TECHNOLOGY MISSION ON
DRINKING WATER IN VILLAGES AND
RELATED WATER MANAGEMENT

TECHNOLOGY PACKAGE ON
SLOW SAND FILTRATION

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE,
NEHRU MARG, NAGPUR- 440 020

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CONTENTS

SLOW SAND FILTER PLANTS

A Few Installations Based on NEERI Design

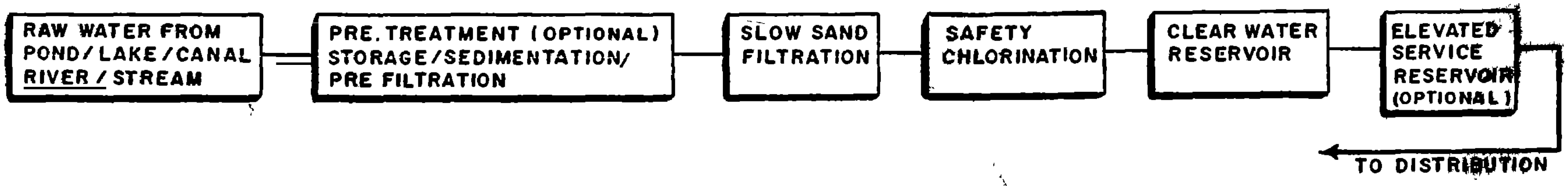


FIG. TREATMENT FLOWSHEET WITH SLOWSAND FILTRATION

SLOW SAND FILTRATION :

Drinking water should be bacteriologically safe, aesthetically acceptable and free from excessive concentration of mineral salts of health significance. Natural waters do not often satisfy all these requirements and therefore need treatment. Slow sand filtration is a simple process for purifying polluted surface waters such as from village ponds, lakes, canals, streams and rivers.

WHY SLOW SAND FILTRATION :

Because it has several desirable features. These are :

Simplicity of design, construction, operation and maintenance; often local materials and skills could be readily employed with the advantage of cost reduction.

Efficiency - near total removal of pathogens and viruses, highly efficient in removal of turbidity and organic matter, little wastage of water and low production of waste sludge.

Reliability Minimum of mechanical and electrical equipments that can go wrong or need replacements and repairs.

Economy Less energy intensive, no need for expensive chemicals which are difficult to procure, dose and control.

Acceptability Filtered water less corrosive and more uniform in quality than that of a chemically treated water.

WHEN TO ADOPT SLOW SAND FILTRATION :

Purification by slow sand filtration can be adopted when:

* The raw water turbidity is generally less than 30 NTU and exceeds this limit only occasionally for short periods. If the suspended

solids, especially turbidity or raw water is high, the SSF has to be preceeded by a simple pre-treatment unit such as plain sedimentation tank/roughing filter/infiltration gallery etc. to reduce the turbidity to a level acceptable by SSF.

* Land, labour and filter sand are readily available and at low cost.

* Chemicals and equipments are difficult to procure.

* Skilled personnel for operation and maintenance are not locally available.

BASIC ELEMENTS OF A SLOW SAND FILTER :

o **An open box** about 3.0 m deep, rectangular or circular in shape and made of concrete, masonry or ferro-cement.

o **Supernatant water layer**, usually 1.0 m. deep. Provides the driving force for water to flow through the filter and to overcome frictional resistance.

Allows improvement in water quality due to sedimentation, natural flocculation, removal of biodegradable organic material and die-off of bacteria.

o **Bed of filter sand** usually 80-100 cm initial depth. Provides a framework for biological organisms to develop, multiply and to bring about purification; also serves as a strainer for large suspended particles.

o **Supporting gravel layers and underdrainage system** Supports the filter medium, prevents it from entering and blocking the underdrains and provides a free passage for filtered water.

o **Set of appurtenances** for filter operation and control.

