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STUDY OF RECHARGE TO GROUNDWATER DUE TO MONSOON RAINS USING TRITIUM TAGGING TECHNIQUE IN PARTS OF DISTRICT NARSINGHPUR (M.P.)
PART-II

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ABSTRACT

Estimation of recharge to groundwater is crucial to better water resources management, particularly in arid and semi-arid regions. In general, it is difficult to estimate recharge to groundwater due to rainfall or irrigation using conventional methods due to nonavailability of adequate data. Nuclear methods, specially tritium tagging technique has been used successfully in different countries including many parts in India.

The National Institute of Hydrology has taken up the comprehensive hydrological studies in the Narmada catchment. As a part of these studies the Nuclear Hydrology Division has taken up estimation of recharge to groundwater due to rainfall and irrigation for which the tritium tagging technique has been used to carry out recharge studies in parts of the Narsinghpur district, M.P. under Narmada catchment. In the study area, experiments have been carried out in cultivated as well as in uncultivated fields. In the study area, mainly four types of soils were found, namely clay, clay loam, loam and sandy clay loam in which clay predominant. The average annual rainfall of the area is 1246 mm. The percentage of recharge to groundwater varies from 12.22% to 22.4% in the study area with respect to the type of soil and other geohydrological conditions. This report presents the details of the methodology followed and details about the area including the results obtained with regard to the values of recharge to groundwater obtained mainly due to rains during the monsoon season of the year 1996.

1. INTRODUCTION

The recharge to groundwater from surface to the subsequent layers of soil is governed by the process of infiltration 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 rain and irrigation for the period from June' 1996 to October' 1996 in parts of district Narsinghpur (M.P.) is determined using Tritium Tagging Technique.

2.0 DESCRIPTION OF STUDY AREA

The Bargi multi-purpose project, renamed as Rani Avanti Bai Sagar Project, is one of the major river valley project on Narmada river by the Govt. of Madhya Pradesh as a part of the Narmada Valley Development Plan. On completion of the project, irrigation facilities will be available for 157,000 hectare in Jabalpur and Narsinghpur districts through Left Bank Canal System and 46,000 hectare in Jabalpur district through Right Bank Canal System.

The study area is a part of the Left Bank Canal Command of Bargi Multi-purpose Project. The canal is 132.2 km long and has a discharge capacity of 124.65 cumecs. This canal has culturable command area of 95.000 hectare.

2.1 Location

The study area is a part of Bargi dam left bank canal command area, which is situated in Narmada river basin. This area is a doab which is encompassed by Sher river in west, Umar River in east and Bargi left bank canal in south, having an area of approximately 360 sq. km located in Narsinghpur district of Madhya Pradesh between latitude 22^0 53' N to 23^0 4' N and longitude 79^0 10'E to 79^0 32' E (Fig. 1).

The first site i.e., Nayagaon was selected in tehsil and district Narsinghpur which falls on the right side of Narsinghpur-Sankal road at a distance of about 16 km from Narsinghpur. The second site i.e. Supla was situated in tehsil and district Narsinghpur on the left side of Narsinghpur-Sankal road at about 12 km from Narsinghpur. The third site i.e. Bochhar in Gotegaon tehsil of district Narsinghpur was selected on the right side of Narsinghpur-Karakbel road at about 25 km from Narsinghpur. The fourth site i.e. Mekh in tehsil Gotegaon of district Narsinghpur was situated on the right side of Karakbel-Manegaon road at about 29 km from Narsinghpur. The fifth site i.e. Surwari situated in Gotegaon tehsil of Narsinghpur district on the right side of Narsinghpur- Gotegaon road at a distance of about 22 km from Narsinghpur. The sixth experimental site was selected as Berheta in Gotegaon tehsil of Narsinghpur district on the left side of Narsinghpur-Gotegaon road at a distance of about 25 5 km from Narsinghpur. Location of various test sites is shown in Fig. 2 and these sites are listed in table 1 with other details.

