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STUDY OF SOIL MOISTURE MOVEMENT AND RECHARGE TO GROUNDWATER DUE TO MONSOON RAINS AND IRRIGATION USING TRITIUM TAGGING TECHNIQUE IN SAHARANPUR DISTRICT

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PREFACE

Recharge estimation to groundwater is crucial to better water resources management particularly in arid and semi-arid regions. Conventionally the recharge to groundwater is estimated from the specific yield and the water table fluctuation. But this data is not generally available for the entire basin. Further as the water table elevation is effected by more than one process, conventional method may not be universally applicable. Therefore, nuclear methods specially tritium tagging technique is more useful and increasingly find wider application in the developing world.

The National Institute of Hydrology has taken up various hydrological studies in different parts of the country. As a part of these studies the Nuclear Hydrology Division has applied the tritium tagging technique (radio-tracer technique) to estimate the recharge to groundwater in Saharanpur district. This report presents the details of the methodology adopted and discusses the results. This report will be highly useful to the engineers of water resources organisations of U.P. and other states.

The present study has been carried out by Sh. S.K. Verma, Scientist B and Dr. Bhishm Kumar, Scientist E1 and Head Nuclear hydrology division, and supported by Sh. Rajeev Gupta, RA, Sh. Suresh Kumar, Tech. Grade I, and Sh. V.K. Agarwal, RA, Sh. Alok Kumar Sharma, Attendant and Sh. Dinesh Kumar, Attendant.

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ABSTRACT

District Saharanpur falls under the vast alluvial tract of Quaternary deposits of Indo-Gangetic plains in western U.P. It is bordered by river Yamuna in the west, foot-hills of Himalayas in the north and district Hardwar in the east and district Muzaffarnagar in the south respectively. The area is well drained by a number of rivers and nallahs like Hindon, Kali, Maskara, Krishni and Budhi Yamuna rivers and Katha Nallah etc. The Hindon river is the main source of natural drainage in the area. The Eastern Yamuna canal and Deoband branch of Upper Ganga canal flow across the area which are the main source of recharge to shallow aquifers in the adjoining areas. Total geographical area of the district is 389041 hect. It comprises of 272360 hect. cultivated, 66878 hect. forested, 41314 hect. built-up, 1211 hect. barren land and 7278 hect. uncultivated land. The yearly rainfall in normal year is about 901 mm. Sugarcane, wheat and rice are the main crops grown in the area. The soil in district Saharanpur varies from sandy to silty loam.

The geohydrological data indicate three aquifers system in this region, e.g. shallow within 60 feet depth below ground level (b.g.l.), intermediate within 70-150 feet b.g.l. and deeper aquifer within 300-500 feet depth b.g.l. The average premonsoon and postmonsoon groundwater table fluctuation is around 1.6 m in the study area.

The present study aims to estimate the recharge to groundwater due to monsoon rains through the unsaturated porous media in case of cultivated and uncultivated fields. Artificial radioisotope was injected at two uncultivated and five cultivated sites before the onset of monsoon and soil samples were collected from the injection points after the rainy season. The results of recharge to groundwater vary from 10% to 15% in uncultivated land while 14% to 26% in cultivated land. The values of recharge to groundwater seem justified keeping in view the type of soil and other geo-hydrological conditions prevailing in the study area. Further studies using Neutron Moisture Probe and environmental isotope will throw more light on the interconnections of different aquifer systems, locations of recharge zones to deeper aquifers and major recharge sources.

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1. INTRODUCTION

The process of infiltration governs the recharge to groundwater from surface to the subsequent layers of soil, which is one of the most important parameters to study the movement of water through unsaturated soil. The infiltration may be defined as the process of the water penetrating from ground surface into soil mass.

Estimation of recharge to groundwater is essential for evaluation of groundwater resources. In most of the cases, major source of recharge to groundwater is due to precipitation. However, in the irrigated areas the return seepage also contributes to groundwater recharge significantly.

In addition to the precipitation and irrigation inputs, which contribute to the direct or vertical recharge to groundwater (unconfined aquifers), there is a lateral component of recharge through the sub-surface horizontal flow due to natural hydraulic gradient. The isotope techniques can be employed to estimate the vertical component of recharge.

The vertical component of recharge to groundwater can be estimated using naturally injected environmental isotopes like oxygen-18, deuterium and tritium including artificial tritium, which is required to be injected at the selected sites. In the present study, the artificial tritium has been used to estimate the vertical component of recharge to groundwater.

Tritium is a beta ray emitter having half-life of 12.43 years. It emits beta radiations of 18.6 keV energy. In India, tritium can be obtained from Board of Radiation and Isotope Technology (BRIT), Bhabha Atomic Research Centre (BARC), Trombay, Mumbai.

In the present report, the percentage of recharge to groundwater due to monsoon rain and irrigation for the period from June' 1999 to October' 1999 in Saharanpur district is determined using Tritium Tagging Technique.

2.0 DESCRIPTION OF STUDY AREA

The study area comprises of district Saharanpur having a total area of about 389041 hect. It comprises of 272360 hect. cultivated, 66878 hect. forested, 41314 hect. built-up, 1211 hect. barren land and 7278 hect. uncultivated land. District Saharanpur is located between latitude 29° 33' to 30° 22' and longitude 77° 7' to 77° 57' (Fig. 2.1). Besides, the district Saharanpur is situated just beneath the Shiwalik mountain ranges. The details of the district in terms of its boundary, rivers, canals and test sites are shown in Fig. 2.1.

2.1 Location of Test Sites

First site i.e. Sarsawa in tehsil Nakud and district Saharanpur was selected on Saharanpur-Ambala road at about 17km from Saharanpur. Tritium injections were made on the left side of Saharanpur-Ambala road in an uncultivated field very close to Pal Dhaba. Second site, i.e. Chhutmalpur in tehsil and district Saharanpur was selected on Chhutmalpur-Saharanpur road at about 6 km from Chhutmalpur. The tritium injections were made on the right side of Chhutmalpur-Saharanpur road in a cultivated field situated nearby Mittal Nursery. Third site, i.e. Nakud in tehsil Nakud and district Saharanpur was situated on Saharanpur-Gangoh road at about 25 km from Saharanpur. Tritium injections were made on the right side of Saharanpur-Gangoh road in a cultivated field situated in front of petrol pump. Fourth site, i.e. Rampur Maniharaan in tehsil Deoband and dist. Saharanpur was selected on Saharanpur-Delhi road at about 18 km from Saharanpur. The tritium injections were made on the right side of the Saharanpur-Delhi road in a cultivated land. Fifth site i.e. Gangoh in tehsil Nakud and district Saharanpur was selected on Saharanpur-Gangoh road and the tritium injections were made on the right side of Saharanpur-Gangoh road in a cultivated land very near to the saw-mill of Sh. Bashira. Sixth site, i.e. Nanota in tehsil Deoband and district Saharanpur was selected on Saharanpur-Delhi road at about 30 km from Saharanpur. The tritium injections were made on the left side of Saharanpur-Delhi road in a partly uncultivated field situated near the campus of Singh Straw board factory. Seventh site, i.e. Maheshpur in tehsil Deoband and district Saharanpur was selected on Deoband-Nanota road at about 12 km from Deoband. The tritium injections were made on the left side of Deoband-Nanota road in a cultivated land of Sh. Amee Singh teacher.

Location of various test sites is shown in Fig. 2.1 and these sites are tabulated in Table 2.1 with other details.

2.2 Topography

The area of Saharanpur is almost plain except the presence of Shiwalik mountain range in north. The district is bound by Shiwalik ranges in the north, river Yamuna in the west, districts Hardwar and Muzaffarnagar in the east and south respectively. The area is well drained by a number of rivers and nallahs like Hindon, Kali, Maskara, Krishni and Budhi Yamuna rivers and Katha Nallah etc. The Hindon river is the main source of natural drainage in the area. The eastern Yamuna canal and Deoband branch of upper Ganga canal flow across the study area, which are the main source of recharge to shallow aquifers in the adjoining areas. The eastern Yamuna canal receives its water from river Yamuna itself at Saharanpur.

2.3 Soil

The district Saharanpur is a part of west Indo-Gangetic plain, which is mainly composed of alluvium material brought down by the rivers from the Himalayan region. The alluvium is made of sand, clay, silt, and gravel. The deposits of sand beds are the main source of groundwater in the district.

2.4 Climate and Rainfall

The study area experiences moderate type of sub-tropical monsoon climate. The rainy season in area extends from June to September under the influence of South-West monsoon. The area also receives some rainfall during January and February from North-East monsoon. July and August are the heaviest rainy-months. Normally, the rainfall ceases by the end of September. There is considerable variation in rainfall from year to year as well as month to month in a year. The average annual rainfall of the area is 901 mm of which about 85% rainfall is received during the monsoon season (June-September).

The temperature begins to rise rapidly from about March till May, which is generally hottest month of the year. With the on-set of the monsoon in the fourth week of June, there is

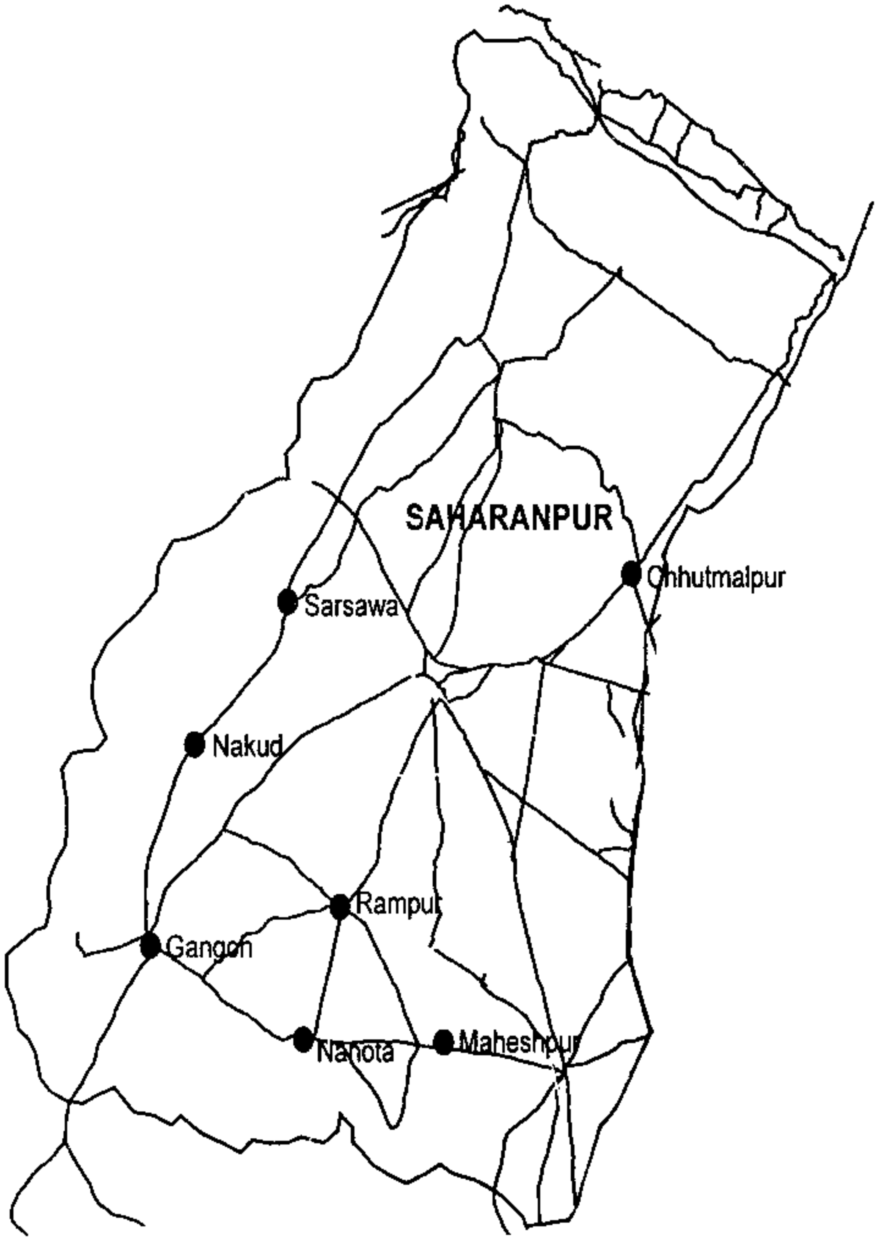

FIG. 2.1: INDEX MAP OF STUDY AREA WITH LOCATION OF TEST SITES

TABLE 2.1: LIST OF TEST SITES ALONG WITH OTHER DETAILS

Sr. No.	Name of Site	Whetner cultivated/ uncultivated land	Date of tritium injection	Date of Tritium sampling
1.	Sarsawa	uncultivated	29.06.99	22.11.99
2.	Chhutmalpur	cultivated	02.07.99	22.11.99
3.	Nakud	cultivated	30.06.99	24.11.99
4.	Rampur Maniharaan	cultivated	02.07.99	25.11.99
5.	Gangoh	cultivated	30.06.99	24.11.99
6.	Nanota	uncultivated	02.07.99	25.11.99
7.	Maheshpur	cultivated	29.06.99	26.11.99

an appreciable drop in day temperature. From mid November onwards, both day and night temperature decreases rapidly. December and January are the coldest months of the year. In winter, cold waves affect the area in the wake of Western disturbances passing across North India. Normally, the temperature varies from 5^0 C to 45^0 C throughout the year. On the whole, the days are warm and nights are cooler. The rainfall data required for the study have been collected for the period from June 1999 to November 1999 from the office of the collector, collection section, Saharanpur which are incorporated in Table 4.9.