A - RAW WATER INLET VALVE

B - SUPERNATANT DRAINOUT VALVE

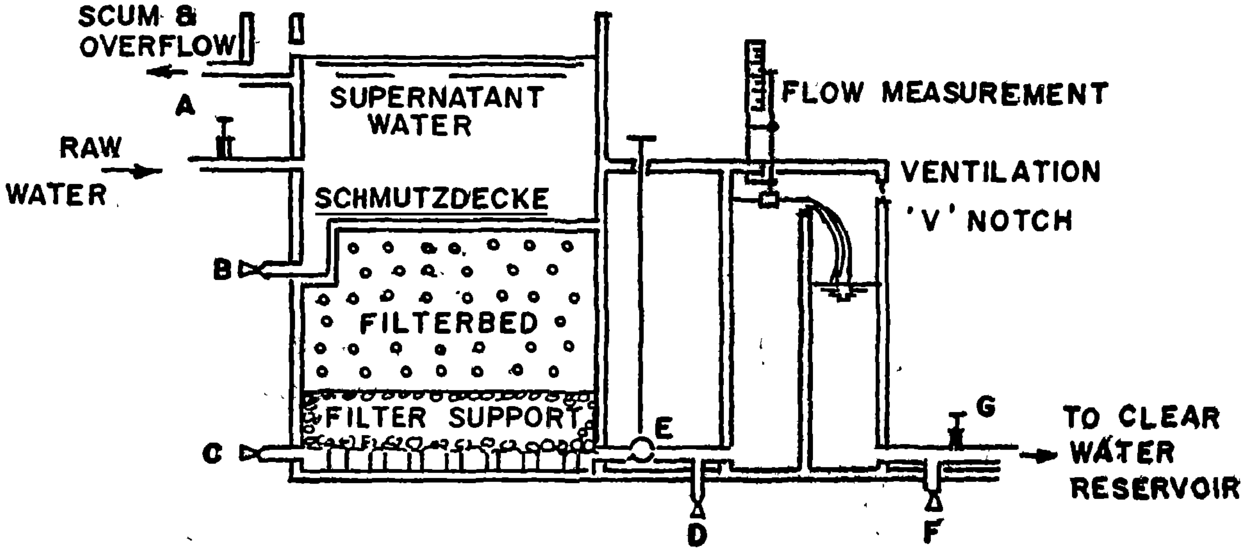
C - RECHARGE VALVE

D - FILTER SCOUR VALVE

E - FILTERED WATER OUTLET VALVE

F - FILTER TO WASTE VALVE

G - FILTERED WATER VALVE



BASIC ELEMENTS OF A SLOW SAND FILTER (SCHEMATIC)

MECHANISM OF PURIFICATION IN SLOW SAND FILTER :

Slow sand filtration is a combination of physical, chemical and biological processes. The phenomena which occur in and above the filter bed are quite complex. These are briefly described below :

Straining : Retention of particles which are too large to pass through the pores of the filter sand grains.

Sedimentaiton : The surface area of sand grains per unit volume is so large, that a slow sand filter acts as an extremely effective sedimentation unit.

Adsorption : Due to a combination of diffusion, mass and electrostatic attraction and other mechanism even colloidal impurities adhere to the surface of the sand grains.

Chemical and biological activities : These play a major role in the purification processes which occur on and within the filter bed.

The presence of sufficient oxygen in water to be treated is essential. Biological oxidation of organic matter in an aerobic environment contributes to high performance of slow sand filters.

Algae play an important role. In the presence of sunlight they are able to buildup cell material from simple minerals such as water, carbon dioxide, nitrates and phosphates and in the process produce oxygen which in turn facilitates biodegration of organic matter.

Although most of the bio-chemical purification occurs in the so called "Schmutzdecke" (the top 10-20 mm of the filter bed) biological activities in the lower part of the filter bed (40-50 cm.) may be considerable.

EXPECTED PERFORMANCE OF A SLOW SAND FILTER :

QUALITY PARAMETER	DEGREE OF PURIFICATION
Natural colour	30-100% removal
Turbidity	To less than 1 NTU
E. coli	95-100% reduction
Cercariae	Virtually complete removal of schistosoma cysts and ova
Viruses	Virtually complete removal
Organic matter (COD)	60-75% reduction
Fe & Mn	Largely removed
Heavy metals	30-90% reduction

DESIGN CONSIDERATIONS :

Decisions that have to be taken right at the design stage are as under :

Design period : Should be small (about 10 years) as there is no economic advantage in building large plants. This will help optimise investment.

Filtration Rate :

Normal operation : 0.1 m/hr.
Maximum overload : 0.2 m/hr.

No. of Filter Units :

Minimum : 2 units

Number can be increased to gain flexibility in operation and to reduce overloading when one or more units are under cleaning.

Optimum number $N = 0.5\sqrt[3]{A}$

A in sq.m.

No need for standby.

Depth of Filter box :

2.5 to 3 m depending upon the type of underdrain.

Filter sand and gravel :

Effective Size	:	0.25 - 0.35 mm.
Uniformity Coefficient	:	Less than 5
	:	Preferably less than 3

Hard broken gravel equally efficient as rounded gravel.

Mode of operation : As far as practical, filters should be designed to run continuously. In rural areas where continuous pumping may not be feasible, 24 hr. operation of filters can be ensured by providing a raw water storage reservoir of adequate capacity to feed by gravity to the filters during non-pumping hours.

SUMMARY DESIGN CRITERIA :

Description		Recommended Design Value
Design period	...	10 years
Filtration rate		
Normal Operation	...	0.1 m/hr.
Maximum overload rate	...	0.2 m/hr.
No. of filter beds		
Minimum	...	2
$N = 0.5\sqrt[3]{A}$ (A in m^2)		
Depth of supernatant water	...	1.0 m.
Free board	...	0.2 m.
Depth of filter sand		
Initial	...	1.0 m.
Final (Minm)	...	0.4 m.

Size of sand		
Effective Size (E.S.)	...	0.2 - 0.3 mm
Uniformity Coefficient (U.C)	...	<5
Gravel depth	...	0.3 m
Top layer 0.7 mm - 1.4 mm	...	6 cm
2nd layer 2 mm - 4 mm	...	6 cm
3rd layer 6 mm - 12 mm	...	6 cm
Bottom layer 18 mm - 36 mm	...	12 cm
Total	...	30 cm
Underdrains (made of bricks or perforated pipes)	...	0.2 m
Depth of filter box	...	2.7 m
Effluent weir level above sand	...	20-30 mm

DESIGN EXAMPLE :

Design Period	...	10 years
Present Population	...	1000 persons
Design Population (assuming 2.5 % increase/year)	...	1250 persons
Design per-captia water supply	...	40 lpd
Total Water demand	...	50 m^3/day
Design Water demand (assuming 15 % water losses)	...	57.5 m^3/day
Design hourly demand	...	2.4 m^3/hr
Design rate of filtration	...	0.1 m/hr
Total filter area required	...	24 m^2
No. of units	...	2 nos.

