GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES
CENTRAL GROUND WATER BOARD

GROUNDWATER EXPLORATION - CONCEPTS AND GUIDELINES

FEBRUARY 2003

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BACKGROUND

Central Ground Water Board has been carrying out exploratory drilling activities since 1954 in various hydrogeological situations by deploying appropriate type, size and capacity of drilling rigs. The board has drilled 16532 boreholes/wells of different categories in all types of geological formations till March 2002.

Perusal of the areas explored under Ground Water Exploration Schemes indicates that though major portion of areas covered by soft formations have been explored, around half of the areas underlined by hard rock terrain is still to be covered. Many of the districts in various states and for flung tribal areas remain unexplored.

This is because of the fact that most of the areas where exploratory drilling has been conducted are again and again covered under various schemes such as accelerated programme, drought mitigation programme and other special studies. This has resulted into a situation where only marginal increase in the coverage of area under ground water exploration is reported in spite of considerable number of wells drilled every year.

In the changed scenario of ground water exploration, advanced technologies acquired by the drilling industry and department, revised scientific requirement for ground water exploration strategies, it has been felt by the board that guidelines for exploratory drilling in various types of formations covering all aspects related to site selection, drilling operation, scientific data collection, drilling data collection, well construction and completion, aquifer performance test, finalisastion of BDRs and handing over of wells to the user agencies need to be reviewed.

A group of following officers was constituted vide letter No.1-7/TS/CHN/XCGWB/02 dated 10.12.2002 to formulate the revised guidelines considering the above aspects.

1. ***Shri G.D.Ojha, Suptdg. Engineer, Nagpur – Member Convenor***
2. ***Shri M.C.Readdy, Suptdg. Hydrogeologist, SWR, Banglore***
3. ***Shri Alok Dube, Executive Engineer, Div.XII, Bhopal.***

The group met between 17 – 19 December 2002 at Division XII, Bhopal, wherein all the suggestions and information received from various offices of the board were reviewed with the previous guidelines made available to the group.

In the absence of specific terms of reference, the group reviewed entire exploratory drilling process in totality. Suggestions and views received from Regional Directors and Executive Engineers were also considered while drafting the guidelines.

The report is a compilation of various aspects pertaining to ground water exploration and issues hither to not covered. It provides guidelines for undertaking ground water exploratory drilling programme by departmental rigs.

GROUND WATER EXPLORATION- CONCEPTS AND GUIDE LINES

1. OBJECTIVES

The objectives of Ground Water Exploration is to locate aquifers capable of yielding water of suitable quality and in economic quantities for drinking, irrigation, agricultural and industrial purposes by employing as required hydrogeological, geophysical, remote sensing, drilling and other techniques. Quality and quantity of water are relative terms that depend on the purpose for which water is intended to be supplied and the exploration therefore is accordingly aimed at. Other information sought during the course of exploration are the depth location of aquifer, its areal extent, type of rock formation to be encountered, quality of water in the aquifer, its sustained yield, feasibility for artificial recharge etc.

Type of exploration needed and sequence of exploration technique to be employed are declared by economic status and availability of data, degree of the ground water development taking place in the area and the hydrogeological conditions. The systematics of the groundwater exploration can be appreciated from the flow diagram given in **Plate1**.

The above objectives can be achieved combinedly or separately through proper planning of ground water exploration program. At present the objective of exploratory drilling being undertaken by the Central Ground Water Board is to explore to the depth of 300-500 m in hard rock formation and upto 900 m depth in alluvial formations. Under Groundwater Exploratory drilling program four types of wells namely Exploratory Well, Observation Well, SlimHole and Piezo Wells are constructed as per the needs. Construction of Slim Holes is basically to delineate the aquifer at different depth horizons and to fill data gaps in areas for delineating the geometry of aquifers in alluvial/ sedimentary formations. The Exploratory Wells or Test Wells are taken up at key locations for conducting comprehensive studies such as pumping tests, computation of aquifer parameters, well characteristics etc.

It is therefore quite essential to plan out the disposition and locations of different types of wells meticulously. However, construction of Slim Holes take much less time as lowering of well assembly is not required and there is no problem of handing over of wells to the user agency. In hard rock formation and bouldery formations where Down the hole hammer rigs and Percussion rigs are respectively utilized, the concept of Slim Holes is not applicable.

2. PREPARATION OF SCHEME

Following steps should be observed for formation of the scheme proposals for an area.

i. Selection of an area for exploratory drilling based on the systematic/Reappraisal hydrogeological survey undertaken or need for scientific exploration to fill up data gaps.

ii. Consultation with state Government/user Organizations for ascertaining their requirements/ priority and to assess the exploration requirement in the area of study vis-à-vis needs of the states..

iii. ***Preparation of comprehensive scheme for ground water exploration bringing out objectives, justification, type of and number of rigs required, depth to be drilled , number of exploratory, Observation Wells, Slim Holes to be drilled, size and type of well design to be adopted with material specifications, tentative geological formations likely to be encountered types of aquifers , expected yield from the well., type of tests, zone test, aquifer performance test to be undertaken, quality regime to be monitored and any other related items. For every Exploratory Well site at least 2 to 3 alternative sites must be available so as to accommodate the request of user agency in view of the constraints on availability of Government land.***

iv. Ground water prospects map is to be considered to draw a scheme for ground water exploration. These maps are prepared for the Rural Development Ministry under the guidance of the National Remote Sensing Agency. Most of the State Remote Sensing agencies are involved in the preparation of these maps. Central Ground Water Board is one of the agencies providing data for these maps. These maps are submitted to the Central Ground Water Board for quality checks and for approval for publication.

The scheme report should be made available to all the parties concerned at least one season in advance to plan material procurement and diversion of rigs and equipments.

3. NORMS FOR DENSITY OF EXPLORATORY WELLS

Perusal of the area so far explored by the Central ground Water Board indicates that most of the districts in various states still remain unexplored. This is indicative of the fact that most of the areas where exploratory drilling has already been carried out are again and again covered under various schemes such as accelerated drilling programme, drought mitigation programme and other special studies. This has resulted in to a situation where proportionate increase in coverage of the area under ground water exploration is not being achieved inspite of drilling considerable number of boreholes year by year.

It is therefore opined that while deciding strategy for second phase of exploration, priority may be given to such areas hitherto unexplored, so that the entire country is covered from the view point of ground water exploration for delineating ground water potential areas and to estimate ground water resources.

The proposed density of borehole for ground water exploration will be one well/200 sq.km in consolidated formations, one well/300 sq.kms in bouldery formations and one well/500 sq.km in unconsolidated formations. The above norms are not sacrosanct and as per the prevailing hydrogeological situation and objectives of ground water exploration, the density of Exploratory Wells can be decided.

WORK ESTIMATES

Based on the scheme report Estimates for the work to be carried out during the AAP indicating type of machine and equipments proposed to be deployed, materials proposed to be used during the operations, period of operation etc. should

be submitted in April of the current AAP for obtaining technical sanction of the Competent Authority.

4. SITE SELECTION METHODOLOGY FOR GROUNDWATER EXPLORATION

Selection of successful site is a difficult task, especially so in hard rocks . to study the status of information available for the area needs

- Reconnaitory surveys in the field for studying geology, geomorphology and hydrogeology of the area.
- Identification of rock type and the environment in which it was formed
- Stratigraphy, geological history and the depositional environment - marine, lacustrine, estuarine in respect of sedimentary rocks
- Nature of sediments and geomorphology in respect of alluvial formations
- Geomorphology, geological structure and the secondary porosity in respect of hard rock
- Aeromagnetic maps indicating fracture system, remote sensing and aerial photos.

The concept of the ground water basin is an important factor for locating the sites. In ground water recharge areas (uplands), the depth to water level is deep and water level fluctuations are high. Therefore, even if it is high, a well in the recharge area is subjected to excessive drawdowns on pumping. The valley bottoms form the ground water discharge areas where depth to water level are near surface and show very less water level fluctuations. Nearly flat to low gradients of water table prevail in discharge area unlike in ground water recharge areas. Though the Transmissivity is moderate to low, well drawdown will be low and equilibrium conditions will be reached early during pumping. Therefore, a well sited in valley bottom is an advantage.

Similarly, the slope factor is high and the success rate of drilling vary highly from upland to valley bottoms, when compared to soft sedimentary rocks or the alluvial formations.

***Well Siting Methodologies In Different Rocks* :**

Unconsolidated formations (Alluvial areas) :

There are fourteen major river basins (catchment area more than 20,000 sq.km) and forty four medium river basins (catchment area between 2000 to 20,000 sq,kms). Apart from them, there are minor river basins with catchment of less than 2000 sq.km mostly in coastal areas. Most of these rivers contain recent alluvium, older alluvium and coastal alluvium which form important unconsolidated sediments that include potential aquifer.

The important alluvial basins having considerable dimensions are Sindu-Ganga basin, Upper Yamuna and Ghaggar basin. The river basins of Godavari, Krishna, Narmada, Tapi, Cauvery and their tributary rivers also contain river alluvium in moderate dimensions. All other small rivers/streams contain alluvium in localized pockets. They comprise clay, silt, sand, gravel, pebbles, cobbles, boulders, etc., of which sand and gravel form potential aquifers. Clays and silty clays which are aquicludes form confining layers. To tap these aquifer, one has to identify their geometry. If they form shallow aquifers, the remote sensing techniques will help in mapping these aquifers identified by the fluvial features like palaeo channels, river meanders ,ox bow lakes etc. However, in broad river valley extensive deposits/forming lenses of sand of considerable sizes occurring at several depths. Generally, they are topped and bottomed by clay or sandy clay beds. Depending on the geologic history, sedimentation and cyclic repetitions of the gravel sand-clay sequence. The sand lenses are well connected and gets recharged to form good aquifers. Their deep lying aquifers however are to be explored systematically in the entire basin and their geometry has to be worked out from the pre existing exploratory/production borehole data. Several cross sections and fence diagrams are to be constructed from this subsurface data so that their geometry of the aquifers can be deciphered. The Transmissivity and specific yield/storage coefficients have to be estimated from aquifer tests conducted in the tubewells constructed.

Coastal Aquifers :

Ground water exploration in coastal aquifers will pose certain unique problems. The problem faced in general is the brackish/saline nature of water near the sea. Ground water occurs in such areas in interbedded sands, silts and clays deposited under lagoon, estuarine and marine environment. The fresh water aquifers generally occur in the estuarine mouths along the present stream courses or their palaeo-channels. In all, such cases the fresh water floats at shallow depths on the saline water. Fresh water aquifers do exist in a similar way along the palaeo or present beach ridges or strand lines. Aerial photographs/satellite imageries help greatly in locating the present Paleocene channels or beach ridges. The presence of seasonal strand lines occurring as parallel ridges can be seen several kilometers inland in the coastal districts of Andhra Pradesh and Tamilnadu. They are conspicuously seen especially in Ramanathapuram district, Tamilnadu.

Semi – consolidated formations (soft sedimentary rocks) :

The soft sedimentary basins in India comprise the Gondwana sediments of late carboniferous to early cretaceous age and Cenozoic sediments (Eocene to Pliocene). To understand the nature of the lateral and vertical extent of the sedimentary aquifer, the lithology, stratigraphy and structure of the rock has to be worked out. By rigorous field work to map the surface out crops or the aerial photographs or high resolution satellite imagery can help in mapping them. However, the subsurface geology and hydrogeology can be worked out from the Test Well drilling only through geological sections and fence diagrams.

Consolidated formations :

The consolidated formations or hard rock formations can best be classified as igneous, metamorphic or consolidated sedimentary rocks. The igneous rocks among them are crystalline rocks including non-volcanic/volcanic igneous rocks and metamorphic rocks. The sedimentary rocks based on the nature and degree of consolidation, loose the primary porosity and so are treated as hard rocks.

Selection of exploratory or even production well sites in hard rock area is entirely different from that of alluvial or sedimentary formations. Since the primary porosity is absent in the hard rock aquifer, we may have to look for the secondary porosity. For this purpose, we should first understand how the secondary porosity is imparted to a particular type of rock.