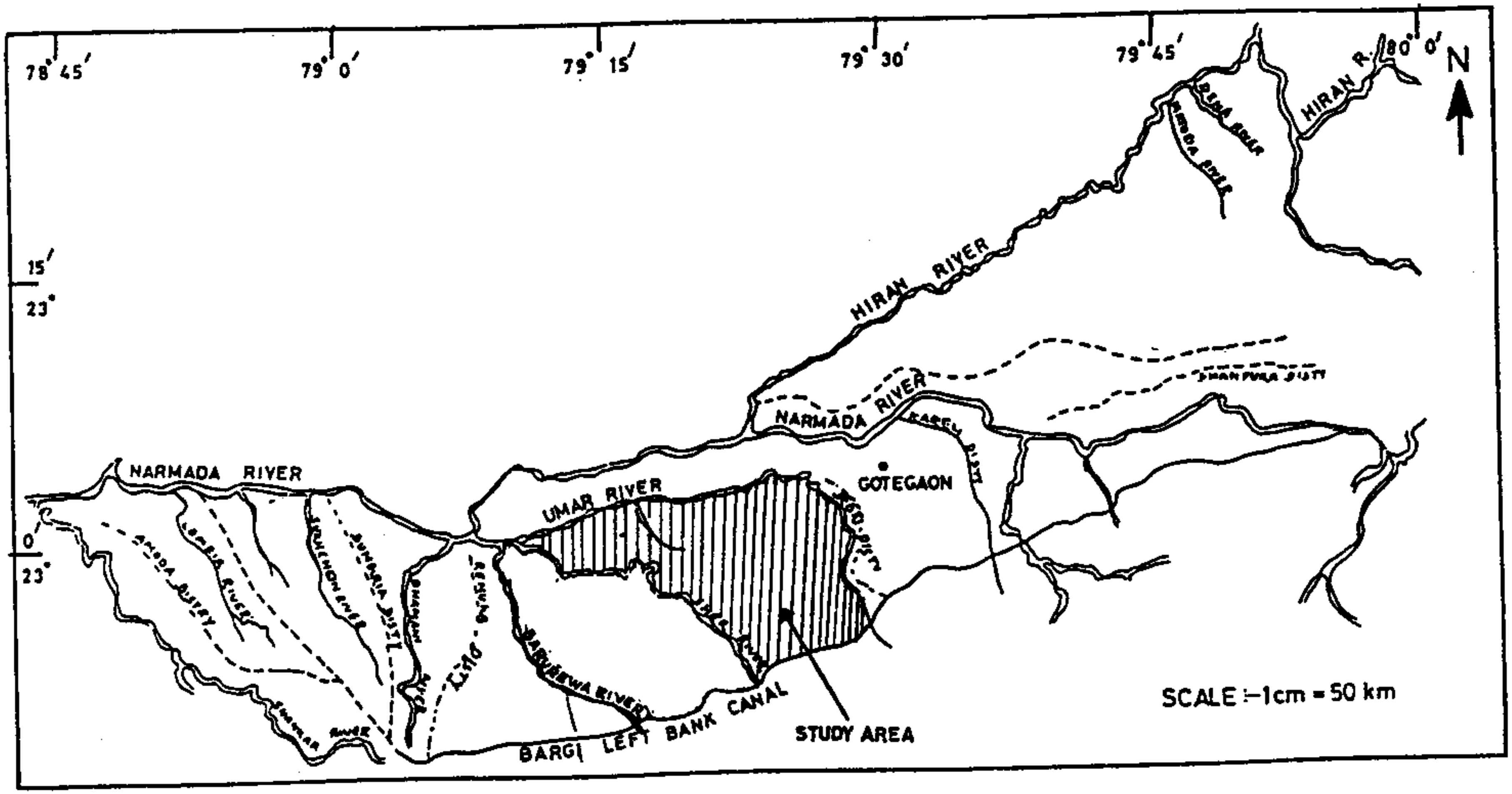


FIG.1 - BARGI LEFT BANK CANAL PROJECT

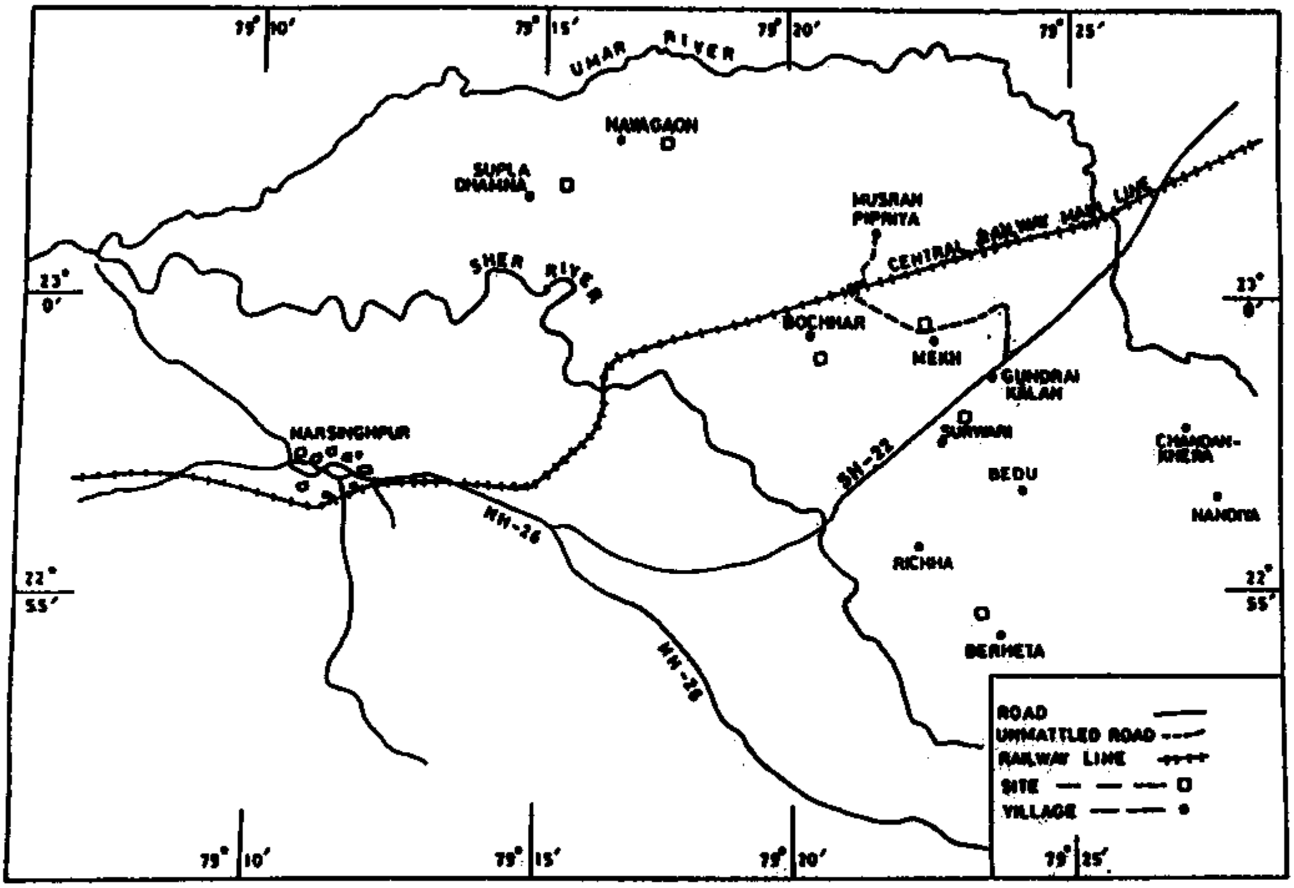


FIG.2: LOCATION OF TEST SITES

Table 1: List of Experimental Sites with Other Details

S.No.	Name of Site	Whether Cultivated/ uncultivated	General soil type
1.	Nayagaon	Cultivated	Silt clay
2.	Supla	-do-	Silt clay
3.	Bochhar	-do-	Clay
4.	Mekh	-do-	Clay
5.	Surwari	-do-	Clay
6.	Berheta	-do-	Clay

The study area lies in the east of Narsinghpur town and is traversed by the State Highway No. 22 from Jabalpur to Hoshangabad. The main broad-gauge railway line from Howarh to Bombay also passes through the study area.

2.2 Topography

The study area occupies a part of the southern part of the Narmada Valley which is most fertile and populus part of Narsinghpur district. The elevation of the study area (which falls mainly in Bargi dam left bank canal command area in Narmada basin) above mean sea level varies from 338 m to 360 m. The general topography of the area appears to be flat except in the vicinity of the rivers, where deep gullies and ravines have formed giving rise to undulating to rolling topography. As such, the entire area is a broad plain of low relief. Local difference in elevation is small due to adaptations of "Haveli System" of cultivation, which has checked the erosion. The "Old Haveli System" of cultivation is practised in rabi. The preference to rabi cultivation is due to the high clay content of the soil which is difficult to work in rainy season. Broadly speaking, under Haveli system a large area is bunded and utilized for collecting rainwater during the monsoon and is left fallow during kharif season. The rain water stored as soil moisture helps to grow rabi crops. In the plain area, the slope ranges from 0 to 3%, but in area having undulating topography, the steeper slopes even upto 15% are noticed.

2.3 Soil