$N = 0.5 \sqrt[3]{A}$ (Rectangular

$= 1.44$ Say 2 with common wall)

Size of each unit	...	4 m x 3 m

The layout of filter along with details of piping/appurtenances/valves etc. are shown in the drawings. (Annexure)

PLANT LAYOUT :

Local topography, placement of pump house and other facilities and possible future expansion influence the plant layout.

Wherever topography permits, gravity flow of raw water to the plant should be preferred, even if laying of additional pipe line is required. This will cut down recurring energy costs and facilitate easy operation and maintenance of the plant.

The layout of the treatment plant should be compact enough to facilitate effective day-to-day operation and maintenance of the plant.

Filters may be circular or rectangular in shape. Circular filters are not economical except for small installations. Rectangular filters facilitate common wall construction, easy operation and maintenance.

CONSTRUCTION ASPECTS :

The construction of slow sand filters should be based on sound engineering principles. The structural design, the construction methods and materials are governed by local conditions.

Aspects that need careful consideration are : (1) the type of soil and its bearing capacity; (ii) the ground water table and its fluctuation and (iii) the availability and cost of construction materials and labour.

Filters may be constructed of reinforced concrete, masonry, brickwork or ferrocement, or an excavated structure with protected sloping walls. Filters with protected sloping walls are usually rectangular in shape.

Water-tight construction of the filter box should be guaranteed, especially when the ground water table is high.

The top of the filter should be at least 0.5 m above the ground level in order to keep away dust, children and animals.

The danger of short-circuiting of raw water along the walls may be prevented by roughening the inner surface of side walls from bottom upto the sand bed level.

The inlet structure should be so designed and constructed as to cause minimum disturbance to the sand bed by incoming raw water.

The outlet structure usually incorporates a means for measuring the filter flow and for backfilling with clean water after the filter has been scraped. The crest of the outlet weir should be located at or slightly above the top of the sand bed to avoid occurrence of negative head in the filter bed.

A supernatant drain-out chamber with its top just above the sand level should be provided to facilitate drainout of supernatant in short time.

An overflow pipe/weir should be provided to facilitate drainage of surplus water entering the filter and floating scum.

ECONOMIC AND COST ASPECTS :

The cost of a filter excluding pipes and values is made up of two components; the total cost for floor, underdrains, sand and gravel; and the cost of walls of the filter box.

This cost in general is :

$$C = K_A A + K_P P$$

where A is the total filter bed area in m^2, P the total wall length in m, K_A the cost per unit area of filter bed and K_P the cost per unit length of wall.

For rectangular filters arranged in a row with common walls the condition for minimum filter cost is :

$$l = \left(\frac{2A}{n+1}\right)^{1/2}$$

$$\text{and } b = \frac{(n+1)\,l}{2n}$$

where n is the breadth and l is the filter length.

CAPITAL COST

The general expression for the minimum cost is :

$$C = K_A A + 2\,K_P\left(\sqrt{2A\,(n+1)}\right)$$

A general cost model (Nagpur 1986 prices) for filter bed works out to :

$$C = 2000\,A^{0.869} \quad (A \text{ in } m^2)$$

Detailed cost analysis indicates that SSF are cost effective for plant capacities upto 8 mld in comparison to conventional rapid gravity filters.

TREATMENT COST :

The cost of treatment by SSF ranges from 0.5 to 1 Re/m^3.

STARTING UP A NEW FILTER :

While commisioning, a newly constructed filter is charged with water from bottom through the outlet chamber till the water level rises 10-15 cm above the sand be. This ensures expulsion of entrapped air in the filter bed and the underdrain. The filter is then filled with raw water from top to the normal working level (MWL) by opening the inlet valve. Initially, the rate of filling should be low to prevent scouring of sand around the inlet. The filter is put into operation by opening the outlet valve and gradually increasing the rate to the design value over a period of 4 to 6 hours. The filter is run continously to allow the active biological film to be formed and get established on the sand bed. This initial ripening or maturation of the filter may take 3-5 weeks. Till then, the filtrate is run to waste or put into supply only after adequate chlorination. The ending of the ripening period is determined by the bacteriological quality of filtered water which should meet the prescribed specification.

ROUTINE OPERATION :

For best results a mature filter should run continuously at the design filtration rate. The rate control is achieved either at the inlet or at the outlet of the filter.

In an inlet-controlled filter, the filtration rate is set at the inlet weir chamber by regulating the inlet valve. Frequent manipulation of the valve is rarely required. At first the water level over the filter will be low but gradually it will rise to compensate for the increasing resistance of the filter bed. Once the level has reached the overflow outlet, the filter has to be taken out for cleaning.

Inlet rate control minimises the routine work of the operator. The rate of filtration will be nearly constant with this method and the build-up of resistance in the filter is directly visible. On the other hand, the influent water is not retained for long at the beginning of the filter run, which may reduce the efficiency of treatment.

