

PREPARATION OF VILLAGE LEVEL AQUIFER MANAGEMENT PLAN

INTRODUCTION

Groundwater is one of the sources to meet up the requirement for agriculture, domestic water supplies and industrial water needs. In India, the use of ground water has been unhindered mainly because of its wide spread availability and the ease with which it would be developed. However the relative water scarcity and quality hazards of groundwater are being noticed in many parts of the country which need close monitoring in order to plan suitable management strategy. A reliable data base for optimal ground water is required to understand the total picture of ground water condition of any area.

Groundwater occurs below ground surface and the hydrogeological set up varies in different parts of country which control the ground water potentials. Ground water utilization basically depends upon both the hydrogeological situations and local demands. Based on the demand the cases of over-exploitation and associated problems occur.

Ground water is a replenishable each year and is the major source of water. The ground water development planning needs estimation of long term recharge. In these context historical records of ground water levels vis-a vis rainfall and other factors contributing to recharge assume paramount importance.

Fresh water constitute only 3% of the total water available on earth, out of which 2.15% remains in glaciers and ice caps and 0.05% is seen on the earth as surface water in the form of rivers and lakes. The remaining occurs as ground water.

It is well understood that ground water plays a vital role in sustainability of life for human settlement and agriculture economy. The ground water mainly occurs in weathered, fractured part of hard rock ,in the pore spaces of sand and gravel, called alluvium formation and also in sedimentary formation – these is called aquifer as a whole.

Large number of stakeholders is spread over in vast areas and they need to manage these aquifer system at local level may be village wise or a group of village wise or in small watershed basis.

The ground water is a community resource as such active role of community is essential to prevent depletion of water level in the aquifers, deterioration of water quality in the aquifers. By evolving common consensus in uses the demand of water can be assessed during the lean rain years.

The village community has traditionally been involved in managing water on self sustainable basis. Adequate knowledge about the extension aquifer, its water yielding capacity and quality and the vulnerability can be planned. Participation of the stakeholders in monitoring and management of groundwater may be a key towards of this precious resource in an area.

HYDROGEOLOGICAL CONCEPTS

What is groundwater?

When rain falls to the ground surface, some of it flows along the surface to form streams or lakes, some of it is used by plants, some evaporates and returns to the atmosphere, and some percolates into the ground. Imagine pouring a glass of water onto a pile of sand. Where does the water go? The water moves into the spaces between the particles of sand. In the similar fashion the portion of water percolates down below ground surface and form ground water.

Groundwater is water that is found underground in the cracks and spaces in soil, sand and rock. The portion of the area below ground surface where groundwater is stored in--and moves slowly through--layers of soil, sand and rocks called aquifers. Aquifers typically consist of gravel, sand, of different sizes or mixture of sand and gravel in alluvial areas. In hard rock areas weathered parts of rocks at shallow depth and fracture and joined parts at deeper depth form aquifers. These materials are permeable because they have large connected spaces that allow water to flow through. The speed at which groundwater flows depends on the size of the spaces in the soil or rock and how well the spaces are connected.

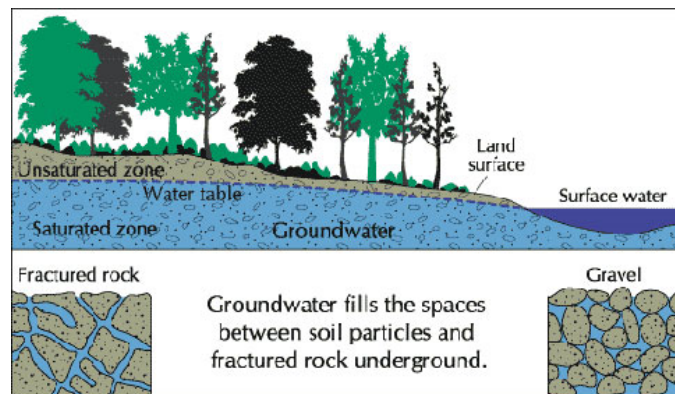


Image compliments of US Geological Survey, adapted by The Groundwater Foundation.

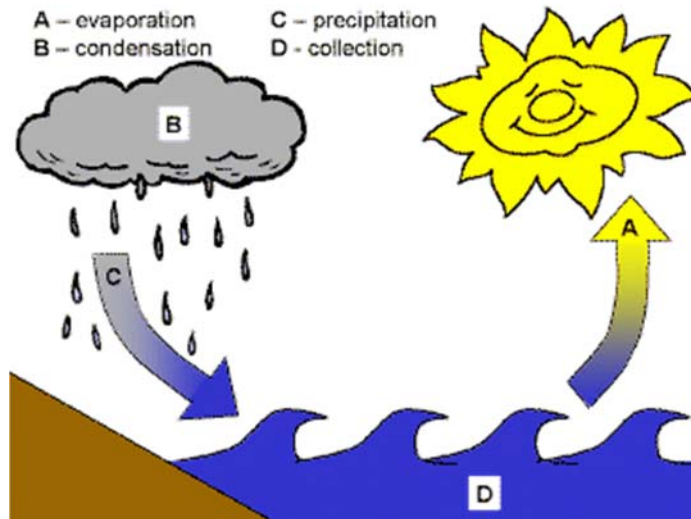
Water Cycle: The rain water falls on the surface some parts goes to sea through rivers and streams, and some percolates below, the water from sea evaporates and form clouds and during condensation it reaches to surface as rain. The process continues and what we call the "Water Cycle". This cycle is made up of a few main parts:

Evaporation (and transpiration)

Condensation

Precipitation

Collection/Accumulation



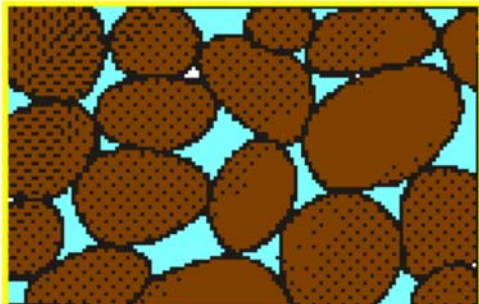
Porosity: Porosity is defined as the ratio of volume of void spaces to the total volume of the rock. It is expressed as a ratio or percentage

Porosity can be divided into two broad categories:

Primary Porosity: The porosity forms during formation of soil zone, sand layer and gravel layer.

Secondary Porosity: The porosity forms due to weathering, fracturing jointing after formation of rocks.

Primary Porosity

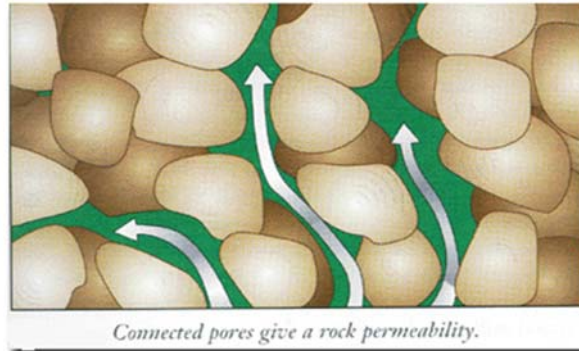


Secondary Porosity



Permeability : Expressed as a co-efficient ie the rate volume of water that will move in unit time under a unit hydraulic gradient through a unit area measured at right

angles to the direction of flow. Recently the term hydraulic conductivity is being widely used in preference of permeability. The unit is m/day.



Specific yield: The capacity of a saturated rock to drain water under the force of gravity is termed as specific yield. It is expressed as the percentage volume of water yielded by draining a saturated rock to its total volume.

Water Bearing Formations

The water bearing properties of various geological formations can be classified on the basis of their hydraulic properties. The best known classification is based on rock porosity and permeability is as follows:

AQUIFER: - An aquifer is defined as a saturated geological formation that is permeable enough to yield significant quantities of water to wells and springs. Thus, a porous and permeable water bearing formation is called an *aquifer*.

AQUICLUDE: - It is a saturated formation through which virtually no water is transmitted. Aquicludes may have high porosity but relatively have very low permeability and hence do not yield appreciable quantities of water to wells. In other words, a highly porous and an impervious (that does not transmit water at all) geological formation is called an *aquiclude* e.g. clay and shale.

AQUITARD:- Aquitard is a saturated formation that has low permeability and yields water slowly in comparison to the adjoining aquifers. In other words, aquitards are rock layers that are partly impervious and transmit water at a lower rate than aquifer (e.g.) sandy clay. Most aquitards do yield some water but usually not enough to meet even the modest demand.

AQUIFUGE :- It is a formation which is neither porous nor permeable and hence neither stores nor transmits water (e.g.) massive igneous and sedimentary rocks (compact limestone).

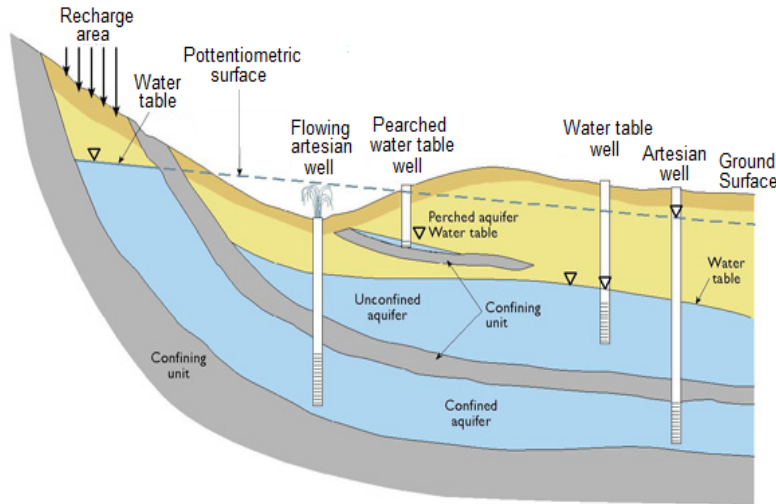
AQUIFER	Saturated, Porous & Permeable Storage capacity Water holding and yielding
AQUICUDE	Saturated Porous & impermeable Storage capacity Water holding but not yielding
AQUITARD	Saturated Porous & Semi-permeable Storage capacity Only seepage is possible
AQUIFUGE	Non-saturated Non-porous & Non-permeable (impervious/impermeable) No storage capacity

Types of Aquifers

A further classification of aquifers in an area can be made on the basis of their location in the ground water basin, and the position of their associated water levels. Aquifers are of three types: a) Unconfined b) Confined

Unconfined Aquifers:

An unconfined aquifer is not overlain by any confining layer but it has a confining layer at the bottom. The upper surface is defined by the water table and it is in direct contact with the atmosphere. Water in a well penetrating an unconfined aquifer is under atmospheric pressure and therefore does not rise above the water table. The water table in unconfined aquifers is often termed as phreatic water level.



Schematic Cross-sections of Aquifer Types

Confined Aquifers

A confined aquifer is bounded above and below by an aquiclude, which is impermeable to water flow. It has an overlying confining layer. Water in the confined aquifer occurs under pressure, which is usually more than the atmospheric pressure, so that if a well taps the aquifer, the water level will rise above the top of the aquifer i.e. above the base of the overlying confining bed. It will rise up to an elevation at which it is in balance with the atmospheric pressure. If this elevation is greater than that of the land surface at the well, the water will flow from the well and such wells are termed *artesian* or *flowing wells*.

Ground water Extraction Structures: In India different ground water abstraction structures e.g. Dug well, tube wells/ bore wells and springs are in use mainly on the basis of utility (domestic, agriculture, industry).

The type of structure and its construction depends on local condition like geomorphology, water level, yield and uses. Besides availability of equipments/ drilling machine, water requirement, financial aspects are factors for deciding type of structures.

Dug wells are generally circular in shape, but rectangular, square are not uncommon in some areas. They may range from 1 to 10 meter diameter and a few meter to over 100 m depth, depending on the depth of the water table.

Shallow bore wells are excavated by hand or power augers, in unconsolidated formation. They are generally less than 15 meter deep, but sometimes with power augers it can be drilled up to 100 m. usually smaller in diameter

Drilled wells are large in diameter, and constructed by using drilling rigs. Lakhs of tube wells more than 100 m depth have been constructed in the Indo-Gangetic plain and coastal areas of the country. In hard rock terrain millions of bore wells have been drilled, depth varies from 40 to 200 meter in general and sometimes more.

GROUND WATER DEVELOPMENT IN INDIA

Of late, ground water investigation and development have gained momentum not only in our country but also the World over to cope with the increasing demand for fresh water resources due to the population explosion and the corresponding industrial and agricultural growth. The unregulated ground water development in some parts of the country has resulted over exploitation, while in some areas the introduction of canal irrigation has led to water logging and salinity conditions.

The ground water development in areas underlain by fissured rocks in the country has been restricted till recently to only dug wells. The advent of DTH drilling rigs introduced construction of deep bore wells down 200 m or more in recent times.

Ground water development from the aquifers occurring within 300m in some of the areas underlain by porous formation is going on at an accelerated rate to meet various demands. The Central Ground Water Board has undertaken exploration down to a depth of 600m, and in some areas down to 750 m to assess the ground water potential of the deeper aquifers for future requirements.

Ground water development has some constraints of a special characters in certain in certain tracts which are broadly classified as under:

- a) Piedmont zone,
 - b) Fringe sediments zone.
 - c) Coastal/ Deltaic tract
 - d) Arid tract
 - e) Water logged area.
- a) Piedmont zone : The zone constitute recharge belt of Indo-Ganga - Brahmaputra valley happen to have large ground water storage, but the construction of tube wells involve hazards of penetration through hard boulders and high lifts due to the deep water table. These factors contribute directly to the well field economics.
- b) Fringe sediments zone: It represents the fringe zone between the peninsular shield and the alluvial basin, particularly in selected tracts of Uttar Pradesh, Haryana salinity hazards restrict ground water development. Withdrawals are to

be so regulated as not to create situations leading to contamination of fresh water by saline ground water.

