty the effluent in the discharge box.

(v) Disposal channel, open & buried: Discharge channels are of rectangular masonry or concrete pipe drains which carry the sump effluent from the discharge box to open earthen drain under gravity. The length of the open disposal channel vary according to location of surface drain. In most of the cases the disposal channels are constructed on the surface. In certain cases disposal is more feasible through buried pipe. Design of disposal channel is shown in Figure-6.

(vi) Drain inlet structure: To facilitate entry of effluent brought through disposal channel under gravity into the earthen surface drains, inlet structure is constructed. Its main purpose is safety of disposal channel and protection of the earth surface drain from erosion due to head differential. Design of drain inlet structure for open channel and buried pipe is shown in Figures 7 and 8.

(vii) Baffle wall: Baffle wall is a circular masonry cylinder 4 1/2 inch thick masonry plastered on both sides constructed in-side the sump well providing an annular clearance of 12 inches between the sump and baffle wall. Baffle wall is constructed from the floor of the sump and has openings at bottom at regular interval. The height of the baffle wall extends above the top incomming drain pipe. The primary function of the circular baffle wall is to guide the flow from the incoming pipe away from the bell-mouth of the pumps and avoiding splashing. The flow from the pipe plays on the baffle wall and is deflected down-ward. The effluent is fed to the pump impeller without turbulence and vortices. The requirement of baffle wall was determined through model experiment of the pumps to maintain operational efficiency. Design and location of baffle wall is shown in Figure-5.

10. Trenching and problems encountered.

Tranching for laying pipe is always initiated from the sump. Invert level of the pipe discharging in the sump is determined during design and survey. Open pit is excavated at the sump and the trencher is brought on the line and trench box lowered in the pit. The pipe is pushed

through the pipe tunnel of the trench box and placed in the opening in the sump wall. The joint is properly covered with hessian cloth and gravel. The pipe is laid for few feet at proper slope and it is covered with gravel. The trenching machine starts cutting the trench and placing the pipe alongwith gravel at the required slope. Intensive checking is made through laser control and levelling instrument with stakes to ensure that pipe is laid at proper grade. The machine moves slowly and the top of pipe and gravel are continuously checked, till it is ensured that the pipe is being laid at proper grade. The specification allows not more than 5-10 percentage stretch on the pipe during laying process. A continuous check is made for the actual length of pipe being fed through the pipe tunnel and the distance covered by the machine to observe the pipe stretch.

Laying of pipe at pre-determined grade with required thickness of gravel presents no difficulty at shallow depths. However, some problems have been experienced during the construction of drains deeper than 3 meters, i.e. (i) the flow of gravel under the pipe through gravel tunnel trench box becomes irregular at deeper depth and ultimately stops(ii) there is excessive stretch in the pipe and (iii) proper grade is not maintained and pipe becomes snaky.

The reasons for the above mentioned difficulties can be attributed to (i) variable soil texture(ii) high water-table causing excessive hydro-static pressure and (iii) gradation of gravel. The variable soil and water-table conditions apparently cause up-heaval of the bottom soil due to differential hydro-static pressure. This up-heaval tends to block the gravel chute. The pipe is pushed up-ward thus disturbing the grade. Non-uniform flow of gravel also contributes to extra stretch on the pipe.

These difficulties are countered through suitable modification of trench boot and gravel chute openings. Some time gravel has to be forced through auger. An experienced operator counters these difficulties through proper control on trencher speed during construction. De-watering of pipe trench at deeper depth or at location where such difficulty is experienced is also a feasible solution. In addition to that some time use of double laser is adopted to maintain level of trench bottom and pipe tube.

11. Laser plane control system.

The laser control system consists of laser transmitter and receiver. The command post consists of tripod, elevating base and laser transmitter. The command post is set up at convenient location in the field. The transmitter generates a thin red laser beam which is rotated 5 time per second in horizontal plane. At this speed of rotation the laser forms a perfectly flat plane of light extended out over the work area. It is this plane of light that is used as the reference from which the digging mechanism of the trenching machine is controlled. The plane of light can be tilted

to any desired grade from dead level (0%) up-to 10%. The transmitter is completely self levelling and constantly maintains the desired grade or grades regardless of ground vibration or wind. The receiver is mounted on a telescopic mast fitting to the trenching machine. The receiver has vertical sets of photo cells which pick up the laser light from the command post and determines whether the machine is digging at, or above, or below the predetermined depth from the light plane. The receiver picks up the signal from the command post from any direction throughout 360 degrees. The receiver is hydraulic mast which is driven by a hydraulic motor. The mast provides electric signal to the control box electronic counter which dis-plays the mast height. The control box is mounted in the operator cabin. With the help of laser transmitter and receiving system a trench can be excavated at pre-determined grade.

12. Use of double laser.

A single laser system on a trenching machine is normally effective in placing a pipe at proper grade when the trench is limited to 2.5 meter depth, trench width is smaller and the soil is stable with low water table condition. Single laser is also very effective on machines which are of light structure and lay pipe without gravel.