In hard rock areas, ground water occurs under water table (Phreatic) conditions in the weathered and joined portions near surface, which generally support the dugwells (large diameter wells) and shallow bores or dug-cum-boreholes within 30m below ground level. The deep seated fractures when encountered at deeper depths sometimes constitute potential aquifers and support large yields even upto 20 lps. To study the geometry of these fracture system, the regional and local tectonics are to be understood properly. Study of aerial photographs and satellite imagery are very useful in mapping the fracture in various litho units. The Dolerite dykes, major and minor fractures, outcrop boundaries can be mapped using these techniques – The results of the exploratory drilling programme demonstrated that the boreholes located in tensile fractures have yielded significant quantities of water in relation to the other type of fractures.

Crystalline rocks:

The permeability of these types of rocks depends on the nature of the weathered material and on the size of the open spaces of the fractures. In general, the granitic terrain contains good aquifers as compared to gneiss, schist, phyllite, slate, pegmatites, dolerites, volcanic (igneous) rocks.

They include a variety of rock types like basalts, rhyolites, agglomerate etc., when the lava flows cools down, vesicles are developed towards the surface and bottom as the entrapped gases escape out. Sufficient time interval between the lava flows give rise to the top weathered portions of the flows. Basaltic flows cover an area of about 5,10,000 sq.km in parts of the States of Gujarat, Maharashtra, Madhya Pradesh, Karnataka and Andhra Pradesh. In basalts the water table configuration is similar to the subsurface topography.

Carbonate rocks:

The carbonate rocks like the other hard rocks lack the primary porosity but develop secondary porosity when fractured or weathered. They differ from other rocks in that they are highly soluble in water rich in carbon dioxide. Dolomites are some what less soluble. Limestone and karstificiation are the other rock types.

5. PINPOINTING OF SITES

Beneficiary

Before taking up the site selection it is mandatory to have consultation with State Government/Organisations for ascertaining their requirements/priority and to assess the exploration requirement vis-à-vis needs of the State. In several situations sites selected without involving the State Government organizations result in problems when bore wells are to be handed over after ground water exploration.

Site selection team

Formulation of site selection team consisting of the following are made considering the involvement of personnel for successful execution of the exploration. The team however in certain circumstance may be changed to suit the local condition/rules.

1) ***Hydrogeologist from Central Ground Water Board***
2) ***Hydrogoelogist/Engineer from State Government responsible or taking over of the well.***
3) ***Assistant Executive Engineer/Incharge of the drilling unit, Central Ground Water Board***
4) ***Local village Head/Revenue authorities competent for acquiring the site if the exploration is to be carried out in a private land***

Survey by Drilling Wing

The approachability of site for the drilling rigs to be deployed needs to be considered. The climatic conditions especially rainy season, crop season, road/bridge conditions are the main factors to be considered for deployment of rigs. Survey by drilling wing includes availability of water source for drilling, camping facilities, communication facilities, provision or possibilities of disposal of pumped water and drilling wastes.

Pinpointing of site

Sites are pinpointed as far as possible on the Government lands, keeping in view the approachability, utility, command area, etc. In case of sites being located on private lands, the revenue authorities should acquire the land and given to Central Ground Water Board so that legal complications/well handing over problems can be averted. Mere written consent in this regard will be of no use and may lead to complications at later stage. The basis for the site selection should be on the following:

1. Hydrogeological condition should not change over short distances and should be representative of the area under consideration or at least a large part of it.
2. The site should not be as far as possible near railways or motor ways passing trains or heavy traffic might produce measurable fluctuations in the hydraulic head of a confined aquifer.
3. ***The site should not be in the vicinity of existing discharge well or Tank/Stream beds or near high tension power lines.***
4. The pumped water should be discharged in a way that prevents its return to the aquifer.
5. The gradient of the water table or piezometric surface should be low
6. Man power and equipment must be able to reach the site easily and camp there.

Site description

The site characteristics may be described on a format and a large scale drawing of the site location with respect to the known reference point is made on a suitable scale on the back side of the format.

Pinpointing of all the sites must be carried out in two installments. First in December of previous Annual Action Plan and the second in June of the current AAP, so that Drilling Division can plan the operations economically.

Geophysical prospecting:

A number of geophysical techniques and methods have been developed for use in exploration for ground water in alluvial, semi-consolidated and hard rock areas. ***The most common method adopted for site selection for ground water exploration is Vertical Electrical Sounding(VES).***

Geophysical methods use the principle of physics to know the subsurface geological conditions. The aim is to find the anomalies in physical properties and interpret them in terms of subsurface geological and/or hydrogeological conditions.

Besides commonly used method i.e. electrical resistivity, other methods like electromagnetic and seismic methods are also used.

The objectives of Geophysical Surveys are to estimate overburden thickness, characterization of lithology, delineation of fracture, joints, etc., and to know the quality of ground water.

Vertical Electrical Sounding (VES) is carried out in the area selected for electrical resistivity surveys. ***During VES, the site hydrogeologist must be associated with the geophysical party.*** Using standard curve matching and computer interpretation techniques the obtained data is interpreted. The layer parameters are adjusted till theoretically generated curves match with the field curves and the resistivity variations with depth are obtained. Based on this, the sites for exploratory boreholes are recommended giving the depth of overburden, the depth to basement, ground water potential zones and depth to be drilled etc.

The site characteristics may be described on the format and a drawing of site location (not to scale) with respect to the known respect points should be made on the back side of the format Plate – 2.

6. SELECTION OF TYPE AND CAPACITY OF RIG

The Central Ground Water Board has got five types of drilling rigs i.e. Direct Mud Rotary rig, Down the hole hammer rig , Direct Rotary-cum-DTH rig, Percussion rig, Direct Rotary-cum-Percussion rig. Some of the DTH rigs are provided with additional attachments like Simultaneous Casing Driver, ODEX system to tackle top loose formation in hard rock areas and in bouldery formations. The Schramm rig is provided with angular drilling attachment also.

The rigs available with CGWB are given below. *

Sl No.	Make	Model	No of Rigs	Year of Purchase	Rated Capacity (m)	Present Capacity (m)
1.	Failing	1500	3	1955	455	200
2.		2000	1	1972	610	350
3.		3000	2	1980	915	900
4.	Frank		7	1955	610	200
5.	Forkey		3	1969	760	450
6.	Wabco	2500	9	1969	760	450
7.	LMP	DR1500	2	1972	455	250
8.		DR1500	4	1988	455	450
9.	L & T	Hole Master	2	1979	457	350
10.	Voltas	Vollam	2	1975	450	350
11.	Russian	2000	6	1988	350	250
12.	Schramm	685 DHH	4	1984,86	450	350
13.	Hydreq Grephone	Major	2	1977	300	240
14.	Hydreq Grephone	Minor		1977	150	120
15.	LMP	Rotaham 1000	11	1987	300	300
16.	ReCp	T-650	12	1986, 1988	300/200	300/200
17.	RMT	--	1	1977	300	300
18.	Failing	Converted	2	1967	455	100
19.	IR	T-4	1	1976	300	150
20.	IR	ITH-20	3	2001	300	300
21.	Walkneer	S-46	2	1986	R-762 P-610	R-762 P-610
22.	Walkneer	S-48	1	1977	R-750 P-305	R-600 P-305
23.	Walkneer	S-33	1	1969	457	250
24.	Drillmac	—	1	1977	485	130
25.	LMP	CP_20	2	1988	200	200
26.	Sankyo	SM-36	7	1991 to 1993	300	300

* Data provided by CHQ's.

The general practice is to carryout exploratory drilling up to the present depth capacity of rig. However, due to ageing the depth capacity of some rigs has been lowered to far less than fifty percent. Such rigs are either deployed for work other than groundwater exploration or in some cases to shallower depths in areas already explored to much deeper depths. This has resulted into a situation where explored area by the organization the past years is not increasing proportionate to the number of exploratory wells drilled. Many unexplored areas, which are inaccessible to the heavy rigs, are yet to be taken up by the Board. In the present situation CGWB needs to equip itself with the following state of the art rigs to retain it's status of apex organisation.

1. ***All terrain rigs for far flung tribal areas.***
2. ***Environmental rigs for ground water pollution studies.***
3. ***Separate fleet of medium capacity DTH drills for natural calamity mitigation programme.***

Selection of type and capacity of rig is therefore to be made jointly by the Engineer and Hydrogeologist from the available fleet of rigs in the operational area.

7. DRILLING OPERATIONS

Flow charts of all the activities required to be performed for drilling an Exploratory Well by Percussion drilling, Direct Mud Rotary Drilling, Open Hole Percussion Drilling and Down the hole hammer drilling techniques are enclosed (Annexure I to IV). The bore hole depth vis-à-vis bit size program to be followed for carrying out drilling operations by above mentioned techniques are given below:

Percussion drilling*

Borehole depth (mtrs)	Borehole size (inches)
0 to Overburden	36
Overburden to 60	24
60 to 90	20 / 16
90 to targeted depth (120 or 150 m)	14 / 12

*Availability of casing size may be considered.

Direct Mud Rotary drilling

Borehole depth (mtrs)	Borehole size(inches)
0 to Overburden	14
Overburden to 300	9-7/8 and 8 ½
Overburden to 600 *	12-1/4, 9-7/8 and 8-1/2

*Telescoping of the borehole at appropriate depths should be carried out. At least 2 to 4 drill collars of appropriate size must be used for carrying out drilling beyond 200meters.

Open hole Percussion drilling

Borehole depth (mtrs)	Borehole size (inches)
0 to 6	30-36
6 to 75	24 / 20
75 to 300	16 / 14 / 12

Down the Hole Hammer Drilling *

Volumetric capacity of Compressor (cfm)	Bit Size/Hole Size in m.m						
	311	254	216	203	165	152	142
	Tentative depth of bore holes in metres						
750 (LMP/RECP Rigs)	-	-	40	60	150	200	NA
850 (SCHRAMM Rigs)	-	-	60	80	175	300	NA
1200 Spare Compresoor	40	80	100	125	225	300	300
1250 (IR Rigs)	40	80	100	125	225	300	300

* Dry air flushing velocity of 4000 fpm is assumed.

8. DATA COLLECTION

The site hydrogeologist and the Driller Incharge should invariably camp at the drill site and record the following on the prescribed formats.

Detailed description of the lithology of borehole cuttings through out at every meter of drilling in case of soft formations and every 3 meter in case of hard rock drilling.

Details of the type of Rig deployed, size and type of bit used, nature of drilling fluid, size and depth of casing pipe, etc. Loss of drilling fluid (air or mud) while drilling if any due to leakage into the formations must be observed and recorded. The pressure drop in the drilling fluid if noticed during the operations should also be recorded.

The time in minutes should be recorded for every meter of drilling in soft formations and 3 meters of drilling in case of hard formations or whenever change in formation takes place Formats of drill time log enclosed (Annexure V to VII).

The bit records must be maintained in the formats enclosed at Annexure VIII to X.

The depth at which first wet sample is encountered and the depth where water is struck first (in case of air rotary drilling).

Wherever essential coring, must be carried out to decipher information on the nature and type of formation.

In case of direct mud rotary drilling, mud parameter such as density, viscosity and sand contents must be measured and recorded at site.

Discharge measurement in case of hard rock drilling whenever increase or decrease in discharge is noted.

The temperature and specific conductance measurements may be carried out after each discharge measurement is taken.

Water sample should be collected from each aquifer encountered or whenever change in specific conductance is noted for chemical analysis. The quality of water sample should not be less than half a litre.

In case of drilling by Percussion/Down the hole hammer technique static water level measurement should be recorded before start of drilling every day till the borehole is completed.

A record of water level fluctuations in neighboring wells due to drilling of the exploratory bore hole should be maintained with details of location, type of well and so on.

In case of hard rock drilling following information may be recorded and tips noted for better drilling

Trip-in and trip-out size of bits should be recorded.

RPM of the drill string must be maintained between 12 to 30.

Load on the bit may be given @ 4.5 kg to 9 kg /mm diameter of the bit.

Reaming of borehole in hard rock drilling should be avoided.