2.5 Water-table Condition

The geo-hydrological data indicate three aquifers system in the study area, e.g. shallow within 60 feet depth below ground level, intermediate within 70-150 feet below ground level. and deeper aquifer within 300-500 feet depth below ground level. The average pre-monsoon and post-monsoon groundwater table fluctuation is around 1.6 m in the study area.

The pre-monsoon and post-monsoon groundwater levels in the wells located in the study area for the year 1999 are given in Table 2.2. The groundwater department of U.P. in the year 1999 measured these levels.

2.6 Irrigation Practices and Crops

As the general topography of the area under study is plain, surface/sub-surface methods of irrigation are most commonly used. The ploughing is done either by oxen or tractors. Somewhere land is irrigated by tube wells/bore wells while somewhere it is irrigated by canal or river water. The important crops of the area are sugarcane, rice, wheat, gram, mustard etc. These crops are grown generally in rabi and kharif seasons.

TABLE 2.2: WATER LEVELS IN THE WELLS (BGL) AT TEST SITES

(Source: U.P. Groundwater Department, Roorkee)

Sr. No.	Name of Site	Pre-monsoon (m)	Post-Monsoon (m)
1.	Sarsawa	5.04	N.A.
2.	Chhutmalpur	4.67	3.62
3.	Nakud	9.27	8.90
4.	Rampur Maniharaan	3.78	2.53
5.	Gangoh	N.A	N.A
6.	Nanota	4.75	2.35
7.	Maheshpur	3.97	3.17

3.0 REVIEW OF STUDIES CARRIED OUT IN INDIA

This method was first applied by Zimmerman et al. (1967 a,b) in West Germany. Munnich (1968 a,b) also studied the moisture movement in the unsaturated zone by Tritium tagging method. The concept of water movement through soils, termed the piston flow model was developed.

Datta (1975) carried out pioneering work in India using tritium tagging method. Datta et al. (1973,1977) has first taken up this study in Western UP, Haryana and Punjab. The average recharge values reported by them in Western U.P., Punjab and Haryana are 25%, 18% and 15% of the average rainfall, 98.9 cm, 46 cm and 47 cm respectively. Datta et al. (1977) also measured the rate of downward movement of soil water alongwith groundwater recharge in Sabarmati basin in Gujarat covering an area of 22000 sq. km . The downward movement rate varied from 5 cm/yr. to 280 cm/yr., while recharge value was found to be 10% of the average rainfall, 80cm. Datta et al. has also developed a conceptual model for the study of transport of soil water or recharge through unsaturated soil zone.

Athavale(1977) has estimated recharge to the phreatic aquifer of lower Maner basin, covering 1600 sq. km area and having seven different geological formations using tritium tagging technique and found the recharge values ranging from 4.7 cm to 24 cm with an average for the entire basin, 9.5 cm for annual average rainfall 125cm. Athavale et al. (1978,1980) have also carried out the recharge measurements in few basins namely, Godavari-Purna basin, the Kukadi basin in Deccan traps and Banganga basin between Jaipur and Agra.

Datta et al. (1980) and Gupta and Sharma (1984) have also carried out study of recharge to groundwater in Sabarmati basin and Mahi right-bank canal command area respectively. About forty representative stations were established in different parts of the Sabarmati basin and soil moisture movement was monitored for a period of three years (1976-79). The results obtained for the percentage of recharge indicated a moderate to low values i.e. 18%, 14% and 6%. About 14% of the total average rainfall was estimated to be stored in the Sabarmati basin. In Mahi right-bank canal command area, the percentage of recharge to groundwater was estimated little higher (23%) indicating a high return flow from irrigation. A comparison drawn from the results of recharge obtained in Sabarmati basin with those for the Ganga, the Ramganga and the Yamuna basins in Northern India indicated a relatively higher ground water recharge (18%).

Empirical formulae based on the experimental results have also been established by Datta et al.(1979). Studies of soil moisture movement and groundwater recharge carried out by PRL scientists in Thar desert using tritium tagging method indicated the factors which control groundwater recharge. The groundwater recharge was found to vary between 5-14% of the annual rainfall.

Sharma and Gupta (1985) and Bhandari et al. (1986) have completed two major projects i.e. Sabarmati hydrology project and isotopic study of soil moisture movement in Thar desert. The scientists of PRL used various radioisotopes like tritium, radiocarbon, Si-32 and Uranium isotopes along with dissolved chemical constituents to find out the values of ground water recharge from infiltration of rain water in Sabarmati basin, Mahi Right Bank Canal command area and coastal Saurashtra.

Mukherjee (1986) and Muhkerjee et al. (1987) have also carried out study of recharge to groundwater in rain fed alluvial area and in IARI farm using tritium tagging technique. This group has also carried out a few experiments to study the recharge at different places having similar soil conditions but different crops and irrigation practices. These studies showed that more recharge takes place in fields with irrigation watering and less fractional recharge through fields with vegetation.

Rao and Jain (1985) have used potassium-cobalt-cyanide as a tracer instead of tritium for recharge measurements and reported its advantage over the tritium for recharge measurements. Its movement can be monitored in-situ by radiation logging of the ^{60}Co through an adjacent bore hole. This group has also carried out study of recharge to groundwater using tritium tracer in Tap alluvial region in Maharashtra and in some parts of Rajasthan. Some studies are also carried out in Karnataka.

Singh and Satish Chandra (1978) have studied the recharge to groundwater due to rains using tritium tagging technique in Sharda Command area of Uttar Pradesh.

Raja et al.(1983) also carried out extensive studies of recharge to groundwater due to rain using tritium tagging technique in various areas of Uttar Pradesh like Gandak Command area, Ganga-Sarda area, Agra-Mathura area, Roorkee area, Deoband Branch Command area, Eastern Yamuna Canal Command area, Sarda Sahayak Command area, Saryu Canal command area and percentage recharge due to rain for these areas were found to be 21.38, 24.1, 22.54, 18.5, 18.2, 21.0, 20.85, and 21.25 respectively.

The U.P. Ground Water Department, Lucknow has also covered the Bundelkhand districts of U.P. by carrying out yearly study of recharge to groundwater due to rain and irrigation using tritium tagging technique in Bundelkhand and Vindhyan regions. The results of the recharge to groundwater due to rains in rainy season varied from 9% to 29% in Bundelkhand region. These studies are continued by U.P. Ground Water Department, Lucknow in Uttar Pradesh to cover other districts.

4.0 METHODOLOGY

4.1 Tritium Tagging Method

As it is clear from its name; tritium, a radioactive isotope is used as a tracer to trace the movement of water as it fulfils the requirement of an ideal tracer. An ideal tracer should have the following characteristics:

a) The tracer should behave same as normal water and should not be lost or reiterated due to adsorption or ion exchange. Generally anions and neutral molecules are better in this regard to cations.

b) The tracer should have a high detection sensitivity.

c) The health and handling hazards should be minimum.

d) The duration of the study is generally about 1 to 2 years and hence the radio-tracer should have considerable half life (about 1 year) from the study point of view but less half life from health hazard point of view. Therefore, radio-isotopes are selected keeping in view the both aspects.

Tritium as Tracer

a) It behaves similar to normal water as it is a molecule of water.

b) It is a pure beta emitter of low energy (18.6 keV) and belongs to the lowest radio-toxicity class.

c) It can be measured with a high detection sensitivity.

d) It has comparatively long half-life (12.23 years) and hence useful for soil moisture movement studies. The long half-life makes it possible to store the tracer in the laboratory and no particular shielding is required.

Principle of the Technique

The principle of the tritium tagging technique is mainly based on the following assumptions [Zimmermann et al. (1967) and Munnich, K.D. (1968)].

The vertically downward movement of soil moisture is very slow due to which the lateral mixing between soil moisture portions of different flow velocities even with the stationary also takes place and the moisture flows in discrete layers in such a way that if any fresh water will be added to the top surface of the soil, the infiltrated layer of the water pushes the older layer downward in the soil system and so on till the last layer of moisture reaches the saturated zone. This concept of water flow in unsaturated zone has been treated as the concept of piston type flow.

On the basis of these assumptions, if a radio-isotope (tritium) is tagged below the active root zone and also not affected by sun heating (say below 75cm to 1m), the tagged radio-isotope will be mixed with the soil moisture available at the depth and act as an impermeable sheet. Therefore, if any water will be added to the top of the soil surface, it will be infiltrated into the ground by pushing down the older water, thus the shift in the tritium peak can be observed after some time (say after laps of one season). But, the tritium peak will be broadened due to molecular diffusion, stream line dispersion, asymmetrical flow and other hetrogeneties of the soil media.

The soil samples from the injection point are collected at the interval of 10 or 15 cm depth after pinpointing it very accurately. The soil core so removed are collected and kept in an air-tight plastic container or polythene pack. The soil moisture is obtained from soil samples by vacuum distillation and also the dry density and moisture content determined by gravimetric method using either oven or infra-red moisture balance, the later is preferred due to superiority over the normal gravimetric method. The tritium contents are determined in the soil moisture, obtained by the distillation of the soil samples, with the help of Liquid Scintillation Spectrometer using suitable liquid scintillator. The counting rates so obtained, say counts per minute or per 100 seconds or per 2 minutes depending upon the number of counts obtained per second in order to increase the total number of counts to reduce the statistical error, are plotted with respect to depth and the center of gravity of the tritium peak so obtained is calculated. By subtracting the depth of injection from the C.G. of the tritium peak, the shift of the tritium peak can be obtained. Now as per the principle laid down by the founder investigators (1967), the multiplication of the tritium peak shift and effective average volumetric moisture content in the tritium peak shift region will provide the information of recharge to ground water during the time interval of tritium injection and sampling. The effective average volumetric moisture content in the peak shift region can be obtained by subtracting the field capacity of the peak shift region from the average volumetric moisture content in the peak shift region at the time of sampling. Mathematically the equation for the estimation of percentage of recharge to ground water can be written as:

$$R = \theta_v\, d\, (100/p)$$

where,

R	is the percentage of recharge to ground water
θ_v	is the effective average volumetric moisture content in the tritium peak shift region
d	is the shift of tritium peak in cm
p	is precipitation and/or irrigation in cm

Source of Errors and Precautions

The use of tritium tagging technique may lead to the various source of errors due to different practical problems involved. The main source of errors can broadly be categorised in three steps, used to perform this study.