Three independent factors namely topography, climate and vegetation of soil formation have a profound impression on the formation of soils of the area. Broadly speaking, the soils of the area are in various shades of darkness and are derived from the trap rocks. Generally, the depth of soil goes more than m. Below the dark brown soil, a yellowish layer is found. Towards the banks of river, the texture of the soil moves towards a lighter grade i.e. from clay to clay loam, loam, sandy loam and finally sandy. The colour of the soil also changes from dark greyish brown to brown, yellowish brown and finally yellow grey.

In some places, the soils have been formed from sand stone parent material in which a lot of textural variation is found. It varies from sandy loam to clay. The soil crust is deep and has a fair amount of gravel or kankar along the depth of profile.

The soil survey of the area had been carried out by soil survey unit, Jabalpur(1974-75) under Department of Agriculture, Govt. of Madhya Pradesh. In the study area, there are only three types of soil i.e. clay, clay loam, silty clay loam, in which clay and silty clay loam are predominant. The types of soil for the study area is shown in Fig. 3.

2.4 Climate and Rainfall

The tract enjoys a sub-tropical climate. The rainy season in area extends from June to October 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. However, in quite a large number of years, October receives good rainfall. 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 1246 mm. The rainfall data required for the study have been collected for the period from June 1996 to October 1996 from the office of the Superintendent, Land Records Department, Narsinghpur which are incorporated in table 9.

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 second week of June, there is 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 2^0 C to 45^0 C throughout the year. On the whole, the days are warm and nights are cooler.