- c) Coastal/ Deltaic tract : The unconsolidated deltaic and coastal sediments belonging to Quaternary and Upper Tertiary periods contain thick and regionally extensive aquifers which have prolific yield potential that can sustain deep, moderate to high capacity tube wells. Although enormous fresh ground water resource is identified in the extensive major deltaic and coastal tracts, particularly all along east coast, its development suffers heavily from the inherent salinity hazards.
- d) Arid tract : Though unconsolidated to semi consolidated porous formations have been found to have moderate to good yield potential at places, the low rainfall and high evapotranspiration in the region resulting in low recharge potential appear to act as a constraint to large scale development. Additional constraints exist in the form of saline water pockets in the adjoining areas often with high salinity of ground water at all levels. In this tract, in some of the areas of Gujarat, Rajasthan and Haryana, a critical stage of development reached.
- e) Water logged area: Areas with water table 0-2 m below ground level are classified as water logged and areas with water table 2 to 3 mbgl are categorized as prone to water logging. The intensive application of water for irrigation within canal command area has resulted in the rise of water table in localized parts of several States, particularly in Punjab, Haryana, Tamilnadu, Karnataka, Uttar Pradesh, Andhra Pradesh and Orissa.

GROUND WATER CONDITION IN DIFFERENT AQUIFER UNIT IN INDIA

The ground water behavior in India is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Studies carried out over the years have revealed that aquifer groups under alluvial / soft rocks even transcend the surface basin boundaries considering the geological set up of the aquifers are divided into depending on characteristically different hydraulic parameters of these formations viz. Porous Formation and Fissured Formation as described in the following paragraphs. Aquifer map of India is depicted in the Figure 1

Porous Formations: The Porous formations have been further subdivided into Unconsolidated and Semi – consolidated formations.

Unconsolidated Formations

The Quaternary formations comprising Recent alluvium, Older Alluvium (inland and coastal area are by and large the important unconsolidated formations that include potential aquifers. These sediments are essentially composed of clay, silt, sand, and gravel and sand and gravel zones form potential aquifer. The aquifer materials vary in particle size shape and in the degree of sorting and rounding of particles. Consequently, their water storing and yielding capabilities vary considerably and compaction of formation form most significant groundwater reservoirs. The piedmont zone of Himalayas is skirted by an artesian belt under free flowing conditions extending from Punjab to Western Uttar Pradesh. The hydrogeological environment and groundwater condition in the Indus, Ganga, Brahmputra basin indicate the existence of potential aquifers down to an explored depth of 750 m. Bestowed with high incidence of rainfall and these ground waste reservoir get replenished every year. Generally the shallow aquifers are unconfined, while the deeper aquifers are under Confined condition and yield varies from less than 10 to more than 40 lps.

In some places lenticular sedimentary formations are seen and thick sedimentary sequence down to 4000 m which shows a multi layered and multi quality aquifers. The thickness of sediments increases towards the downstream areas. In

general, ground water occurs here under unconfined to confined condition. Normally unconfined conditions prevail down to a substantial depth some times 100 m depth due to absence of persistent and thick confining clay beds. In coastal areas the fresh water and saline/brackish aquifer are separated by thick impervious clay layers. Deterioration of Ground water quality due to seawater ingress has been reported along the coastal tracts.

Semi-Consolidated Formations

The semi-consolidated formations chiefly consisting of shales, sandstones, siltstones, clays, carbonaceous sediments etc. Their water bearing and yield capacity varies widely due to lithological variations and degree of consolidation. The semi-consolidated sand and gravel horizons and weathered, fractured and friable sandstones in these formation form aquifer zone. The yield is generally restricted within 15lps.and also 25 to 30 lps in local pockets. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents forms some of the most productive aquifers. Tertiary sandstone also forms moderate aquifer wherever predominately arenaceous. Potential aquifers of these formations exhibit transmissivity from 100 upto 2000 m²/day. In selected tracts of northeastern India, these water-bearing formations are quite productive. The Upper Gondwanas, which are generally arenaceous, constitute prolific aquifers. Under favorable situations, these formations give rise to free flowing wells with 1to 2 lps free flow discharge. The potential semi-consolidated aquifers of Gondwanas and Tertiaries show transmissivity values from 100 to 1000 m²/day while hydraulic conductivity varies from 4 to 70m/day.

Fissured Formations (Consolidated Formations)

The consolidated formations occupy almost two-third part of the country. The consolidated formations except vesicular volcanic rocks have negligible primary porosity. From the hydrogeological point of view, fissured rocks are broadly classified into four types viz. (1) Igneous and metamorphic rocks excluding volcanic and carbonate rocks, (2) Volcanic rocks, (3) consolidated sedimentary rocks excluding carbonate rocks and Carbonate rocks.

1. Igneous and Metamorphic Rocks Excluding Volcanic and Carbonate rocks.

The most common rock types are granites, gneisses, charnokites, khondalites, quartzites, schists and associated phyllites, slates, etc. These rocks

possess negligible primary porosity but attain porosity and permeability due to fracturing and weathering. Ground water yield also depends on rock type and possibly on the grade of metamorphism like granite gneiss, khondalite and biotite gneiss are better sources than that of charnokites. The various scientific tool used to in studies these rocks indicate existence of deeply weathered and fractured zones capable of yielding potential supplies of water to the well. The occurrence of groundwater in the fracture system has been identified in the depth span of 20 to 100 m and even up to 200m locally. In most of the granite gneiss terrain, the weathered residuum serves as effective groundwater repository. It has been noted that deeper fracture system are generally hydraulically connected with weathered residuum. The yield potential of the crystalline and meta sedimentary rocks show wide variation. The yield from the fractured rocks generally increases in the vicinity of structurally disturbed areas. The Transmissivity value of fractured rock aquifers vary from 25 to 500m²/day and the bulk hydraulic conductivity varies from 0.3 to 25m/day.

Volcanic rocks

The pre-dominant types of the volcanic rocks are the basaltic lava flows of Deccan Plateau. The Deccan Traps with its contrasting water bearing properties of different flow units controls ground water occurrence. The Deccan Traps have usually poor to moderate permeability depending on the presence of primary and secondary fractures. Aquifers are known to exist down to 200m bgl. The transmissivity values of Deccan trap aquifer vary from 25 m²/day to over 450 m²/day and bulk hydraulic conductivity varies from 0.05 to 15 m/day.

Consolidated Sedimentary Rocks

Consolidated sedimentary rocks occur in Cuddapahs, Vindhyan groups and their equivalents. The formations consist of conglomerates, sandstones, Limestone, shales, slates and quartzites. The presence of bedding planes, joints, contact zones and fractures controls the ground water occurrence, movement and their yield potential. They yield limited to moderate supplies wherever they are well. The transmissivity values range from 4 to 10 m²/day and the bulk Hydraulic conductivity range from 0.1 to 1.5 m/day. In the Cuddapah, Vindhyan and Bijawar group, the circulation of water creates solution cavities in the carbonate rocks (Limestone, marbles and dolomites) thereby increasing the permeability of the aquifers. The

solution activity leads to widely contrasting permeability within short distances. The bore wells in them pierced to a depth of 100m bgl yields in the range of 3 to 10 lps where as in the fractured and the karstified horizons they yield from 3 to 10 lps. The transmissivity values range from 10 to 1000 m²/day.

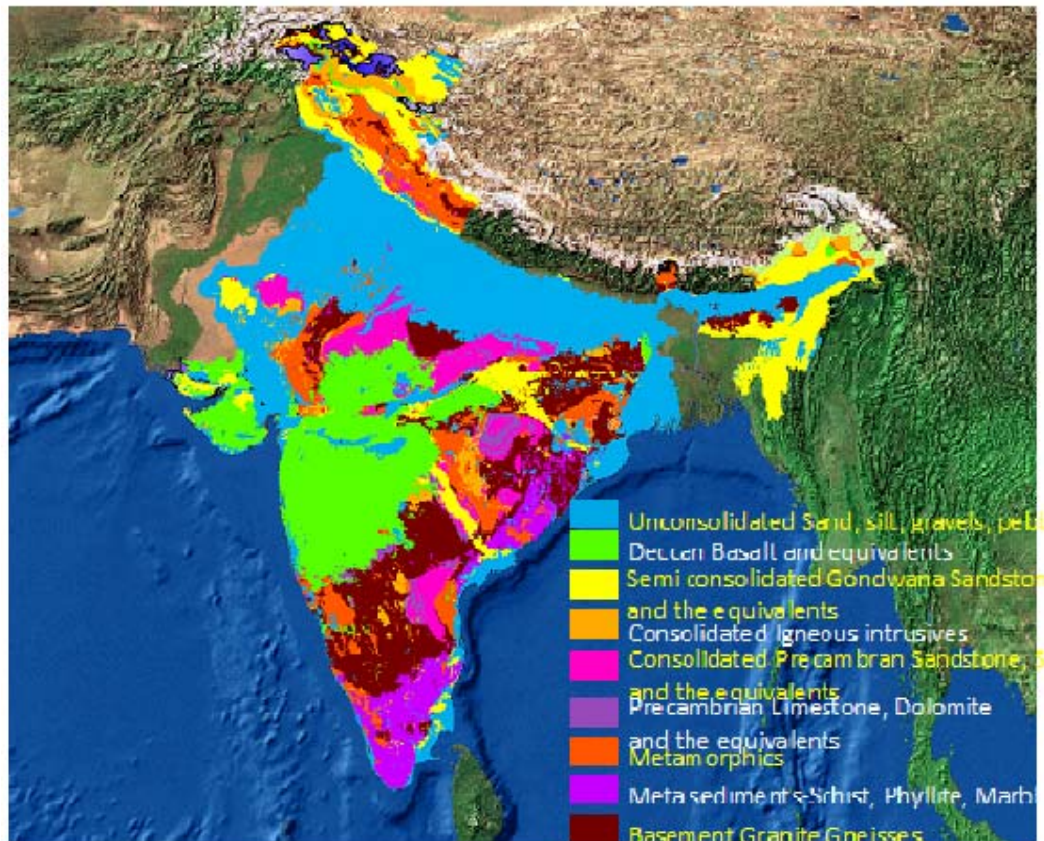


Figure 1

GROUND WATER REGIME MONITORING - SIGNIFICANCE

Ground water systems are dynamic in nature and adjust continuously to short term and long-term changes in climate, groundwater withdrawal and land use. The groundwater storage fluctuates in response to natural conditions as well as artificial conditions. The natural condition involves recharge from rainfall, discharge by evapo-transpiration and sub surface inflow/outflow.

Ground water meets the rural as well as urban particularly in alluvial areas including coastal tract drinking water needs of 80% of the population of the country and hence is vital in the day to day life of the population. To have a proper planning and management of this precious resource, the quantity and quality assessment is the pre requisite. This can be achieved by having precise data on the groundwater draft and recharge. Major part of groundwater draft is done in private sector without any regulation or control and hence quantification is a great challenge. On the recharge side the major source is the rain fall, a part of which infiltrates into the ground to form groundwater. The recharge depends on various factors viz. the intensity and frequency of rainfall and its quantity, the soil and geology of the area, slope, depth to groundwater and also land use pattern etc. which makes it complex. The change in ground water levels are the cumulative effects of the draft and recharge. Thus groundwater measurements are one of the important activities connected with ground water studies. Generally, water level measurements are carried-out from dug wells or from purpose-built piezometres (observation bore wells or tube wells). Ground-water-level data are used to quantify aquifer recharge, as a calibration tool for ground-water models, and to support water-quality investigations.

The ground water occurs in pore spaces of granular soil/lithological formation and in fractures and the same is replenishable in each year and also it flows to lower level through aquifer zones therefore it is under dynamic condition and fluctuates. The aim of ground water level monitoring is as below:

- a. To understand an overview about the ground water regime. This gives very good idea on water scarcity, water logging or to find out any changes in water level.
- b. To understand about the natural recharge/withdrawal and seasonal fluctuation.

- c. To demarcate the area falling under semi-critical, critical and overexploited due to massive withdrawal.
- d. Delineation of the area where ground water augmentation is required/ possible through artificial methods.
- e. Selection of pump type and its depth of lowering.

With the above aims and objectives, there is provision to monitor the water level four times in a year and collection of water samples once (April/May) once in a year through different ground water abstraction structures as above monitoring of ground water regime is an effort to obtain information on ground water levels and chemical quality. The monitoring gives an idea on anthropogenic influences pumpage from the aquifer, recharge due to irrigation systems and other practices like waste disposal etc.

The database generated through regime monitoring forms the basis for planning the ground water development and management programme. The ground water level and quality monitoring is of particular importance in coastal as well inland saline environment to assess the changes in salt water/fresh water interface as also the gradual quality changes in the fresh ground water regime. This data is used for assessment of ground water resources and changes in the regime consequent to various development and management activities.

METHODOLOGY:

It is essential to know about the type and condition of ground water abstraction structures from which water level would be recorded. There are some important criteria to fix the well as observation well which are sometimes mentioned as recording station

1. The well should be in use and have regular withdrawal.
2. It must be representative for the general geomorphic set up prevailing in the area.