1) Conducting field experiment.
2) Estimation of tritium and volumetric moisture contents.
3) Estimation of recharge to ground water using experimental data.

Conducting Field Experiment

In order to conduct the field experiment, the following steps are involved which should be dealt very carefully to minimise the possible errors.

1) Selection of representative field (site).
2) Marking of site for relocation.
3) Quantity of activity and injection of tritium at certain depth.
4) Relocation of site, collection and storing of soil samples.

The procedure to be followed in the steps mentioned above, although purely depends on the practice and common sense of the user of this technique but the following criteria can be adopted in order to minimise the possible errors and variations that may occur in case of different users.

1) Selected site should represent the area i.e., it should have the topographical and geomorphological features similar to the nearby area.

2) Site should be plain for all practical purposes as this technique is not practically valid for hilly and very high sloppy areas.

3) The site should be at a place where the marking points like tree, electric poles or other similar types of natural or man made identification marks exist in maximum possible directions at some distance (not very close to site). Otherwise, the identification marks will have to be fixed by the user.

4) Besides the identification marks already existing at some distance from the tritium injection point, few additional marks, like iron nails should be fixed at very close distance, say 1 or 2 m around the injected point in order to reduce the inaccuracy that may occur in the measurement of long distances of natural or man made identification marks.

5) The availability of rainfall and/or irrigation data should be ensured before the selection of a particular site.

6) For correct estimation of the recharge to the ground water, the site should be selected in both types of field i.e., cultivated and uncultivated fields.

7) Tritium should be injected directly at the specified depth using a syringe, plastic pipe and metallic pipe.

8) 2 ml of tritium having specific activity at least 25 to 40 μCi/cc should be injected at a depth well below the root zone and zone of sun heating, say 70 cm for temperate region to 100 cm for arid region, in all the five holes, each 10 cm apart after making a set of injection points, as shown in Fig. 4.1. The holes should be completely filled with soil after injecting tritium in order to reduce the direct loss of injected tracer due to evaporation and also to avoid the direct entry of water.

9) Layout of the experimental site should be prepared very carefully for the relocation of the site.

10) The site should be relocated very precisely and soil sample should be collected at the interval of 10cm or 15cm either using a hand auger or any other coring device having sampling tubes.

11) All precautions should be taken to collect the soil sample in vertically downward direction.

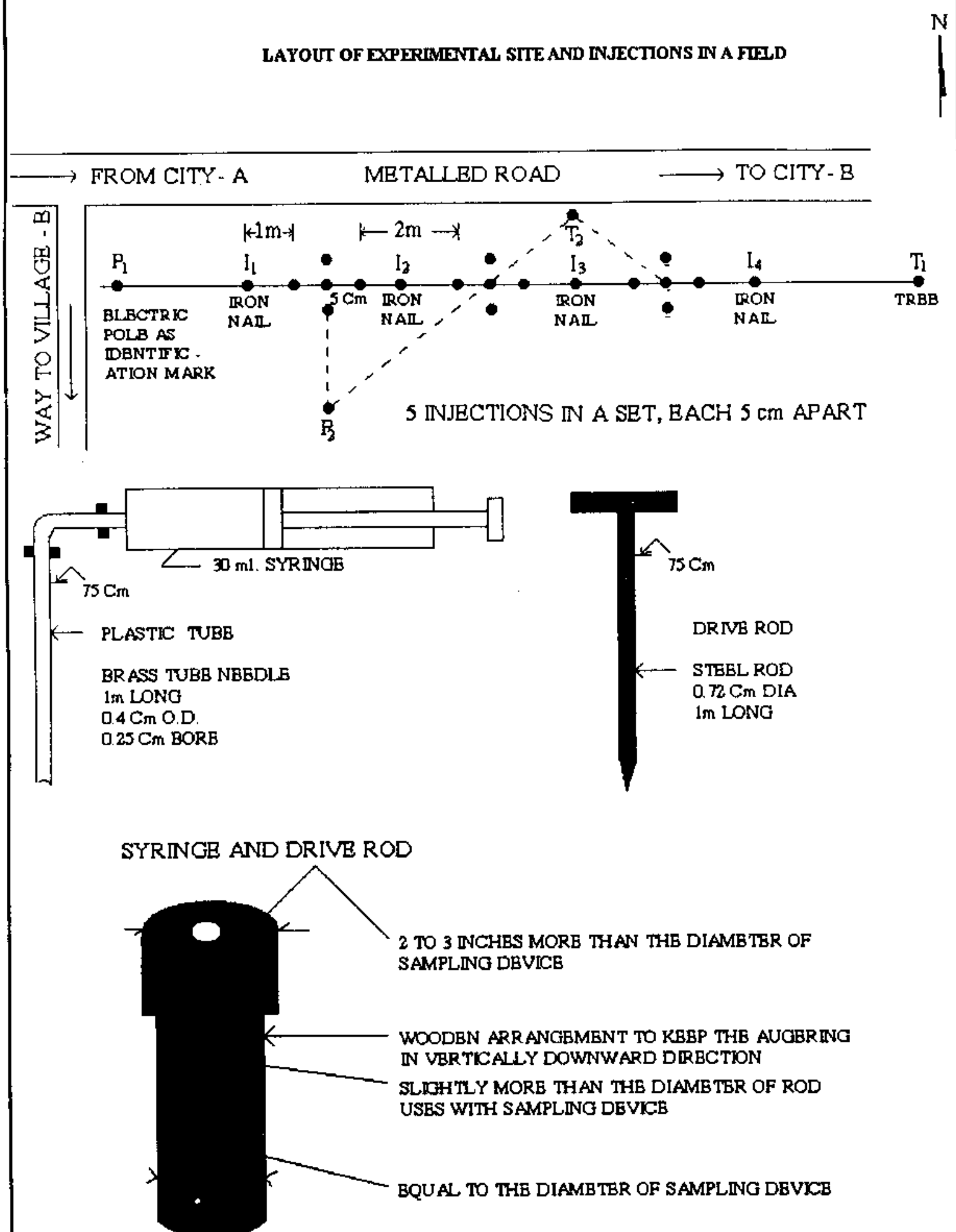

FIG. 4.1: SYSTEMATIC DIAGRAM OF INJECTION LAYOUT AND IMPLEMENTS FOR ARTIFICIAL TRITIUM INJECTION AT TEST SITE

12) In order to minimise the contamination of soil samples at lower depths, all precautions should be taken at the time of lowering the sample collection device so that it could not touch to the side walls of the bore hole.

13) In order to minimise the loss of trotted water content due to evaporation, the soil samples should be kept in an air tight plastic box or plastic bags to bring them to laboratory for various analyses.

Estimation of Tritium and Volumetric Moisture Contents

In order to estimate the tritium and volumetric moisture content, the following steps are involved, which should be taken very carefully:

1) Measurement of volume and weight of the soil samples.
2) Gravimetric analysis of the soil samples.
3) Vacuum distillation of the soil samples.
4) Selection of the proper liquid scintillator and counting system.
5) Volumetric measurement of scintillator and tritiated water sample.
6) Measurement of tritium activity and counting time.

The points mentioned above are quite familiar and precautions, which should be taken during the steps mentioned at sl.no.1 to 3, are very common. But, the selection of proper liquid scintillator and counting system needs some special attention in order to minimise the statistical error. Although, more tritium counts can be obtained either by increasing the counting time or by injecting more tritium into the ground to minimise the statistical error but, the first option is better as the injection of high activity should be avoided for all practical purposes. In addition, the selection of suitable liquid scintillator and counting system is also an important aspect to get the higher accuracy in the measurement of tracer activity.

The repeatability in the measurement of volumes of the liquid scintillator and tritiated water in case of each sample is very important in order to locate the tritium peak at its real position. The counting time should be increased to get the more tritium counts if all other precautions have already been taken into account and still tritium counts are appearing less per sec or per minute.

Estimation of Recharge to Ground Water

In order to estimate the correct recharge to ground water the following points should be considered carefully:

1) Centre of gravity of tritium peak.
2) Average volumetric moisture content in the peak shift region at the time of sampling.
3) Rainfall and/or irrigation data.
4) Type of soil and topography of the field.
5) Position of the ground water level.
6) Time period of the study.
7) Percentage of the cultivated and uncultivated fields in the study area.

Although the points mentioned above are self explanatory, but even if the required data like rainfall and/or irrigation, type of soil, water level fluctuations, groundwater withdrawal, tritium peak shift, and moisture content etc. are available for the test sites, the common sense is required to arrive at any conclusion on the basis of the experimental data e.g., the recharge to ground water can not be more than the precipitation and/or irrigation while in certain conditions, the field may be completely submerged of water due to short duration flood or the site may be located at a place where the water from the nearby fields stores during the rainfall, the obtained value will show more ground water recharge at that site than the amount of water supplied, but in such a case the recharge value can not represent the nearby area. Similarly, if any area is having more %age of uncultivated land, the values obtained only for the cultivated fields can not be applied to calculate the total recharge to ground water due to precipitation and or irrigation to the aquifer existing in that area.

4.2 Field Experiments

Field experiments consisted of tritium injections at various sites located in the study area before on-set of monsoon season and carrying out sampling immediately after monsoon.

4.2.1 Tritium injection

The selection of any particular site for the study was done, considering only the type of surface soil and accessibility of the area. Tritium injections were carried out at 7 sites, which are shown in Fig. 2.1.

Two sets of tritium injection were made at 7 sites during June/July 1999. These sets were located on a line fixed by choosing appropriate bench marks (usually electric or telephone poles). Each set of injection consisted of one central injection on the line and four injections in a circle of radius 10 cm around it. This is done in order to make sure that the tracer is not lost due to a possible slight misalignment in pin-pointing the injection point while sampling the site. The drive rods (10 mm diameter) were first hammered into the soil, for making 70 cm deep holes. The drive rods were then pulled out and stainless steel pipe (injection pipe) was inserted into each hole. The tritium of specific activity of 200 mCi/cc bought from BARC, Mumbai was diluted to the specific activity of 40 μCi/cc. About 2 ml of tritium of specific activity of 40 μCi/cc was injected in each hole with the help of plastic syringe through the injection pipe care being taken that there was minimum disturbance to the natural condition of the soil due to the injection. Each hole was completely filled up with the soil after carrying out tritium injection in the same. At each site few iron nails were hammered on the line of sets of injection and left in the ground, which acted as markers for subsequent location of the sites. The field was left for its normal use by the farmers (for application of irrigation and/or precipitation).

4.2.2 Sampling

The soil sampling was carried out at the time of injection and immediately after the monsoon i.e. during the month of November 1999. Soil samples were collected layer by layer (10cm sections) with the help of a hand auger of 2" diameter starting from ground surface to about 250 cm. The soil samples were carefully collected and packed in properly sealed polyethylene bags so that there was no exchange of the moisture with the atmosphere and brought to the laboratory for the analysis.

4.3 Laboratory Experiments

The laboratory experiments consisted of estimation of soil moisture content, particle size analysis and measurement of tritium counts in the soil samples.

4.3.1 Soil moisture content

The moisture content of the soil samples on wet weight basis was estimated by gravimetric method using infrared moisture balance.

Wet weight of each soil sample was determined by weighing the sampling using electronic balance. After that small amount of soil sample (approximately 10gm) was kept on the infrared moisture balance in order to dry the sample due to the radiations of the equipment which gave direct value of soil moisture content (percentage by wet weight basis of the sample). Bulk density for each sample was determined by dividing the wet weight of the sample by the volume of the each sample, which was equivalent to the volume of hand auger of known diameter for a particular depth of soil column. Volumetric moisture content for each soil sample was estimated by multiplying the moisture content obtained by infrared moisture balance on wet weight basis and bulk density of the soil. The values of volumetric moisture contents are tabulated in Table 4.1 to 4.7.