Heavy intrusion of water into the borehole affects performance of the hammer since the standing water column causes increased back pressure at the exhaust. The rate of penetration therefore drops considerably. ***Whenever the rate of penetration due to hydrostatic back pressure falls to 1/3rd of the normal rate of penetration further drilling becomes uneconomical and hence the operations may be called off. However, use of drilling foam, (5 to 10 percent) facilitates better flushing of the cuttings and formation water and improves penetration rates marginally.***

9. GEOPHYSICAL LOGGING

A number of geophysical well logging techniques are available for use in groundwater exploration. The utility of borehole geophysical logging in exploratory drilling is as given below:

- a. ***Delineation of permeable and impermeable zones and defining the aquifer boundaries.***
- b. ***Delineation of quality of water in different horizons. Separation of saline aquifer with a view to seal such zones from fresh water aquifers.***
- c. ***Running of spontaneous potential, point resistance, natural gamma, deferential temperature gradient and caliper logs in the boreholes drilled into different types of formations. Based on the lithology geophysical logging of the pilot hole drilled, aquifers are delineated and quality of groundwater aquifer system deciphered.***
- d. ***In case of hard rock wells boreholes can be logged after its completion.***
- e. ***Whatever available borehole camera logging may be carried out to understand size, shape and orientation of fracture system.***

Whenever the data generated from pilot hole drilling and geophysical logging do not provide firm indication on the quality of formation water, zone tests are conducted.

10. DRILL STEM TEST

Drill stem test is conducted to decipher information on Chemical quality of water from a particular formation by collecting water sample from that zone. It is a system wherein the desired section of borehole is isolated by a packer and drill stem is used as a conduit to pump formation water to the surface by airlift pumping.

Indigenously fabricated conical packers made of (a) conical rubber washers (b) coir rope over a conical frame made from rods with plates (c) solid cone made from steel pipes can be used.. Schematic diagram of drill stem test conducted with cone type solid packer made from 250 or 300mm diameter pipe with 60 cm or 90 cm of conical lengths is given in **Plate 3**. Its minimum diameter is 100mm as the bottom to which assembly pipe is connected. At the top is connected with drill pipe DST is conducted in the pilot hole starting from the top most aquifer zone. The stepwise procedure for conducting DST is given below:-

Step (i) The borehole is reamed to the next larger size (preferably slightly more than the maximum diameter of conical packer) down to the depth of stiff clayey formation where the packer is set. The testing zone section of the borehole is then washed. The packer assembly consisting of 100mm dia slotted pipe at the bottom and drill pipe at the top is lowered and set it at the predetermined depth in such a way that the screen is against the zone meant for testing.

Step (ii) A "T" shaped discharge pipe is connected at the tip of the drill pipe at the surface and an airline is lowered.

Step(iii): The annular space between drill pipe and reamed hole above packer is filled with mud.

Step(iv): The compressed air is then let into air pipe with the help of a compressor. Initially muddy water comes through discharge pipe. After sometime, fresh formation water starts coming out of the discharge pipe. This water sample is collected for chemical analysis.

Step (v): The process is repeated for testing aquifers located at deeper depths.

Precautions: i) Packer should be set on hard/stiff clay.

ii) change in mud level in the borehole when compressor starts is indicative of leaky packer setting.

11. WELL ASSEMBLY RECOMMENDATIONS

Based on the preliminary investigations carried out in the area, data generated from the lithology, sieve analysis of the formation material and geophysical logging well

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11. WELL ASSEMBLY RECOMMENDATIONS

Based on the preliminary investigations carried out in the area, data generated from the lithology, sieve analysis of the formation material and geophysical logging well assembly consisting of housing , blank casing pipe, slotted pipe and bail plug is decided by the site hydrogeologist for lowering into the borehole. ***The slot size and gravel size are to be determined from the sieve analysis of the lithological samples collected during pilot hole drilling.***

The depth of well should be adequate to penetrate saturated aquifer thickness completely. The housing size of the well should be adequate to accommodate pump and the column pipes during development and testing. The well assemblies may be lowered after joining the pipes either by welding or by screw and socketted system.

12. REAMING OF THE BOREHOLE.

The size of reamed hole depends on the size of the assembly and thickness of artificial gravel pack provided. ***The reaming operations should normally be nor more than in two stages.***

Size of assembly (inches)	Pilot hole size (inches)	Reamed hole size (inches)		
		1st Stage	2nd Stage	3rd Stage
4	9-7/8, 8-1/2	-	-	-
6	9-7/8, 8-1/2	12-1/4	-	-
8	9-7/8, 8-1/2	13-3/4	-	-
10	9-7/8, 8-1/2	12-1/4	16	-
12	9-7/8, 8-1/2	13-3/4	18	-
14	9-7/8, 8-1/2	13-3/4	20	-
18	9-7/8, 8-1/2	13-3/4	20	24

13. WELL CONSTRUCTION AND COMPLETION

Two types of Exploratory Well completions in unconsolidated and semi-consolidated formations are generally adopted.

Type I: ***Single length well assembly consisting of a Housing, reducer, blank and screen pipes (well intake) and a bail plug. The length of housing must be sufficient enough to enable lowering of pump upto the maximum pumping water level with an additional allowance of 5 meters. The diameter of housing must be sufficient to accommodate the pump with a clearance of 5 cm to 10 cm. Lengths of bail plug 1-3 m depending on the requirement.***

Type II: ***Two length well assembly is lowered under special circumstances when the conductor pipe lowered during Pilot hole drilling operations is retained as housing pipe. It must be ensured that length and diameter of the pipe is adequate to accommodate the pump The well intake portion with bail plug is lowered separately with a reverse socket at the top. After placing the gravel pack, seal is provided and pipe length above reverse socket is unscrewed and withdrawn.***

Gravel pack material used in well construction should be of appropriate size and well rounded quartz material chemically inert smooth, hard and free from dust/clayey material **Plate – 4.**

Following types of well construction are feasible in consolidated formations depending on the site specific conditions.

Type I ***Top overburden is cased with appropriate size of blank pipe grouting around annulus and rest of the borehole left uncased.***

Type II ***Aquifer in the top weathered zone tapped with desired lengths of screen blank pipe and rest of the hole left uncased,***

Type III ***An assembly of appropriate size lowered in the borehole with or without pack material when the borehole walls are not stable.***

Type IV ***Intermediate unwanted zones (zones with poor quality of water/casing zones) cased with part assemblyborehole telescoped, drilled and rest of the borehole left uncased. However top overburden is cased.***

Type V. ***Sealing of bottom undesired zones by cement grouting and adopting any of the above type design as per site conditions..***

Type VI ***Sealing of top undesired zones by extending casing depths and resorting to any type of designs.***

14. INSTALLATION OF PART ASSEMBLY

Most of the common practice of installation of part assembly is to lower the assembly down to the desired depth using a reverse socket at the top of a assembly, fixing

16. OBSERVATION WELLS

Depth of Observation Well:

Observation Wells should be drilled to the same depth as the middle of the well screen in the pumped well. An exception to this rule is when Observation Wells are terminated in strata above or below the one tapped by the pumped well to see if there is any hydraulic inter-connection between the formations. The depth of the Observation Well is at least as important as their distance from the Test Well. ***In isotropic and homogeneous aquifers, the Observation Well should be placed at a depth that coincides with that of half the length of the well screen. For example, if the well is fully penetrating and its screen is between 10 and 20 m below ground the surface the Observation Well should be placed at a depth of about 15 m.***

Spacing of Observation Wells

In constant discharge test, Observation Wells are necessary for accurate determination of the properties of transmissivity and storativity of the aquifer. Existing wells should be used it, their dimensions and locations are suitable. In other cases, the Observation Wells may need to be constructed. Preliminary calculations using estimated transmissivity eg. estimated from existing borehole data, should be made to indicate the likely response in the Observation Wells to pumping and hence to determine their spacing from the Test Well and to time of observations.

Two factors dictate special requirements for placement of Observation Wells. First, the aquifer is almost always stratified to some degree and is not uniform from top to bottom. Second the length of the screen in the pumped well may be considerably less than the full saturated thickness of the aquifer. Both of these factors distort he distribution of hydraulic head and draw down in the vicinity of the pumped well during the aquifer test. The vertical permeability of a stratified sand formation is less than its horizontal permeability. This means that changes in the head in the aquifer caused by pumping occur more slowly in the vertical direction than in the horizontal direction. At any moment after test pumping is started, the observed draw down at a given distance from the pumped well may be different at various depths within the aquifer. These differences become less as time of pumping increases. Also, the effect of stratification upon distribution of draw down diminishes with distance from the pumped well.

The non-uniform distribution of head or draw down which results from using a short screen in the pumped well is most serious near the well, and the situation becomes normal at some distance from the well. This screen length effect is more pronounced also at the beginning of the test and decreases as the time of pumping increases.

The Observation Wells should not be located too close to the pumped well. The abnormal effects probably disappear, in a practical sense, at distance equal to 3 to 5 times, the aquifer thickness.

Setting Observation Wells at distances of 30 to 90 mtrs from the pumped well in hard rock areas will work out best in most cases. When the Observation Wells are too close to the pumped well, the draw down readings may lead to incorrect results. Locating the Observation Wells too far away is not always convenient because the pumping test must be continued for a longer time in order to produce draw down of sufficient amount at the most distant points.

Since the cone of depression in a water table situation spreads at a slower rate than in an artesian formation, the Observation Wells for the test of water table aquifer must necessarily be close to the pumped well. ***For thick artesian aquifers that are considerably stratified the distances must be greater and Observation Wells may have to be placed at 90 to 200m or more, from the pumped well, in order to get the proper data.***

Number of Observation Wells

The number of Observation Wells to be employed depends upon the amount of information that is desired and upon the funds available for the test programme. The data obtained by measuring the draw down at a single location outside the pumped well permit calculation of average permeability and transmissivity of the aquifer and its coefficient of storage. If two or more Observation Wells are placed at different distances, the test data can be analyzed in two ways by studying with the time draw down and the distance draw down relationships. Using both these methods of analysis gives a check on the results and enhances the dependability of the conclusion. It is always best to have two to three Observation Wells as conditions may allow.

The aquifer test should be for a period of at least 48 hours to have the desired effect in the Observation Well. In cases where the Observation Wells must be located at considerable distance from the pumped well, the pump must be operated continuously for several days.

Ideally the minimum number of Observation Wells is four arranged in two rows at right angles to each other, but in most instances one to two Observation Wells will suffice. The Observation Wells should be constructed in the same stratigraphic level as the Test Well. In certain cases, however, in order to investigate particular localized phenomenon, they may be drilled to a shallow depth than the Test Well. In case of multi layered aquifers inaccuracies will arise where Observation Wells penetrate only the upper most layer or layers, the option available to this case are to drill one of the following.

a) a single Observation Well to the full depth of Test Well and to install piezometers against each aquifer level.

b) A number of Observation Wells to different levels, bringing out all levels except one in each well.

c) A single Observation Well open to the some stratigraphic levels as in the main well

17. PIEZOMETER WELLS

The main criteria in constructing piezometers is to have a sufficient control to determine the hydrostatic potential in the various lithological units of a basin. The other purpose is to provide the information for calculating the specific yields of the Phreatic aquifers and the leakage parameters in natural and stressed conditions.

The following steps are to be followed before and during piezometer installation in hard rocks:

Pre-installation work

(i) Collect all pertinent well completion data from the data bank.

(ii) Determine the depths of piezometer settings, and the open area to be left in the borehole for each piezometer and water table Observation Well.

(iii) ***Ensure the availability of the required materials at the site, such as sand, gravel, cement, pipes, steel plate, cutting and welding equipment, winch and tripod, elevators, air compressor, grouting equipment, steel tapes, depth probing equipment, and all other necessary tools.***

Installation Procedures

i. Measure water level in the borehole before installation.

ii. Measure the total depth of the borehole before starting the installation.

Installation of Piezometer I (P_1) at the bottom of the hole

i. Add a small quantity of fine gravel or coarse sand to the bottom of the Hole.

ii. Measure the required lengths of Piezometer pipes add a small margin of about 0.50m, so that the Piezometer tubes will extend above ground level.

iii. Measure and note the lengths of the slotted portions of the pipe.

iv. Construct the piezometer tube by welding the pipes "end-to- end" (the threads should be cut off).

v. The slotted or open pipe is kept at the bottom of the piezometer tube. Care should be taken to see that the joints are welded watertight. The pipe should stand on the bottom of the boreholes extended to 0.5 m above the ground level.

vi. Add fine gravel until the borehole is filled to 0.5 metre approximately, above the slotted lower end of the Piezometers .

vii. Sound and measure the hole, to make sure that the entire length of the slotted portion of the pipe is covered with gravel. Pack the gravel thoroughly around the Screen by vibrating the pipe and by tamping the gravel filter with sounding rod. This tamping is effected by dropping the sounding rod one end of the sounding line several times.

viii. After the gravel is well settled, measure and note the depth at this point.

ix. This measurement is necessary for the calculation of the area of the borehole which is open to the lower end of the Piezometer tube, and the calculated value is essential for analyzing subsequent permeability tests in the Piezometers.

x. Add little fine sand, which supports the cement grout.

xi. Fill up the Piezometer tube with water and cap the pipe with a plastic bag, to retain the water pressure. The water will slowly flow away into the aquifer. Where all of the water is retained in the piezometer tube, the piezometer has to be checked. Make sure it is cleaned and water level responses are normal.

xii. Insert the gout seal at this point and allow it to settle for some time.