The depth of cut by digging chain as well as depth of laying are controlled and maintained by single laser. Large trenching machines are built to instal large size pipe of 15 to 18 inch internal dia-meter at deeper depth. Such machines function better with double laser control due to large weight of the machine structure. In case of heavier machines it has been observed that double laser system independently controls the level of trench and the level of pipe. However the operation of double laser is very critical and needs to be controlled manually by a skilled operator other-wise automatic system is required for operation.

13. Consolidation of pipe trench.

The purpose of consolidation of back fill in pipe trench to ensure that the longitudinal cracks, fissures resulting from the trenching process do not provide functional path to irrigation water and possible migration of soil particles into pipe through gravel. The other purpose is to provide firm ground for farm machinery after construction of drains.

The material excavated is usually wet and cannot be dozed immediately. However, it dries quickly and is dozed back after 24 hours. Back filling and consolidation is done in such a manner that there is no vertical or horizontal disturbance of either the pipe line or gravel envelope. The density of the consolidated back fill material is envisaged to equal to the dry density of the

original un-disturbed soil adjacent to the tubing. A proper watch is maintained along the tubing after trenching and any cavity formed in the back-fill after first few irrigations is re-filled and properly consolidated.

14. Automatic pumping of sumps.

The effluent coming to a sump under gravity is lifted through automatic pumps and discharged into open surface drain. The pumps procured on the Project are vertical type single stage centrifugal driven by electric motors. One, two or three pumps are installed according to the effluent coming to a sump. The capacity of each pump is 2.25 Cfs. This is to minimize variation of design and layout arrangements. It also allows for easy change over of pump duties. The pump settings are 16.5, 18.5 and 20.5 ft. The pump setting is such that there is at least 1 ft. clearance between the pump bell-mouth and the sump floor. This is to accommodate the deposition of fines i.e., silt and sand if being discharged in the sump.

The control gear in addition to electrical safety devices consists of main isolator, 7 days flush time relay for weekly change over of pump duty. There is voltage restoration time relay to facilitate delay to start operation of first pump on restoration of electric supply and has time delay of 5 second. The pumps delay time relay to stagger other pump starting to avoid over-loading of transformer is 30 seconds. The combination of 3 pumps requires 3 float level switches(automatic mercury float) i.e. high level switch, single level switch and the low level switch. High level float switch is installed at the deepest drainage line coming in the sump to ensure free flow. The low level float is installed at 1.5 ft above the bell-mouth of the impeller to avoid damage to pump due to cavitation. The single level switch is installed in between the low level and the high level switches. These float switches and controls follow a tank emtying scheme. The operation of mercury float level switch is such that it closes up-ward with the rise of water in the sump and opens down-ward when the water recedes in the sump. The on/off/auto switch of control panel is put on auto position for automatic operation of the pumps.

15. PVC drain tubing production.

Polyvenyle chloride (PVC) is used to manufacture drain tubing. Polyethylene(PE) is also commonly used for the same purpose. The actual production of PVC tubing requires blending of a number of other ingredients with the resin. The manufacturing process includes blender, extruder, corrugator, perforator and coiler. PVC resin is mixed with other additives in a blender. The blended compound is fed into the barrel of the extruder. The blended compound is plasticized

inside the barrel and extruded through the die by means of two screw conveyors. The die pushes out plain PVC tubing through the corrugator through hot air. The mould blocks of the corrugator are cooled through chilled water and cold air. Corrugated tubing then passes under the perforator which cuts the slots. Tubing up to 8" dia is coiled and larger size tubing is produced in straight lengths. It is continually inspected and tested by the manufacturer as well as the Engineer. ASTM standards are used to maintain quality control at all stages of production. The laboratory tests prescribed are for measurement of dimensions and perforations: stiffness; elongation, joint separation, impact and bending and straightening. The manufactured tubing is prone to ultra violet light. It should have the capability of with-standing effect of ultra violet light for reasonable time for handling and storage in field conditions before placement underground.

16. Gravel envelope.

Silty soil without a protective filter around a pipe drain is likely to lead to its failure. The ultimate selection of the envelope material depends on the stability, texture and the permeability of the base material in the vicinity of the drain. Two main functions of the envelope are (i) to act as a filter to prevent soil particles from entering the drain and (ii) to improve permeability around the pipe drain and facilitate the flow of water towards and into it. The criteria generally followed for the design of gravel filter are the one advocated by U.K. Road Research Laboratory (RRL), U.S.A. Soil Conservation Service (SCS) and U.S.Bureau of Reclamation (USBR). The best design is usually evolved after due monitoring of the field result. Gravel envelope material is presently being hauled from the crushers at querries established in vicinity of Sargodha hills. The gradation and behaviour of crushed material is being monitored. Best material is one which meets gradation requirements as envelope and lends itself easy placement through gravel chute of the trencher hopper.