2.5 Water-table Condition

Water table is a guiding factor which controls the movement of water through soil, though, by physical character, a soil may have different drainability. The level (depth) of

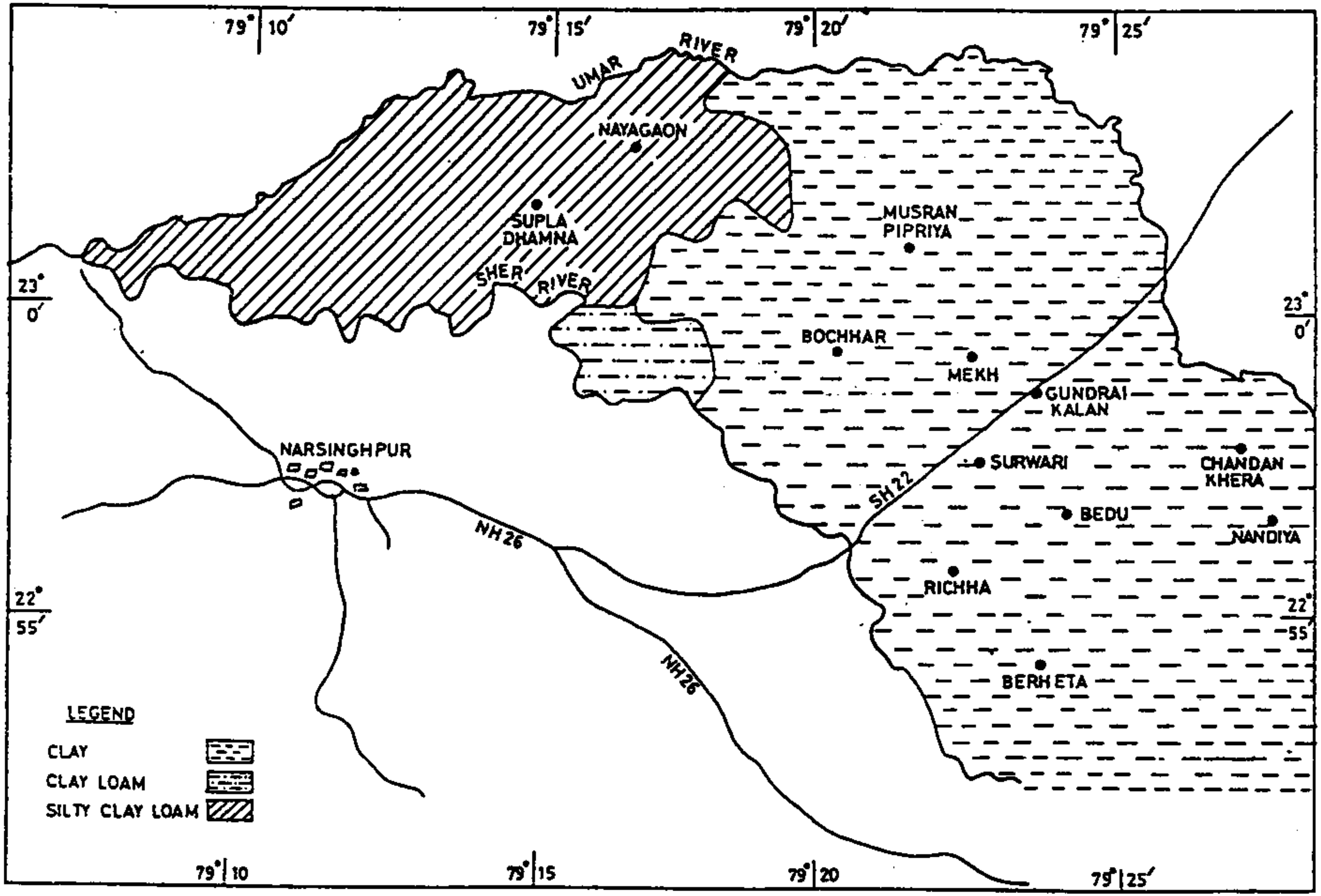


FIG. 3 : Soil type map of the Sher-Umar river doab

water table was recorded at each site from its nearby open well with the help of water level indicator. It is a dry battery operated indicator. As soon as the needle point of indicator touches water, a sound is recorded. This needle is tagged with a plastic measuring tape, which directly indicates the depth of water table from ground. The depth of water table of those open wells were recorded in which pumps were not operative for a few days to get the actual level. But for a few wells water may be taken for domestic purposes.

The water levels measured at Bochhar site in the month June '96 and October '96 were 7.71 m and 7.45 m from ground surface while the water levels at Berheta site were 2.46 m and 2.15 m from ground surface measured in the month of June'96 and October' 96. No well was located in other four sites namely Nayagaon, Supla, Surwari and Mekh.

2.6 Irrigation Practices

As the general topography of the area under study is somewhat irregular, soil is highly impermeable due to its high clay content and more over surface/sub-surface methods of irrigation are not efficient for the study area, sprinkler method of irrigation is in general practice to irrigate the fields located in the study area. This method of irrigation consists of applying the water to the field in the form of a spray, somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually generated by pumping. However, the initial investment of the sprinkling and pumping system is high.