Installation of P_1 at any desired depth (other than that at the *bottom* of the borehole) and or instillation of other piezometers P_2, P_3,etc.

i) Sound and measure the depth of the borehole.

ii) Back fill the bore hole with coarse gravel to one metre below the proposed depth of setting, eg. If the proposed depth is 46.00m (b.g.l) bring the level up to 47.00m (b.g.l). This margin of one metre is required for the cement seal While filling the hole count the number of pails of gravel required, as this indicates the presence of cavities etc., in the hole at different depths.

iii) Measure the required lengths (after cutting off threaded portion) of pipes keeping a margin of 0.50 m, so as to keep the pipe above ground level. Measure and note the length of the slotted portion of the tube.

iv) Install the pipes by welding face to face (joining should be perfect and there should not be any leakage), keep the clamp at 0.50 m., and allow the pipe to hang in the hole.

v) Add little fine sand to the bottom of the hole (as a seat for the grout).

vi) Seal the bottom of the hole with cement grout (the grout can be added through the piezometer pipe so that it reaches the bottom of the hole directly, without mixing up with water in the borehole).

vii) Backs fill the hole with gravel to the depth at which the piezometer is to be set. Sound and measure the hole and add more gravel, if necessary.

viii) Connect the compressor to the piezometer pipe, lift the pipe to about 4 to 5 Metres and then develop the zone till the water is clear. While developing the pipes can be gradually lowered.

ix) Add a little sand to complete the setting of the grout. Set the piezometer at this point.

x) Add fine gravel to one-half metre above the slotted portion of the tube.

xi) Pack the gravel well by vibrating the pipe and by tamping with the probe.

xii) Add fine sand (seat for grout).

xiii) Fill up the piezometer tube with water and cap it with plastic bag and check up the working of the piezometer tube.

xiv) Sound the hole and measure the open area at this point of the hole.

xv) Add grout and seal the zone at this point (this time the grout should not be added through this piezometer tube. It should be added from outside the tube). The whole process has to be repeated for installation of other piezometers.

Installation of water table observation tube

The entire process of installation is same as that of the other piezometers, excepting that in this case no development is required and ¾ of the entire length of water table tube has to be slotted.

1. The hole should be back filled with gravel to within one metre of the depth of the water table zone. Then, the bottom of the hole should be sealed as before. After the hole is cleared, the water table piezometer should be set.
2. Back fill the hole with gravel to within one metre of the ground surface.

Completing steps

i. Number all the piezometers, on the individual caps as well as on the tubes giving no scope for misplacements.

ii. Enclose the entire nest (all the tubes in 6" or 8" casing), as a protective cover and fix it into the ground with a loose concrete mix.

iii. Add the concrete mixture inside to ensure that no water leaks into the borehole.

iv. Give the depths of setting of the different piezometers and Water table on the casing pipe. So that any visitor can know the setting on the spot. Finally cap the casing.

Describe all details of piezometers nest installation with, 3 to 4 piezometers tubes and a water table Observation Well form one piezometer nest. This type of installation is possible in a six inch borehole thus saving construction cost of individual borehole for each piezometer. It is equally mandatory on the part of the drilling crew to ensure proper construction of piezometer tubes, for efficient utilization on long term basis.

Well Field Construction

The main criteria in selecting aquifer Test Well field are to have a sufficient control to determine the aquifer parameters in the various lithological units in the study basin basin. At least two or three test sites with well fields each in recharge and discharge areas distributed uniformly are constructed.

Not less than two Observation Wells each in three directions at 120° from the pumping well are found to be optimum in granitic terrain within the expected zone of influence. But in certain areas of granitic terrain and more so in basalts this choice is restricted when the zone of depression extends in a particular direction depending on the permeability distribution. In such cases, two or three holes are drilled first, studying their yields and drawdown pattern in the other wells during drilling and short duration air tests. Based on this information, the position of the pumping well and the number and direction of other Observation Wells can be decided, so that these serve as the controls to define the zone of influence.

The other main purpose of these Observation Wells is to provide the information for calculating the specific yields of the Phreatic aquifer and the leakage parameters in natural and stressed conditions. This necessitates the following types of Observation Wells:

i. Piezometer nests (PN) having Piezometers lowered down to the Phreatic and other aquifers.

ii. Water table wells (WT) tapping the Phreatic aquifer: It's diameter convenient enough to install the automatic water level recorder.

iii. Dye well close enough (or the distance to be decided by the site hydrogoelogist) to the pumping well to introduce colour dyes to measure ground water velocities during pumping.

iv. Observation Wells (OW) convenient for installation of water level recorders.

18. HYDROLOGICAL TESTS

For determination of aquifer properties like transmissivity, storativity specific capacity well losses etc. hydrogeological tests such as preliminary yield test PYT), Slug Test, Step Drawdown test (SDT) and Aquifer Performance Test (APT) are conducted on Exploratory Wells.

Preliminary Yield Test

Preliminary yield test is conducted on wells in hard rock areas when the bore well is yielding less than 3 litres per second. Preliminary yield tests is carried out with the air compressor attached with the rig for 100 minutes duration. During the test, drawdown and recuperation readings are recorded to compute aquifer parameters and the specific capacity of the well.

In hard rock areas PYT is to be conducted for the first zone and also the cumulative of each successive zones encountered during drilling.

In soft formations PYT has to be carried out after the well is developed by the air-compressor.

Slug Test

Slug tests are useful to estimate the transmissivity of aquifers when no facility exists for carrying out pump test. The test provide preliminary information on the aquifer characteristics, but the transmissivity characterizes only a very small are around the Test Well . Generally a slug of 10 to 20 lts of water is introduced instantaneously and observe the dissipation of water for a period of 30 minutes to 60 minutes. Inmost cases the complete dissipation will take place within 15 to 20 minutes. ***The residual***

head can be measured with the help of DWLR's for accuracy and more number of observations. Similarly slug of say 5000 to 10,000 litres of water will be introduced to find out the intake capacity of the bore well for studies in connection with artificial recharge processes. ***Slug test may not feasible when the SWL is very deep and also in formations having high transmissivity.***

Step drawdown test

A step drawdown test is a single well test in which the well is pumped at a low constant discharge rate until the drawdown within the well stabilizes the pumping rate is increased to a higher constant- discharge rate and the well is pumped until the drawdown stabilizes once more. This process is repeated through at least three steps, which should all be of constant duration say from 30 minutes to 2 hours each. Step draw down test need not be conducted on tubewells with discharge less than 2 lps or the specific capacity of the well is less that 6 lps/m drawdown and also on boreholes drilled in hard rock areas.

Aquifer performance test

An aquifer test is designed to impose a hydraulic stress on the aquifers in such a way that measurements of the response to the stress well fit in a theoretical model of aquifer is subjected to stress and one or more Observation Wells in which the response is measured. By conducting such tests the following are determined.

i. Hydraulic characters of aquifer and the confining beds
ii. The possible influence and nature of aquifer boundaries

The arrangements for an aquifer test must permit the following controls and measurements:

i. Constant pumping rate, even though the pumping level may vary during the pumping period.
ii. Accurate measurement of drawdown in the pumped well and in one or
iii. more Observation Wells (if constructed), some distance away.
iv. Accurate record of time each measurement is taken as puming proceeds.

v. Accurate record of water level recovery in each well with rate of pumping of nearly wells if such wells cannot be idle during the period of pumping and during the period of recovery after pumping is stopped.

In hard rock areas on boreholes with less than 3 lps discharge APT need not be conducted.

Schematic diagram showing equipments used during slug test, PYT, SDT and APT is given at Plate – 8.

All the hydrololgical test must be completed within a weeks time from completion of the wells. Testing of wells drilled in hard rock areas must be carried out by the rig unit itself. Wells drilled in soft formation will be tested by pumping unit attached with the rig.

The formats given in the manual for pumping tests may be followed for uniformity and consistency.

19. EXPLORATORY DRILLING FOR DROUGHT MITIGATION

During severe drought, Central Ground Water Board suspends the regular exploratory drilling as per AAP and diverts the rigs to take up construction of production wells. On such occasions, the construction of wells will be to meet the needs for drinking water/domestic use. The following procedure may be followed to expedite the work on war footing.

i. Programme for construction of production wells should be obtained from the Chief Executive Officer of Zlla Panchayat of the district who will take over the well after completing the tests.

ii. Drilling should be stopped soon after encountering production zones at sufficient depths and not to insist on 200 m or 300 m of drilling. If the yield is good say more than 3 lps, drilling should be stopped or if the drilling penetration is slow, drilling has to be stopped provided the discharge is reasonable.

iii. If the yield is less than 3 lps only preliminary yield test for 60 minutes will be conducted. No other test will be conducted.

iv. Drilling should be restricted to two to three taluks in the district so that minimum shifting of rig and manpower is involved thereby saving man-days.

v. Step drawdown and aquifer performance tests should be completed within two days.

vi. Site Hydrogeologist should record in the Register the successful/failure of the well and discharge of the well

vii. Site Hydrogeologist should submit basic data report within a week of shifting of the rig to the next site

viii. Water samples should be collected and analysed on priority.

20. ANNULAR SEALS

A seal is provided to protect against contamination and prohibit vertical migration of water from unfavourable zones. Both bentonite and neat cement can be used as seal materials. Wherever temporary seals are required bentonite can be used. Bentonite slurry is prepared by mixing dry bentonite into fresh water in a ratio of 1:3 by weight. A positive displacement pump should be used to implace the seal at desired depth,

Cement seals are permanent seals. Neat cement slurry is prepared in fresh water by mixing one bag of 50 kgs cement with approximately 20 to 25 litres of water. The mixture yields 40 litres of slurry with a specific gravity of 1.8. About 2 to 6 percent of bentonite is added to this slurry to improve its workability. The grout should be mixed either manually or with a mechanical mixer to a relatively stiff consistency and immediately used.

Sealing operations are carried out by i) Gravity method and ii) Pump grouting. About 30 centimeter of fine sand layer should be placed before grouting operations are carried out.

Gravity method of placement by using a pipe of 38 mm diameter lowered up to the required depth in the annulus and the slurry poured through a funnel. This method may be adopted for depths up to 100 meters.

Seals at deeper depth should be placed by using a grout pump. The pump so used should immediately be cleaned with fresh water after grouting operations are completed.

21. DRILLING HAZARDS

Depending on the formation characteristics following hazards may be met with while exploratory drill operations in soft rock formations.

a. ***Loss of drilling fluid.***

b. ***Caving of formation causing struck pipes.***

c. ***Slow rate of penetration.***

d. ***Artesian pressure.***

e. ***Drilling through saline aquifers***

The problem of mud loss generally occurs due to non-formation of mud cake on the borehole wall. The mud should be reconditioned by mixing by fibrous material and circulating the same so that mat like structure is formed on the borehole wall. Another practice to overcome this situation is to switch over to low density mud.

In areas prone to surface caving, the length of conductor pipe must be sufficient enough (50 to 60 mtrs) to avoid caving. In some cases, water loss from the mud results into thickening of return mud cake. Thick mud cake forms on the borehole wall which some times results into caving. Reconditioning of mud with CMC are Kutch is require to overcome this type of problem.

When relatively hard formations with dipping beds are encountered, slower rate of penetration is common. Sufficient length of drill collars of appropriate size must constitute the drill string to provide required weight on the bit for negotiating hard formations.

Whenever artesian pressures are anticipated, heavy mud must be used, by adding Barites in appropriate proportions to increase specific gravity of mud.