4.3.2 Particle size analysis

The samples collected from the field were tested in the Soil and Groundwater laboratory, National Institute of Hydrology, for carrying out particle size distribution. Particle size distribution of the soil samples was carried out by sieve analysis and master sizer analysis. Soil samples were washed with distilled water to remove the soluble salts. The washed samples were separated into two fractions i.e. +75 micron and -75 micron through wet sieving. Sieve analysis was performed for the fraction of soil retained on 75micron sieve (+75 micron). The portion passed through the 75micron sieve (-75 micron) was analysed by master sizer. The test results of the analysis for various sites are given in Table 4.8(a) to 4.8(g).

TABLE 4.1: VOLUMETRIC SOIL MOISTURE CONTENT, NET TRITIUM COUNT RATE AND RECHARGE TO GROUNDWATER SARSAWA SITE

Depth (cm)	Vol. Soil Moist. Content	Net Tritium Count/min/ml	Determination of recharge to groundwater for the period from 28.06.99 to 22.11.99
0-10	0.036	224	Depth of tritium injection = 70 cm Tritium peak shift (d) = 129.93 cm Average vol. soil moist. content in peak shift region = 0.134 Field capacity in peak shift region = 0.099 Effective vol. moist. content in peak shift region (θ_v) = 0.035 Recharge to Groundwater (R) = θ_v * d = 4.44 cm
10-20	0.057	1997	
20-30	0.081	2046	
30-40	0.100	1722	
40-50	0.133	852	
50-60	0.139	1889	
60-70	0.157	992	
70-80	0.157	540	
80-90	0.131	864	
90-100	0.079	917	
100-110	0.127	1074	
110-120	0.140	283	
120-130	0.144	2217	
130-140	0.142	2191	
140-150	0.139	335	
150-160	0.137	248	
160-170	0.162	379	
170-180	0.137	367	
180-190	0.130	395	
190-200	0.112	626	
200-210	0.110	895	
210-220	0.116	1336	
220-230	0.125	357	
230-240	0.123	102	
240-250	0.107	87	

TABLE 4.2: VOLUMETRIC SOIL MOISTURE CONTENT, NET TRITIUM COUNT RATE AND RECHARGE TO GROUNDWATER CHHUTMALPUR SITE

Depth (cm)	Vol. Soil Moist. Content	Net Tritium Count/min/ml	Determination of recharge to groundwater for the period from 02.07.99 to 22.11.99
0-10	0.150	47	Depth of tritium injection = 70 cm
10-20	0.160	31	Tritium peak shift (d) = 128.85 cm
20-30	0.177	86	Average vol. soil moist. content in peak shift region = 0.240
30-40	0.235	75	Field capacity in peak shift region = 0.144
40-50	0.271	100	Effective vol. moist. content in peak shift region (θ_v) = 0.096
50-60	0.297	27	Recharge to Groundwater (R) = θ_v * d = 12.38 cm
60-70	0.257	33	
70-80	0.268	31	
80-90	0.317	16	
90-100	0.269	5	
100-110	0.285	92	
110-120	0.332	16	
120-130	0.335	14	
130-140	0.318	28	
140-150	0.236	26	
150-160	0.180	51	
160-170	0.165	91	
170-180	0.166	18	
180-190	0.125	28	
190-200	0.131	7	
200-210	0.127	1123	
210-220	0.205	663	
220-230	0.358	21	
230-240	0.392	54	
240-250	0.469	59	

TABLE 4.3: VOLUMETRIC SOIL MOISTURE CONTENT, NET TRITIUM COUNT RATE AND RECHARGE TO GROUNDWATER AT NAKUD SITE

Depth (cm)	Vol. Soil Moist. Content	Net Tritium Count/min/ml	Determination of recharge to groundwater for the period from 30.06.99 to 24.11.99
0-10	0.074	128	Depth of tritium injection = 70 cm Tritium peak shift (d) = 94.58 cm Average vol. soil moist. content in peak shift region = 0.197 Field capacity in peak shift region = 0.142 Effective vol. moist. content in peak shift region (θ_v) = 0.055 Recharge to Groundwater (R) = $\theta_v * d$ = 5.20 cm
10-20	0.094	114	
20-30	0.117	38	
30-40	0.136	34	
40-50	0.156	23	
50-60	0.158	74	
60-70	0.163	94	
70-80	0.186	299	
80-90	0.178	94	
90-100	0.195	37	
100-110	0.195	47	
110-120	0.181	115	
120-130	0.192	840	
130-140	0.195	578	
140-150	0.194	317	
150-160	0.213	1028	
160-170	0.239	1126	
170-180	0.267	1031	
180-190	0.260	1105	
190-200	0.211	1114	
200-210	0.254	565	
210-220	0.287	18	
220-230	0.293	31	
230-240	0.303	37	
240-250	0.403	7	

TABLE 4.4: VOLUMETRIC SOIL MOISTURE CONTENT, NET TRITIUM COUNT RATE AND RECHARGE TO GROUNDWATER AT RAMPUR MANIHARAAN SITE

Depth (cm)	Vol. Soil Moist. Content	Net Tritium Count/min/ml	Determination of recharge to groundwater for the period from 02.07.99 to 25.11.99
0-10	0.300	231	Depth of tritium injection = 70 cm
10-20	0.214	335	Tritium peak shift (d) = 89.57 cm
20-30	0.260	25	Average vol. soil moist. content in peak shift region = 0.384
30-40	0.360	48	Field capacity in peak shift region = 0.265
40-50	0.368	89	Effective vol. moist. content in peak shift region (θ_v) = 0.083
50-60	0.414	339	Recharge to Groundwater (R) = θ_v * d = 10.66 cm
60-70	0.410	348	
70-80	0.336	279	
80-90	0.391	1154	
90-100	0.391	1234	
100-110	0.366	1208	
110-120	0.366	1250	
120-130	0.355	1155	
130-140	0.420	1193	
140-150	0.398	1183	
150-160	0.435	951	
160-170	0.421	883	
170-180	0.433	771	
180-190	0.415	920	
190-200	0.434	936	
200-210	0.470	1296	
210-220	0.467	879	
220-230	0.464	1064	
230-240	0.557	937	
240-250	0.516	942	

TABLE 4.5: VOLUMETRIC SOIL MOISTURE CONTENT, NET TRITIUM COUNT RATE AND RECHARGE TO GROUNDWATER AT GANGOH SITE

Depth (cm)	Vol. Soil Moist. Content	Net Tritium Count/min/ml	Determination of recharge to groundwater for the period from 30.06.99 to 24.11.99
0-10	0.100	0	Depth of tritium injection = 70 cm Tritium peak shift (d) = 102.49 cm Average vol. soil moist. content in peak shift region = 0.233 Field capacity in peak shift region = 0.121 Effective vol. moist. content in peak shift region (θ_v) = 0.112 Recharge to Groundwater (R) = θ_v * d = 11.48 cm
10-20	0.144	102	
20-30	0.150	105	
30-40	0.209	78	
40-50	0.208	103	
50-60	0.218	113	
60-70	0.204	131	
70-80	0.230	108	
80-90	0.245	520	
90-100	0.263	1961	
100-110	0.272	462	
110-120	0.255	1077	
120-130	0.222	1147	
130-140	0.223	1155	
140-150	0.203	499	
150-160	0.204	429	
160-170	0.216	492	
170-180	0.233	1347	
180-190	0.237	1743	
190-200	0.145	785	
200-210	0.116	804	
210-220	0.114	1275	
220-230	0.123	1344	
230-240	0.105	1997	
240-250	0.145	1451	

TABLE 4.6: VOLUMETRIC SOIL MOISTURE CONTENT, NET TRITIUM COUNT RATE AND RECHARGE TO GROUNDWATER AT NANOTA SITE

Depth (cm)	Vol. Soil Moist. Content	Net Tritium Count/min/ml	Determination of recharge to groundwater for the period from 02.07.99 to 25.11.99
0-10	0.346	2763	Depth of tritium injection = 70 cm Tritium peak shift (d) = 00.00 cm Average vol. soil moist. content in peak shift region = 0.346 Field capacity in peak shift region = 0.278 Effective vol. moist. content in peak shift region (θ_v) = 0.068 Recharge to Groundwater (R) = θ_v * d = 7.18 cm
10-20	0.300	2595	
20-30	0.297	2282	
30-40	0.262	2760	
40-50	0.316	2777	
50-60	0.316	2878	
60-70	0.235	2312	
70-80	0.300	73	
80-90	0.290	459	
90-100	0.320	40	
100-110	0.352	47	
110-120	0.300	58	
120-130	0.366	528	
130-140	0.406	57	
140-150	0.390	437	
150-160	0.364	435	
160-170	0.359	504	
170-180	0.358	476	
180-190	0.333	67	
190-200	0.445	1631	
200-210	0.406	2391	
210-220	0.385	50	
220-230	0.356	372	
230-240	0.412	29	
240-250	0.416	22	

TABLE 4.7: VOLUMETRIC SOIL MOISTURE CONTENT, NET TRITIUM COUNT RATE AND RECHARGE TO GROUNDWATER AT MAHESHPUR SITE

Depth (cm)	Vol. Soil Moist. Content	Net Tritium Count/min/ml	Determination of recharge to groundwater for the period from 29.06.99 to 26.11.99
0-10	0.082	1161	
10-20	0.151	1267	Depth of tritium injection = 70 cm
20-30	0.170	669	Tritium peak shift (d) = 125.47 cm
30-40	0.200	502	Average vol. soil moist. content in peak
40-50	0.216	2079	shift region = 0.305
50-60	0.234	2021	Field capacity in peak shift region = 0.217
60-70	0.248	2233	Effective vol. moist. content in peak shift
70-80	0.249	1296	region (θ_v) = 0.088
80-90	0.255	2456	Recharge to groundwater (R)
90-100	0.296	1148	$= \theta_v * d = 11.04$ cm
100-110	0.290	1227	
110-120	0.300	1507	
120-130	0.311	1326	
130-140	0.320	2180	
140-150	0.317	1044	
150-160	0.340	628	
160-170	0.323	673	
170-180	0.327	1515	
180-190	0.286	1603	
190-200	0.350	1524	
200-210	0.339	646	
210-220	0.334	668	
220-230	0.412	640	
230-240	0.457	635	
240-250	0.416	631	

TABLE 4.8(a): PARTICLE SIZE DISTRIBUTION FOR SARSAWA SITE

Sr. No.	Depth (cm)	Gravel (%) (>2.0 mm)	Sand (%) (2 mm-0.075mm)	Silt + Clay (%) (<0.075 mm)
1.	0-30	0.40	72.44	27.15
2.	30-60	0.05	70.83	29.12
3.	60-90	0.67	70.79	28.53
4.	90-120	1.26	75.26	23.48
5.	120-150	0.43	80.81	18.76
6.	150-180	1.54	82.21	16.25
7.	180-210	0.77	79.00	20.23
8.	210-240	2.59	84.74	12.67
Average		0.96	77.01	22.02

TABLE 4.8(b): PARTICLE SIZE DISTRIBUTION FOR CHHUTMALPUR SITE

Sr. No.	Depth (cm)	Gravel (%) (>2.0 mm)	Sand (%) (2 mm-0.075mm)	Silt + Clay (%) (<0.075 mm)
1.	0-30	0.73	35.90	63.37
2.	30-60	0.43	32.78	66.79
3.	60-90	0.91	30.41	68.67
4.	90-120	0.77	34.15	65.08
5.	120-150	2.10	48.61	49.28
6.	150-180	0.34	71.89	27.76
7.	180-210	0.16	67.42	32.42
8.	210-240	0.05	22.19	77.76
Average		0.69	42.91	56.39