In an outlet-controlled filter, which is more common, the rate of filtration is set with the outlet valve. Daily or every two days this valve has to be opened a bit to compensate for the increase in resistance in the filter. The disadvantage of this method is that the outlet valve has to be manipulated on a regular basis. The operator has to visit the plant atleast every day, otherwise, the output will fall. The water is retained for five to ten times as long as in the inlet-controlled filter at the beginning of the filter-run, which may make purification more efficient. Removal of scum will also be much simpler than with inlet-controlled filtration. In many situations electricity and diesel fuel are not available all the time, so existing SSF plants sometimes function only for part of the day. In such cases either a raw water storage reservoir which can feed water to the filters under gravity supply should be built, or 'declining rate filtration' should be used to ensure satisfactory filtrate quality. That is, when the raw water pumping is stopped all valves remain in the same position and filtration continues at a declining rate as the water level in the filter falls. When the raw water supply is restored, the water standing over the sand bed will rise to its earlier level. Where declining rate filtration is used, a larger filter area is needed.

FILTER CLEANING :

When the filter has attained the maximum permissible headloss, it is taken out of service for cleaning. The inlet is closed and the supernatant is drained out or allowed to filter through so as to expose the sand bed. The water level is lowered 10-15 cm below the top of the sand bed by opening the scour valve. Without allowing the bed to dry up, the filter is cleaned manually by removing the top layer of 2-3 cm of sand along with the filter skin. The filter is returned to service by admitting through bottom filtered water from the adjacent filter to a level a few centimeters above from top. The removed sand is washed, dried and stored for future use.

RESANDING :

Due to periodic cleaning, when the sand depth is reduced to a minimum of 30-40 cm, it is necessary to make up the sand depth to the original level. This is done by replenishing with a fresh lot of sand taking care to see that the remaining old sand is placed on top of the new sand. This avoids accumulation of dirt in the deeper layers of filter bed and helps in quick ripening after resanding.

DAILY OPERATION ROUTINE :

Activity	Procedure
1. Regulation of supernatant water level	Manipulate inlet valve (A) to maintain a constant supernatant water level and to avoid overflow
2. Removal of scum and floating matter	Allow temporarily the supernatant with the scum to overflow or manually remove using long handled wire net.
3. Checking the filtration rate	Observe flow indicator and note the rate.
4. Regulation of filtration rate	Manipulate filter outlet valve (E) to maintain desired constant rate.
5. Shutting-off the filter	Cleaning is necessary when the filter outlet valve (E) is fully opened but desired rate is not achieved.

SCHEDULE OF ACTIVITIES FOR CARETAKER :

Daily

- check the raw water intake (some intakes may be visited less frequently).
- visit the slow sand filters.
  check and adjust the rate of filtration.
  check water level in the filter.
  check level in the clear water well.
  sample and check water quality.
- check all pumps
- maintain the logbook of the plant.

Weekly

- check and grease all pumps and moving parts.
- check the stock of fuel and order, if needed.
- check distribution network and taps and arrange repairs, if necessary.
- communicate with user public for problems if any in water supply.
- keep the plant-site clean.

Monthly or less frequently

- scrape the filter beds (s) as and when necessary.
- wash the scrapings, dry and store the washed sand.

Yearly or less frequently

- clean and disinfect the clear water well
- check the filter and the clear well for water-tightness.

Every two years or less frequent

- resand filter unit(s) as may be necessary.

SELECTED REFERENCES

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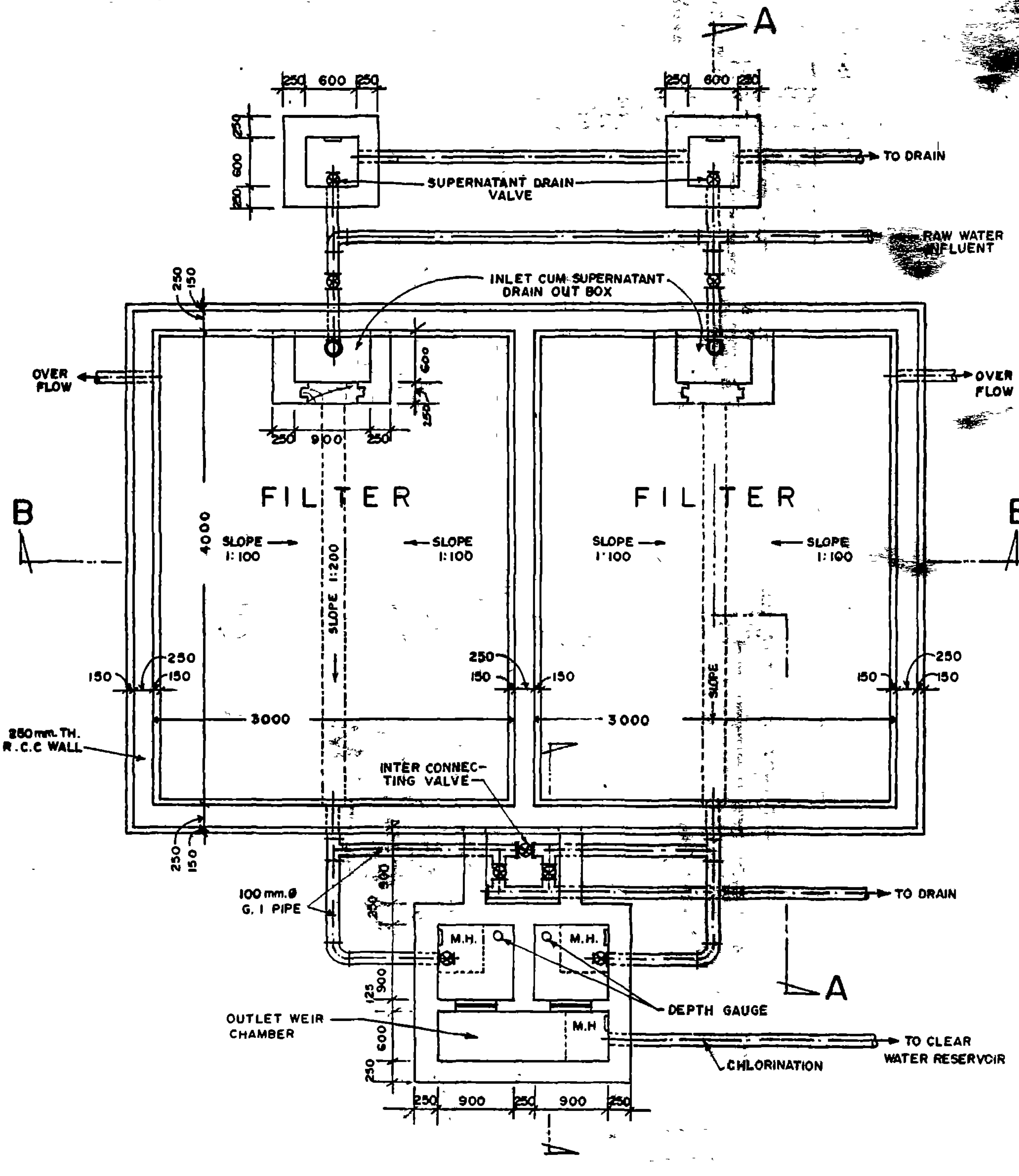
ANNEXURE