Occurrence of saline aquifer in coastal tracts could be noticed when the mud gets flocculated thereby its thixotropic property gets destroyed. Such problems are tacked by mixing lime in appropriate quantity (15 to 25 kgs) to the bentonite mud

The common problems encountered in hard rock drilling are

a. ***Thick overburden,***

b. ***Down the hole hydraulic pressure of the formation water.***

c. ***Intermediate loose formations***

d. ***Plugging of poor quality zones***

Thick overburden is negotiated with Direct mud rotary drilling method, Simultaneous Casing Driving, or ODEX system of drilling, depending on the nature and type of overburden. However, these techniques can successfully be adopted upto to the rated capacity of the rigs

If intrusion of formation water into the borehole is heavy the performance of hammer drops due to increased back pressure at the exhaust.

In order to maintain an annular flow of mixture of air water drill cuttings, a certain pressure over and above the hammer operating pressure is required to counter the back pressure. As most of the modern high pressure down the hole hammers require a minimum of 150 to 180 psi just to start functioning, the balance pressure will be available to counter the back pressure. With a 250 psi capacity compressor about 70 to 100 psi will be available to counter the back pressure. Similarly, a compressor with 350 psi capacity will be able to counter down the hole hydrostatic pressure upto 170 to 200psi. Thus with the presence of large quantity of water a rig equipped with 250 psi compressor can handle a back pressure of equivalent to about 65 meters of water column and those equipped with 350 psi compressor can handle a back pressure equivalent to 150 meters of water column. However the exact depth at which drilling has to be terminated due to hydrostatic back pressure would depend on a number of factors such as static water level, yield from the aquifer, rate of recoupration etc.

It is therefore, suggested that whenever the rate of penetration drops to 1/3 of the normal rate of penetration drilling operations may be stopped since it becomes too uneconomical to further proceed with.

Intermediate loose caving formations and zones of poor quality can be cased by lowering part assembly in the borehole. However the number of reduction to case such formations are limited by the diameter of the borehole at that depth.

22. SURFACE COMPLETION.

A cement concrete platform (1 : 3:6) measuring 0.5 x 0.5 x 0.6 meters (0.3 meter above ground level and 0.3 m below ground level) should be constructed around the well casing to protect entry of the pollutants in the well. In places where settlement

of gravel is anticipated during the course of utilisation of tube well, gravel feed pipe of 38 to 50 mm diameter may be provided.

After the operations are completed, the area utilised for drilling, camping and other facilities must be levelled, pits filled and cleaned before the unit leaves for the next site.

Wherever necessary protection box may be fitted for safety of equipment and tools lowered for hydraulic measurements.

23. VERTICALITY TEST

After completion of the Exploratory well verticality test must be conducted.

24. BASIC DATA REPORT

The basic data report in respect of each site must be completed and submitted within 3 weeks from the completion of hydrogeogical tests. The Basic data report must include following information.

i. Name of scheme/project. . .

ii. Objectives of the scheme.

iii. Location.

iv. Geology.

v. Hydrogeology.

vi. Geophysical surveys and logging.

vii. Description of drilling rigs and tools.

viii. History of drilling operations.

ix. Data collected and analysis.

x. Well design and completion.

xi. Well hydraulics .

xii. Chemical analysis of water samples.

xiii. Conclusions and recommendations indicating type and capacity of pump and utilisation of the wells.

xiv. Annexures and plates.

25. OFF SEASON REPAIRS

Every rig unit should invariably be moved to Divisonal Head quarters during the non-operational season for carrying out maintenance and off-season repairs so that the unit operates without break downs during the operational periods. The off-season period may be decided depending on the monsoon season in the respective area. This lay off will also help in completion of hydrogeological reports and other related issues by the site hydrogeologist.

26. ABANDONMENT OF WELLS

Timely decision on abandonment of Exploratory Wells saves idling of drilling rigs. The reasons for abandonment on account of premature conclusion of drilling operations could be a. Mechanical breakdowns, b. Drilling, c. Poor quality or poor yield of water from the zones.

Abandonment of wells due to poor yield or poor quality of water must be conveyed by the site hydrogeolosist immediately after the tests are completed.
In case an Exploratory Well is to be abandoned midway due to mechanical/drilling reasons, feasibility of completion of wells up to the drilled depth may be examined and decision conveyed immediately for abandoning the well.

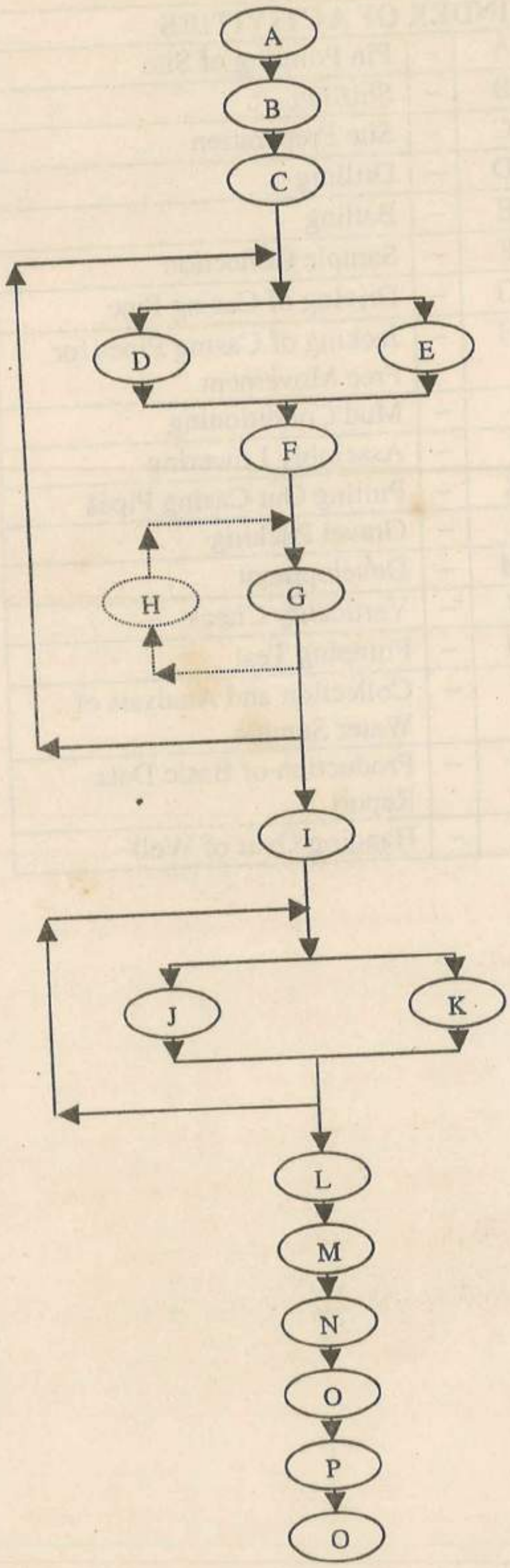
27. HANDING OVER OF WELLS

The Exploratory well must be handed over to the user agency within four weeks of its completion along with the Basic data report.

28. FIELD INSPECTION

The Supervisory Officers must conduct field inspections as per the guidelines already issued from the Central Head Quarters and submit inspection reports to the next higher authority for perusal. The instructions issued at the site must be recorded in the instruction book which could be reviewed during the next visit.

Flow Chart of Activities for Construction of Exploratory Wells in Bouldry Formations (Cased Hole Method)

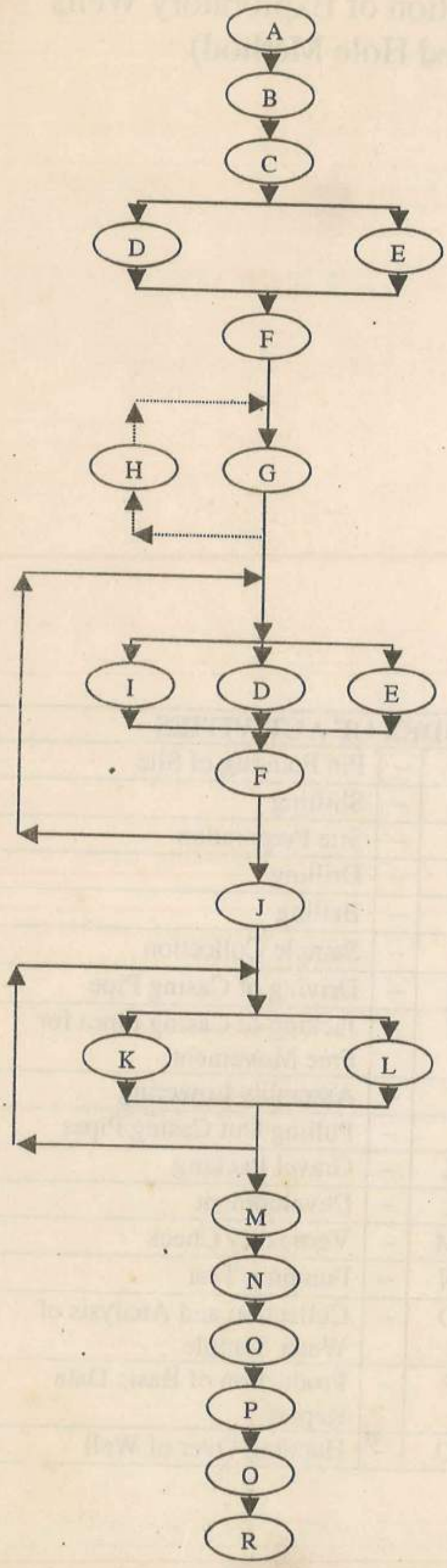


INDEX OF ACTIVITIES		
A	–	Pin Pointing of Site
B	–	Shifting
C	–	Site Preparation
D	–	Drilling
E	–	Bailing
F	–	Sample Collection
G	–	Driving of Casing Pipe
H	–	Jacking of Casing Pipes for Free Movement
I	–	Assembly Lowering
J	–	Pulling Out Casing Pipes
K	–	Gravel Packing
L	–	Development
M	–	Verticality Check
N	–	Pumping Test
O	–	Collection and Analysis of Water Sample
P	–	Production of Basic Data Report
Q	–	Handing Over of Well

2

Annexure II

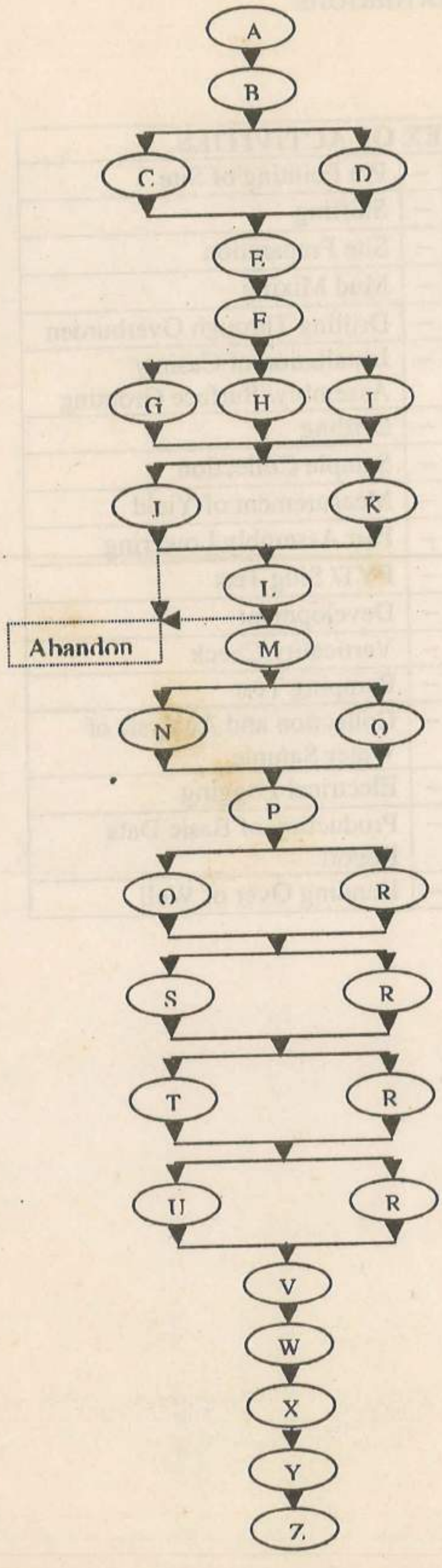
Flow Chart of Activities for Construction of Exploratory Wells in Bouldry Formations (Open Hole Method)