For most of the sites which are cultivated, the soyabean was sown just before the onset of South-West monsoon i.e. during the months of June-July 1996 and which was harvested just after the monsoon i.e. during the months of October-November 1996. As the water requirement of the soyabean crop is very small during the monsoon period, no watering was done during the period from June '96 to October '96.

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.

Pioneering work in India using tritium tagging method was carried out by Datta(1975). Datta et al.(1973,1977) have 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. have 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 radiations 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 Tapi 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 doing 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 a 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 a air tight plastic container or polythene packs. 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 average field capacity in the tritium peak shift region will provide the information of recharge to ground water during the time interval of tritium injection and sampling. But, it has been observed that in order to calculate the recharge to ground water, the users of this technique multiply tritium peak shift by the average volumetric moisture content in the peak shift region, which is obtained at the time of sampling (not at the time of injection which may be considered as field capacity of the soil strata provided there should be no rainfall or irrigation applied to the field for the sufficient time in past). This later procedure seems to be more accurate. 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 average volumetric moisture content in the tritium peak shift region obtained at the time of soil sampling
- 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 categorized 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 minimize 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 minimize 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 same distance (not very close to site), otherwise, the identification marks will have to be fixed by the user.

4) Besides the identification marks already exist at some distance from the tritium injection points, few additional marks, 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.

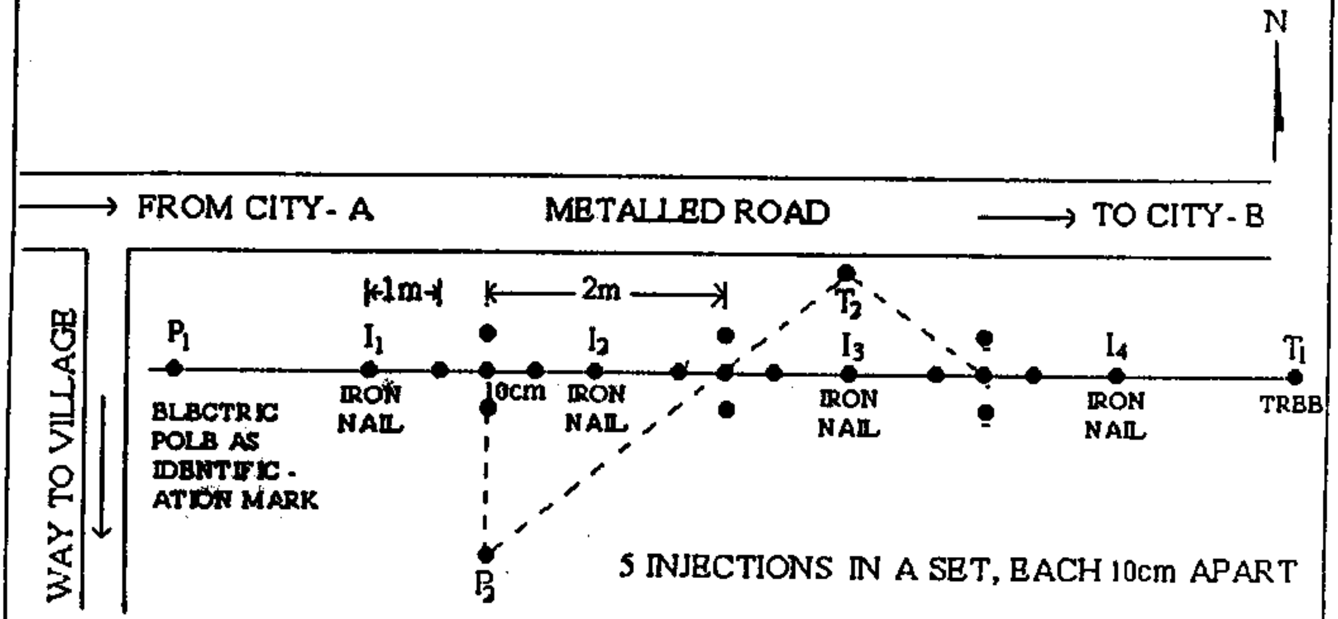
6) For correct estimation of the recharge to the ground water, the site should be selected in both type of fields i.e., cultivated and uncultivated fields.

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

8) 2ml of tritium having specific activity atleast 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. 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.