FREQUENCY OF MEASUREMENT

The frequency of measurement is one of the most important considerations in designing of a water level and water quality monitoring programme. The development of a plan for monitoring is dependent on the objectives of the programme. The frequency of measurement should be adequate to detect short term

and seasonal groundwater level fluctuation of interest and to discriminate between the effects of short and long term hydrologic stresses. The frequency of measurement is also dependent on several factors like aquifer type and position, groundwater flow and recharge rate, status of development and climatic conditions.

Water levels measurements are carried out for a number of reasons including:

- estimating the average piezometric head,
- computing groundwater resource availability,
- design of groundwater management structures,
- Identify the short-term changes due to pumping, tidal effects, isostatic changes, tides, etc.,
- Ground-water investigations for specific purposes.
- To have a background information against which future changes can be suggested.
- To have an early tracing system for both quality and quantity variation.
- To study inter relationship between ground water and climatic parameters such as rainfall.
- To evaluate the impact of surface water irrigation system on groundwater regime.
- To study the influence of geology, geomorphology and land use on ground water regime.
- To understand the role of groundwater in hydrological cycle and influence of recharge/discharge on ground water storage.
- To study the hydrochemical behaviour of groundwater.
- To study the temperature variation of ground water in space and time

Important Groundwater Records for fixing observation well.

- Name of Well (Village) , Type of Well : Dug well/ Tube-well
- Location of Well/ District/ Block Name
- Toposheet No.
- Date & Time of Measurement

- Depth to Water level (Meter Below Ground level)
- Elevation of Ground Surface (Meter Above Ground level)
- Height of measuring point.(Meter)
- Monitoring well Status (pumping/non-pumping) and surrounding condition that might effect.

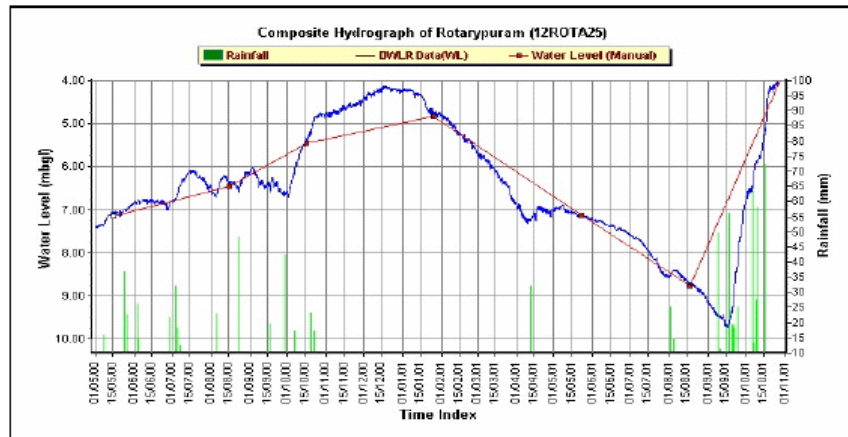
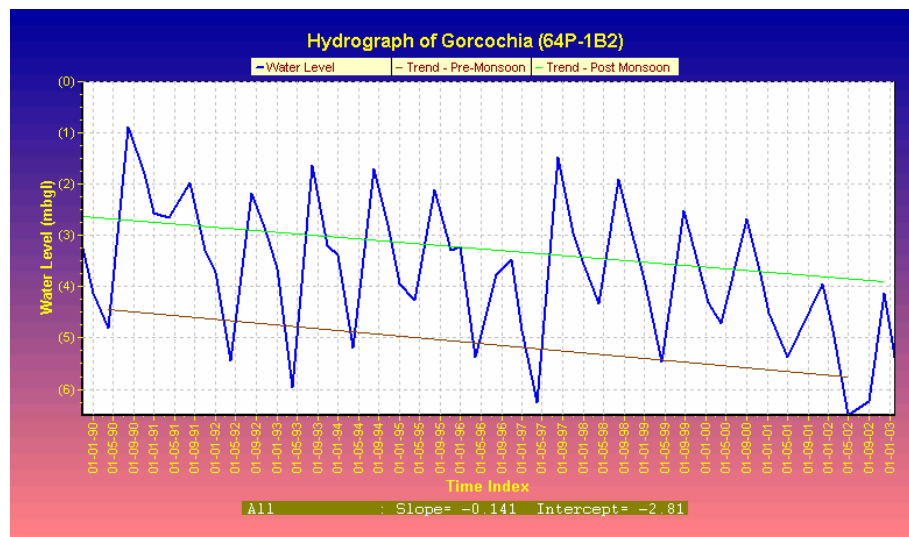


Figure -2 Hydrograph comparing the water level data emerging from continuous monitoring (every six hours) with seasonal monitoring (4 measurements/ year).



TYPICAL HYDROGRAPH

GROUNDWATER QUALITY

Due to growth of population, urbanisation, industrialisation and agricultural activities ground water resources are under stress. There is growing concern on the deterioration of ground water quality due to geogenic and anthropogenic activities.

The International Standard Organisation (ISO) has defined monitoring as “the programmed process of samplings, measurements and subsequent recording or signalling or both, of various water characteristics, often with the aim of assessing conformity to specified objectives

CHEMICAL CONSTITUENTS OF GROUND WATER

Sodium (Na): is widely distributed in soils, plants, water and foods. Most of the of sodium-containing minerals is sodium chloride (salt). Sodium is often naturally found in groundwater. In water, sodium has no smell but it can be tasted by most people at concentrations of 200 milligrams per litre (mg/L) or more. All groundwater contains some sodium because most rocks and soils contain sodium compounds from which sodium is easily dissolved. The most common sources of elevated sodium levels in ground water are:

- Erosion of salt deposits and sodium bearing rock minerals
- Naturally occurring brackish water of some aquifers
- Salt water intrusion into wells in coastal areas
- Infiltration of surface water contaminated by road salt
- Irrigation and precipitation leaching through soils high in sodium
- Groundwater pollution by sewage effluent
- Infiltration of leachate from landfills or industrial sites.

Potassium (K) is an element commonly found in soils and rocks. In water, potassium has no smell or colour, but may give water a salty taste. Sources of potassium include

- weathering and erosion of potassium-bearing minerals, such as feldspar
- leaching of fertilizer.
- sea water, in areas susceptible to saltwater intrusion

Calcium (Ca): It enters the freshwater system through the weathering of rocks, especially limestone (marble, calcite, dolomite, gypsum, fluorite and apatite also contribute) and from the soil through seepage, leaching and runoff. Surface water generally contains lower concentrations of calcium than groundwater. Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+} ions. Magnesium is the other hardness determinant.

Magnesium (Mg): Magnesium may contribute undesirable tastes to drinking water. Sensitive people may find the taste unpleasant at 100 mg/L. The average person finds the taste unpleasant at about 500 mg/L. Magnesium in drinking water may have a laxative effect, particularly with magnesium sulphate concentrations above 700 mg/L.

Carbonate & Bicarbonate: The primary source of carbonate and bicarbonate ions in ground water is the dissolved carbon dioxide in rain and snow, which as enters the soil dissolves more carbon dioxide. Decay of organic matters also releases carbon dioxide for dissolution. The pH of water indicate the form in which carbon dioxide is present in water. Under usual condition bicarbonate may range from 100 to 800 ppm in ground water.

Sulphate: The sulphur content in atmospheric precipitation is only about 2 ppm, but wide range in sulphate content is made possible in ground water through oxidation, precipitation, solution and concentration as water traverses through rocks. The primary source of sulphur is the sulphide minerals present in igneous and metamorphic rocks and gypsum & anhydrides present in sedimentary rocks. Apart from that application of fertilizer and soil conditioner also plays great role in its abundance in ground water. Reduction of sulphate by bacteria and precipitation of gypsum may also cause the removal of sulphate from ground water.

Chloride: It is an important entity in ground water, though its presence in crustal rocks is insignificant. However processes like evaporation, repeated evaporation and dissolution of salts, contact with evaporitic bodies, presence of entrapped water during sedimentation and sea water intrusion are few processes responsible for the high content of chloride in ground water. Chloride salts are highly soluble and free from chemical reaction with minerals of the reservoir rock and remains in sodium

chloride form. Calcium and magnesium chloride rich ground water are quite rare. Abnormal concentration may due to sewage and industrial wastes.

Nitrate: Nitrate is a very minor constituent of rocks, but is a major constituent in the atmosphere. The average concentration of nitrate in rain water is only 0.2ppm and hence its average concentration in ground water remains below 5 ppm. So the main contribution of nitrate comes from decaying of organic matters, sewage wastes and the application of fertilizers. As such high concentration of nitrate is found in localized areas.

Drinking Water Standard

Water quality standards were developed by health authorities and sanitary engineers when the relationship between water borne diseases and drinking water was established. In 1983–1984 and in 1993–1997, the World Health Organization (WHO) published the first and second editions of the Guidelines for Drinking-water Quality. WHO Guidelines for Drinking Water Quality-2004 is the most recent one.

Indian standard drinking water specifications were first prepared in 1983 by the Bureau of Indian Standards (BIS) with an objective to assess the quality of drinking water and to check the effectiveness of water treatment and supply. These standards are reviewed and modified periodically. In 2009, the BIS proposed the second revision of the drinking water standards (IS 10500 (2009)). The standard mentions the acceptable limit and indicates its background. It recommends implementing the 'acceptable limit'.

Sl No	Substance or Characteristics	Requirement (acceptable Limit)	Undesirable effect outside the acceptable limit	Permissible limit in the absence of alternative source
1	Colour, Hazen unit, Max	5	Consumers acceptance decreases	15
2	Odour	Agreeable	-	Agreeable
3	Taste	Agreeable		Agreeable
4	Turbidity, NTU, Max	1	Consumers acceptance decreases above 5	5
5	Dissolved solids, mg/l, Max	500	Beyond this palatability decreases and may cause gastro-intestinal irritation	2000
6	pH value	6.5 – 8.5	Beyond this the water will affect the mucous membrane and/or water supply system	No relaxation

7	Total Hardness (as CaCO ₃), mg/l, Max	200	Incrustation in water supply structure (scaling), excessive soap consumption, calcification of arteries	600
9	Calcium (Ca), mg/l, Max	75	Incrustation in water supply system and adverse effect on domestic use	200
10	Magnesium (Mg), mg/l, Max	30	Incrustation in water supply system and adverse effect on domestic use	No relaxation
11	Sodium (Na), mg/l, Max	No guideline	Harmful to persons suffering from cardiac, renal & circulatory disease	
12	Potassium (K), mg/l, Max	No guideline	An essential nutrient, but in excess is laxative	
13	Chloride (Cl), mg/l, Max	250	Taste, palatability, digestion are affected. Adverse to persons having heart & kidney disorder, cause corrosion	1000
14	Sulphate (SO ₄), mg/l, Max	200	Beyond this causes gastrointestinal irritation when Mg or Na is present	400
15	Nitrate (NO ₃), mg/l, Max	45	Causes Methaemoglobinemia in babies and indicative of pollution	No relaxation
	Fluoride (F), mg/l,	1.0	High fluoride causes fluorosis	1.5
16	Iron (Fe), mg/l, Max	0.3	Taste affected, stains clothes, promotes iron bacteria	No relaxation
17	Aluminum (Al), mg/l, Max	0.03	Cumulative effect causes dementia	0.2
18	Copper (Cu), mg/l, Max	0.05	Astringent taste, discolouration and corrosion of pipes, fittings & utensils	1.5
19	Manganese (Mn), mg/l, Max	0.1	Taste & appearance affected, adverse effect on domestic uses & water supply system	0.3
20	Zinc (Zn), mg/l, Max	5	Cause astringent taste and opalescence in water	15
21	Barium (Ba) mg/l, Max	0.7	May lead to cardiovascular problem	No relaxation
22	Silver (Ag), mg/l, Max	0.1	-	No relaxation
23	Selenium (Se), mg/l, Max	0.01	Beyond this water becomes toxic	No relaxation

24	Molybdenum (Mo), mg/l, Max	0.07	Cause osteoporosis or bone disorder	No relaxation
25	Boron (B), mg/l, Max	0.5	-	1.0
26	Residual free Chlorine, mg/l, Max	0.2	Excess free chlorine may cause asthma, colitis & eczema	No relaxation
27	Chromium (Cr ⁺⁶), mg/l, Max	0.05	May be carcinogenic above this limit	No relaxation
28	Arsenic (As), mg/l, Max	0.01	Beyond this water becomes toxic	0.05
29	Mercury (Hg), mg/l, Max	0.001	Beyond this water becomes toxic	No relaxation
30	Cadmium (Cd), mg/l, Max	0.003	Beyond this water becomes toxic	No relaxation
31	Lead (Pb), mg/l, Max	0.01	Beyond this water becomes toxic	No relaxation
32	Nickel (Ni), mg/l, Max	0.02	Beyond this water becomes toxic	No relaxation
33	Cyanide (CN), mg/l, Max	0.05	Beyond this water becomes toxic	No relaxation
34	Bromoform, mg/l, Max	0.1	May be carcinogenic	No relaxation

In the present system monitoring of water quality is done by analysing water samples collected from dug wells/ tube wells tapped mostly the phreatic aquifer.

But due to deterioration of water quality and the purpose of present study it is suggested the water samples are to be collected from different group of aquifers i.e shallow, intermediate and deeper aquifers, to find out the quality of groundwater when the aquifers are under stress condition. This process of continuous monitoring of water quality will create a background data bank of different chemical constituent in ground water and also help to compare with the earlier data, to set up the frequency of sampling and location of sampling.

The location of monitoring stations and number of monitoring wells and frequency of sampling are very important aspect. Because of slow rate of ground water movement ground water quality does not normally change rapidly in space and time. However in case of unconfined aquifers changes in quality is faster as compared to confined aquifer.