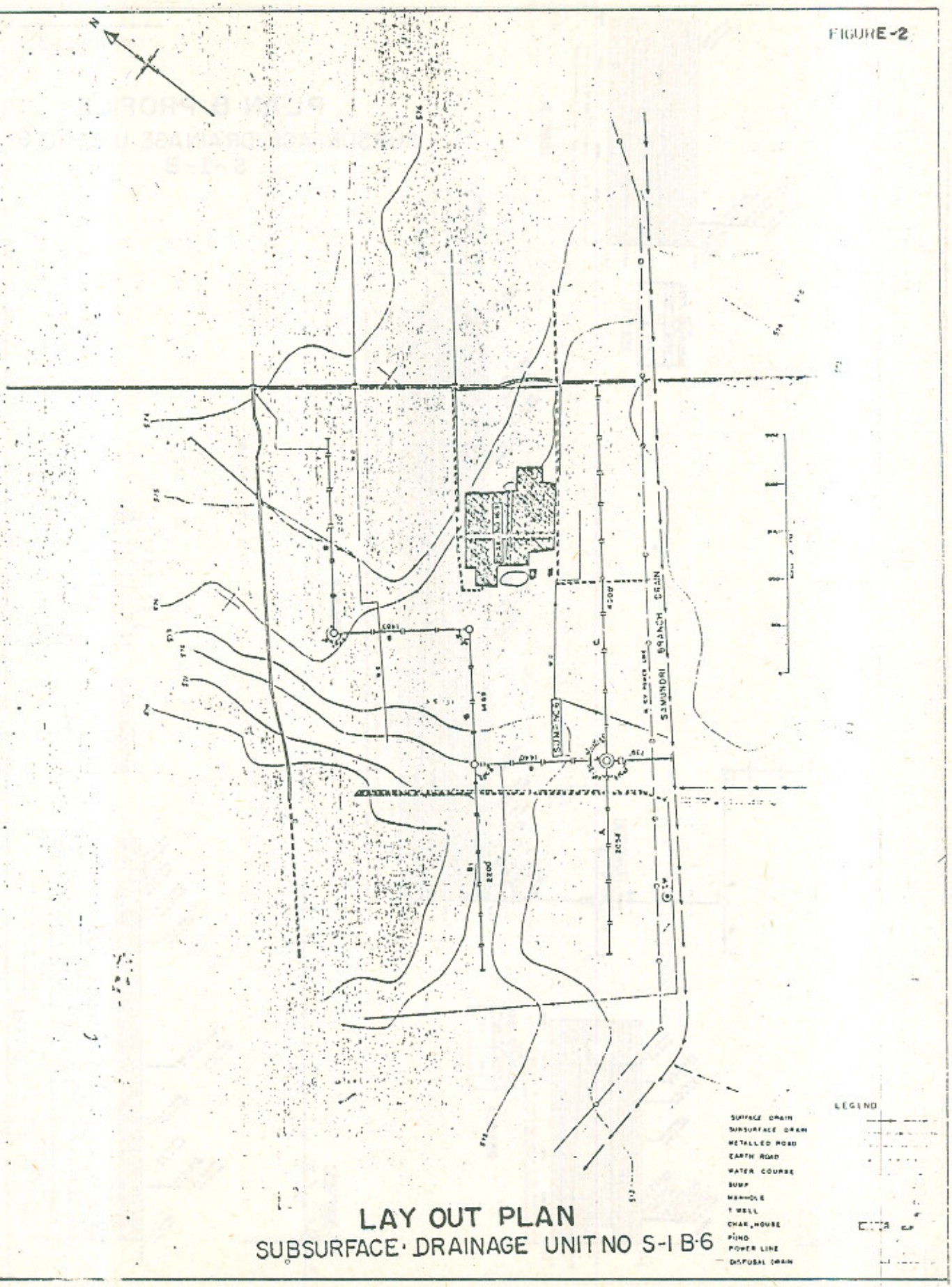
FIGURE - I





PROJECT AREA
FOURTH DRAINAGE PROJECT FAISALABAD

FIGURE-2



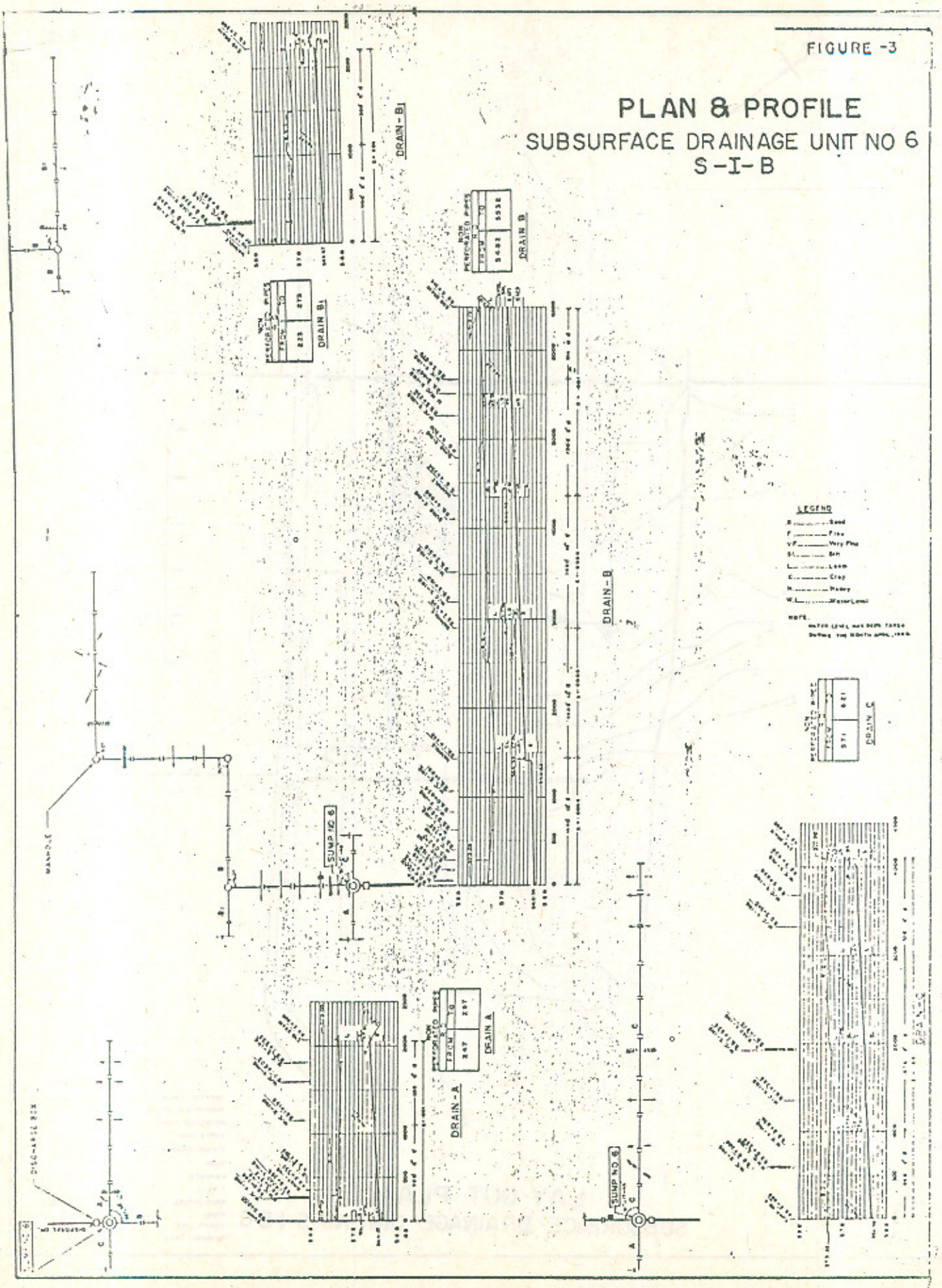
LAY OUT PLAN