LAYOUT OF EXPERIMENTAL SITE AND INJECTIONS IN A FIELD

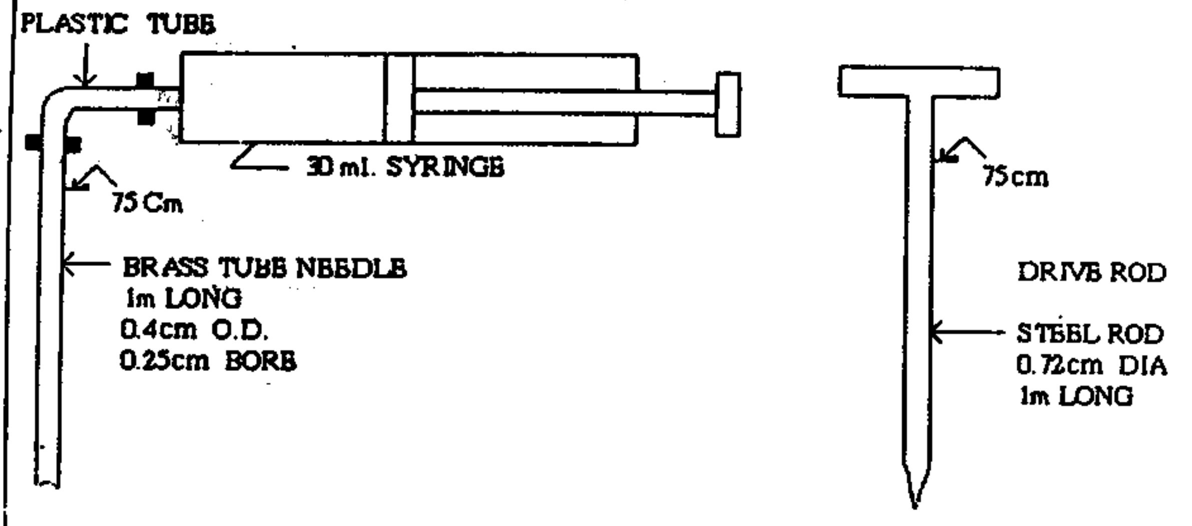


FIG. 4: SYSTEMATIC DIAGRAM OF INJECTION LAYOUT AND IMPLEMENTS FOR ARTIFICIAL TRITIUM INJECTION AT FIELD SITE

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

12) In order to minimize 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 minimize the loss of tritiated 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 minimize 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, ground water withdrawl, 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 injection were carried out at 6 sites which are shown in fig. 2.

Two sets of tritium injection were made at 6 sites during June 1996. 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 dia) 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 sampling was carried out immediately after the monsoon i.e. during the month of October, 1996 (giving the recharge due to rainfall). Soil samples were collected layer by layer (10cm sections) with the help of a hand auger of 2" dia starting from ground surface to 200 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 2 to 7.

4.3.2 Particle size Analysis

The samples collected from the field were tested in the soil water laboratory, National Institute of Hydrology, Roorkee, for the particle size distribution. Particle size distribution of the soil samples was carried out by sieve and sedimentation analysis. Soil samples were washed with distilled water to remove the soluble salts. The washed samlpes were separated into two fractions i.e. +75 micron and -75 micron through wet seiving. Sieve analysis was performed for the fraction of soil retained on 75 micron sieve (+75 micron). The portion passing through the 75 micron sieve (-75 micron) was analysed by sedimentation analysis using hydrometers. The test results of the analysis are given in table 8.

Table 2: **Volumetric moisture content, tritium activity and recharge to groundwater at experimental site: Nayagaon, Tehsil: Narsinghpur, District: Narsinghpur(M.P.)**

Depth (cm)	Volumet. moisture content	Net tritium activity (counts/min)	Determination of recharge to groundwater for the period from 27.6.96 to 27.10.96
0-20	0.077	212.8	
20-30	0.215	3.1	
30-40	0.220	10.5	
40-50	0.421	315.0	Date of tritium injection:27.6.96
50-60	0.338	660.0	Date of soil sampling:27.10.96
60-70	0.421	1099.5	Depth of tritium injection= 70cm
70-80	0.317	1207.1	Tritium peak shift(d)= 28.61 cm
80-90	0.325	3766.8	Av. volumetric moisture content
90-100	0.394	326.1	in peak shift region(θ_v)= 0.345
100-110	0.266	1939.4	recharge to groundwater(R)
110-120	0.343	7258.0	= 9.87 cm
120-130	0.275	1710.2	
130-140	0.448	1524.2	
140-150	0.353	88.3	
150-160	0.403	255.9	
160-170	0.404	815.3	
170-180	0.402	702.8	
180-190	0.421	649.9	
190-200	0.394	637.1	

Table 3: Volumetric moisture content, tritium activity and recharge to groundwater at experimental site: Supla, Tehsil: Narsinghpur, District: Narsinghpur(M.P.)

Depth (cm)	Volumetric moisture content	Net tritium activity (counts/min)	Determination of recharge to groundwater for the period from 27.6.96 to 27.10.96
0-20	0.109	924.1	
20-30	0.190	375.7	
30-40	0.171	404.8	Date of tritium injection:27.6.96
40-50	0.182	17.8	Date of sampling:27.10.96
50-60	0.201	389.0	Depth of tritium injection= 70 cm
60-70	0.193	1223.5	Tritium peak shift(d)= 33.8 cm
70-80	0.184	1388.6	Av. volumetric moisture content
80-90	0.277	842.2	in peak shift region(θ_v)= 0.229
90-100	0.228	1569.6	Recharge to groundwater(R)=7.74 cm
100-110	0.218	928.2	
110-120	0.238	912.6	
120-130	0.299	818.5	
130-140	0.316	768.1	
140-150	0.254	399.3	
150-160	0.337	979.0	
160-170	0.299	379.0	
170-180	0.414	623.9	
180-190	0.264	553.5	
190-200	0.282	699.2	