Collection of Water samples from tube wells/ Piezometer : Quality monitoring from shallow piezometers will lead to study the effect of leaching of nitrogen nutrients

from soil to ground water, the effect of operational landfills like NCT Delhi, for high concentration of heavy metals, pesticide uses on agricultural crops, mining activity. Monitoring of second or third group or deeper aquifers may give an idea to study the geogenic source of pollution or free from pollution.

Sampling in these piezometers will be done by lowering a sampling device (known as bailer or grab or depth sampler) into the piezometer allowing filling with water at a known depth before closing and retrieving to the surface for transfer of the water sample to sample bottle.

Based on the existing data base of CGWB and initial field study in the pilot project area the number of sampling location and sampling frequency may be increased in the hot spot/ vulnerable areas (in the areas where industrial growth and urban growth has taken place extensively) to find out the anthropogenic and bacteriological contamination in ground water.

Treatment Methods

Parameter	Treatment Methods
Turbidity	Cloth filtration
	Slow sand filtration
	Coagulation
	Candle filtration
Odour	Aeration
	Carbon Filtering using Charcoal
	Boiling
Colour	Carbon Filtering using Charcoal
	Slow sand filtration
Fluoride	Activated Alumina Technology
	Nalgonda Technique
Ammonia	Chlorination
	Boiling
Iron	Oxidation & Setting.
Hardness	Boiling & Setting/ Filtration
Chloride	Reverse Osmosis
Arsenic	Ion exchange. Alum Iron Coagulation

Gram Mitra for monitoring : An example of water quality Monitoring

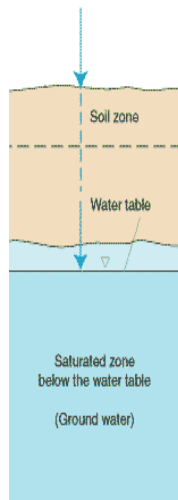
To strengthen the village level water quality monitoring, teams by the name of Gram Mitra are being involved in the villages across Gujarat. Training is organized at the block level in coordination with the Government of Gujarat, block level functionaries with the support of NGOs. As hands on exercise, the Gram Mitras are asked to get one sample from a drinking water source in the village along with the sanitary survey of that source. During the training the testing of these samples link between the sanitary situation around the source and the quality of water is established. These Gram Mitras undertake monitoring of water sources in villages across the state and also spear awareness on ways and means to keep surroundings of water sources clean.

GROUND WATER RECHARGE PROCESSES

Precipitation is the most important and major component of recharge to Ground Water. The major types of precipitation are drizzle, rain, snow and hail. The areal distribution of rainfall in a basin for a given storm or period is expressed in terms of *Isohyets* which are drawn by joining points of equal precipitation in an area.

Infiltration is the process of absorption of water from rainfall or other surface water bodies into the ground.

The water absorbed in the soil infiltrates downward through openings in rocks. A part of this water remains just below the land surface and forms the soil moisture which sustains the plant life. The remaining water moves down (percolates) through a zone which is partly filled with water called the zone of aeration (vadose zone) till it reaches a zone which is totally saturated i.e. all the interstices (openings) are filled with water (zone of saturation) and here it gets stored. Water within the ground moves downward through the unsaturated zone under the action of gravity, whereas in the saturated zone it moves in a direction determined by the surrounding hydraulic situation.



The subsurface occurrence of ground water may be divided into zones of aeration and saturation. The zone of aeration consists of interstices occupied partially by water and partially by air. In the zone of saturation, all interstices are filled with water under hydrostatic pressure. In the zone of aeration vadose water occurs. This vadose zone may further be divided into soil water zone, intermediate vadose zone and capillary zone. In soil water zone, water exists at less than saturation

except temporarily when excessive water reaches the ground surface as from rainfall or irrigation. Part of the pores is filled with water and part with air. Nonmoving vadose water is held in place by hygroscopic and capillary forces. The capillary zone (or capillary fringe) extends from the water table up to the limit of capillary rise of water. The pore spaces can be visualized as capillary tubes. The thickness of the capillary fringe may vary from negligible thickness to a few meters.

A number of things can impair the process of groundwater recharge. If groundwater supplies is over utilized, recharging may not make up the huge quantity of which is taken outward for the water table will be lowered also when a considerable part of the aquifer is dried up due to huge withdrawal of ground water, the dried part of the aquifer becomes filled up with air which may not allow the water to be stored within the dried up portion of the aquifer. As the water table drops, wells may go dry. Salts can also build up in the soil as the flushing action of water is taken away. Human activities such as different construction and water logging due to excessive use of surface water can also impair groundwater recharge by preventing water from entering the ground at all.

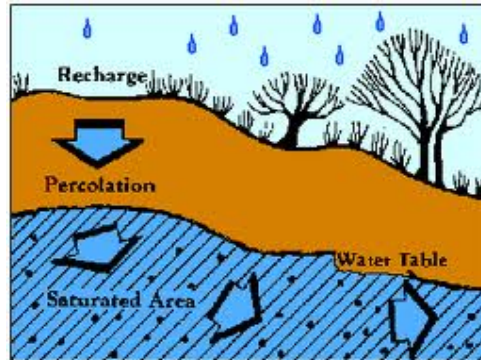
As concerns about water resources have grown around the world, many communities have begun to address the issue of groundwater recharge. Some communities have taken small steps to increase the amount of water which flows back underground, such as using permeable pavement which allows water to trickle down underground, rather than allowing water to pool on the surface and evaporate.

The groundwater table, usually called the water table, is the depth below ground surface at which the ground becomes saturated, or filled to maximum capacity, with water. When water reaches the surface of the earth, either through rain, flooding, or some other means, the water begins to infiltrate, or pass into, the ground. The subsurface water trickles downward through pores in rocks and soil until it reaches a point where all available spaces are full. Though the term is often used loosely, groundwater technically refers only to water at or below this level. In this way, the groundwater table can be thought of as the top surface of groundwater.

The ground can be divided into two parts: the unsaturated zone that lies above the groundwater table and the saturated zone that lies below the water table. The subsurface water that travels through the top six to ten feet (1.83-3.05 meters) of the ground nourishes the roots of plants and is called *soil water*. As the subsurface water travels downward past the roots in the unsaturated zone, it becomes known as vadose water. Vadose water makes its way down to the saturated zone through

pores, or small holes, in rock and sediment until it reaches the water table and becomes groundwater.

Recharge area: Area of land allowing water to pass through it into an aquifer by surface infiltration.



Rainfall is the principal source of ground water which accumulates in the aquifer. Apart from this, recharge from other sources like canal seepage, recharge from tanks & Ponds, Surface water bodies etc and return flow from irrigation also contribute to the groundwater recharge. Groundwater resource comprises two parts – Dynamic resource and Static Ground Water resource.

Dynamic ground water resource occurs within the zone of water level fluctuation and reflects seasonal recharge & discharge of aquifers.

Static ground water resource occurs below the water level fluctuation zone and it remains perennially saturated except in the areas of over exploitation or ground water mining etc.

Ground water resources of India

Central Ground Water Board monitor network observation well all over the country and water level data are collected. Different State Ground Water Department or other related State departments also monitor observation wells for the same purpose and assessment of dynamic ground water resources is being taken up at an interval of 3 to 4 years. The stage of development of each assessment unit is worked out based on annual recharge from all sources and draft for all uses eg. Irrigation, drinking and industries etc.

The time series water level data of observation well are plotted to find the trend of water levels whether rising or falling. Based on the water level trend and stage of development the blocks are categorized as over exploited, critical, semi critical and safe.

The overall assessment of resources reveal that out of 5842 numbers of assessed administrative units (Blocks/Taluks/Mandals), 802 units are categorized as Over-exploited, 169 units as Critical, 523 units are Semi-critical, and 4277 units are categorized Safe. Apart from these unites, there are 71 units observed completely saline.

The ground water resources of the country have been estimated for freshwater based on the guidelines and recommendations of the GEC-97. The total Annual Replenishable ground water resources of the country have been estimated (in 2009) as 431 billion cubic meter (BCM). Keeping 35 BCM for natural discharge, the net annual ground water availability for the entire country is 396BCM. The Annual ground water draft is 243 BCM out of which 221 BCM is for irrigation use and 22 BCM is for domestic & industrial use.

QUALITY HAZARD & POLLUTION

Groundwater plays is the major source of drinking water for millions of rural and urban families.. According to some estimates, it accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs in India. Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies. Also, the natural impurities in rainwater, which replenishes groundwater systems, get removed while infiltrating through soil strata. But, In India, where groundwater is used intensively for irrigation and industrial purposes. The use of pesticides, excessive chemical fertilizers and untreated industrial effluent discharge directly on the surface may pollute the ground water in a large way. Apart from these the geological formation in pockets sometimes may contain excessive fluoride, chromium etc which may pollute ground water in pockets.

Extent and Impacts of Groundwater Contamination and Pollution

The incidence of fluoride above permissible levels of 1.5ppm occur in 14 Indian states, namely, Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal affecting a total of 69 districts, according to some estimates. Some other estimates find that 65 per cent of India's villages are exposed to fluoride risk. Excessive concentrations are known to cause skeletal deformities.

Iron content above permissible level of 0.3 ppm is found in 23 districts from 4 states, namely, Bihar, Rajasthan, Tripura and West Bengal and coastal Orissa and parts of Agartala valley in Tripura.

High levels of arsenic above the permissible levels of 50 parts per billion (ppb) are found in the alluvial plains of Ganges covering 8 districts of West Bengal.

Presence of heavy metals in groundwater is found in 40 districts from 13 states, viz., Andhra Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, and five blocks of Delhi.

Non-point pollution caused by fertilizers and pesticides used in agriculture, often dispersed over large areas, is a great threat to fresh groundwater ecosystems. Intensive use of chemical fertilizers in farms and indiscriminate disposal of human

and animal waste on land result in leaching of the residual nitrate causing high nitrate concentrations in groundwater.

Nitrate concentration is above the permissible level of 45 ppm in 11 states, covering 95 districts and two blocks of Delhi and in many other densely populated areas in India.

DDT, BHC, carbamate, Endosulfan, etc. are the most common pesticides used in India. But, the vulnerability of groundwater to pesticide and fertilizer pollution is governed by soil texture, pattern of fertilizer and pesticide use, their degradation products, and total organic matter in the soil.

Pollution of groundwater due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters in India. A survey undertaken by Central Pollution Control Board identified 22 sites in 16 states of India as critical for groundwater pollution, the primary cause being industrial effluents. A recent survey undertaken by Centre for Science and Environment from eight places in Gujarat, Andhra Pradesh and Haryana reported traces of heavy metals such as lead, cadmium, zinc and mercury. Shallow aquifer in Ludhiana city, the only source of its drinking water, is polluted by a stream which receives effluents from 1300 industries.

Excessive withdrawal of groundwater from coastal aquifers has led to induced quality deterioration in the form of seawater intrusion in Katch and Saurashtra in Gujarat, Chennai in Tamil Nadu and Calicut in Kerala.

Mercury is reported to cause impairment of brain functions, neurological disorders, retardation of growth in children, abortion and disruption of the endocrine system, whereas pesticides are toxic or carcinogenic. Generally, pesticides damage the liver and nervous system

Arsenic contamination of drinking water causes a disease called arsenicosis, for which there is no effective treatment, though consumption of arsenic free water could help affected people at early stages of ailment to get rid of the symptoms of arsenic toxicity. Arsenic contamination is by far the biggest mass poisoning case in the world putting 20 million people from West Bengal

Issues in Tackling Groundwater Contamination and Pollution

The first step towards evolving measures to prevent and cure groundwater quality deterioration is generating reliable and accurate information through water quality monitoring (WQM) to understand the actual source/cause, type and level of contamination. However, there are a few observation stations in the country that cover all the essential parameters for water quality and hence the data obtained are not decisive on the water quality status.

Secondly, WQM involve expensive and sophisticated equipments that are difficult to operate and maintain and require substantial expertise in collecting, analyzing and managing data. The existing methodology for WQM is inadequate to identify the various sources of pollution. Integration of data on water quality with data on water supplies, which is very important from the point of view of assessing water availability for meeting various social, economic and environmental objectives, is hardly done. And finally, in the absence of any stringent norms on water quality testing, results can change across agencies depending on sampling procedure, time of testing, and testing in In Indian context, it is not economically viable to clean aquifers. In the case of arsenic, methods for *in situ* treatment have already been in use in developed countries. In the United States, zerovalent, iron permeable reactive barriers (PRBs) are used *in situ* to remove chromium and several chlorinated solvents in groundwater and are tested successful for removing arsenic. India is too poor to afford some of the technologies that are successfully tried out in the West, especially United States because they are prohibitively expensive. The cost of cleaning the aquifer in the Rajasthan case was estimated to be Rs. 40 crores. In India, groundwater quality monitoring is primarily the concern of the Central Ground Water Board and state groundwater agencies, where each of them set up their monitoring network.

But there are issues concerning adequacy of scientific data available from them:

- The network of monitoring stations is not dense enough.
- Water quality analysis excludes critical parameters that help detect pollution by fertilizer and pesticide, heavy metals and other toxic effluents.
- The available scientific data, particularly that on pollution is of civil society institutions, and there is a paucity of such institutions that are capable of

carrying out such professionally challenging, technologically sophisticated, and often politically sensitive tasks.

POLLUTION CONTROL SET UP/ FRAME WORK

The task of controlling pollution today is not easy due to tremendous type of sources. The most effective means of controlling pollution results from cooperation between scientists , legislators, citizen and industry.