TABLE4.8(c): PARTICLE SIZE DISTRIBUTION FOR NAKUD SITE

Sr. No.	Depth (cm)	Gravel (%) (>2.0 mm)	Sand (%) (2 mm-0.075mm)	Silt + Clay (%) (<0.075 mm)
1.	0-30	0.29	29.97	69.73
2.	30-60	0.01	18.88	81.11
3.	60-90	0.00	16.56	83.44
4.	90-120	0.09	12.48	87.43
5.	120-150	0.13	9.66	90.21
6.	150-180	0.12	4.18	95.70
7.	180-210	1.17	4.00	94.82
8.	210-240	0.49	4.53	94.98
Average		0.28	12.53	87.17

TABLE 4.8(d): PARTICLE SIZE DISTRIBUTION FOR RAMPUR MANIHARAAN SITE

Sr. No.	Depth (cm)	Gravel (%) (>2.0 mm)	Sand (%) (2 mm-0.075mm)	Silt + Clay (%) (<0.075 mm)
1.	0-30	2.09	32.64	65.27
2.	30-60	0.55	15.46	83.98
3.	60-90	0.04	5.64	94.31
4.	90-120	0.23	7.33	92.44
5.	120-150	1.79	10.28	87.92
6.	150-180	6.04	6.32	87.65
7.	180-210	4.15	5.85	89.99
8.	210-240	9.69	3.01	87.30
Average		3.07	10.81	86.10

TABLE 4.8(e): PARTICLE SIZE DISTRIBUTION FOR GANGOH SITE

Sr. No.	Depth (cm)	Gravel (%) (>2.0 mm)	Sand (%) (2 mm-0.075mm)	Silt + Clay (%) (<0.075 mm)
1.	0-30	0.16	50.68	49.22
2.	30-60	1.41	45.14	53.45
3.	60-90	1.53	44.09	54.38
4.	90-120	0.54	42.23	57.23
5.	120-150	0.05	79.48	20.47
6.	150-180	0.03	41.75	58.22
7.	180-210	0.02	47.62	52.36
8.	210-240	0.01	47.54	52.45
Average		0.47	49.81	49.72

TABLE 4.8(f): PARTICLE SIZE DISTRIBUTION FOR NANOTA SITE

Sr. No.	Depth (cm)	Gravel (%) (>2.0 mm)	Sand (%) (2 mm-0.075mm)	Silt + Clay (%) (<0.075 mm)
1.	0-30	0.31	15.78	83.90
2.	30-60	0.54	12.96	87.26
3.	60-90	0.03	7.52	92.45
4.	90-120	1.46	10.53	88.00
5.	120-150	3.23	12.20	84.57
6.	150-180	1.80	18.06	80.14
7.	180-210	9.92	14.29	75.79
8.	210-240	18.04	15.73	66.23
Average		4.42	13.38	82.29

TABLE 4.8(g): PARTICLE SIZE DISTRIBUTION FOR MAHESHPUR SITE

Sr. No.	Depth (cm)	Gravel (%) (>2.0 mm)	Sand (%) (2 mm-0.075mm)	Silt + Clay (%) (<0.075 mm)
1.	0-30	0.96	17.08	81.97
2.	30-60	0.07	13.95	86.03
3.	60-90	0.50	8.76	90.74
4.	90-120	0.53	11.79	87.68
5.	120-150	1.70	11.67	86.63
6.	150-180	0.65	11.05	88.29
7.	180-210	0.11	11.95	87.91
8.	210-240	0.00	6.92	93.08
Average		0.56	11.64	87.79

4.3.3 Water extraction from soil samples

After determination of soil moisture content for the soil samples collected from each 10 cm depth using infrared moisture balance, each sample was subjected to distillation under low pressure to avoid volatile impurities being collected along with the water. Water from the each soil sample was extracted and stored in the plastic/glass vials.

4.3.4 Tritium activity measurement with LSC

Radioactivity is the result of an unstable combination of protons and neutrons in the nucleus, and the attempt to arrive at a more stable combination. This stable combination is frequently attained by the emission of an alpha or beta particle associated with or without gamma radiations.

Beta Particles are energetic electrons emitted from the nucleus (neutron-->electron + proton + ν) of many radioisotopes. The energy released by this emission is dependent on the radioisotope and is shared between the beta particle and the anti-neutrino (ν). Because of this energy sharing and the fact that the anti-neutrinos are not detectable, beta spectra are very broad. Normally they start at 0 keV (all energy is given to the anti-neutrino) and end at some E_{max} keV depending on the radioisotope.

Usually beta particles do not travel far after emission; they rarely penetrate through the vial in which they are contained. Therefore for beta particles it is necessary to put the "detector" as close to the decay particles as possible, that is, inside the vial. This detector is the liquid scintillation cocktail. A scintillation sample vial consists of the following:

1. Radioactive sample and
2. A liquid scintillation cocktail

   Normally consisting of the following components:

   Solvent: Typically toluene, xylene, pseudocumene or alkyl benzene (biodegradable) type solvent.

   Emulsifier: A detergent type molecule (like Triton X-100) that ensures proper mixing of aqueous samples in organic solvents.

Fluor: A fluorescent solute (like PPO).

The function of the scintillation cocktail is to convert the energy of the radioactive decay particles into visible light, which can be detected by the scintillation counter.

The amount of light being emitted from the vial is proportional to the energy of the particle. That is, the higher the energy of a particle, the more solvent molecules it is able to excite and, therefore, more light is generated.

This light is emitted from the LS sample vial in all directions and is "directed" in to two photomultiplier tubes (PMT's) which convert the light into a measurable electrical pulse.

The liquid scintillation system which is at present being used at Nuclear Hydrology Laboratory of National Institute of Hydrology, Roorkee is Model 'System 1409' (Wallac Oy, Finland) whose efficiency is around 60%. The system provides an elegant way of counting the activity of tritium using 'Easy Count' approach.

Ten ml of scintillation cocktail 'W' (SRL, Mumbai) was poured in to each scintillation vial depending upon the number of samples to be analysed. Cocktail 'W' is commercially available and is composed of the following:

1,4 - Dioxane	1 litre
2,5 - Diphenyl oxazole (PPO)	10gm
[1,4-Di-2,(5-Phenyloxazolyl)-Benzene] (POPOP)	0.25 gm
Naphthalene	100 gm

The scintillation vials containing 10 ml of Cocktail 'W', were placed in the counting chamber of the liquid scintillation counter for 300 seconds and back ground counts (in counts per minute) for cocktail 'W' were obtained by the system. One ml of tritiated water extracted from each soil sample was mixed with 10 ml of cocktail 'W' (whose background counts was already measured with LSC) in the scintillation vials.

The vials containing 1 ml of soil water and 10 ml of cocktail 'W' were placed in the counting chamber of the liquid scintillator counter 'System 1409' in order and each sample was counted for 300 seconds and consequently count rate (in counts per minute or cpm) for each sample was obtained by this system. These count rates were corrected for background counts in order to get net tritium counts per minute. These net tritium count rates for various sites are tabulated in Table 4.1 to 4.7.

4.4 Determination of Recharge to Groundwater

The net tritium count rate (counts per minute or CPM) for various sites were plotted as a histogram against the individual depth intervals which shows position of the original and shifted peaks of injected tritium. The movement of injected tritium and soil moisture at various test sites are shown in Fig. 4.2 to 4.8. After getting the shifted tritium peak, the centre of gravity of the peak was determined and the shift of the peak from original depth of injection of 70 cm was calculated.

The recharge to groundwater for various sites were determined by multiplying the peak shift of tritium as calculated above and effective average volumetric moisture content in the peak shift region and are given in Table 4.1 to 4.7.

The percentage of recharge to groundwater at various experimental sites due to monsoon rain for the year 1999 and irrigation is given in Table 4.9.