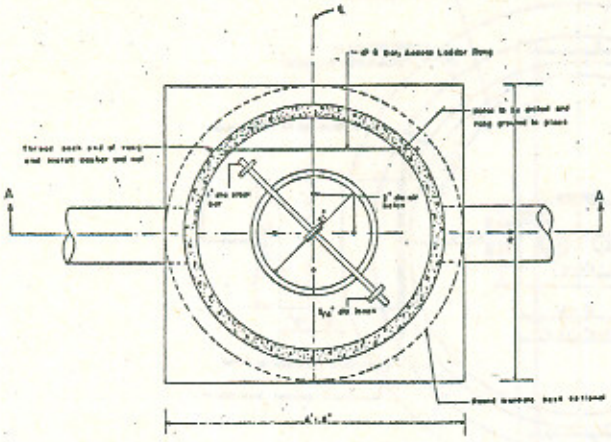
SUBSURFACE DRAINAGE UNIT NO S-I B-6

FIGURE -3

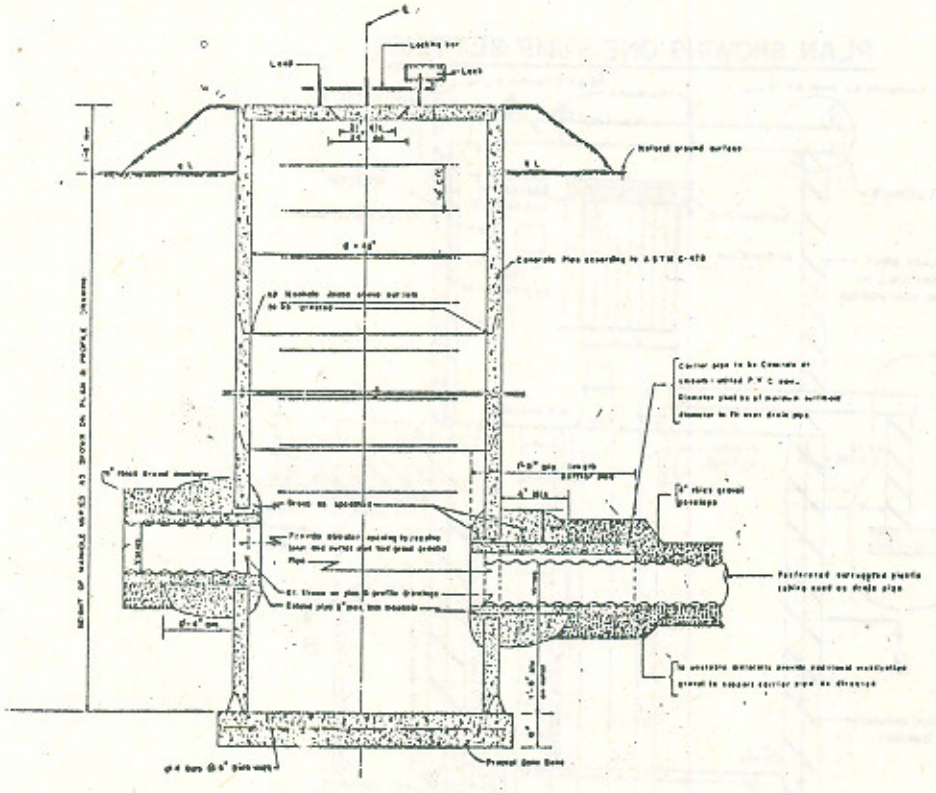
PLAN & PROFILE

SUBSURFACE DRAINAGE UNIT NO 6