Role of scientists :

- Identify sources and type of pollution.
- Determine the concentration of pollution.
- Study the effect of pollution.
- Recommend safe pollution levels
- Study and design pollution control methods.
- Develop pollution remediation and clean up plans control programme.
- Monitor effectiveness of cleanup efforts.
- Research for new treatment technologies.

Role of legislators

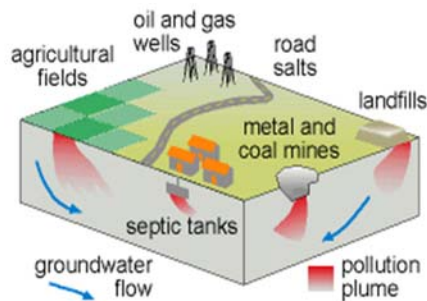
- Support research/ education
- Enact laws that limit pollution levels
- Levy fines and penalties against polluters.
- Co-ordinate state pollution control efforts.
- Create environmental protection plans.
- Provide mechanism to monitor pollution.

Role of Citizen Groups

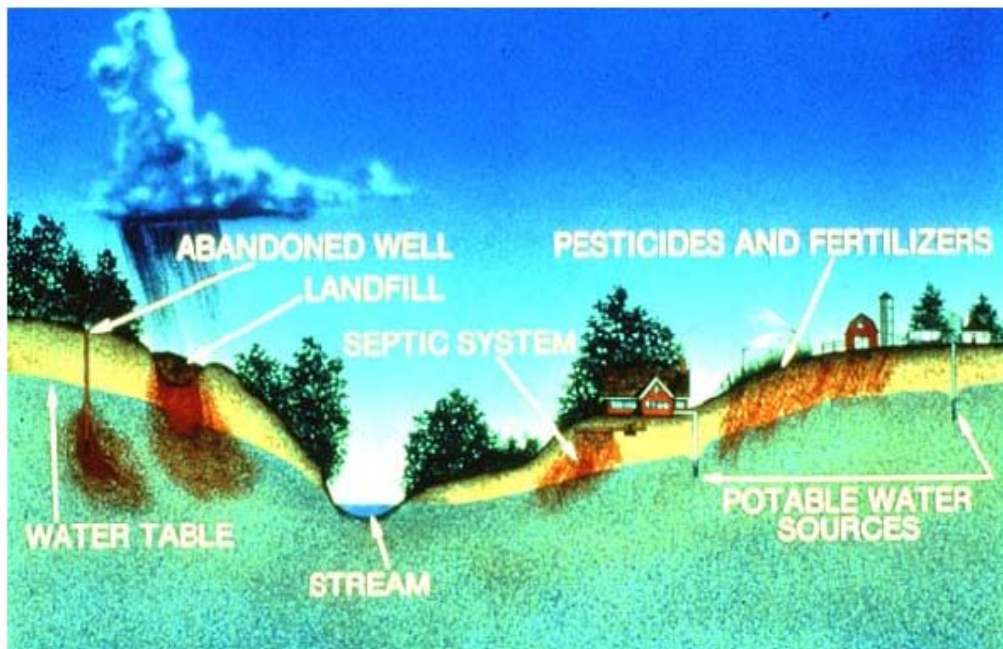
- Lobby for beneficial laws.
- Educate public of pollution dangers
- Identify sources of pollution and notify authorities and public
- Encourage consumer, conservation and recycling
- Volunteer to clean up polluted areas.
- Provide public information

Role of Industry

- Support education programme
- Establish quality control to limit pollution
- Develop recycling programs
- Find commercial uses for wastes and by-products.
- Research for better production methods.
- Monitor water quality of discharges.
- Work with general public to protect natural resources.



CONTAMINATION PROCESS



CONTAMINATION SOURCES

AQUIFER INFORMATION SYSTEM DEVELOPMENT

In the present scenario, the ground water assessment and management is broadly based on administrative boundaries, in some of the states surface water shed boundaries are used to collate the information on regional geology, hydrogeology, aquifer characteristics and ground water geochemistry. These facts underscore the need for broad regional study of the major aquifer systems of the country. It is therefore proposed to take up aquifer mapping at watershed level in the country. Is a multidisciplinary scientific process wherein a combination of geologic, geophysical, hydrogeologic, hydrologic, isotopic and quality data are integrated to characterize the quantity, quality, and distribution of ground water in aquifers. This will provide much needed information for aquifer management, planning and development of the ground water resources of the country.

AQUIFER MAPPING: The aquifer maps are the maps depicting aquifer disposition, giving lateral and vertical extension. The maps will also provide information on the quantity and quality. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological, and quality data are integrated to characterize the quantity, quality and movement of ground water in aquifers.

Objective of Pilot Aquifer Mapping

- To define the aquifer geometry, type of aquifers, ground water regime behaviors, hydraulic characteristics and geochemistry of Multi-layered aquifer systems on 1:50,000.
- Intervention of new geophysical techniques and establishing the utility, efficacy and suitability of these techniques in different hydrogeological setup.
- Finalizing the approach and methodology on which National Aquifer mapping programme of the entire country can be implemented.
- To develop an Aquifer Information and Management System for sustainable management of ground water resources based on the aquifer maps prepared.
- The experiences gained can be utilized to upscale the activities to prepare micro level aquifer mapping.

Uses of Aquifer Mapping

Identification and study of aquifers to guide future groundwater development

Identification of streams susceptible to reduced base flows as a result of heavy groundwater use

Identification of areas for artificial recharge (what measures could be adopted to maintain a sustainable supply of groundwater?)

Input for the Development of Aquifer Information and Management System

Placing of aquifer information on public domain for the use of all Stakeholders.

Preparation of thematic layers (GIS Data Creation)

This activity would involve preparation of layered thematic maps using 1:50,000 scale digital data, Paper maps / remote sensing data / Satellite data as per NRIS code. NRSC being the nodal agency and custodian of satellite and remote sensing data shall be involved for this activity in project mode. The probable thematic layers to be generated are given below:

- a. Administrative map with location of Major towns linked with census data
- b. Administrative boundary up to Panchayat / Village
- c. Topographical map depicting Relief/ physiography / altitude contours
- d. Geomorphology map
- e. Drainage map with Basin / sub basin / watershed boundaries (Source: CGWB)
- f. Water bodies, water conservation structures, tanks etc
- g. Landuse/ Land cover map
- h. Canal Command areas
- i. Soil map with Infiltration characteristics and chemical composition
- j. Surface water Irrigation schemes
- k. Drinking water supply schemes along with attribute table giving population covered drinking water sources, etc.
- l. River gauge data locations.

- m. Demographic data (Human and live stocks)
 - n. Ground water level (Pre / post / trends)
 - o. Ground Water Quality parameters
 - p. Geophysical survey
 - q. Isotopic parameters
 - r. Lithological and Aquifer Boundaries
 - s. Isopach , top and bottom of aquifers
 - t. Stage of ground water development
- b. Preparation of Aquifer maps : Under this activity, the existing as well as created data in respect of subsurface lithological formations along with the hydraulic properties , isotope and quality aspects shall be combined to delineate the aquifers so as to define the aquifer extent in lateral and vertical dimensions. The aquifers delineated shall be presented in 2D plan, 3D fence diagrams, block diagrams, cross sections and isopach maps with attributes of thickness , aquifer parameters, quality and vulnerability aspects etc. These aquifers shall form the base for developing the aquifer management plan.
- c. Preparation of Aquifer wise ground water management Plan: This activity would involve, integration of aquifers with various thematic layers and water use data along with social parameters so as to formulate the Aquifer wise management plan in GIS platform. The quantification of ground water available in individual aquifers and periodic changes in the volume of ground water will be reflected for sustainable management plan. Aquifer wise vulnerability will be prepared in terms of ground water availability (potential areas / ground water stress areas), water logged areas and quality problem areas. The outcome of the aquifer wise management plan would be in the form of GIS linked maps depicting followings:-
- Feasible areas for ground water development along with yield potential vis a vis depth of well and safe yields etc.
 - Feasible areas for rain water harvesting, conservation and ground water recharge vis a vis aquifer storage potential and surface water available for recharge.

- Demarcation of Ground Water Regulatory Zones (GRZ).
- Demarcation of Ground water Sanctuaries to be reserved for Drought proofing.

The ultimate goal is to construct a ground water flow Simulation models at appropriate scale to arrive at technically and economically feasible Aquifer management options. This work shall be taken up through engagement of state wise short term ground water and GIS experts.

AQUIFER INFORMATION AND MANAGEMENT SYSTEM (AIMS)

For development of Aquifer Information and Management System (AIMS) all the hydrogeological data available with Central Ground Water Board, other central agencies, state agencies, academic institutions and civil societies shall be collected. Then the data gaps to be established and further data generation can be done through hydrogeological mapping and Investigations, geophysical investigations , ground water level and quality monitoring, and drilling of test/exploratory wells, pumping tests and other studies etc. All the data will have to be brought to a common platform in GIS format. Aquifer maps will be prepared in GIS platform in 2D/3D.

All the data from different sources shall be integrated and a citizen interface shall be developed. A robust tool of Aquifer Information and Management System (AIMS) on the web platform will be developed from which common people can have access the data. On the basis of participatory ground water management ground water management plan of an area shall be prepared. This will be helpful in solving the ground water problem of the common people.

Initiation to local youth :

First identification of volunteers and imparting training to the volunteers and the volunteers in due course will train the farmers/ villagers to record the data and taking water level measurements. For the purpose of data collection the farmer owning a observation well is the right person to collect water level, similarly a farmer donating land for setting rain gauge observatory may be given the responsibility for collection of rainfall data.

In the training, first orient the volunteers/ farmers towards the concept and content of participatory monitoring and introduces the monitoring tools, then practice by the volunteers/ farmers in handling the equipment and in data collection protocol. The number of trainees should be limited so that personal attention can be given to all participants. Topics like hydrogeological concepts, factors governing tube well/ bore well yields, causes of environmental pollution, issues related to ground water needing immediate attention, Ground water management and need of stakeholders participation to manage the resource on sustainable basis to be included in the

orientation training, visual display/ model on dynamic nature of an aquifer system to be shown to make it more interactive.

Working with communities it is found that although initial enthusiasm is generally high, when it comes to taking up tasks only a few people remain interested, during the training session with interaction the volunteers may be identified to allocate the responsibilities.

Data collection is an uphill task if it is considered as a technical programme, but when translated as a programme with practical utility it becomes easy, without compromising too much on the quality of data, the procedures for data collection should be kept as simple as possible using simple formats with minimum entries. Ground water Management Committee may be formed in the village.

Local youth will be responsible for the following activities:

- a. One-time inventory: Creating a one-time well-inventory for the village – including names of owners of the wells, the dimensions of the structure (well/spring), pump and pumping system, etc. collected from the well-owner(s) / users of wells/springs, for all wells in the village.
- b. Lithologs of wells / boreholes / tube wells – for a sample of about 15-20 wells per village: Observation-based description of rocks and rock types – some with these observations supporting the hydrogeological mapping exercise undertaken by specialized agencies – while conducting the one-time inventory.
- c. Water level and basic in-situ water quality data - for a sample of about 15-20 wells per village: Temporal data like water-levels / spring discharge (monthly), in-situ groundwater quality (quarterly), helping in the collection of water samples for comprehensive testing (representative samples, twice every year)

DATA DISSEMINATION

Ground water level monitorin data collected by the local youth may be transfer to the district level office in hard copy or through wireless transmission system. Collected information can be used for easy processing and communication for comprehenshive ground water management decisions/ plans in district level. The data can be put in a user friendly aquifer information system so that a linkage may

be developed between the user and policy makers.

The outcome of the data analysis may be disseminated to the user agency down to the grass root level for village planning, budgeting of their ground water resources and it will be useful for the village water user association for adopting suitable management strategy, selecting cropping pattern based on the available resource.

Further it will also evoke interest in the stakeholder in participatory groundwater monitoring and in authentication of data collection. The protocol for data dissemination can be programmed based on the need and wisdom by the data managers.

LOCAL AQUIFER MANAGEMENT PLAN

The adequate information gather about the aquifer geometry, rainfall, annual recharge leads to assess the ground water availability in the management unit. The demand of water on the various sectors like agriculture, domestic and industry should also be assessed along with the availability of surface water sources. Any threat existing towards contamination of aquifer should also be considered along with future demand. Base on this the issues pertaining to the areas can be identified and have to be addressed properly for the village level aquifer management plan. There is also a need to work out demand side management i.e., conservation augmentation of the resources through Rain Water Harvesting for ground water recharge and protection from contamination.

Participatory ground water management is envisaged to make a significant step in ground water management at grass root level. Depending upon the site specific problem the management strategy can be planned by adopting water conservation practices, by protecting the available resources from pollution or by augmenting the resources using rainwater harvesting and artificial recharge. The processes are described below:

I. Water conservation practices:

Water conservation refers to reducing the usage of water and recycling of waste water for different purposes. Generally major part of water is used in three sectors i.e. Domestic, Agriculture and Industry. The common practices being adopted presently for conservation of water in these sectors are as follows:

A. Conservation Practices for Domestic Users:

The following are the examples of conservation and water use efficiency practices which can be adopted by the domestic users;

Individual residential water users can install/replace existing equipment that save water or uses less water.

Residential demands account for about three-fourths of the total urban water demand. Indoor use accounts for roughly 60 percent of all residential use, and of this, toilets (at 3.5 gallons per flush) use nearly 40 percent. In new construction there is a great potential to reduce water consumption by installing low-flush toilets. Conventional toilets use 3.5 to 5 gallons or more of water per flush, but low-flush toilets use only 1.6 gallons of water or less. Since low-flush toilets use less water, they also reduce the volume of wastewater produced.