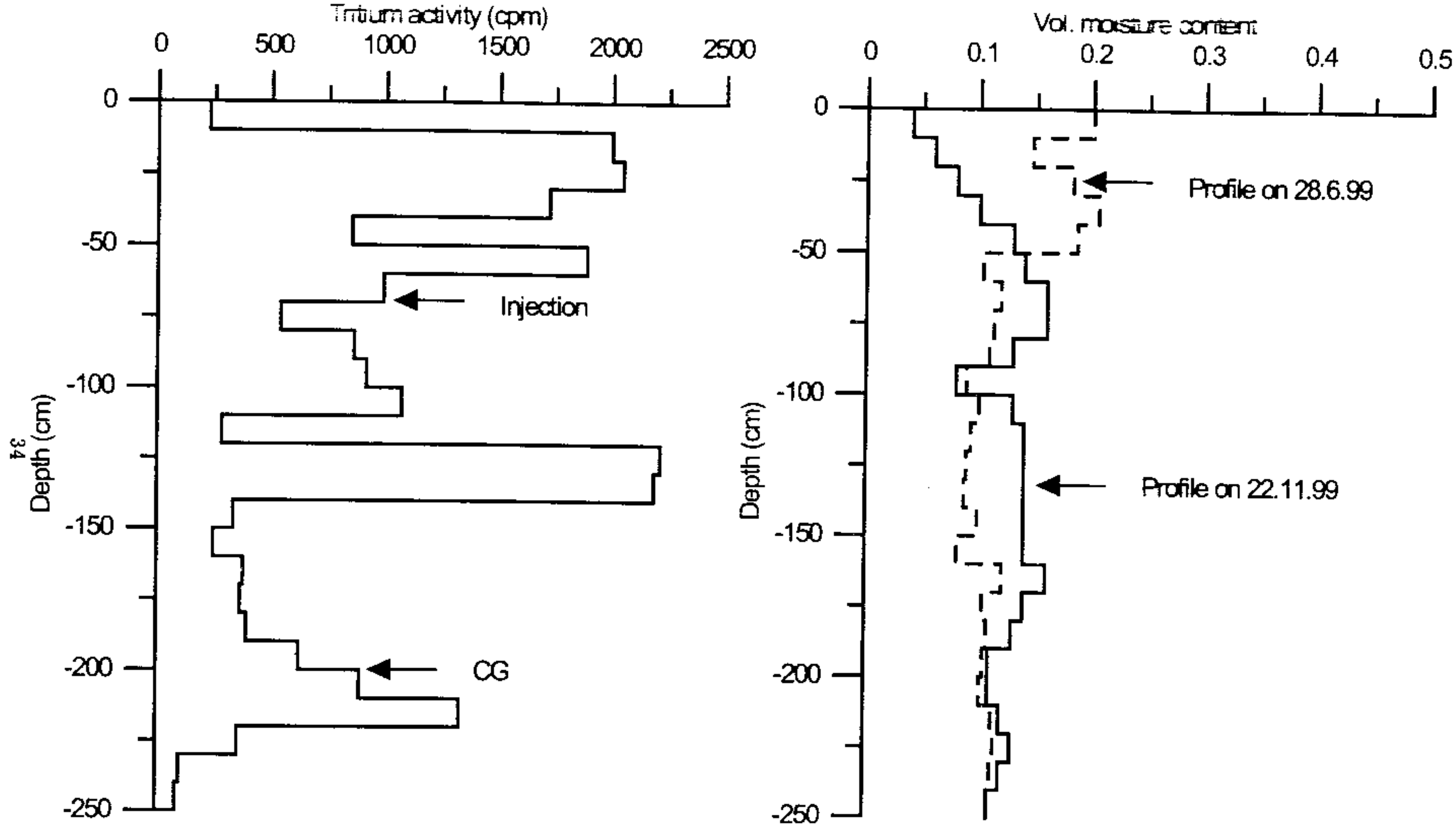

FIG. 4.2: MOVEMENT OF TRITIUM AND SOIL MOISTURE AT SARSAWA SITE

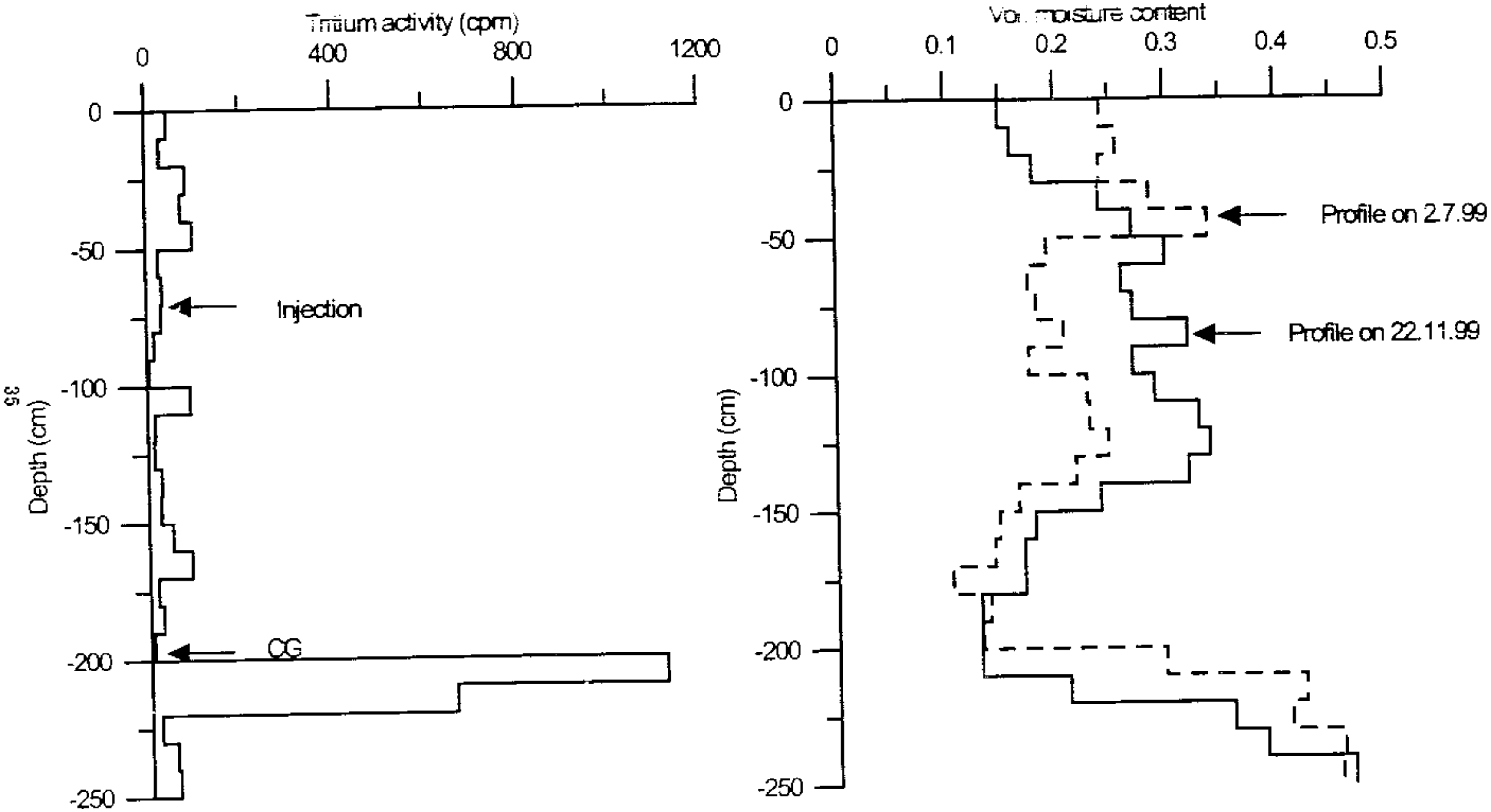

FIG. 4.3: MOVEMENT OF TRITIUM AND SOIL MOISTURE AT CHHUTMALPUR SITE

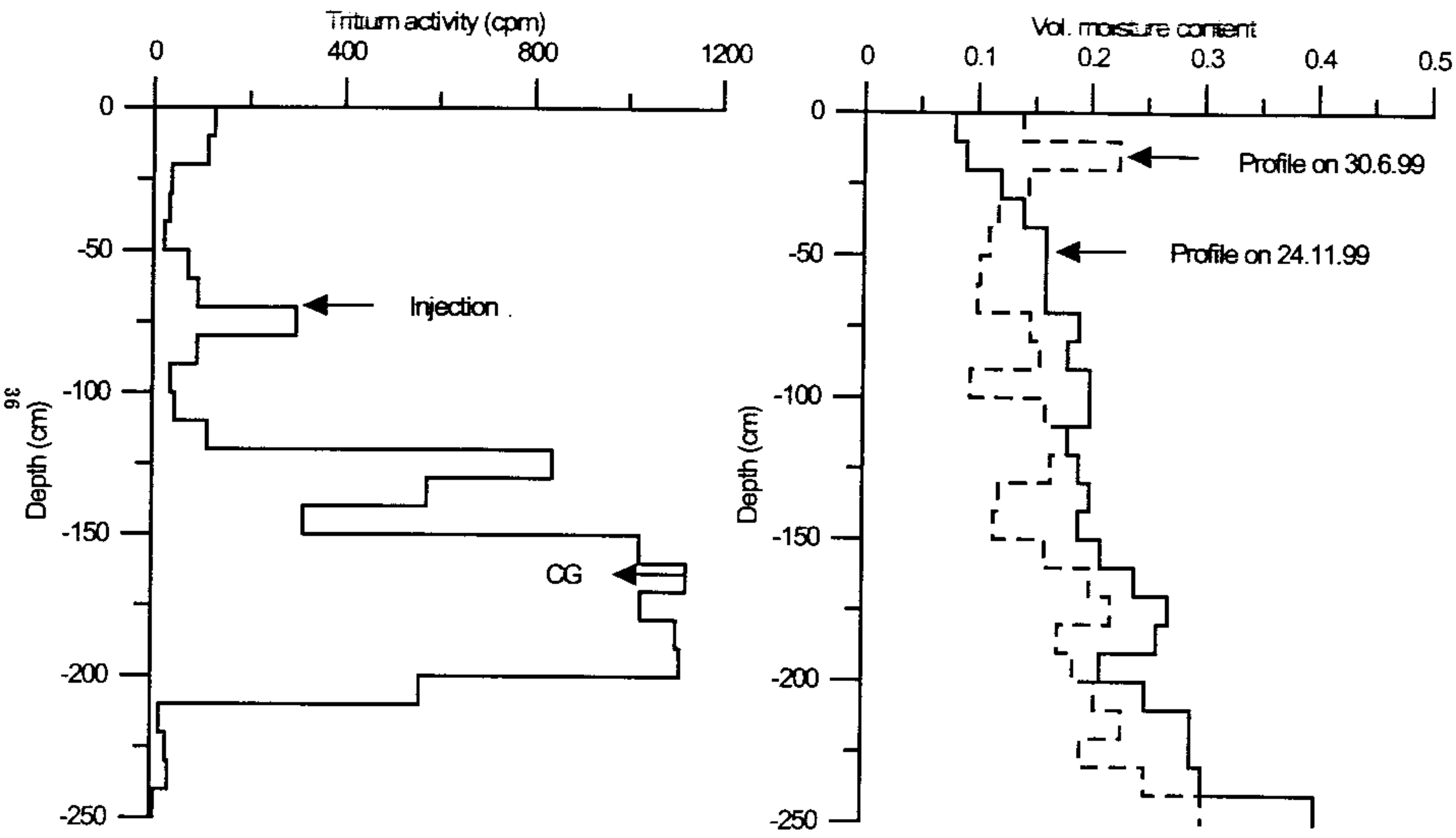

FIG. 4.4: MOVEMENT OF TRITIUM AND SOIL MOISTURE AT NAKUD SITE

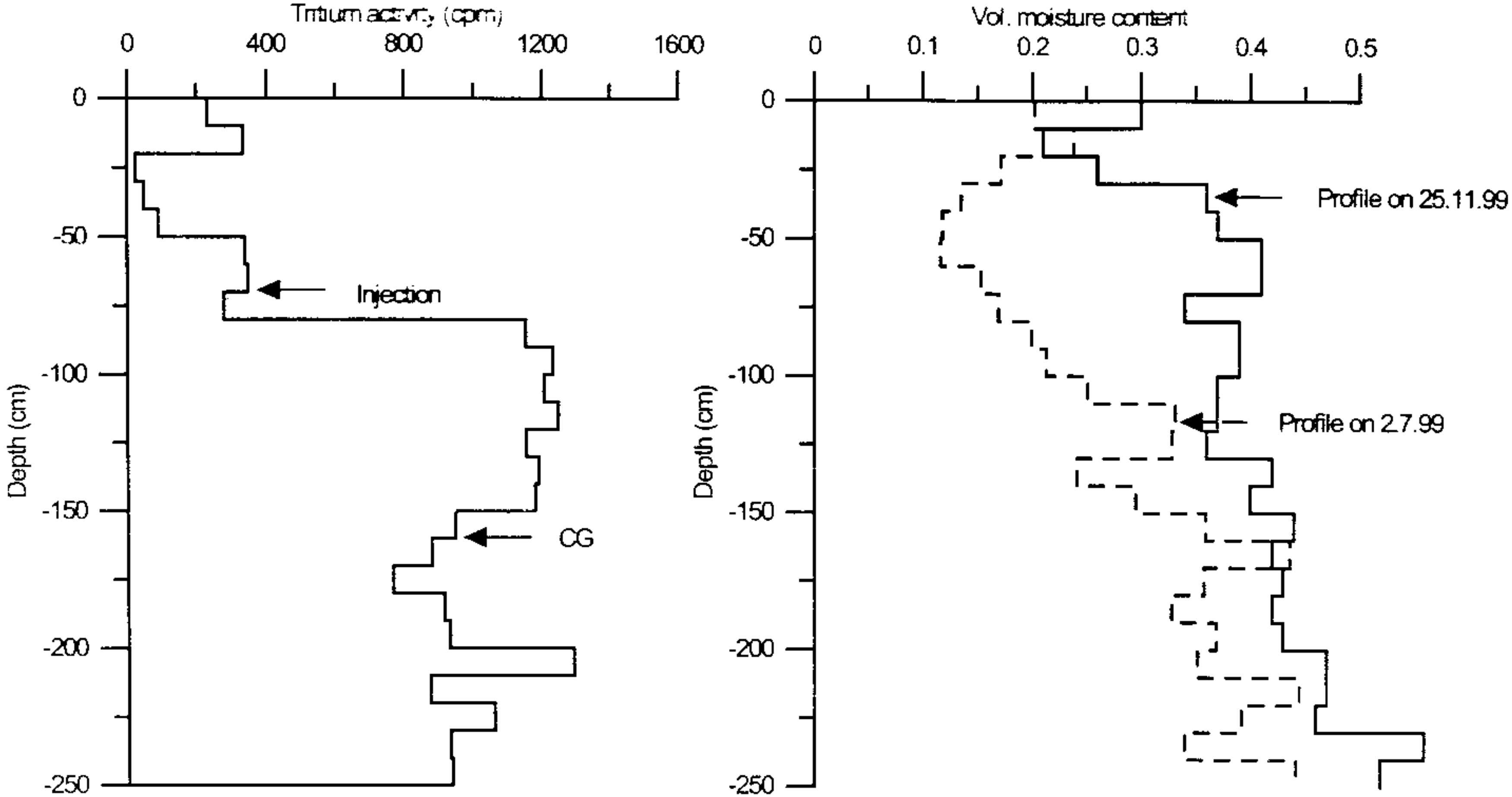

FIG. 4.5: MOVEMENT OF TRITIUM AND SOIL MOISTURE AT RAMPUR MANIHARAAN SITE

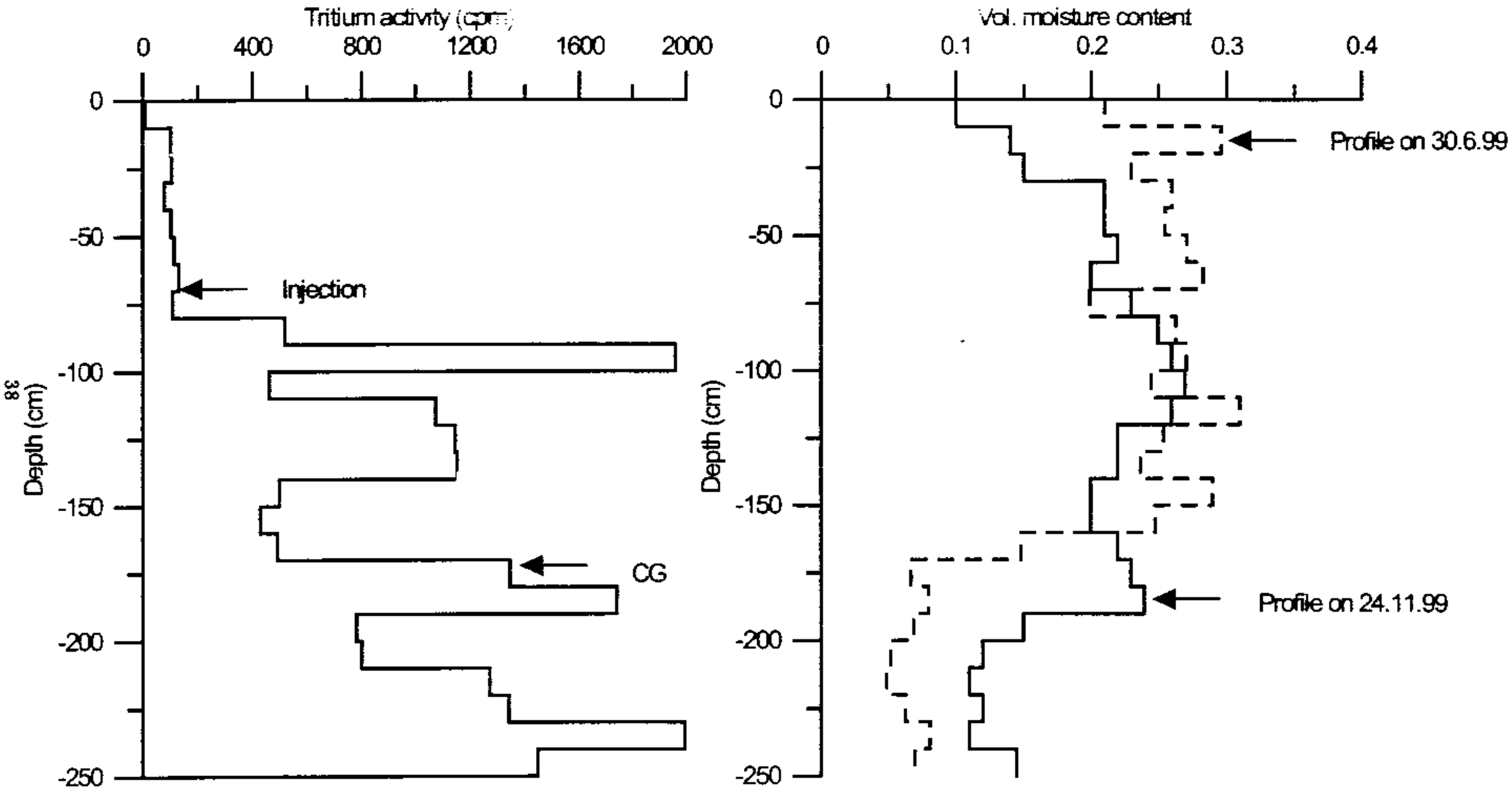

FIG. 4.6: MOVEMENT OF TRITIUM AND SOIL MOISTURE AT GANGOH SITE

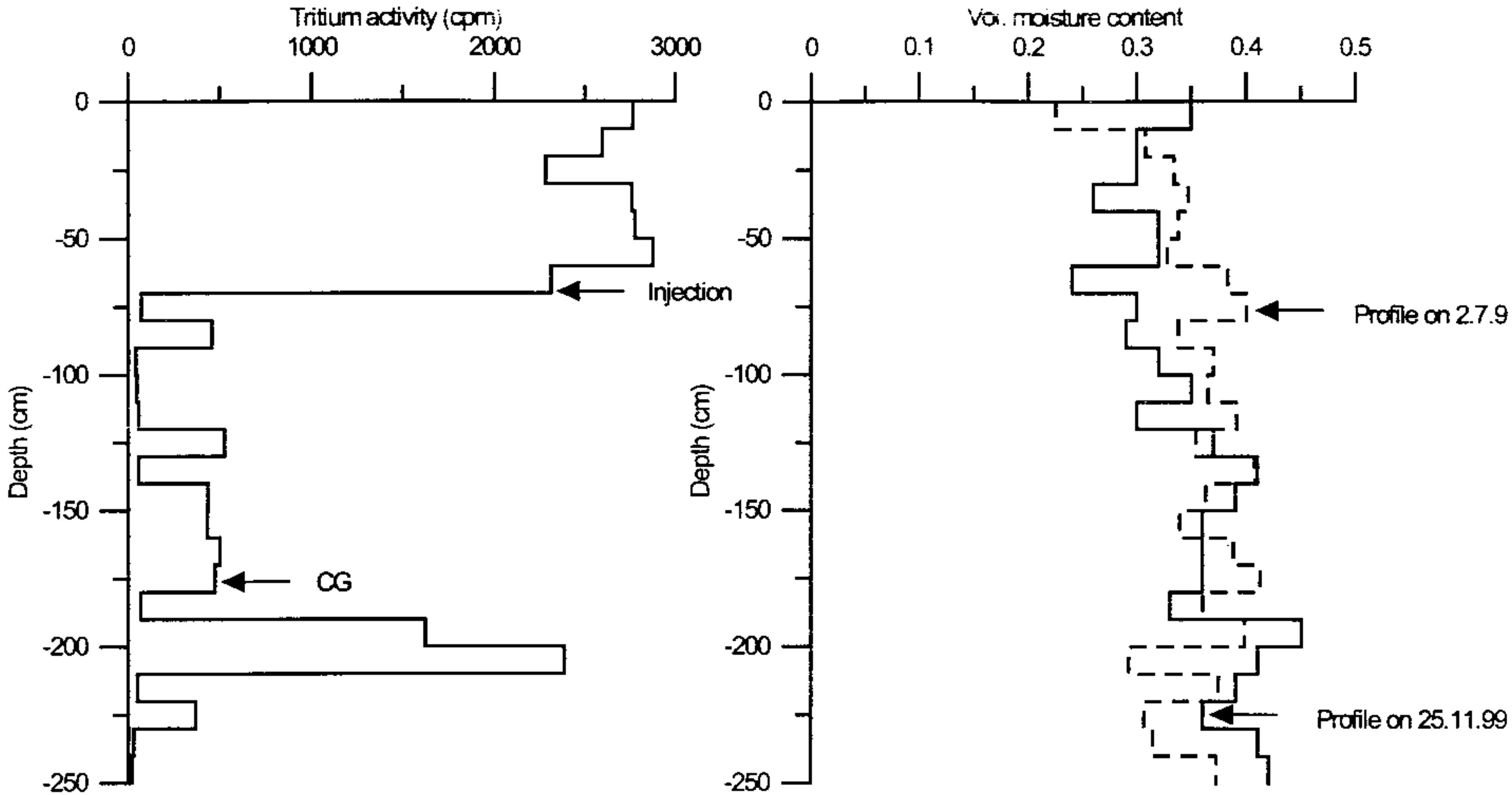

FIG. 4.7: MOVEMENT OF TRITIUM AND SOIL MOISTURE AT NANOTA SITE

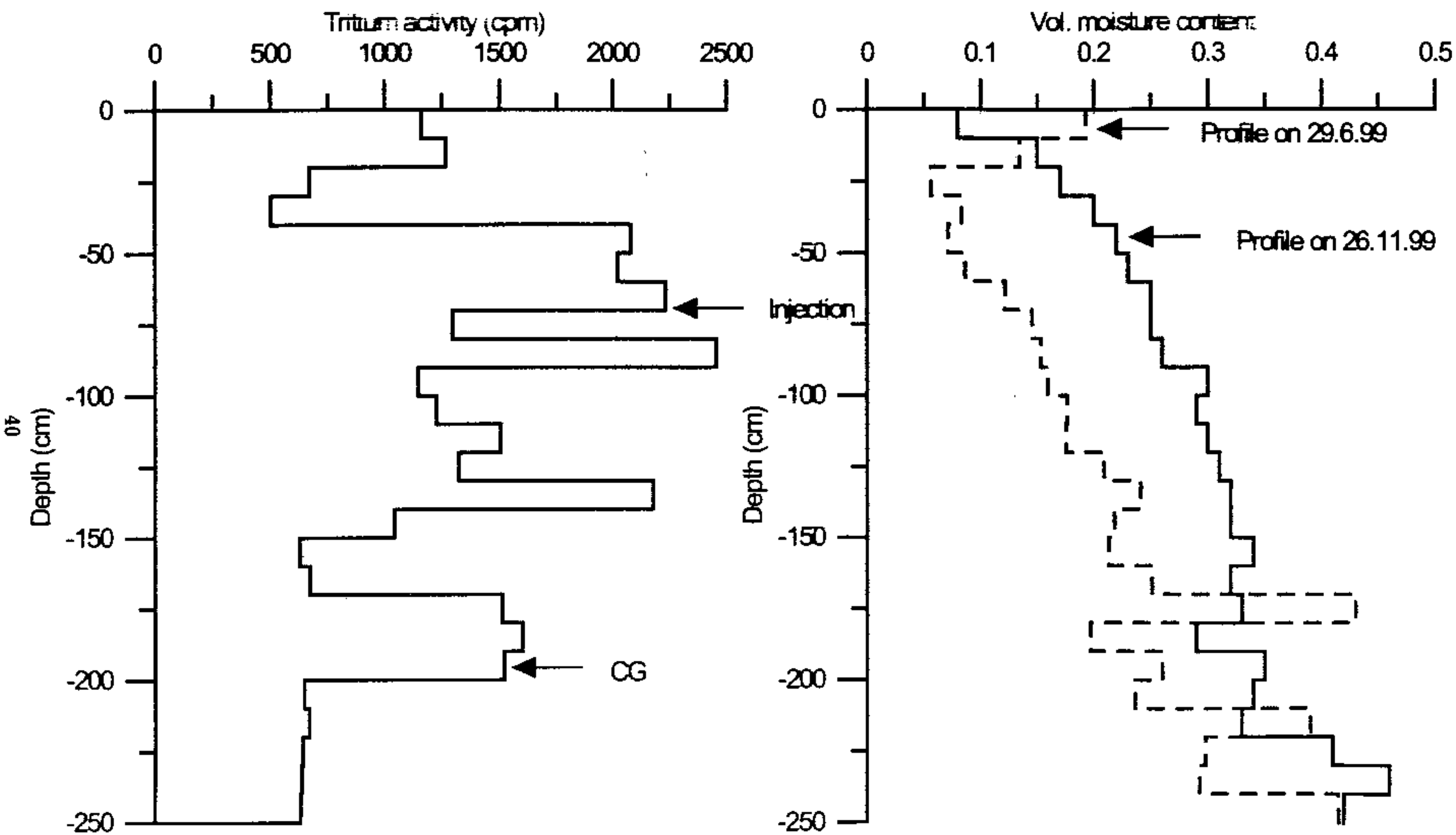

FIG. 4.8: MOVEMENT OF TRITIUM AND SOIL MOISTURE AT MAHESHPUR SITE

TABLE 4.9: PEAK SHIFT, EFF. AV. VOLUMETRIC MOISTURE CONTENT, RECHARGE, RAINFALL, IRRIGATION AND %AGE OF GROUNDWATER RECHARGE FOR VARIOUS EXPERIMENTAL SITES IN DISTRICT SAHARANPUR

Sr. No.	Name of Site	Peak shift (cm)	Av. Volumetric Moist. Content	Field Capacity	Eff. Av. Vol. Moist. Content	Recharge (cm)	Rainfall (cm)	Irrigation (cm)	Recharge (%)