Table 4: **Volumetric moisture content, tritium activity and recharge to groundwater at experimental site: Bochhar, Tehsil: Gotegaon, District: Narsinghpur(M.P.)**

Depth (cm)	Volumetric moisture content	Net tritium activity (counts/min)	Determination of recharge to groundwater for the period from 29.6.96 to 30.10.96
0-20	0.107	379.4	
20-30	0.173	1831.2	
30-40	0.222	3795.6	Date of tritium injection:29.6.96
40-50	0.203	4189.2	Date of soil sampling:30.10.96
50-60	0.185	3884.3	Depth of tritium injection = 70 cm
60-70	0.199	2884.2	Tritium peak shift(d) = 54.5 cm
70-80	0.184	1113.9	Av. volumetric moisture content
80-90	0.259	1193.3	in peak shift region(θ_v) = 0.249
90-100	0.259	721.3	Recharge to groundwater(R)
100-110	0.255	405.1	= 13.625 cm
110-120	0.260	387.5	
120-130	0.280	329.2	
130-140	0.323	1144.0	
140-150	0.262	233.6	
150-160	0.331	275.4	
160-170	0.232	203.3	
170-180	0.279	155.9	
180-190	0.344	115.4	
190-200	0.346	79.1	

Table 5: Volumetric moisture content, tritium activity and recharge to groundwater at experimental site: Mekh, Tehsil: Gotegaon, District: Narsinghpur(M.P.)

Depth (cm)	Volumetric moisture content	Net tritium activity (counts/min)	Determination of recharge to groundwater for the period from 28.6.96 to 30.10.96
0-20	0.063	404.2	
20-30	0.154	530.1	
30-40	0.183	319.4	Date of tritium injection:28.6.96
40-50	0.288	158.2	Date of soil sampling:30.10.96
50-60	0.248	1.1	Depth of tritium injection= 70 cm
60-70	0.216	266.3	Tritium peak shift(d)= 41.76 cm
70-80	0.248	95.4	Av. volumetric moisture content in
80-90	0.290	22.9	peak shift region(θ_v)= 0.290
90-100	0.278	1289.2	Recharge to groundwater(R)
100-110	0.344	2113.6	= 12.11 cm
110-120	0.283	2094.9	
120-130	0.315	605.1	
130-140	0.368	544.9	
140-150	0.350	391.4	
150-160	0.325	115.4	
160-170	0.351	2084.2	
170-180	0.342	2021.1	
180-190	0.357	603.9	
190-200	0.387	433.6	

Table 6: Volumetric moisture content, tritium activity and recharge to groundwater at experimental site: Surwari, Tehsil: Gotegaon, District: Narsinghpur

Depth (cm)	Volumetric moisture content	Net tritium activity (counts/min)	Determination of recharge to groundwater for the period from 26.6.96 to 29.10.96
0-20	0.084	1026.1	
20-30	0.265	164.0	
30-40	0.277	5602.6	Date of tritium injection:26.6.96
40-50	0.364	3004.8	Date of soil sampling:29.10.96
50-60	0.214	6987.2	Depth of tritium injection= 70 cm
60-70	0.221	6189.9	Tritium peak shift(d)= 30.55
70-80	0.224	1865.5	Av. volumetric moisture content
80-90	0.230	2241.0	in peak shift region(θ_v)= 0.285
90-100	0.402	4801.0	Recharge to groundwater(R)
100-110	0.339	4689.0	= 8.72 cm
110-120	0.368	1593.7	
120-130	0.382	1765.0	
130-140	0.302	1673.3	
140-150	0.249	3667.6	
150-160	0.320	3827.5	
160-170	0.363	3071.7	
170-180	0.386	2054.1	
180-190	0.410	1913.2	
190-200	0.363	5745.8	

Table 7: **Volumetric moisture content, tritium activity and recharge to groundwater at experimental site: Berheta, Tehsil: Gotegaon, District: Narsinghpur(M.P.)**

Depth (cm)	Volumetric moisture content	Net tritium activity (counts/min)	Determination of recharge to groundwater for the period from 26.6.96 to 29.10.96
0-20	0.133	0.0	
20-30	0.234	652.9	
30-40	0.110	15.6	
40-50	0.251	962.8	Date of tritium injection:26.6.96
50-60	0.296	891.4	Date of soil sampling:29.10.96
60-70	0.335	2499.8	Depth of tritium injection = 70cm
70-80	0.314	1142.9	Tritium peak shift(d) = 41.2cm
80-90	0.337	1879.5	Av. volumetric moisture content
90-100	0.375	6256.3	in peak shift region(θ_v) = 0.364
100-110	0.399	2629.3	Recharge to groundwater(R)
110-120	0.393	2348.7	= 14.99 cm
120-130	0.426	2516.5	
130-140	0.364	2910.3	
140-150	0.353	2791.2	
150-160	0.326	835.1	
160-170	0.308	179.8	
170-180	0.335	179.0	
180-190	0.396	943.8	
190-200	0.318	3892.3	