Domestic wastewater composed of wash water from kitchen sinks and tubs, clothes washers, and laundry tubs is called gray water. Gray water can be used by homeowners for home gardening, lawn maintenance, and other innovative uses.

Behavioral practices involve changing water use habits so that water is used more efficiently, thus reducing the overall water consumption in a home. These practices require a change in behavior. Behavioral practices for residential water users can be applied both indoors in the kitchen, bathroom, and laundry room and outdoors.

Water can be saved in the bathroom by turning off the tap while brushing teeth or shaving. Water can be saved by taking short showers rather than long showers or baths and turning the water off while soaping. Water can be saved by adjusting water levels in the washing machine to match the size of the load. A laundry tub should be filled with water, and the wash and rinse water should be reused as much as possible.

Outdoor water use can be reduced by watering the lawn early in the morning or late in the evening and on cooler days, when possible, to reduce evaporation. Allowing the grass to grow slightly taller will reduce water loss by

providing more ground shade for the roots and by promoting water retention in the soil.

B. Practices for Agricultural Users:

Water-saving irrigation practices fall into three categories: field practices, management strategies, and system modifications. Field practices are techniques that keep water in the field, distribute water more efficiently across the field. Typically, field practices are not very costly.

Management strategies involve monitoring soil and water conditions and collecting information on water use and efficiency. The information helps in making decisions about scheduling applications or improving the efficiency of the irrigation system.

System modifications require making changes to an existing irrigation system or replacing an existing system with a new one. Typical system modifications include use of sprinkler system, retrofitting a well with a smaller pump, installing surge irrigation, or constructing a tail water recovery system.

Agricultural irrigation represents huge percent of the total water demand nationwide. Given that high demand, significant water conservation benefits could result from irrigating with reused or recycled water. Water reuse for irrigation is already in widespread use in rural areas and is also applicable in areas where agricultural sites are near urban areas and can easily be integrated with urban reuse applications. Depending on the scarcity of water due to low rainfall etc a common decision mechanism to be developed to go for changing crops as per the water availability in a particular area by general consensus. And in places where ground water draft is at high level and scarcity of water exists then we can go for micro irrigation practices like sprinkler and drip irrigation etc .

Behavioral practices for agricultural water users can be applied to irrigation application rates and timing. Changes in water use behavior can be implemented without modifying existing equipment. For example, better irrigation scheduling can result in a reduction in the amount of water that is

required to irrigate a crop effectively. The careful choice of irrigation application rates and timing can help farmers to maintain yields with less water.

C. Practices for Industrial Users:

Industrial/commercial users can apply a number of conservation and water use efficiency practices. Some of these practices can also be applied by users in the other water use categories.

Water reuse is the use of wastewater from one application such as municipal wastewater treatment for another application such as landscape watering. The reused water must be used for a beneficial purpose and in accordance with applicable rules. Some potential applications for the reuse of wastewater include other industrial uses, landscape irrigation, agricultural irrigation, aesthetic uses such as fountains, and fire protection. The reuse of wastewater is beneficial because it reduces the demands on available surface and ground waters.

Water recycling is the reuse of water for the same application for which it was originally used. Recycled water might require treatment before it can be used again.

Efficient use of water by behavioural practices reduces overall water consumption by an industrial/commercial facility up to large extent. Changes in behaviour can save water without modifying the existing equipment at a facility.

Monitoring the amount of water used by an industrial/commercial facility can provide baseline information on quantities of overall company water use, the seasonal and hourly patterns of water use, and the quantities and quality of water use in individual processes. Baseline information on water use can be used to set company goals and to develop specific water use efficiency measures. The use of meters on individual pieces of water-using equipment can provide direct information on the efficiency of water use. Records of meter readings can be used to identify changes in water use rates and possible problems in a system

Public Education: Public education programs can be used to inform the public about the basics of water use efficiency:

- How water is delivered to them
- The costs of water service
- Why water conservation is important
- How they can participate in conservation efforts

Public education is an essential component of a successful water conservation program. A number of tools can be used to educate the public bill inserts, feature articles and announcements in the news media, workshops, booklets, posters and bumper stickers, and the distribution of water-saving devices. Public school education is also an important means for instilling water conservation awareness.

II. Protection of Ground Water from Pollution:

Saltwater encroachment associated with over drafting of aquifers or natural leaching from natural occurring deposits are natural sources of groundwater pollution. Most concern over groundwater contamination has centered on pollution associated with human activities. Human groundwater contamination can be related to waste disposal (private sewage disposal systems, land disposal of solid waste, municipal wastewater, wastewater impoundments, land spreading of sludge, brine disposal from the industry, mine wastes, or not directly related to waste disposal (accidents, certain agricultural activities, mining).

Natural Pollution: Groundwater contains some impurities, even if it is unaffected by human activities. The types and concentrations of natural impurities depend on the nature of the geological material through which the groundwater moves and the quality of the recharge water. Groundwater moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium, and chlorides. Some aquifers have high natural concentration of dissolved constituents such as arsenic, Sulphate and Fluoride . The effect of these natural sources of contamination on groundwater quality depends on the type of contaminant and its concentrations.

Pollution from Sewage Disposal: Sewage is generated by residential, institutional, and commercial and industrial establishments. It includes household

waste liquid from toilets, baths, showers, kitchens, sinks and so forth that is disposed of via sewers. In many areas, sewage also includes liquid waste from industry and commerce.

Sewage treatment is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. Its objective is to produce an environmentally safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse (usually as farm fertilizer). Using advanced technology it is now possible to re-use sewage effluent for drinking water.

Pollution from Industrial waste water: Most industries produce some wet waste although recent trends in the developed world have been to minimise such production or recycle such waste within the production process. However, many industries remain dependent on processes that produce wastewaters.

Industrial effluent treatment covers the mechanisms and processes used to treat waters that have been contaminated in some way by anthropogenic industrial or commercial activities prior to its release into the environment or its re-use. The various types of contamination of wastewater require a variety of strategies to remove the contamination.

Brine treatment involves removing dissolved salt ions from the waste stream that may include membrane filtration processes, such as reverse osmosis; ion exchange processes or evaporation processes.

Most solids can be removed using simple sedimentation techniques with the solids recovered as slurry or sludge. In case very fine solids filtration or flocculation may be used, using alum salts.

Oils can be recovered from open water surfaces by skimming devices whereas biodegradable organic material of plant or animal origin is usually possible to treat using extended conventional sewage treatment processes such as activated sludge or trickling filter¹.

Synthetic organic materials including solvents, paints, pharmaceuticals, pesticides, coking products and so forth can be very difficult to treat. Treatment

methods include Advanced Oxidation Processing, distillation, adsorption, vitrification, incineration, chemical immobilisation or landfill disposal.

Fertilizers as pollutants:

Fertilizers, whether they are artificial or organic, can cause serious problems if they contaminate freshwater and marine ecosystems.

Fertilizer pollution is harder to regulate and reduce than many other kinds of water pollution because it is a type of nonpoint source pollution. Manure contains high levels of nitrogen and phosphorus and causes the same ecological problems as artificial fertilizers. The prodigious and incessant use of nitrogenous fertilizers has resulted into concentration of Nitrate-N ions into the groundwater higher than the World Health Organization limits. This rising trend in nitrate concentration is found to be directly related to increased use of nitrogenous fertilizers. The identification of the vulnerable area is the key need of our country. Vulnerable areas should get intensive efforts to maximize the efficiency of nitrogenous fertilizer to reduce the risk of nitrate pollution from fertilizers. The application rates should be adjusted to ensure both optimum crop yields and permissible nitrate leaching loss.

III. Rainwater harvesting:

Rainwater Harvesting defines collection of rain water, which flows away in the form of excessive runoff, at suitable places and preserves it for future use at the time of need or allow it to recharge to augment the ground water reservoir. The excessive runoff is arrested by construction of different rainwater harvesting structures at suitable places. It can be further used to provide drinking water, water for livestock, water for irrigation, as well as other typical uses. Rainwater harvested at ground surface or from the roofs of houses and local institutions is one solution to conserving precious water which make an important contribution to the availability of drinking water. Ground water recharge may be increased by conservation measures and artificial recharge procedures.

Artificial Recharge: The term artificial recharge refers to transfer of surface water to the aquifer by human interference. The natural process of recharging the aquifers is accelerated through percolation of stored or flowing surface water, which otherwise does not percolate into the aquifers. Artificial recharge is also

defined as the process by which ground water is augmented at a rate exceeding that under natural condition of replenishment.

Artificial recharge aims at augmenting the natural replenishment of ground water storage by some method of construction, spreading of water, or by artificially changing natural conditions. It is useful for reducing overdraft, conserving surface run-off, and increasing available ground water supplies. Recharge may be incidental or deliberate, depending on whether or not it is a by-product of normal water utilization.

Advantages of Artificial Recharge:

Artificial recharge is becoming increasingly necessary to ensure sustainable ground water supplies to satisfy the needs of a growing population. The important advantages of artificial recharge are

- Subsurface storage space is available free of cost and inundation is avoided.
- Evaporation losses are negligible.
- Quality improvement by infiltration through the permeable media.
- Biological purity is very high.
- It has no adverse social impacts such as displacement of population, loss of scarce agricultural land etc.
- It provides a natural distribution system between recharge and discharge points.
- Results in energy saving due to reduction in suction and delivery head as a result of rise in water levels.

Artificial Recharge Techniques and Designs:

Techniques used for artificial recharge to ground water broadly fall under the following categories:

I) Direct Methods

A) Surface Spreading Techniques

B) Sub-surface Techniques

II) Indirect Methods

A) Induced Recharge from Surface Water Sources

B) Aquifer Modification

III) Combination Methods

I. Direct Methods:

A. Surface spreading Techniques:

These are aimed at increasing the contact area and residence time of surface water over the soil to enhance the infiltration and to augment the ground water storage in phreatic aquifers.

Flooding:

This technique is ideal for lands adjoining rivers or irrigation canals in which water levels remain deep even after monsoons and where sufficient non-committed surface water supplies are available. The schematics of a typical flooding system are shown in fig.-1 below. To ensure proper contact time and water spread, embankments are provided on two sides to guide the unutilized surface water to a return canal to carry the excess water to the stream or canal.

Ditch and Furrows method:

This method involves construction of shallow, flat-bottomed and closely spaced ditches or furrows to provide maximum water contact area for recharge from source stream or canal. The ditches should have adequate slope to maintain flow velocity and minimum deposition of sediments. A collecting channel to convey the excess water back to the source stream or canal should also be provided. A typical system is shown in Fig.2 and three common patterns viz. lateral ditch pattern, dendritic pattern and contour pattern are shown in Fig.3.

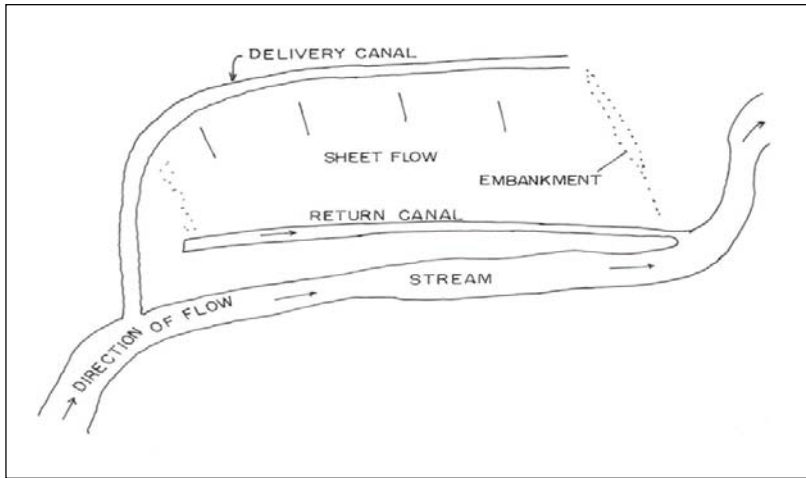


Fig.1 A Typical Flood Recharge System

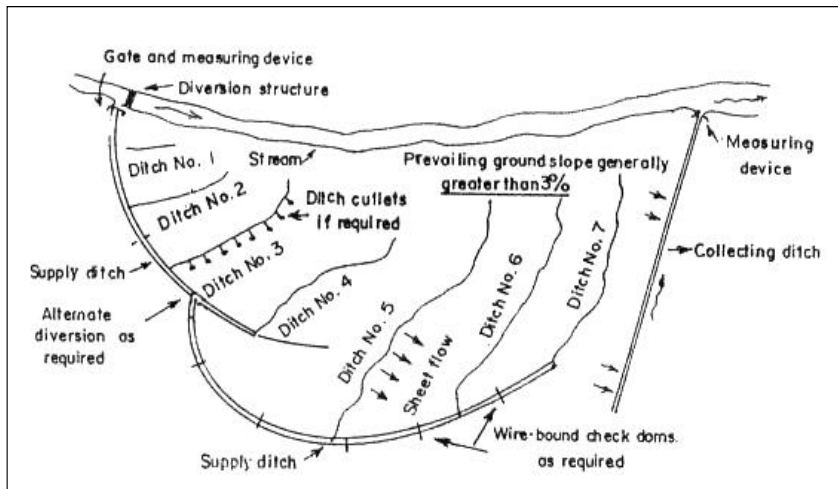


Fig.2 Typical Ditch and Furrows Recharge System

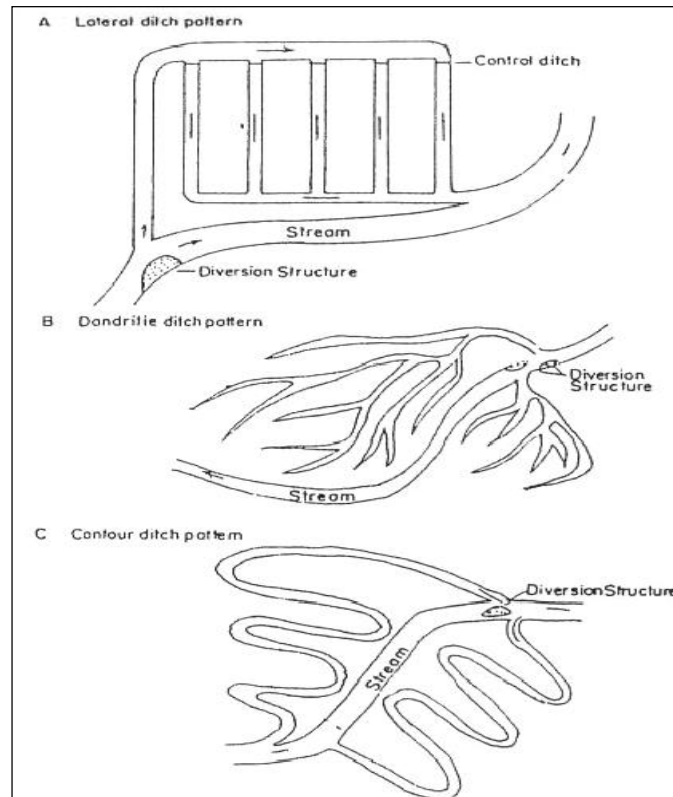


Fig .3 Common Patterns of Ditch and Furrow Recharge Systems.