S-I-B





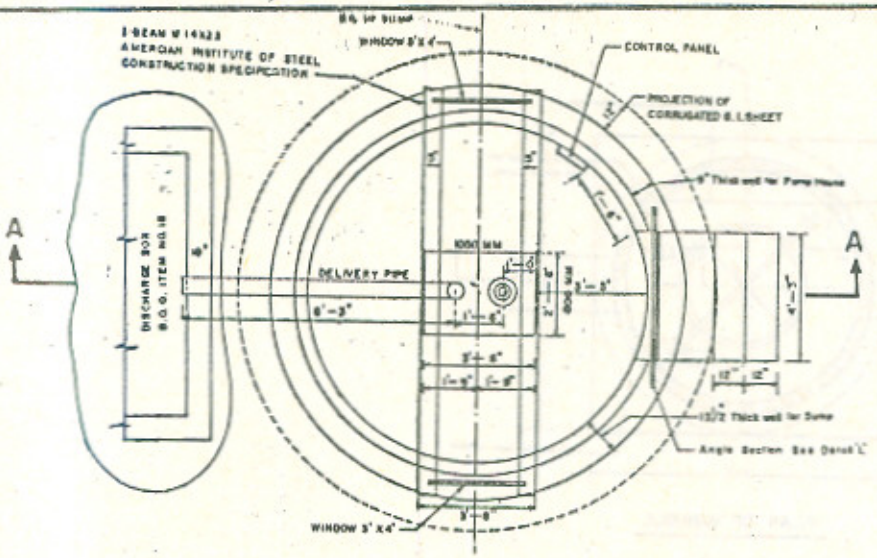
PLAN OF MANHOLE



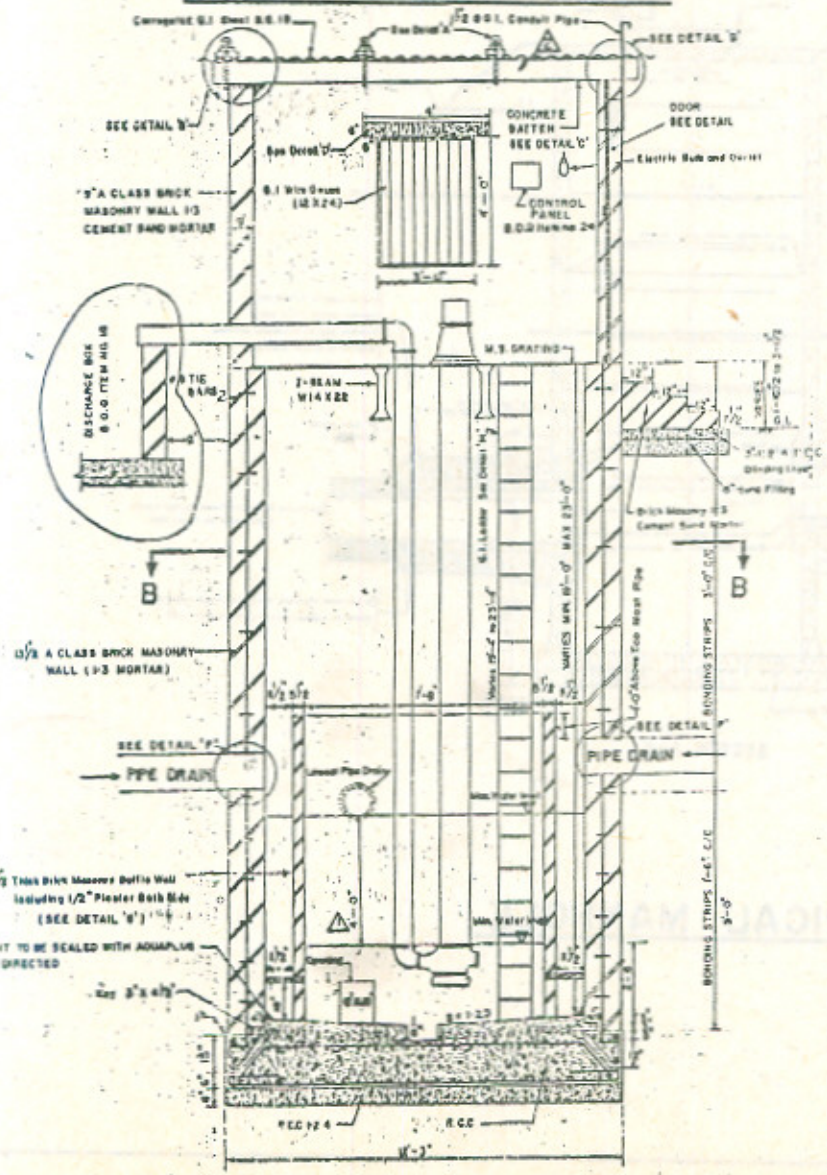
SECTION A–A

TYPICAL MANHOLE

FIGURE- 5