INDEX OF ACTIVITIES		
A	–	Pin Pointing of Site
B	–	Shifting
C	–	Site Preparation
D	–	Drilling
E	–	Bailing
F	–	Sample Collection
G	–	Driving of Casing Pipe
H	–	Jacking of Casing Pipes for Free Movement
I	–	Mud Conditioning
J	–	Assembly Lowering
K	–	Pulling Out Casing Pipes
L	–	Gravel Packing
M	–	Development
N	–	Verticality Check
O	–	Pumping Test
P	–	Collection and Analysis of Water Sample
Q	–	Production of Basic Data Report
R	–	Handing Over of Well

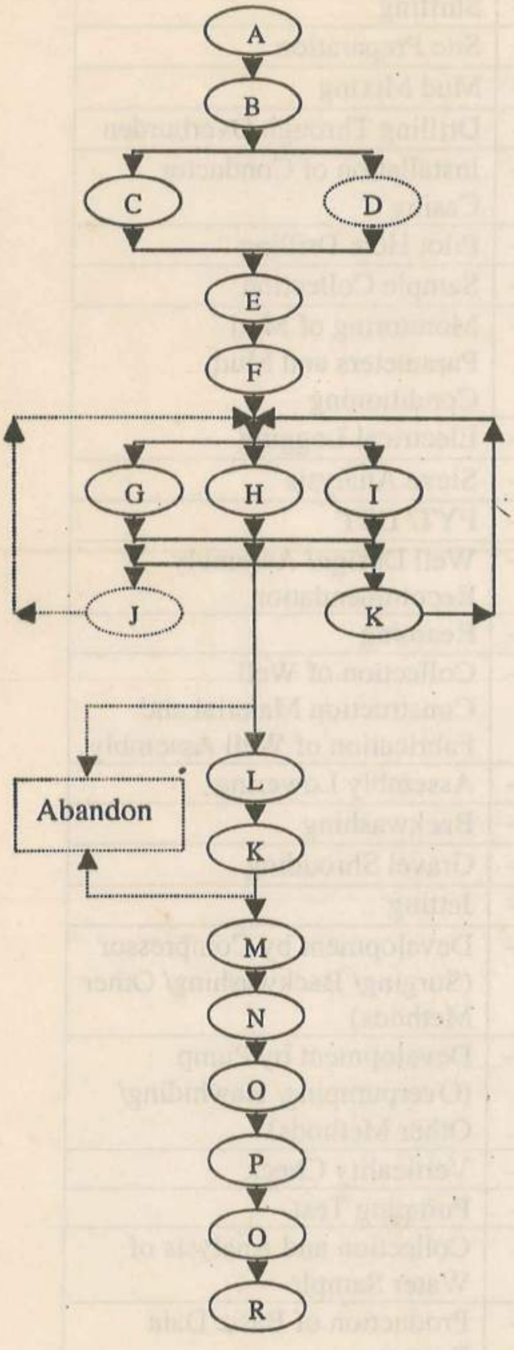
Annexure III

Flow Chart of Activities for Construction of Exploratory Wells in Semi-Consolidated and Unconsolidated Formations



INDEX OF ACTIVITIES		
A	–	Pin Pointing of Site
B	–	Shifting
C	–	Site Preparation
D	–	Mud Mixing
E	–	Drilling Through Overburden
F	–	Installation of Conductor Casing
G	–	Pilot Hole Drilling
H	–	Sample Collection
I	–	Monitoring of Mud Parameters and Mud Conditioning
J	–	Electrical Logging
K	–	Sieve Analysis
L	–	PYT/ DST
M	–	Well Design/ Assembly Recommendation
N	–	Reaming
O	–	Collection of Well Construction Material and Fabrication of Well Assembly
P	–	Assembly Lowering
Q	–	Backwashing
R	–	Gravel Shrouding
S	–	Jetting
T	–	Development by Compressor (Surging/ Backwashing/ Other Methods)
U	–	Development by Pump (Overpumping/ Rawhiding/ Other Methods)
V	-	Verticality Check
W	-	Pumping Test
X	-	Collection and Analysis of Water Sample
Y	-	Production of Basic Data Report
Z	-	Handing Over of Well

Flow Chart of Activities for Construction of Exploratory Wells in Consolidated Formations



INDEX OF ACTIVITIES		
A	–	Pin Pointing of Site
B	–	Shifting
C	–	Site Preparation
D	–	Mud Mixing
E	–	Drilling Through Overburden
F	–	Installation of Casing/ Assembly/ Surface Grouting
G	–	Drilling
H	–	Sample Collection
I	–	Measurement of Yield
J	–	Part Assembly Lowering
K	–	PYT/ Slug Test
L	–	Development
M	–	Verticality Check
N	–	Pumping Test
O	–	Collection and Analysis of Water Sample
P	–	Electrical Logging
Q	–	Production of Basic Data Report
R	–	Handing Over of Well

Annexure - V

Drill Time Log
(Percussion Drilling)

Name of Site
Block
District
Type of Well

		Drilling Time			Drilling Depth			Hydrogeology			Drilling Parameters			
Date	S. No./ Drill Rod No.	From	To	Total (min)	From (m)	To (m)	Total (m)	Sample No.	Formation	Rate of Penetration (m/h)	Type of Operation	Bit Size/ S. No. (mm)	Drilling Fluid Density*	Drilling Fluid Viscosity** (s)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

*Mud Balance may be used for density measurement in case of open hole drilling.
** Marsh Funnel viscosity in seconds may be recorded in case of open hole drilling.

Annexure - VI

Drill Time Log
(Hydraulic Rotary Drilling)

Name of Site
Block
District
Type of Well

		Drilling Time			Drilling Depth			Hydrogeology			Drilling Parameters							
Date	S. No./ Drill Rod No.	From	To	Total	From	To	Total	Sample No.	Formation	Rate of Penetration	Type of Operation	Bit Size/ S. No.	Drill Collar Length/ Diameter	Mud Pump Pressure	Drilling Fluid Density*	Drilling Fluid Viscosity**	Drilling Fluid Sand Content	Return Fluid Sand Content
				(min)	(m)	(m)	(m)			(m/h)		(mm)				(s)	(%)	(%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

*Mud Balance may be used
** Marsh Funnel viscosity in seconds may be recorded.

Annexure - VII

Drill Time Log
(Air Percussion Rotary Drilling)

Name of Site
Block
District
Type of Well

Date	SWL* (before start)	S. No./ Drill Rod No.	Drilling Time			Drilling Depth			Hydrogeology				Drilling Parameters						
			From	To	Total	From	To	Total	Sample No.	Formation	Rate of Penetration	V-Notch Reading/ Yield	Type of Operation	Drilling Fluid/ Flushing Interval	Bit Size/ S. No.	Hammer Make/ Model	Hammer Air Pressure	Rotational Torque**	Pulldown/ Pullback Force**
	(m)				(min)	(m)	(m)	(m)			(m/h)	(mm)		(m)	(mm)				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

*Static Water Level may be recorded every day before resumption of drilling.

** Pressure reading of hydraulic gauges provided to monitor torque/ force may be noted, if no directly calibrated gauge is provided.

Annexure - VIII

Bit Record
(Percussion Bits)

Bit No. | Design of Bit | Date of Receipt

Size | Classification | Date of First Use

Make | | Date of Last Use/ Discard

Date	Name of Site	Type of Well	Type of Operation	Formation	Depth Drilled				Condition of Bit			Redressing Details/ Remarks
					From	To	Total	Cumulative Total	Cutting Edge	Rope Socket	Bit Body	
					(m)	(m)	(m)	(m)				
1	2	3	4	5	6	7	8	9	10	11	12	13

Reasons for discord:

Annexure - IX

Bit Record
(Rock Roller Bits)

Bit No. | Design of Bit | Date of Receipt

Size | IADC Classification | Date of First Use

Make | | Date of Last Use/ Discard

Date	Name of Site	Type of Well	Type of Operation	Formation	Depth Drilled				Condition of Bit			Redressing Details/ Remarks
					From	To	Total	Cumulative Total	Teeth	Rollers/ Bearings	Bit Body	
					(m)	(m)	(m)	(m)				
1	2	3	4	5	6	7	8	9	10	11	12	13

Reasons for discord:

Annexure - X

Button Bit Record

Bit No.
Size
Make

Hammer Style
Design of Bit
No. of Gauge/
Face Buttons

Date of Receipt
Date of First Use
Date of Last Use/
Discard

						Depth Drilled				Diameter of Bit			Condition of Bit			
Date	Name of Site	Type of Well	Type of Operation	Formation	Drilling Fluid/ Flushing Interval	From	To	Total	Cumulative Total	Start	End	After Regrind	Gauge Buttons	Face Buttons	Bit Body	Regrinding Details/ Remarks
					(m)	(m)	(m)	(m)	(m)	(mm)	(mm)	(mm)				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Reasons for discord:

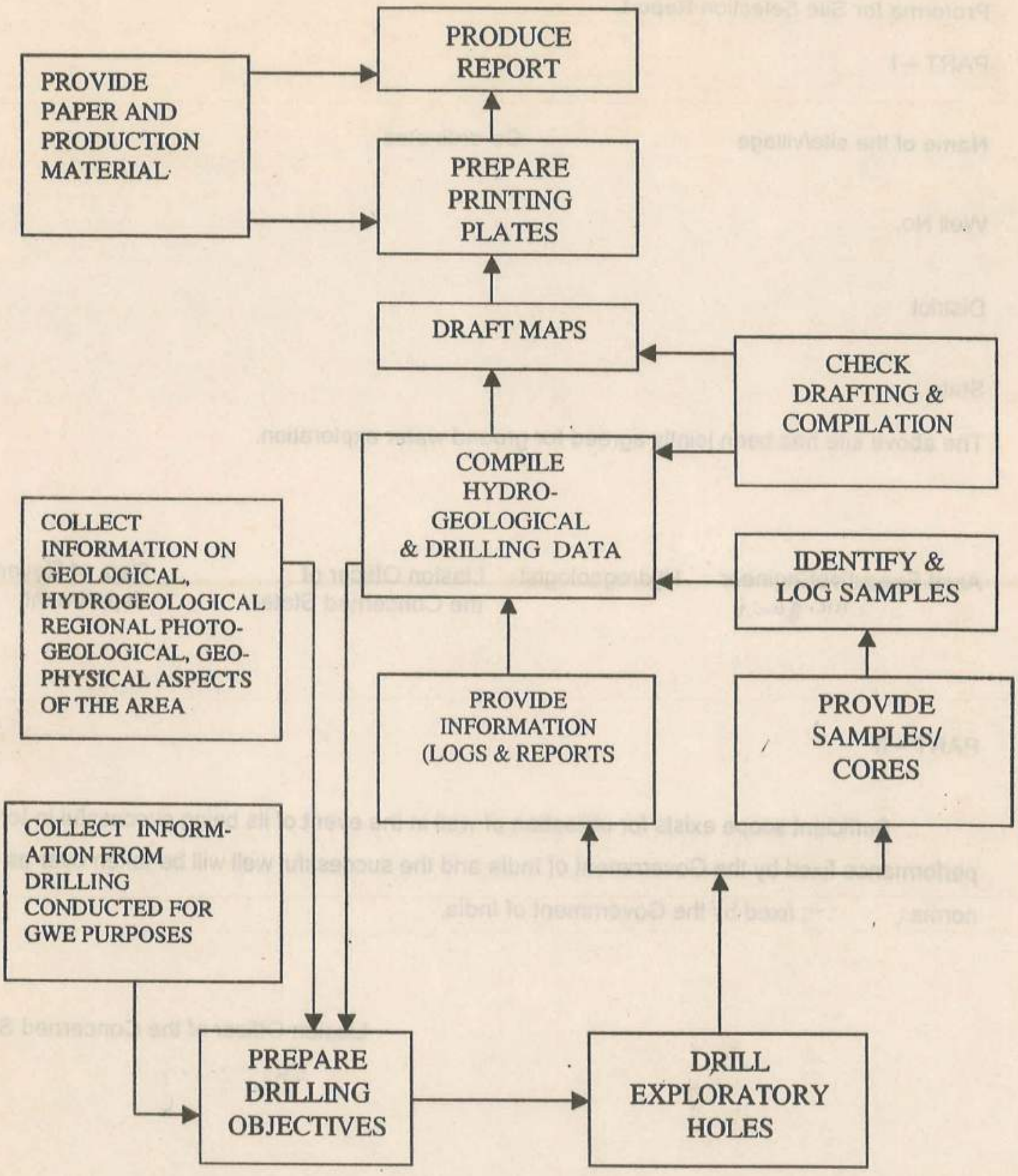


PLATE 1: Objectives Of Ground Water Exploration Project

Plate 2

Proforma for Site Selection Report.