ENGINEERING DRAWINGS

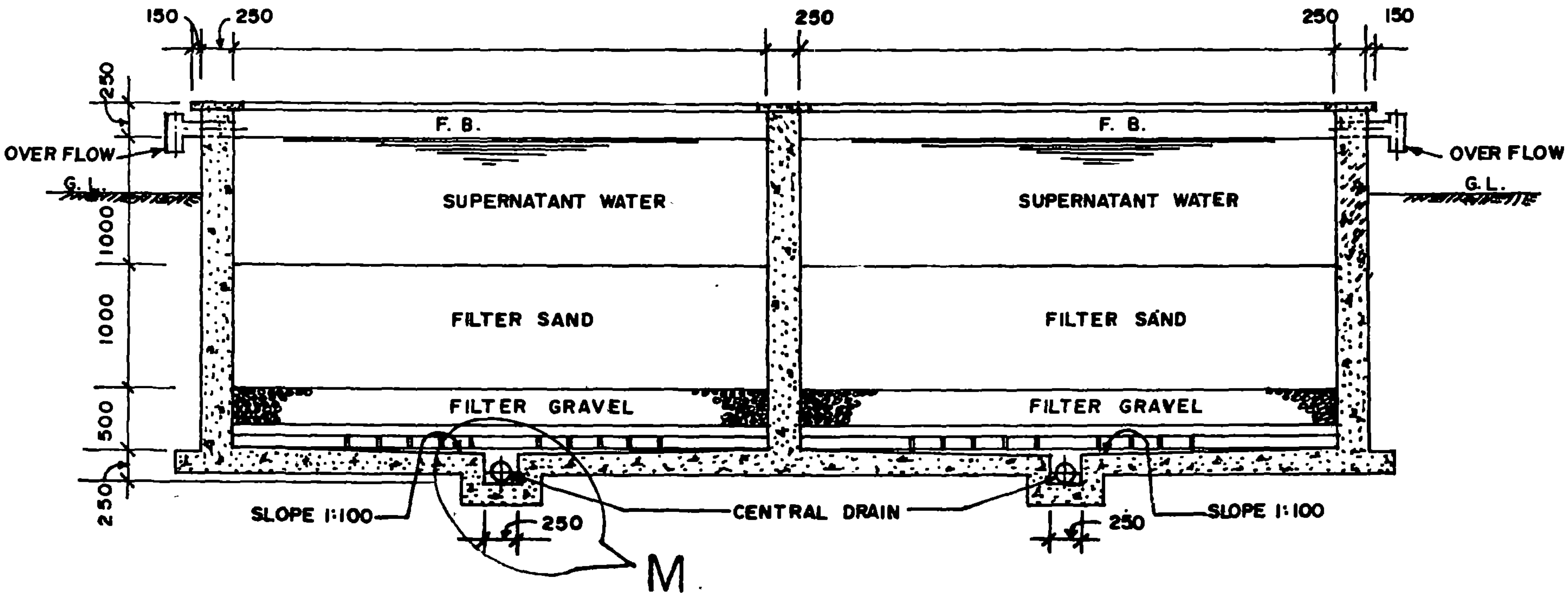
Design Population - 1000

Per-Capita Supply - 40 lpd

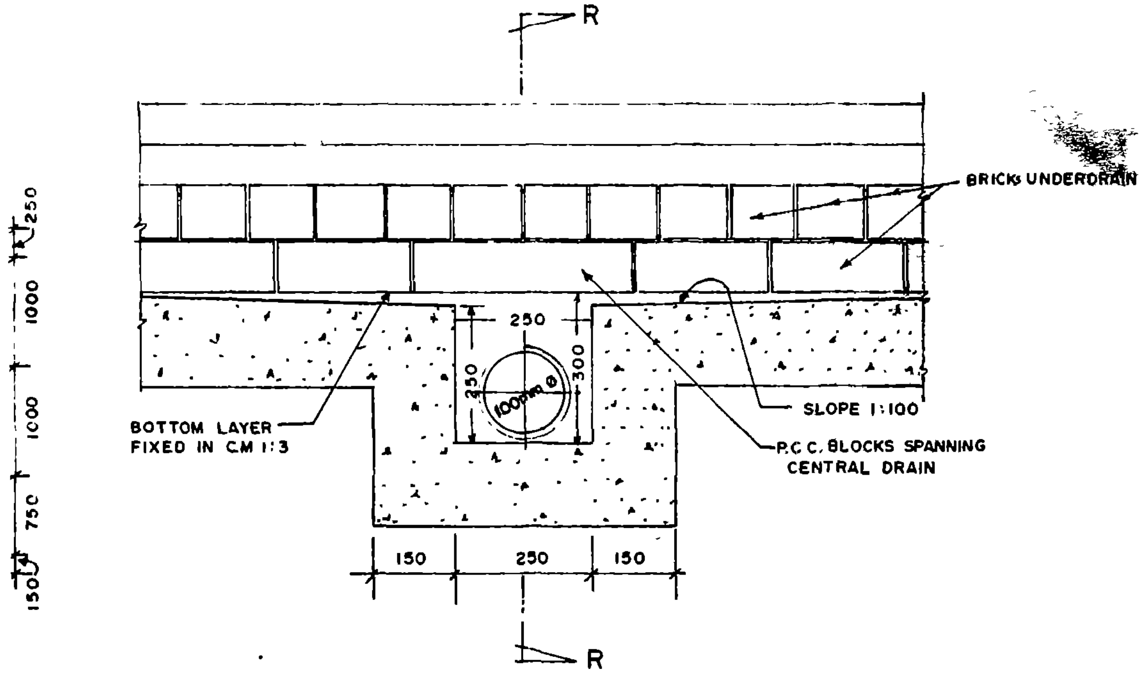


PLAN

SCALE – 1:500

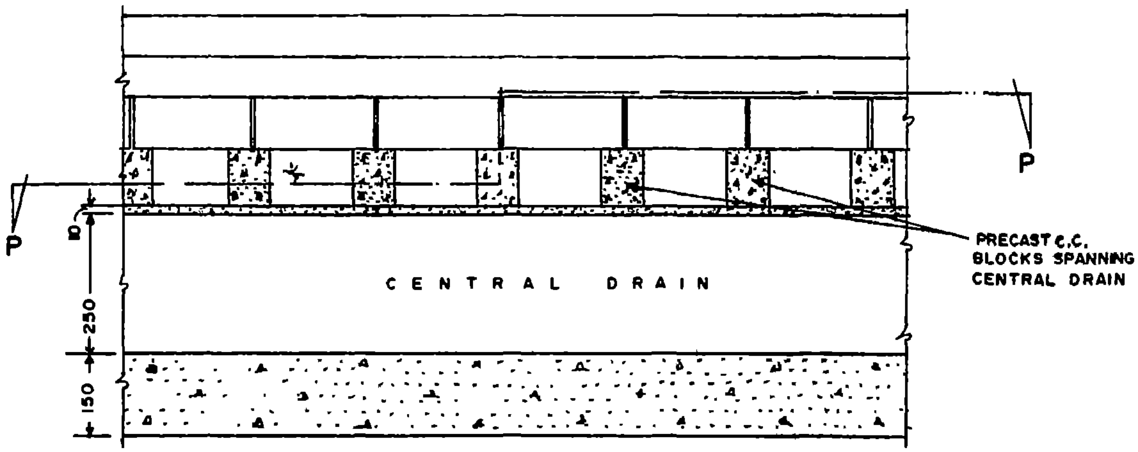

150
250
250
250
150
250
F. B.
F. B.
OVER FLOW
OVER FLOW
G. L.
G. L.
SUPERNATANT WATER
SUPERNATANT WATER
1000
1000
FILTER SAND
FILTER SAND
500
FILTER GRAVEL
FILTER GRAVEL
250
SLOPE 1:100
CENTRAL DRAIN
SLOPE 1:100
250
250
M