PLAN SHOWING ONE PUMP SETTING

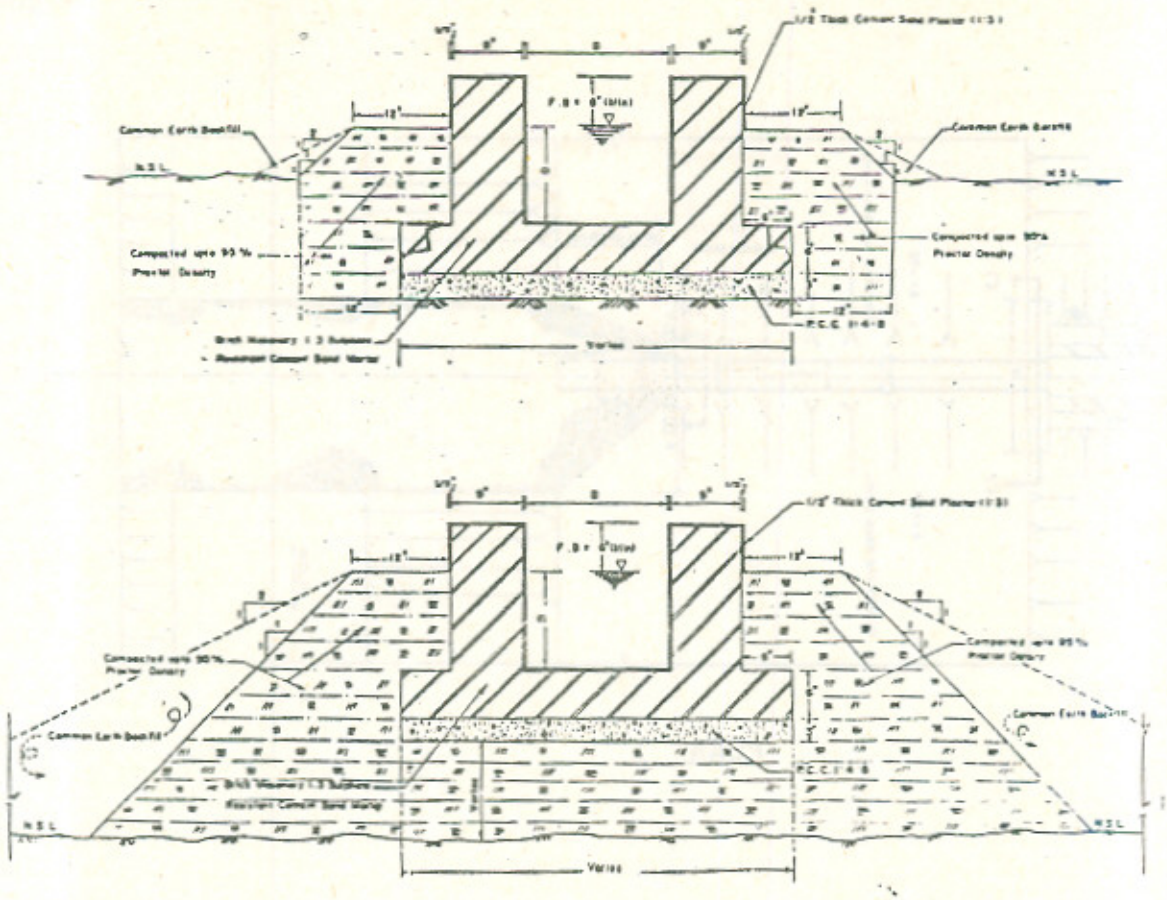


SECTION A-A

TYPICAL SUMP/PUMPING STATION

BRICK MASONRY

FIGURE - 6



TYPICAL BRICK LINED DISPOSAL CHANNEL