Recharge Basins:

Artificial recharge basins are commonly constructed parallel to ephemeral or intermittent stream channels and are either excavated or are enclosed by dykes and levees. They can also be constructed parallel to canals or surface water sources. In alluvial areas, multiple recharge basins can be constructed parallel to the streams.

B. Runoff Conservation Structures:

These are normally multi-purpose measures, mutually complementary and conducive to soil and water conservation, afforestation and increased agricultural productivity. They are suitable in areas receiving low to moderate rainfall mostly during a single monsoon season and having little or no scope for transfer of water from other areas.. The structures commonly used are bench terracing, contour bunds, gully plugs, nalah bunds, check dams and percolation ponds.

Bench Terracing:

Bench terracing involves leveling of sloping lands with surface gradients up

to 8 percent and having adequate soil cover for bringing them under irrigation. It helps in soil conservation and holding runoff water on the terraced area for longer durations, leading to increased infiltration and ground water recharge.

Contour Bunds:

Contour bunding, which is a watershed management practice aimed at building up soil moisture storage involve construction of small embankments or bunds across the slope of the land. They derive their names from the construction of bunds along contours of equal land elevation. This technique is generally adopted in low rainfall areas (normally less than 800 mm) where gently sloping agricultural lands with very long slope lengths are available and the soils are permeable. They are not recommended for soils with poor internal drainage e.g. clayey soils.

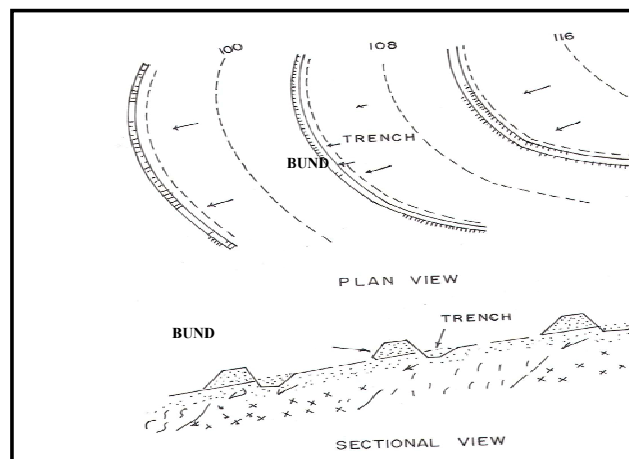


Fig.4 Schematics of a Typical Contour Bund

Contour bunding involves construction of narrow-based trapezoidal embankments (bunds) along contours to impound water behind them, which infiltrates into the soil and ultimately augment ground water recharge. Fig.4

Contour Trenches:

Contour trenches are rainwater harvesting structures, which can be constructed on hill slopes as well as on degraded and barren waste lands in both high- and low- rainfall areas. Cross section of a typical contour trench is shown in Fig.5

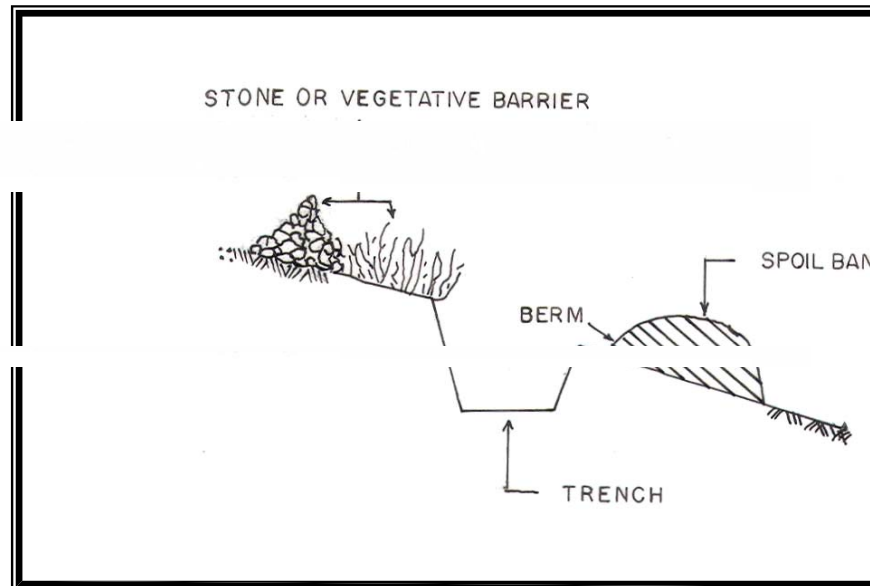


Fig.5 Schematics of a Contour Trench

The trenches break the slope at intervals and reduce the velocity of surface runoff. The water retained in the trench will help in conserving the soil moisture and ground water recharge.

Gully Plugs, Nalah Bunds and Check Dams:

These structures are constructed across gullies, nalahs or streams to check the flow of surface water in the stream channel and to retain water for longer durations in the pervious soil or rock surface. As compared to gully plugs, which are normally constructed across 1st order streams, nalah bunds and check dams are constructed across bigger streams and in areas having gentler slopes. These may be temporary structures such as brush wood dams, loose / dry stone masonry check dams, Gabion check dams and woven wire dams constructed with locally available material or permanent structures constructed using stones, brick and cement.

The site selected for check dam should have sufficient thickness of permeable soils or weathered material to facilitate recharge of stored water within a short span of time. The water stored in these structures is mostly confined to the stream course and the height is normally less than 2 m. These are designed based on stream width and excess water is allowed to flow over the wall. In order to avoid scouring from excess runoff, water cushions are provided on the

downstream side. To harness maximum runoff in the stream, a series of such check dams can be constructed to have recharge on a regional scale. The design particulars of a check dam & Gabion check dams are shown in Fig.6. and fig.7 below.



Fig.6 Check dam



Fig.7 Gabion Structure

Percolation Tanks:

Percolation tanks, which are based on principles similar to those of *nalah*

bunds, are among the most common runoff harvesting structures in India. A percolation tank can be defined as an artificially created surface water body submerging a highly permeable land area so that the surface runoff is made to percolate and recharge the ground water storage. They differ from *nalah* bunds in having larger reservoir areas. They are not provided with sluices or outlets for discharging water from the tank for irrigation or other purposes. They may, however, be provided with arrangements for spilling away the surplus water that may enter the tank so as to avoid over-topping of the tank bund. Fig.8

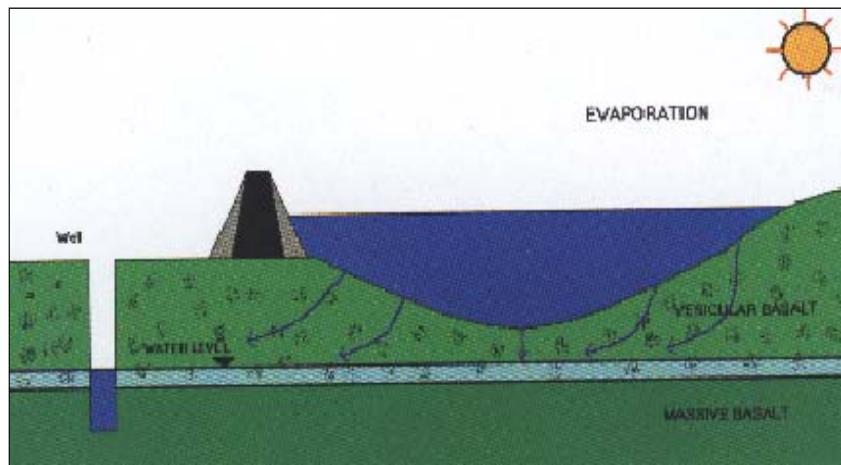


Fig.8 Percolation tank

B. Subsurface Techniques:

Subsurface techniques aim at recharging deeper aquifers that are overlain by impermeable layers, preventing the infiltration from surface sources to recharge them under natural conditions. The most common methods used for recharging such deeper aquifers are a) Injection wells or recharge wells, b) Recharge pits and shafts, c) Dug well recharge, d) Borehole flooding and e) Recharge through natural openings and cavities.

Injection Wells or Recharge Wells:

Injection wells or recharge wells are structures similar to bore/tube wells but constructed for augmenting the ground water storage in deeper aquifers through supply of water either under gravity or under pressure. The aquifer to be replenished is generally one with considerable de-saturation due to overexploitation of ground water. Fig.9 Artificial recharge of aquifers by injection wells can also be done in coastal regions to arrest the ingress of seawater and to combat problems of

land subsidence in areas where confined aquifers are heavily pumped.

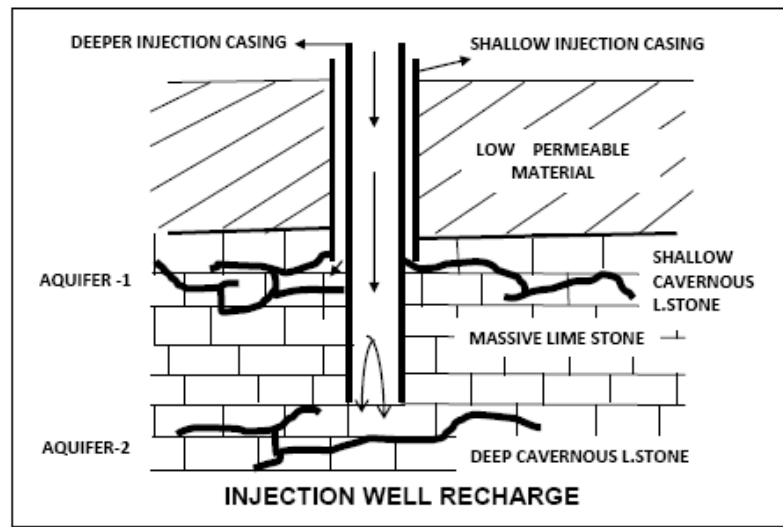


Fig.9 Injection Well

Gravity Head Recharge Wells:

In addition to specially designed injection wells, existing dug wells and tube/bore wells may also be alternatively used as recharge wells, as and when source water becomes available. In areas where considerable de-saturation of aquifers have already taken place due to over-exploitation of ground water resources resulting in the drying up of dug wells and lowering of piezometric heads in bore/tube wells, existing ground water abstraction structures provide a cost-effective mechanism for artificial recharge of the phreatic or deeper aquifer zones as the case may be.

Recharge Pits and Shafts:

Recharge pits and shafts are artificial recharge structures commonly used for recharging shallow phreatic aquifers, which are not in hydraulic connection with surface water due to the presence of impermeable layers. They do not necessarily penetrate or reach the unconfined aquifers like gravity head recharge wells and the recharging water has to infiltrate through the vadose zone.

Recharge Pits: Recharge pits are normally excavated pits, which are sufficiently deep to penetrate the low-permeability layers overlying the unconfined aquifers (Fig.10). They are similar to recharge basins in principle, with the only difference being that they are deeper and have restricted bottom area. In many such

structures, most of the infiltration occurs laterally through the walls of the pit as in most layered sedimentary or alluvial material the lateral hydraulic conductivity is considerably higher than the vertical hydraulic conductivity. Abandoned gravel quarry pits or brick kiln quarry pits in alluvial areas and abandoned quarries in basaltic areas can also be used as recharge pits wherever they are underlain by permeable horizons. *Nalah* trench is a special case of recharge pit dug across a streambed. Ideal sites for such trenches are influent stretches of streams. Contour trenches, which have been described earlier also belongs to this category.