PART – I

Name of the site/village Co-ordinates

Well No.

District

State

The above site has been jointly agreed for ground water exploration.

Asstt.ExecutiveEngineer	Hydrogeologist	Liasion Officer of the Concerned State	Rep. of Revenue department.

PART – II

Sufficient scope exists for utilisation of well in the event of its being successful in terms of performance fixed by the Government of India and the successful well will be taken over as per norms fixed by the Government of India.

Liasion Officer of the Concerned State

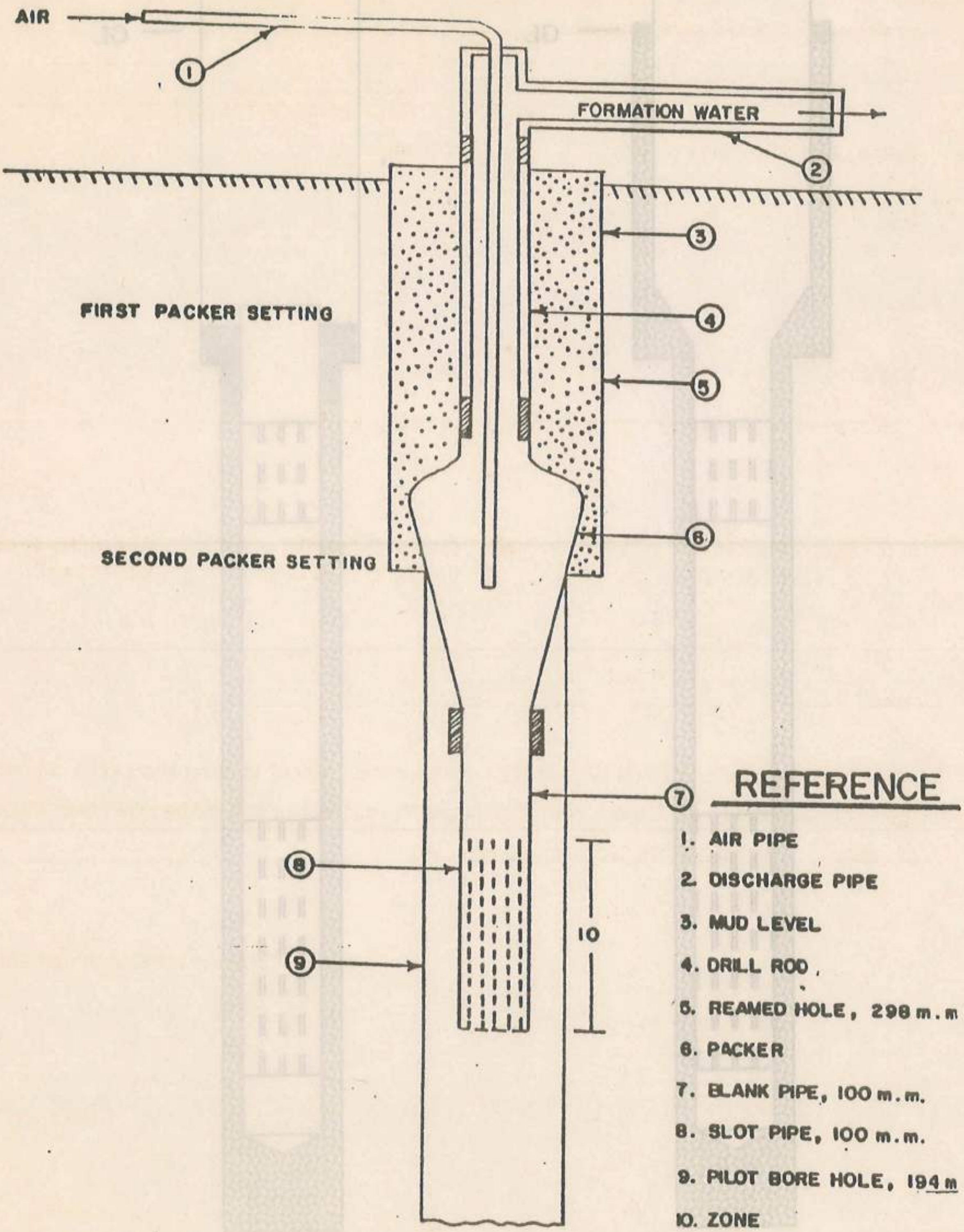