SECTION B-B

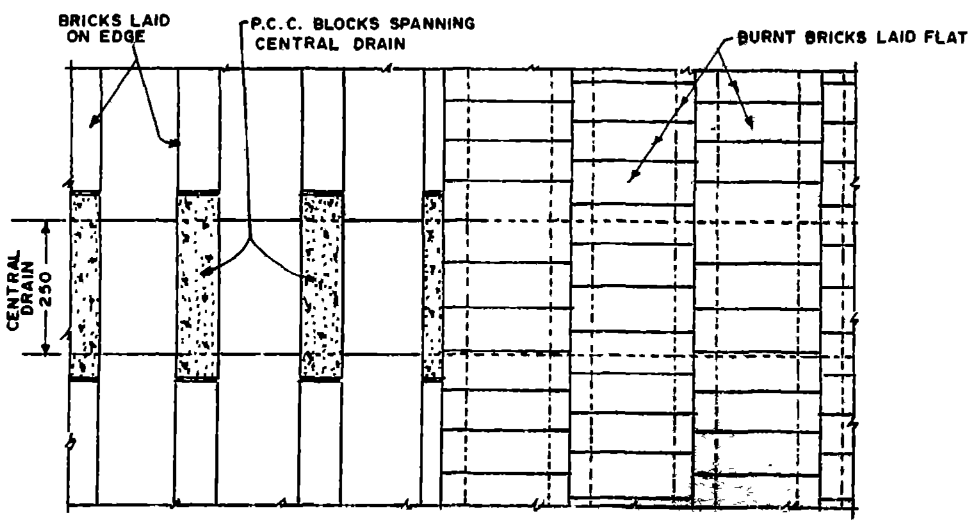


DETAILS AT M

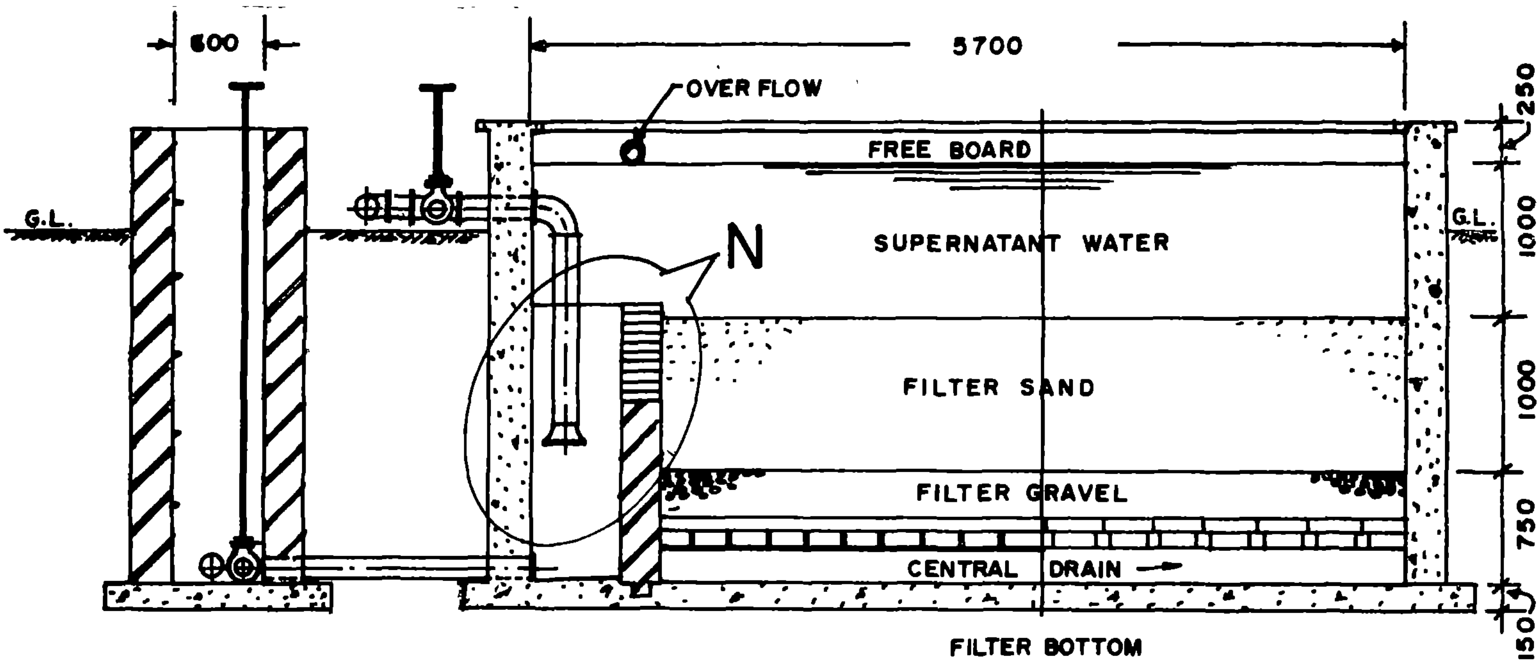
SCALE - 1:100



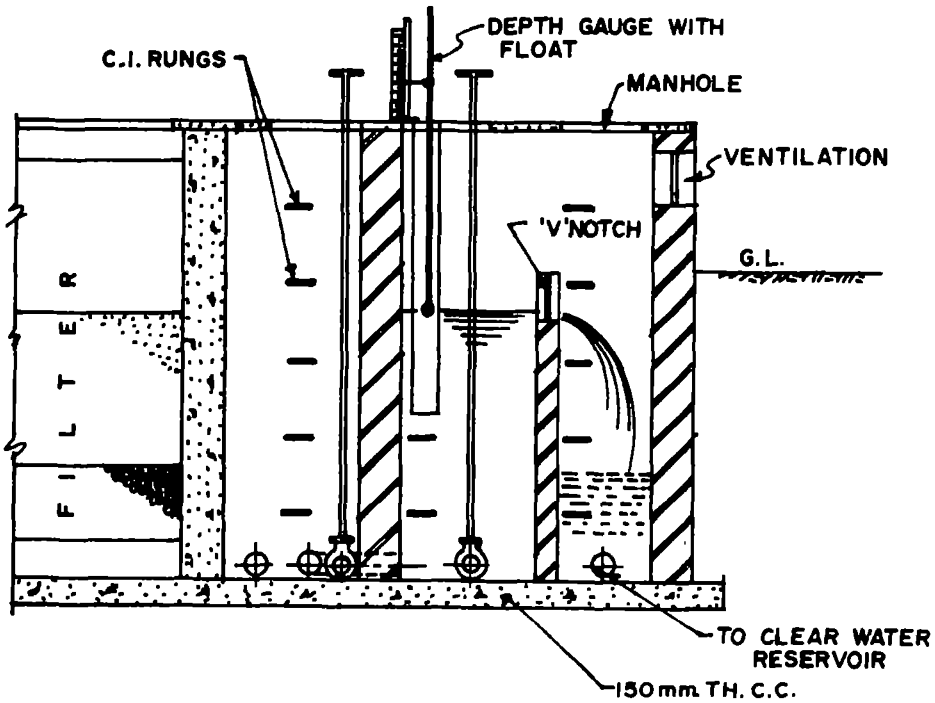
SECTION R-R



SECTION P-P



SECTION A-A

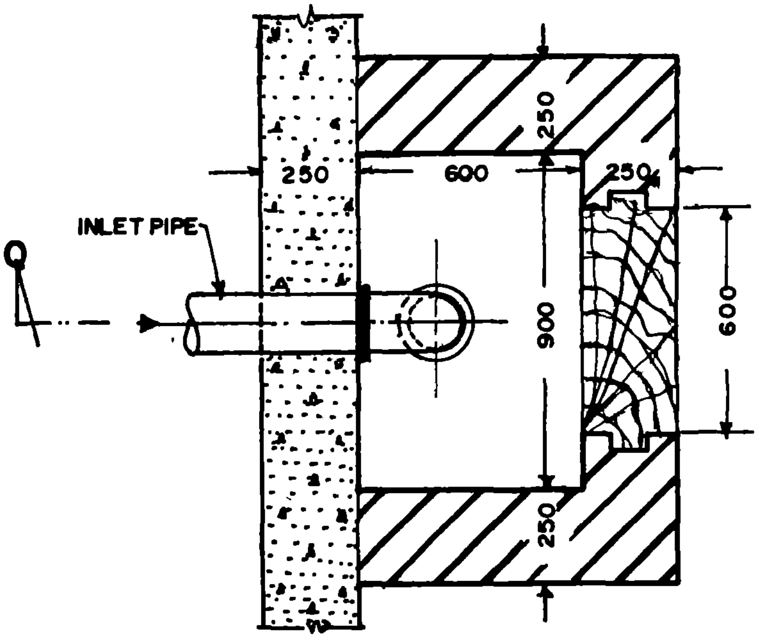