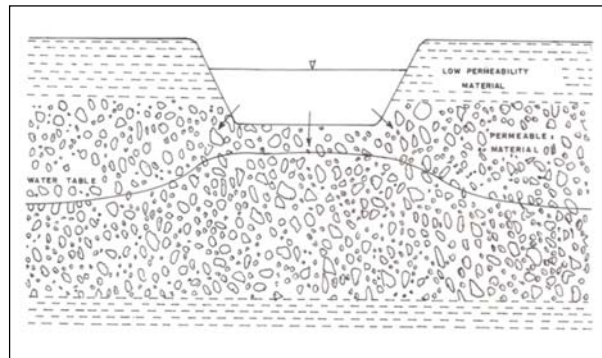


Fig.10 Recharge Pit

Recharge Shafts

Recharge Shafts are similar to recharge pits but are constructed to augment recharge into phreatic aquifers where water levels are much deeper and the aquifer zones are overlain by strata having low permeability (Fig.11). Further, they are much smaller in cross section when compared to recharge pits. Detailed design particulars of a recharge shaft are shown in Fig.11

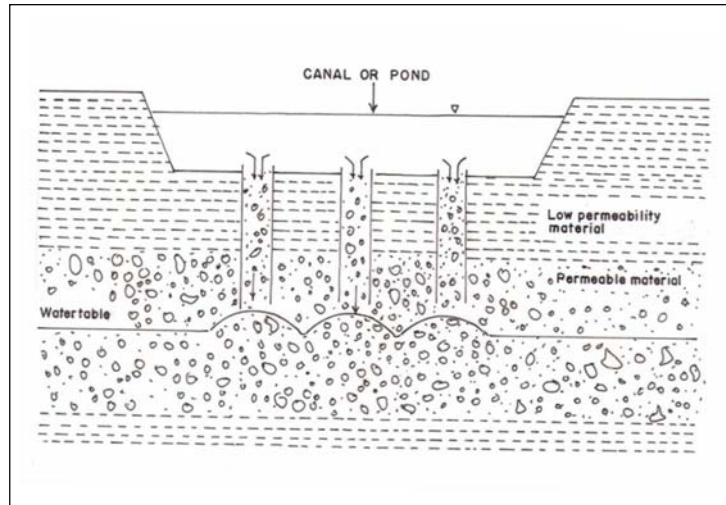


Fig.11 Recharge Shaft

Indirect Methods

Indirect methods for artificial recharge to ground water does not involve direct supply of water for recharging aquifers, but aim at recharging aquifers through indirect means. The most common methods in this category are induced recharge from surface water sources and aquifer modification techniques.

A. Induced Recharge

Induced recharge involves pumping water from an aquifer, which is hydraulically connected with surface water to induce recharge to the ground water reservoir. Once hydraulic connection gets established by the interception of the cone of depression and the river recharge boundary, the surface water sources starts providing part of the pumping yield Fig. 12 Induced recharge, under favorable hydrogeological conditions, can be used for improving the quality of surface water resources due to its passage through the aquifer material. Collector wells and infiltration galleries, used for obtaining very large water supplies from riverbeds, lakebeds and waterlogged areas also function on the principle of induced recharge.

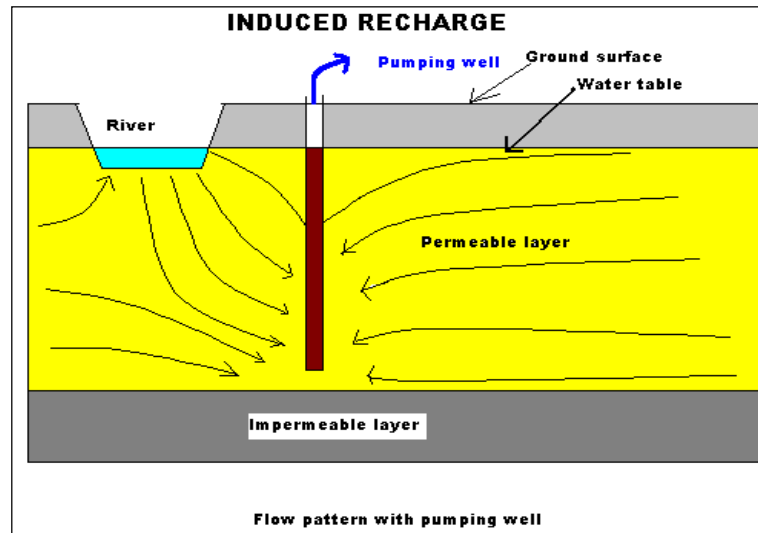


Fig.12 Induced Recharge

III. Combination Methods

Various combinations of surface and sub-surface recharge methods may be used in conjunction under favorable hydrogeological conditions for optimum recharge of ground water reservoirs. The selection of methods to be combined in such cases is site-specific. Commonly adopted combination methods include a) recharge basins with shafts, percolation ponds with recharge pits or shafts and induced recharge with wells tapping multiple aquifers permitting water to flow from upper to lower aquifer zones through the annular space between the walls and casing (connector wells) etc.Fig.13

IV. Ground Water Conservation Techniques

Ground water conservation techniques are intended to retain the ground water for longer periods in the basin/watershed by arresting the sub-surface flow. The known techniques of ground water conservation are a) Ground water dams / sub-surface dykes / Underground 'Bandharas' and b) Fracture sealing Cementation techniques.

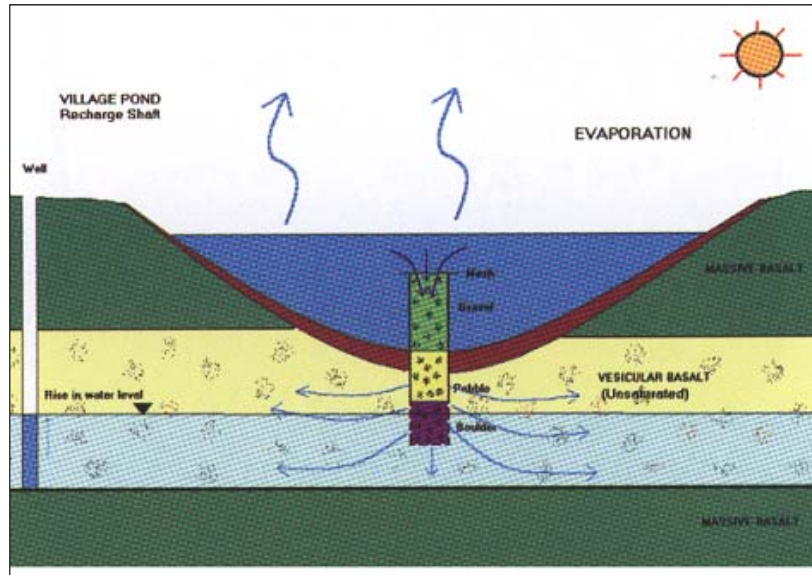


Fig. 13 Percolation pond with recharge well

Sub-Surface Dykes / Ground Water Dams / Underground 'Bandharas'

A sub-surface dyke / ground water dam is a sub-surface barrier constructed across a stream channel for arresting/retarding the ground water flow and increase the ground water storage. At favourable locations, such dams can also be constructed not only across streams, but in large areas of the valley as well for conserving ground water. Schematics of a typical sub-surface dyke are shown in Fig.14.

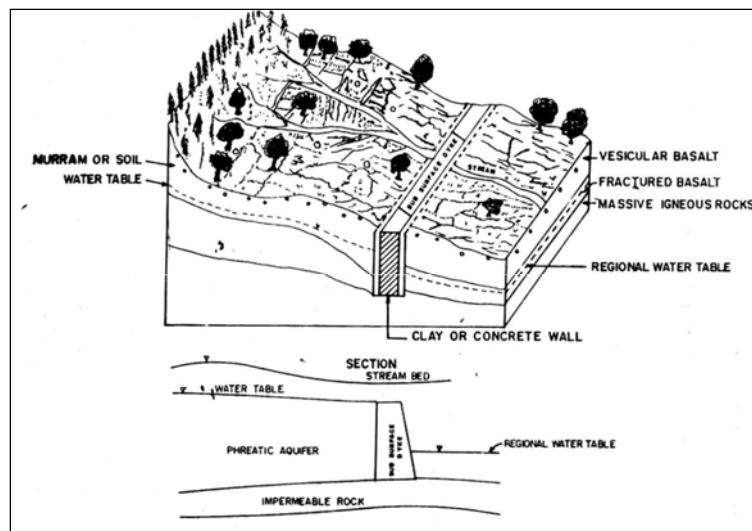


Fig.14.Sub-SurfaceDyke

PARTICIPATORY GROUND WATER MANAGEMENT

Ground water is the common pool resource used by millions of farmers in the country and remains the predominant drinking water source for rural water supply. It also supports industrial usages. The scarcity of water resources and ever increasing demand of these vital resources require identification, quantification and management of ground water in a way that prevents overexploitation and consequent economic and environmental damage, while satisfying demand for water supply of competing sectors. Participatory ground water management is envisaged to make a significant step in ground water management at grass root level to enable the community and stake holders to monitor and manage the ground water as common pool resources themselves.

It is imperative to have the aquifer mapping activity with a road map for groundwater management plan to ensure its transition into a participatory groundwater management programme for effective implementation of the Aquifer Management Plans (AMPs). This would require a coordinated effort involving government departments, research institutes, PRIs, civil society organizations and the stakeholders at the village level who would guide collective sharing and use of groundwater based on a careful understanding of the storage and transmission characteristics of different aquifer units. A National level identified consortium of NGOs is desirable for developing benchmark for this activity and facilitating its implementation.

The implementation of AMPs is proposed through collaborative approach amongst government departments, research institutes, PRIs, civil society organizations and the local community. The stakeholders would include farmers, landless farm workers with appropriate SC, ST and Women's representatives. Consensus based decision making is the goal of local water users association (WUA). Social audit by members not involved in the implementation process is inbuilt within the participatory ground water management. Gram Sabha is proposed to be the final arbiter in case of disputes and for establishing some basic regulatory norms under PRI system. A national level independent agency shall be entrusted for evaluation of the project. The programme envisaged activities towards building capacity, skills and knowledge to ground water users. Programme will be executed by

engaging suitable youth, women etc as grass root ground water workers after providing necessary trainings to them to function as facilitators, trainers and data managers at the village level. Two major issues to be addressed by the proposed programme are:–

- Management of Groundwater
- Monitoring leading to sustainability of Groundwater

Even though Aquifer mapping is a fairly complex exercise involving profound knowledge of Hydrogeology and other disciplines, the role of grass root workers (para-hydrogeologists) cannot be understated. They shall be responsible for collection of primary Hydrogeological data, periodic monitoring of identified key wells, and sensitization of the villagers regarding ground water trends, extensive usage and its ramification. The Central and State organizations shall be assisted by the designated NGOs to identify and facilitate training of grass root workers for the implementation of AMPs. The program will catalyse and scale up the PGWM process to facilitate the field level outreach of ground water development measures.

Role of Women In Water Management

Women plays a crucial role in ground water management particularly in rural areas. Traditionally, and almost universally, regarded as domestic water managers, women's role is neither limited nor static. It is known that women also play a substantial role in food production, although it varies regionally and from country to country. Daily collection of drinking water is always the responsibility of the women in the rural areas.

Women's contribution is not only through physical labour but also through active participation in decision-making. Their knowledge of water conservation techniques is based on sets of empirical observations about local environments and systems of self-management that govern resource use. Women in developing countries are often referred to as water suppliers and water managers.

In rural areas woman is mainly engaged in household work such as cooking, collection of drinking water as well in agriculture and man goes outside to earn their livelihood. The women at most places brings water for drinking, bathing , washing clothes and for cattle from long distance which is time consuming as well tiring. Thus

they are most alert about the conservative use of water. More than 70% of the diseases are water borne. At the time of disease women has to exert fully to take care of ill family member thus if made aware they will ensure that water source and ground water is not contaminated.

The manner in which local women have traditionally made use of nature in order to obtain water can teach us a great deal about meeting our own water needs in situations of scarcity, and doing it without any adverse effects on environment. Women derive water without interrupting the natural processes by which it is regenerated. In the dry season women dig wells usually in paddy fields and also in the tank bed or the riverbed for collection of water. Water user's association can be formed at village level in which women can play important role in protection, utilization and conservation of water. Presently the educated woman can gain the knowledge of occurrence, movement and resources available in aquifer. Training can be given regarding conservation of water and importance of potable safe drinking water in growth of children etc. They can also collect the data regarding rainfall, water level etc. They are the best communicators and can play dedicated role in spreading the message of ground water conservation, protection and management to the stakeholders.

PHOTO GALLERY



COMMUNITY PARTICIPATION IN WATER LEVEL MONITORING

Urban and Rural Water Supply Arrangements



Surface water piped network



Ground water (Borewell/handpump)



Alternative source (Rainwater Harvesting)



Water Vendors

Gadgets for water level monitoring



Electric water Level Indicator



Automatic Water Level Recorder

Gadgets for Quality Monitoring

Portable pH meter



- Range: 0.0 to 14.0pH
- Resolution: 0.1pH
- Accuracy(@20C/68F): 0.1pH
- Environment: 0 to 50C (32 to 122F)

Portable pH meter



- Measuring range: 10-1990uS/cm
- Resolution: 10uS/cm
- Auto. Temp. compensation: 0-50C
- Calibration solutions: 1410uS/cm, 0.01N KCl solution

GLIMPSES OF GENDER & WATER





Dug well the Traditional Ground water abstraction structure



Let us all catch water

Note: Apart from the above, the respective Regional offices may add the specific Ground water related issues prevailing in the area in local vernacular. It is suggested, Poster, exhibitis, quiz, puppet show etc. can be inducted in the program with an overall aim - a way forward for :

Creating	AWARENESS
Enlisting	APPRECIATION
Spreading	ACCEPTANCE
Ensuring	APPLICATION

Towards Ground Water management by stakeholders