1.	Sarsawa	129.93	0.134	0.099	0.035	4.44	42.90	0.00	10.34
2.	Chhutmalpur	128.85	0.240	0.144	0.096	12.38	47.20	0.00	26.24
3.	Nakud	94.58	0.197	0.142	0.055	5.20	35.37	0.00	14.71
4.	Rampur Maniharran	89.57	0.384	0.265	0.083	10.66	46.90	25.00	14.83
5.	Gangoh	102.49	0.233	0.121	0.112	11.48	35.37	10.00	25.30
6.	Nanota	106.73	0.346	0.278	0.068	7.18	47.15	0.00	15.22
7.	Maheshpur	125.47	0.305	0.217	0.088	11.04	64.45	15.00	13.89

5. RESULTS AND DISCUSSION

The values of recharge to groundwater estimated due to rainfall in monsoon season during the year 1999 and irrigation at each experimental site namely, Sarsawa, Chhutmalpur, Nakud, Rampur Manihaaran, Gangoh, Nanota and Maheshpur, using tritium tagging technique (Radio-tracer method) are given in Table 4.9 along with other details. Sites Sarsawa and Nanota were partially uncultivated while other sites were located in cultivated land. The details of particle size analysis of soil samples collected from different sites are shown in Table 4.8(a) to 4.8(g).