Plate 3 DRILL STEM TEST

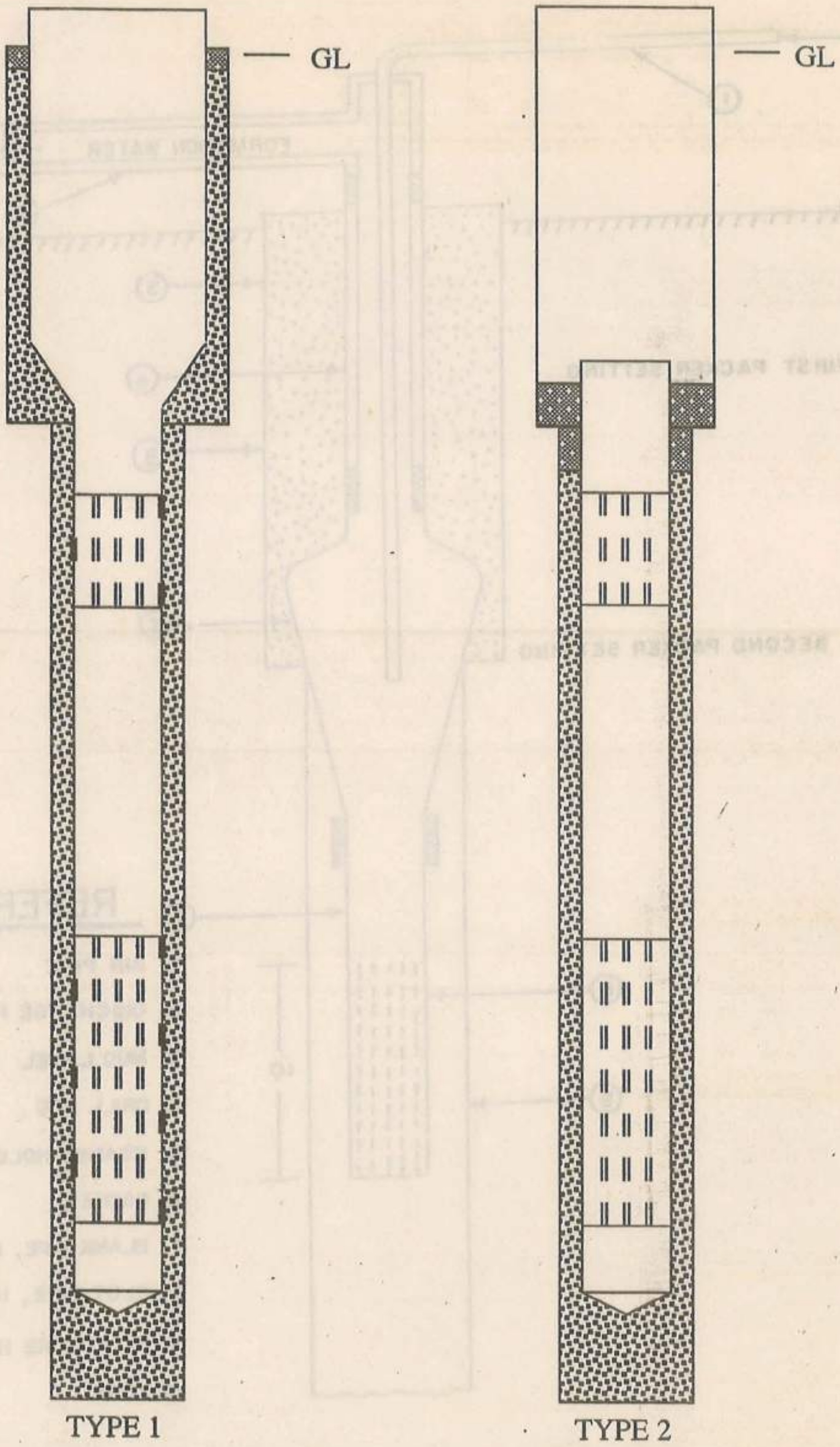


Plate 4 Well Designs: Soft Formation

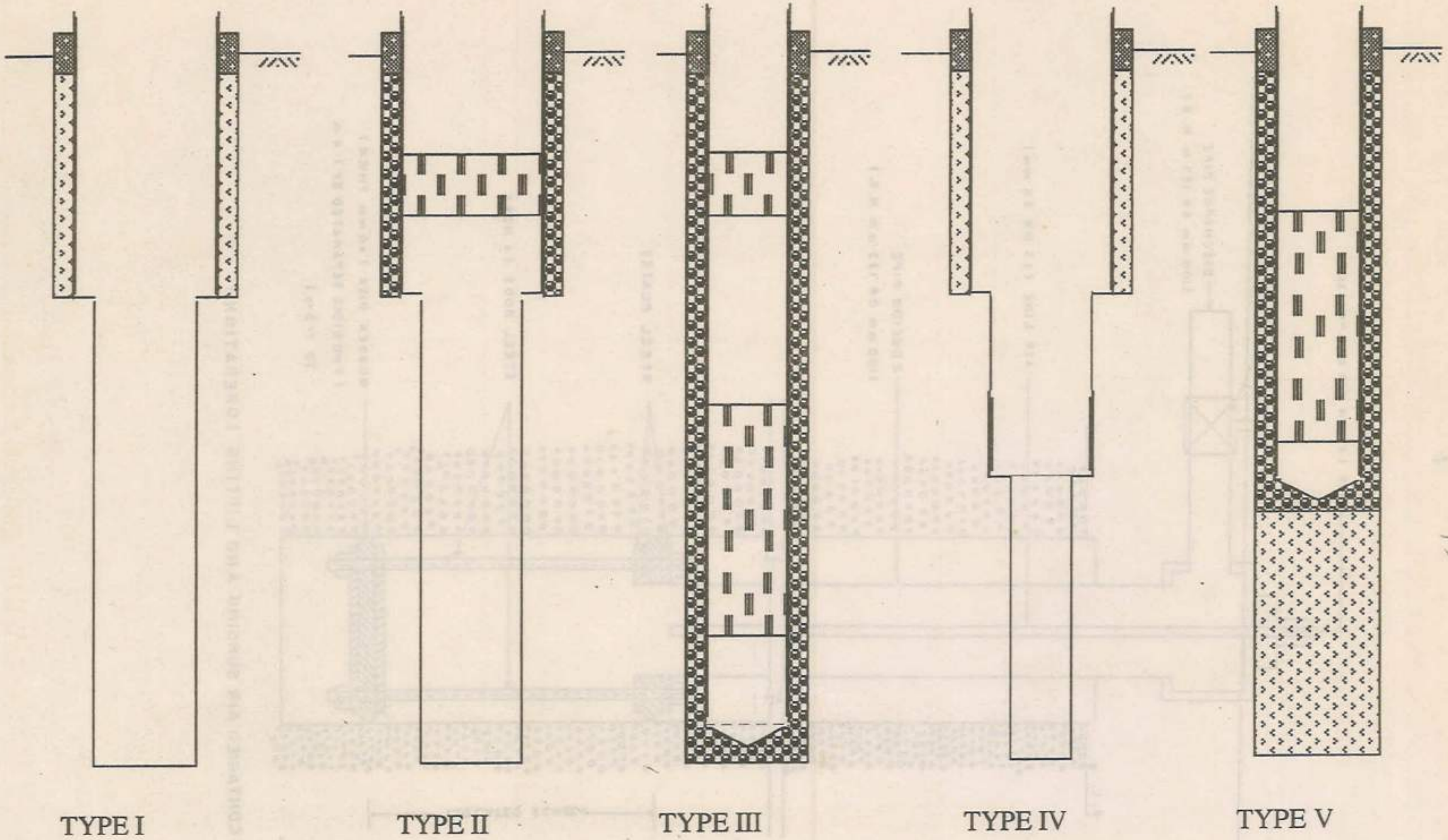


Plate 5 : Well Designs: Hard Formations

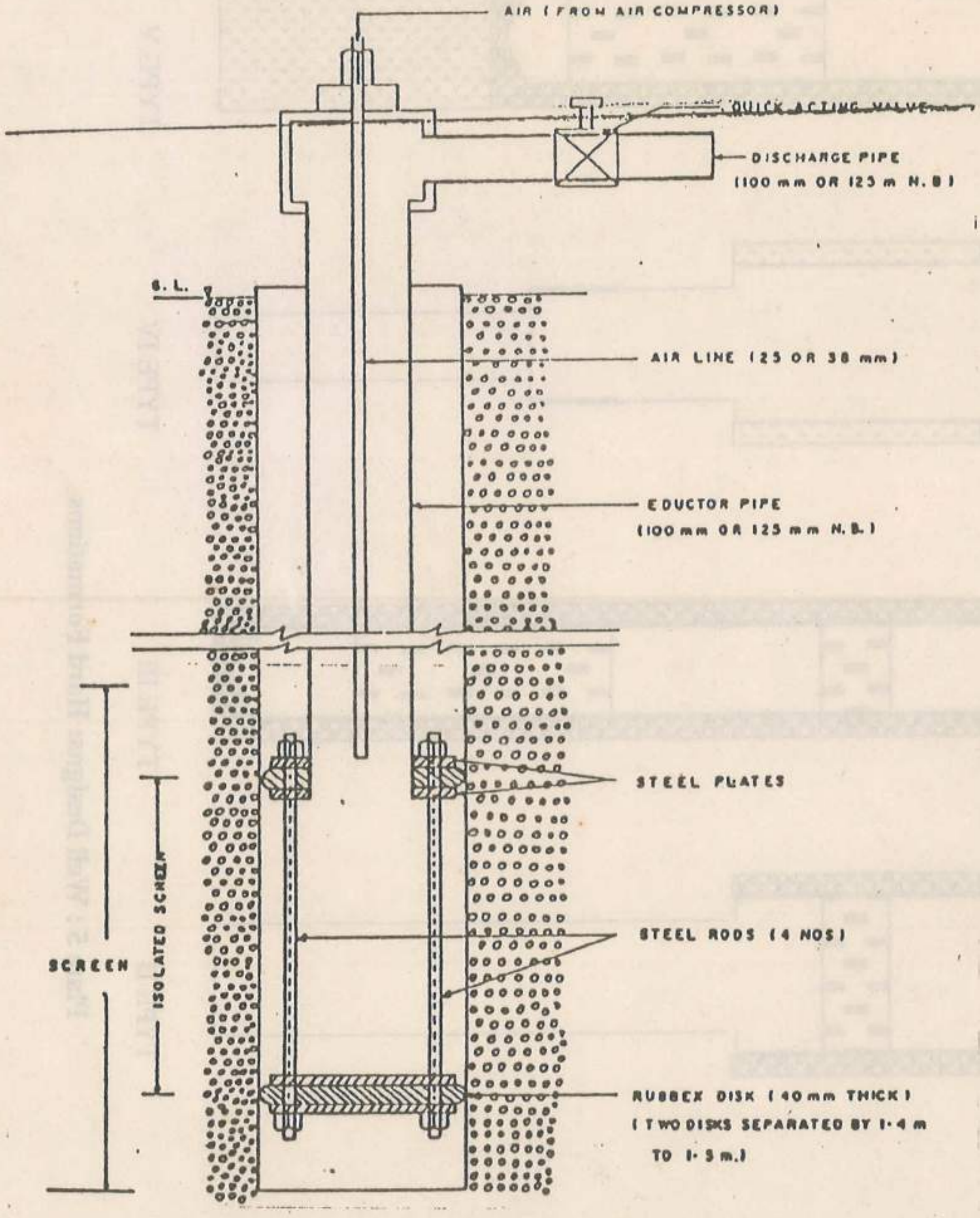


Plate 6 CONTAINED AIR SURGING AND LIFTING (OPERATION)

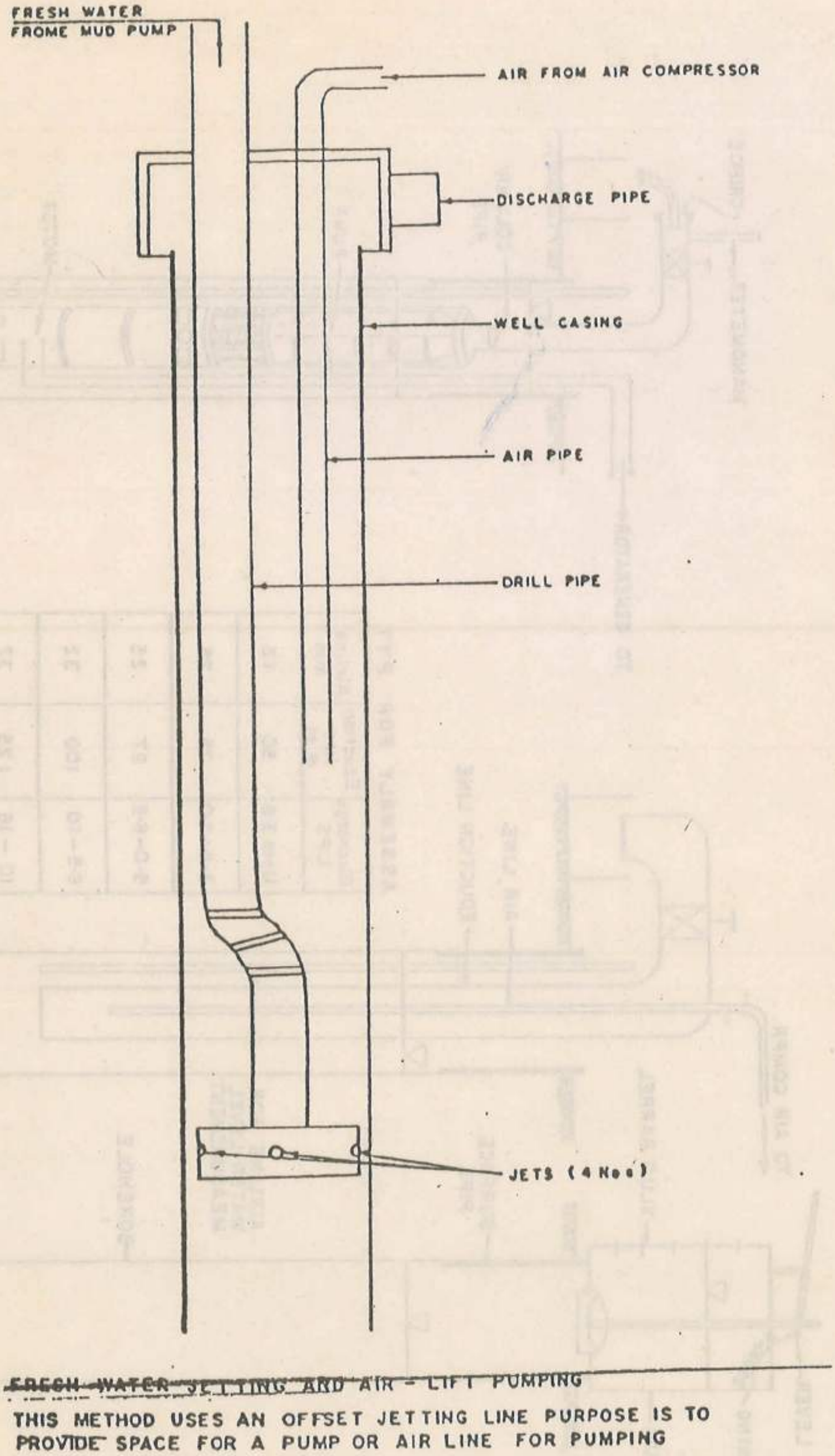
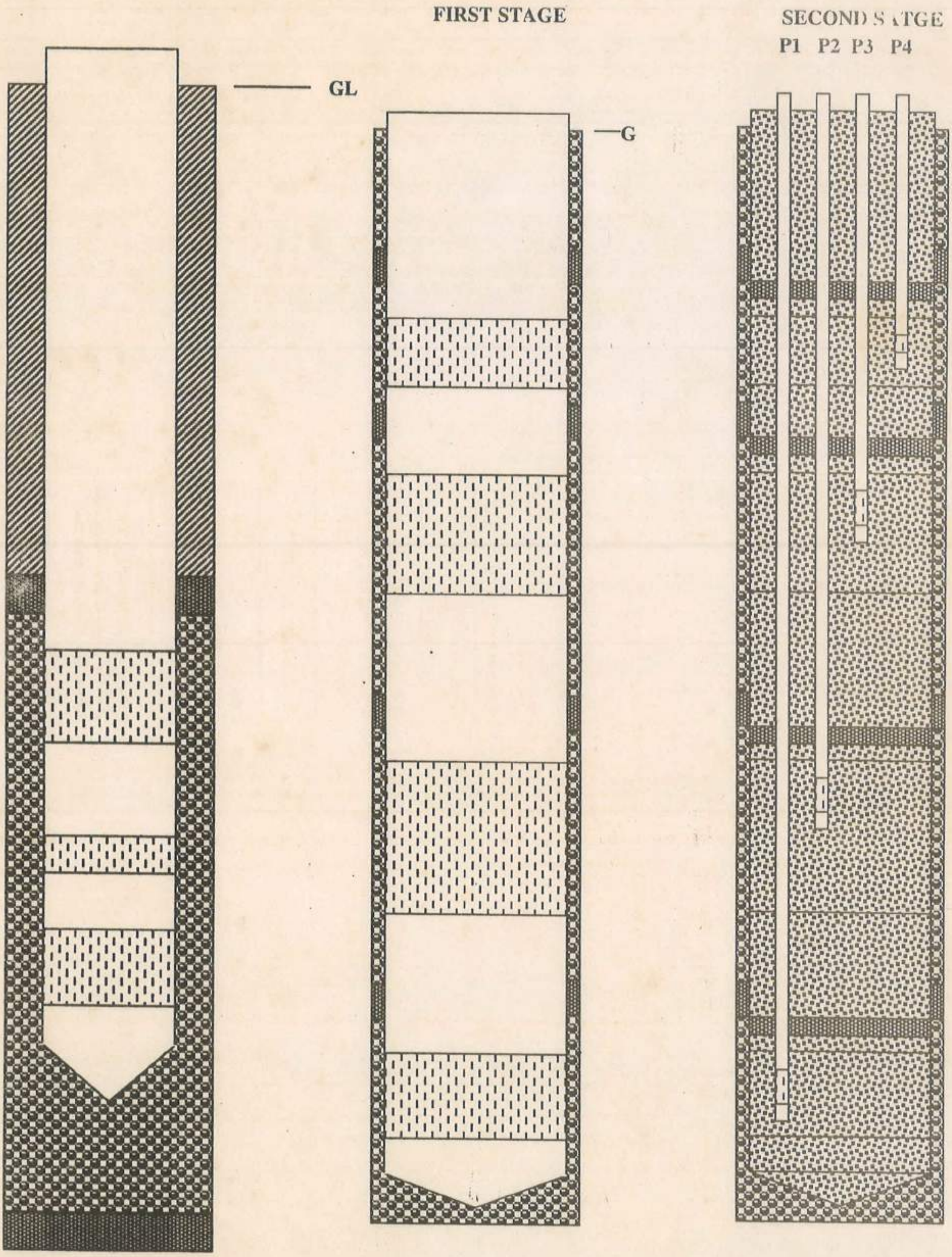


Plate 7 ~~FRESH WATER JETTING AND AIR~~ - LIFT PUMPING

THIS METHOD USES AN OFFSET JETTING LINE PURPOSE IS TO PROVIDE SPACE FOR A PUMP OR AIR LINE FOR PUMPING



OBSERVATION WELL **PLATE 9** **PIEZOMETER NEST**