SECTION Y-Y

SCALE - 1:500

SECTION Y-Y

SCALE – 1:500



PLAN

DETAILS AT N

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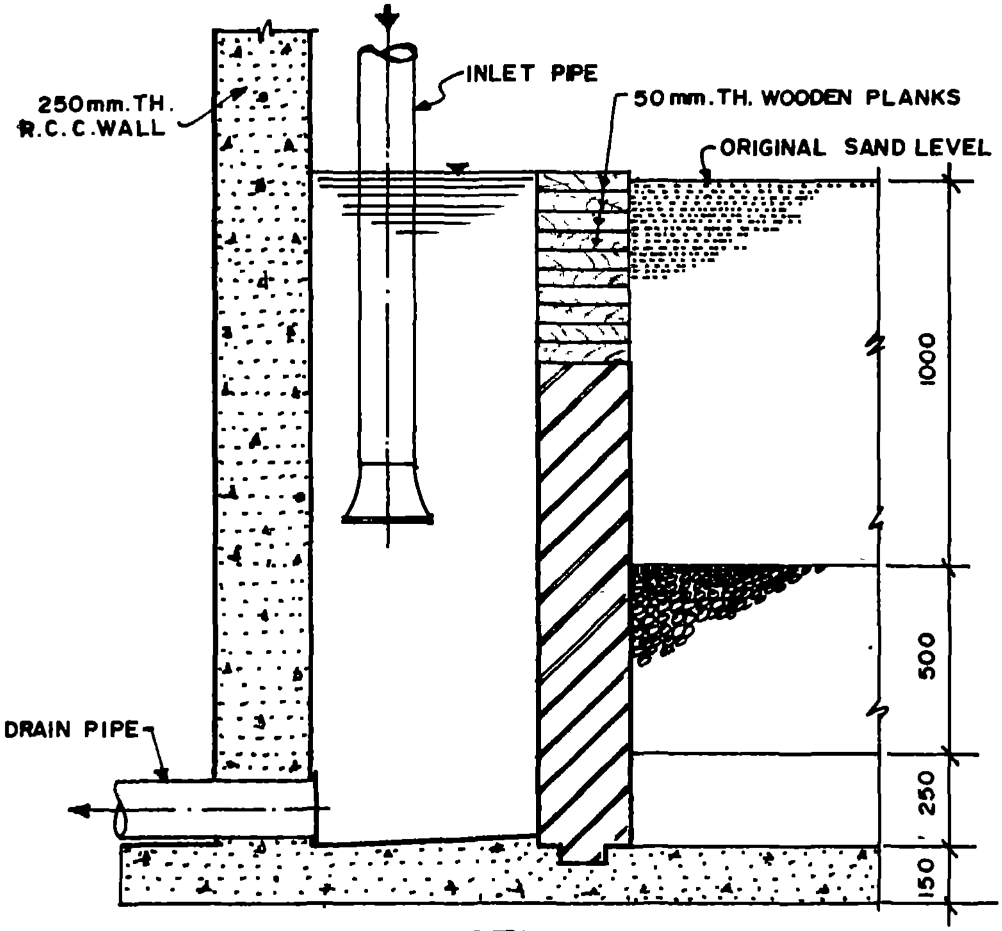

SECTION Q-Q

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