TYPICAL BURIED PIPE FOR DISPOSAL

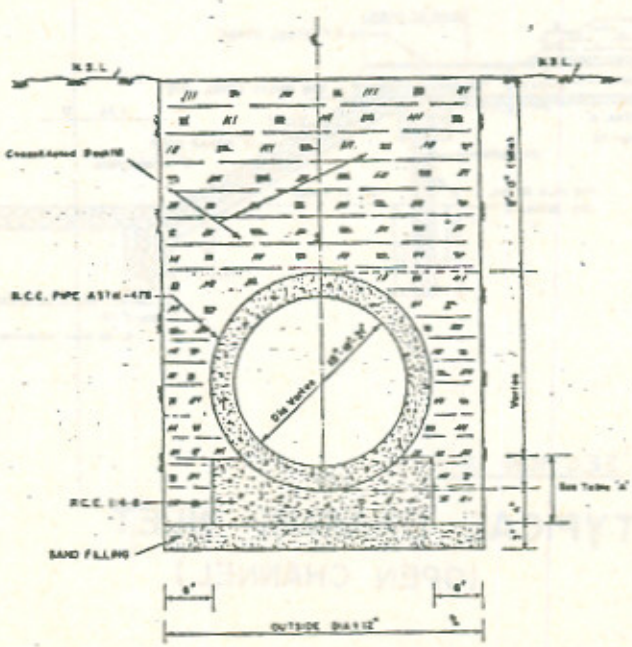
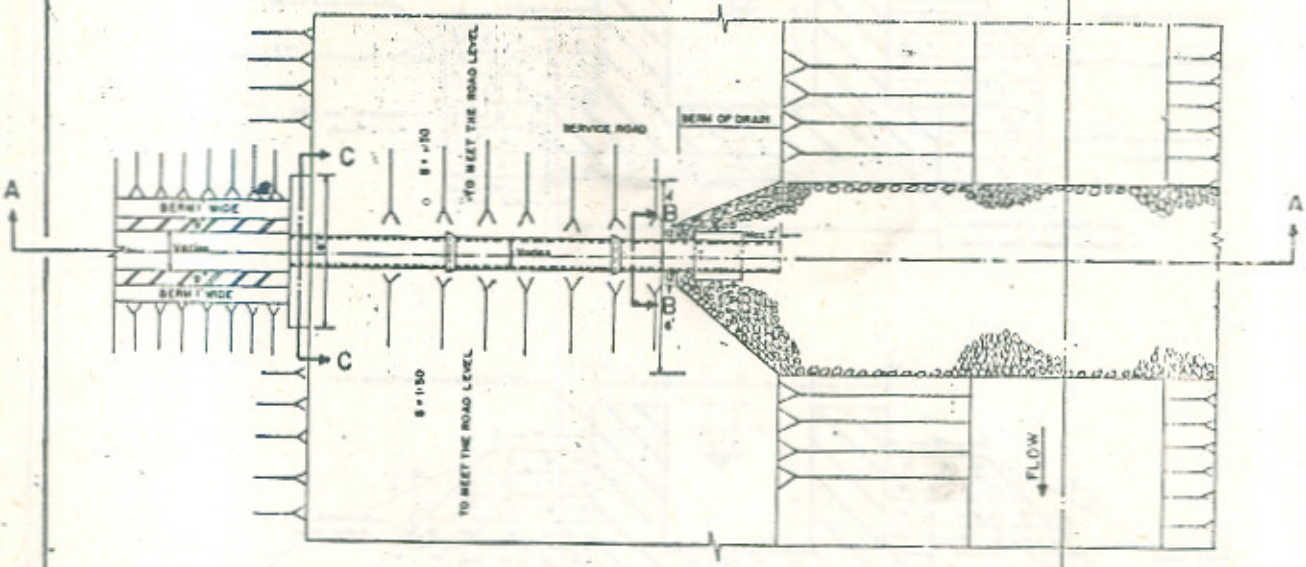
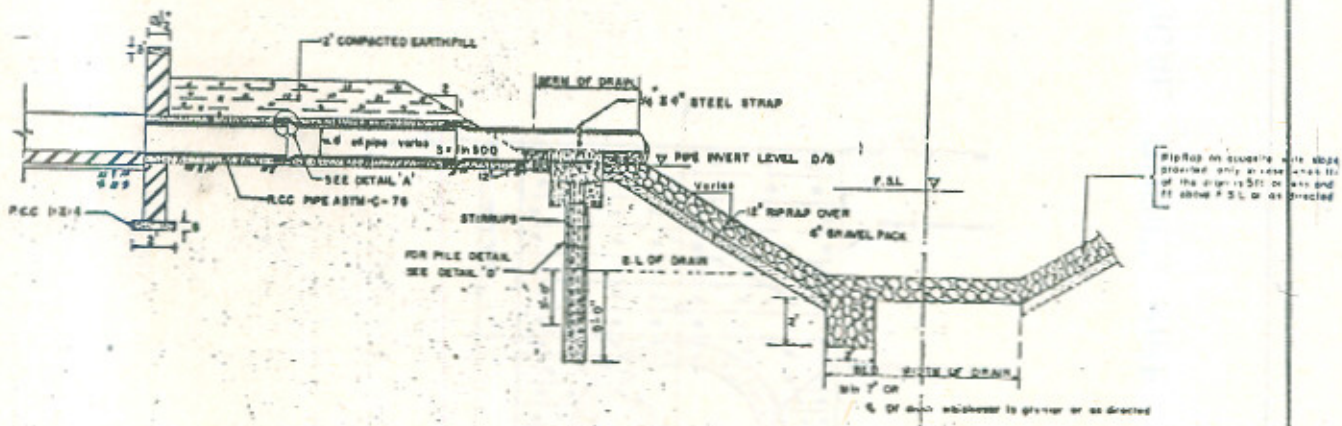