The values of recharge vary widely in the study area with respect to type of soil i.e., at sites Nakud, Rampur Manihaaran, Nanota and Maheshpur, the recharge value may be approximately averaged out to 15% of the rainfall as it was found at most of the places in case of district Hardwar. The silt and clay composition at these sites varies from 80 to 85%. On the other hand at sites Chhutmalpur and Gangoh, the recharge value are around 25% with respect to silt and clay percentage around 50 to 55%. The value of recharge to groundwater at site Sarsawa is 10.34% of the rainfall while silt and clay composition is comparatively very less i.e. only 22%. But, keeping in view the location of site in uncultivated land, the value of recharge to groundwater seems to be justified. However, if we consider the case of recharge value in cultivated land at Sarsawa, it should go up to 35% with 22% silt and clay composition on the pattern of the recharge to groundwater (around 25%) at sites Chhutmalpur and Gangoh with 50-55% composition of silt and clay. Similarly, the value at Maheshpur is little lower in comparison to other similar sites, but as the site was located in a partially cultivated land, therefore, it also seems to be justified.

The value of recharge to groundwater estimated (approx. 15%) at most of the sites is comparatively less in comparison to the value generally considered for rainfall recharge as per the norms (25% of the rainfall) fixed up by the Groundwater Estimation Committee. Similarly at few other sites, the value seems to be near to the accepted value while it might be high (up to 35%) at few places like site Sarsawa.

The area belonging to district Saharanpur is well drained by river Yamuna in the western side and river Hindon that passes from the middle. The eastern Yamuna canal and its distributaries and miners are the good source for recharge to groundwater in most of the cases to shallow aquifers due to seepage from the canals. The groundwater conditions in the study area [Tech. report no.1 Hyd. UPGWD report (R-1, July 2000)] indicate that the natural drainage is very effective as we move towards the district Muzaffarnagar while as we go towards the district Dehradun, the natural drainage becomes less effective. Therefore, this is the reason that the groundwater conditions are comparatively deeper as we go towards the Muzaffarnagar while quite shallow towards the district Dehradun. The effect of recharge from eastern Yamuna canal is also seems not to be effective because of good natural drainage prevailed in the study area. Further analysis of rainfall data, type of soil with estimated value of recharge to groundwater will be carried out for the study area between Saharanpur and Hardwar (separate report has been prepared for district Hardwar) and a publication will be brought out to make the study more meaningful on the pattern of research paper published by B.Kumar and Rm.P. Nachiappan (1995).

In general, the estimated values of recharge to groundwater are in good resemblance with the type of soil and prevailing geo-morphological and geo-hydrological conditions. However, the studies carried out using neutron moisture probe and environmental isotopes for identifying the recharge zones and major recharge sources to deeper aquifers in the study area will throw more light on the groundwater recharge characteristics.

REFERENCES

Athavale, R.N., (1977) Tracer techniques in groundwater hydrology, Proc. of a Workshop on Exploration Techniques for Groundwater organized by Committee on Science and Technology in Developing countries (COSTED), Bangalore, India, 316-358.

Athavale, R.N., C.S. Murti and R. Chand, (1978) Estimation of recharge to the phreatic aquifers of lower Maner basin by using the tritium injection method, National Geophysical Research Institute, Technical Report No. GH-9, NH1, 1-59.

Athavale, R.N., C.S. Murti and R. Chand, (1980) Estimation of recharge to the phreatic aquifers of the Lower Maner Basin, India, by using the tritium injection method, Journal of Hydrology, Vol.45, No.3/4, 185-20.

Bhandari, N., S.K. Gupta, P. Sharma, Prem sagar, V. Ayachit and B.I. Desai, (1986) Hydrological investigations in Sabarmati and Mahi basins and coastal Saurashtra using radio isotopic and chemical tracers, N. Bhandari, HILTECH (Min. of Water Resources, Govt. of India), NIH, Roorkee, 115.

Datta, P.S., (1975) Ground water recharge studies in the Indo-gangetic alluvial plains using tritium tracer, Ph.D. thesis, (unpublished) Department of Chemistry, I.I.T. Kanpur.

Datta, P.S., P.S. Goel, Rama and S.P. Sangal, (1973) Groundwater recharge in Western Uttar Pradesh, Proc. Ind. Acad. Sci., Vol.LXXVIII, No.1, 1-12.

Datta, P.S. and P.S. Goel, (1977) Groundwater recharge in Punjab state (India) using tritium tracer, Nordic Hydrology, Vol.8, 225-236.

Datta, P.S., B.I. Desai and S.K. Gupta, (1977) Hydrological Investigations in Sabarmati basin-Ground water Recharge Estimation using tritium tagging method, Physical Research Laboratory, Ahmedabad, Report No. HYD-77-06.

Datta, P.S., B.I. Desai and S.K. Gupta,(1977) 1. Hydrological Investigation in Sabarmati basin 2. Comparison of Groundwater recharge rates in parts of Indo-Gangetic and Sabarmati alluvial, Physical Research Laboratory, Ahmedabad, Report No. HYD-77-06.

Datta, P.S., S.K. Gupta, A. Jayasurya, B.I. Desai and S.C. Sharma, (1977) Soil moisture movement through Vadore zone in alluvial plains of Sabarmati basin, Physical Research Laboratory, Ahmedabad, Report No. HYD-78-03.

Datta, P.S., B.I. Desai and S.K. Gupta, (1979) Comparative Study of groundwater recharge rates in parts of Indo-Gangetic and Sabarmati alluvial plains, Mausam, Vol.30, No.1, 129-133.

Datta, P.S., B.I. Desai and S.K. Gupta, (1980) Hydrological investigation in Sabarmati basin 1. Groundwater recharge estimation using tritium tagging methods, Proc. Indian National Science Academy, Part A, Physical Science, Vol.46, No.1, 84-98.

Gupta, S.K. and P. Sharma, (1984) Radioactive tracers in groundwater hydrology of Sabarmati basin, Western India: A Case study, paper IAEA-SM-270/71P, Extended Synopsis Volume, Vienna, 157-161.

Gupta, S.K. and P. Sharma, Rain water infiltration: tracing of soil moisture in semi arid parts of India, Proc. International Conference on Infiltration Development and Application (ICIDA), Honolulu, Vol.2.

Gupta, S.K. and P. Sharma, (1984) Water resources and urbanisation An environmental perspective for Gujarat, Souvenir Issue, 51st R & D Session of CBIP, Vadodara, 73-81.

Hydrological study of district Hardwar and Saharanpur, Interim Report (2000) A collaborative study with National Institute of Hydrology, Roorkee, U.P.G.W.D. TM no.1 Hyd. (R-1), Roorkee.

Kumar, B. and Rm. P. Nachiappan, (1995) A mathematical approach based on tritium tagging technique to evaluate recharge to groundwater due to monsoon rains', Tracer Technologies for Hydrological Systems, Proceedings of a Boulder Symposium, July, IAHS publication No. 229 .

Kumar, B. and S. M. Seth, (2000) Isotope hydrology- present status and future prospects in India , ICIWR-2000, Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development, 19-21 December, New Delhi, India.

Mukherjee, P., (1986) Isotope technique to monitor seasonal groundwater recharge in a rain fed alluvial sandy loam agricultural field, (Proc. of a seminar on Water Management in Arid and Semi-arid Zone H.A.U.), Hissar.

Mukherjee, P., T.K. Mukherjee and H. Chandrashekhran, (1987) Radio tracer investigations of vertical recharge characteristic at IARI, (Proc. of Seminar on Hydrology, Association of Hydrologists of India, Madras, Aug.28-30).

Munnich, K.O., (1968a) Moisture movement measurement by isotope tagging, Guide-Book on Nuclear Techniques in Hydrology, IAEA, Vienna, 112-117.

Munnich, K.O., (1968b) Use of Nuclear techniques for the determination of groundwater recharge rates, Guide-book on Nuclear technique in Hydrology, IAEA, Vienna, 191-197.

Raja, R.K., Anil Kumar and S.S. Chhhabra, (1983) Estimation of groundwater recharge by isotopic method, T.M. No.54-RR (G-8) and 54-RR(G-9).

Rao, S.M. and S.K. Jain, (1985) Tracer transport modelling for unsaturated zone effect of anion exclusion and immobile water, Isotopenpraxis 21(12), S-433 bis-438.

Sharma, P. and S.K. Gupta, (1985) Soil Water movement in semi-arid climate- an isotopic investigation, in Stable and Radioactive Isotopes in the Study of the Unsaturated Soil Zone, IAEA-TECDOC-357, IAEA, Vienna, 55-69.

Singh, B.P. and Satish Chandra, (1978) A report on the study of recharge to groundwater in eastern districts of U.P. using tritium tagging technique, An internal communication to U.P. Groundwater Department, Lucknow.

Study of recharge to groundwater due to rain and irrigation in Bundelkhand districts of Uttar Pradesh, U.P. Ground Water Department, Lucknow.

Sukhija, B.S., Reddy, D.V., Nagabhushanam, P. and Chand R., (1988) Validity of the environmental method for recharge evaluation of coastal aquifers, India, Journal of Hydrology, V-99, 349-366.

Sukhija, B.S., Nagabhushanam, P., Reddy, D.V., (1996) Groundwater recharge in semi-arid regions of India, an overview of results using tracers, Hydro-geology Journal, V-4(no.3), 50-71.

Sukhija, B.S., Reddy, D.V., Nagabhushanam, P. Syed Hussain, Giri, V.Y., and Patil D.J., (1996a) Environmental and injected tracers methodology to estimate direct precipitation recharge to a confined aquifer, Journal of Hydrology, V-174 (nos. 1& 2), 77-97.

Sukhija, B.S., Reddy, D.V., Nagabhushanam, P. Syed Hussain, Giri, V.Y., and Patil D.J., (1996b), The use of environmental isotopes and chloride as natural tracers to investigate the effects of depressurisation of a coastal aquifer for lignite mining, India, Hydro-geology Journal, V-4 (no. 20), 70-88.

Zimmerman, U., D. Ehhalt and K.O. Munnich,(1967a) Soil water movement and evapotranspiration: changes in the isotopic composition of water, Isotopes in hydrology, Proc. Symp. Vienna, 567.

Zimmerman, U., K.O. Munnich and W. Roether, (1967b) Downward movement of soil moisture traced by means of hydrogen isotopes, American Geophysical Union, Geophysical monograph no. 11, 1967b, 28.

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