FIGURE-8



PLAN

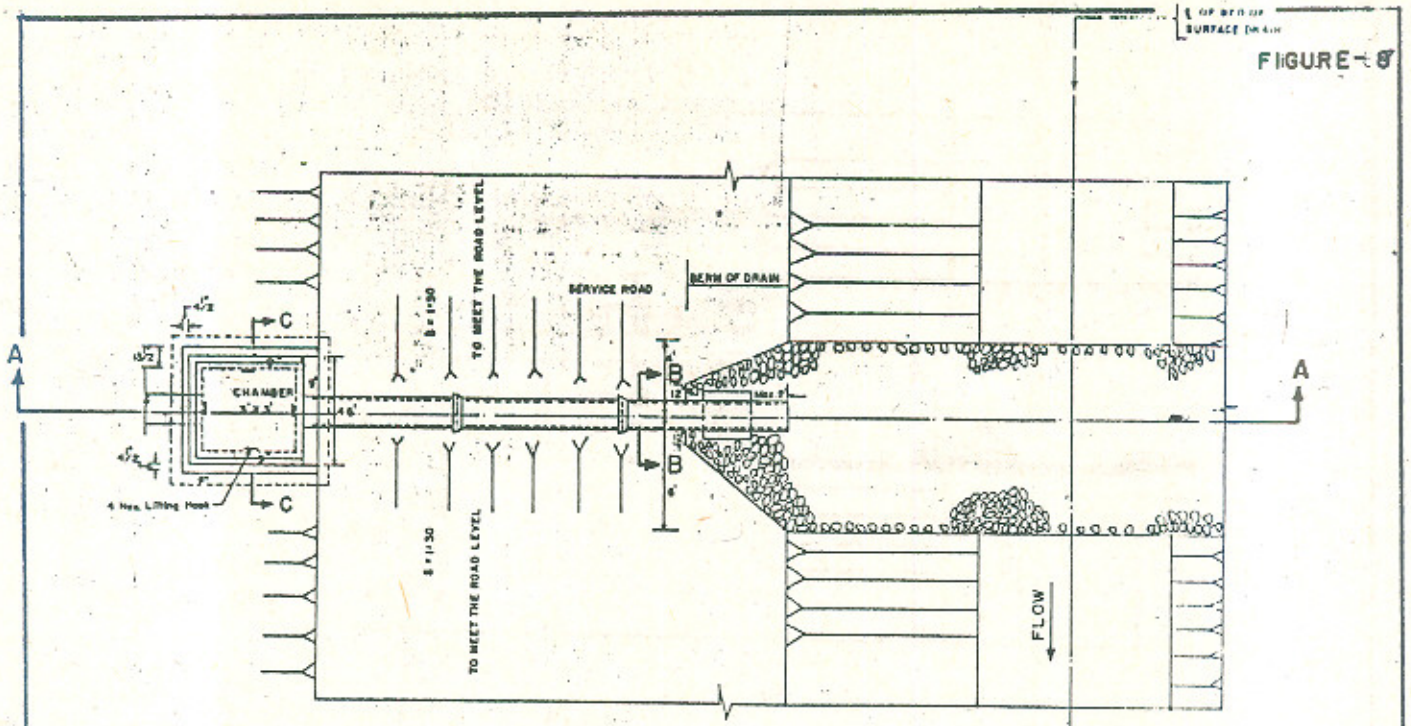


SECTION A-A

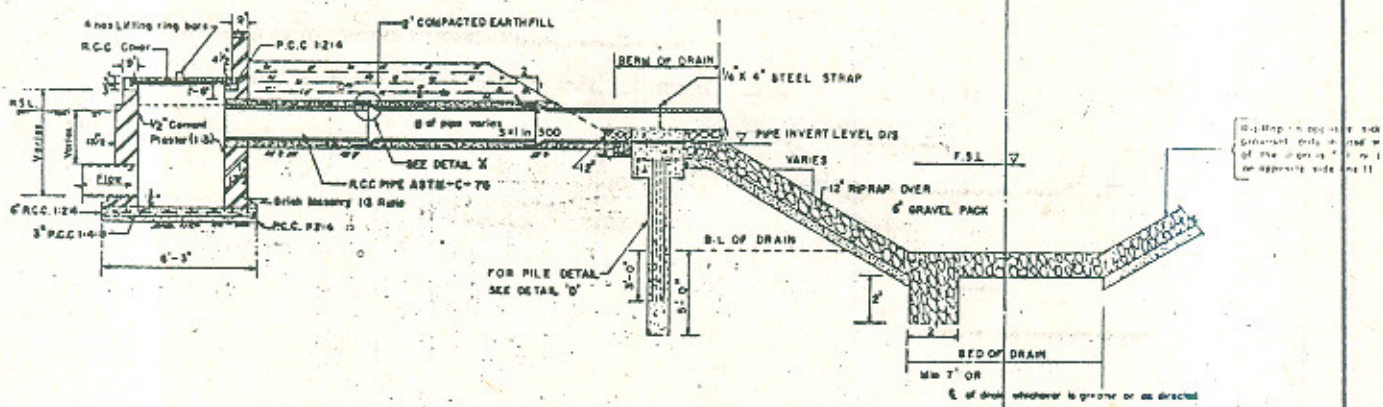
TYPICAL DRAINGE INLET

(OPEN CHANNEL)

FIGURE - 8



PLAN



SECTION - A-A

TYPICAL DRAINAGE INLET

(BURIED PIPE)