Table 8 : **Particle size Distribution for the study area**

S. No.	Name of site	Gravel (%) > 2mm	Sand (%) (2mm to 0.075mm)	Silt (%) (0.075mm to 0.002mm)	Clay (%) < 0.002 mm	Silt + clay (%)
1.	Nayagaon	4.9	5.4	62.1	27.6	89.7
2.	Supla	0.0	8.9	61.7	29.4	91.1
3.	Bochhar	1.6	10.3	34.7	53.4	88.1
4.	Mekh	1.0	14.0	21.8	63.2	85.0
5.	Surwari	0.0	6.0	26.8	67.2	94.0
6.	Berheta	2.4	20.2	24.8	52.6	77.4

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 alongwith 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 + v) 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 (v). 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 an 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" into 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.

One ml of the soil water extracted from each 10 cm layer was mixed with 10 ml of scintillation cocktail 'W' (SRL, Mumbai) and stored in the plastic/glass vials. Cocktail 'W' is commercially available and 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

This vial was placed in the counting chamber of the liquid scintillation counter for 300 seconds and back ground counts (in counts per minute) for cocktail 'W' was 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 teflon vials.

These 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) 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 3 to 8.

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. 5 to 10. 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 average volumetric moisture content in the peak shift region and are given in table 2 to 7.

The percentage recharge to groundwater at various experimental sites due to monsoon rains of 1996 are given in table 9.

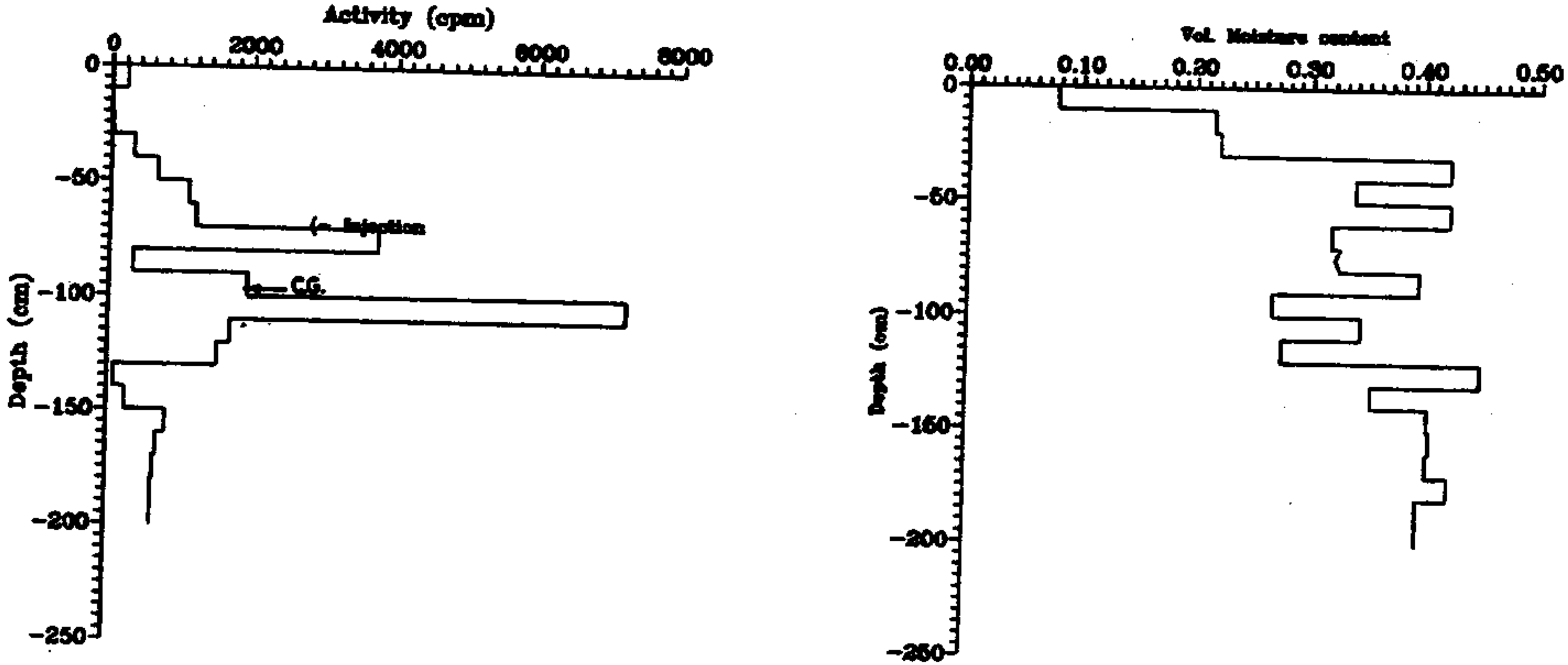


Fig. 5 : Movement of Injected Tritium and Soil Moisture at Nayagaon site

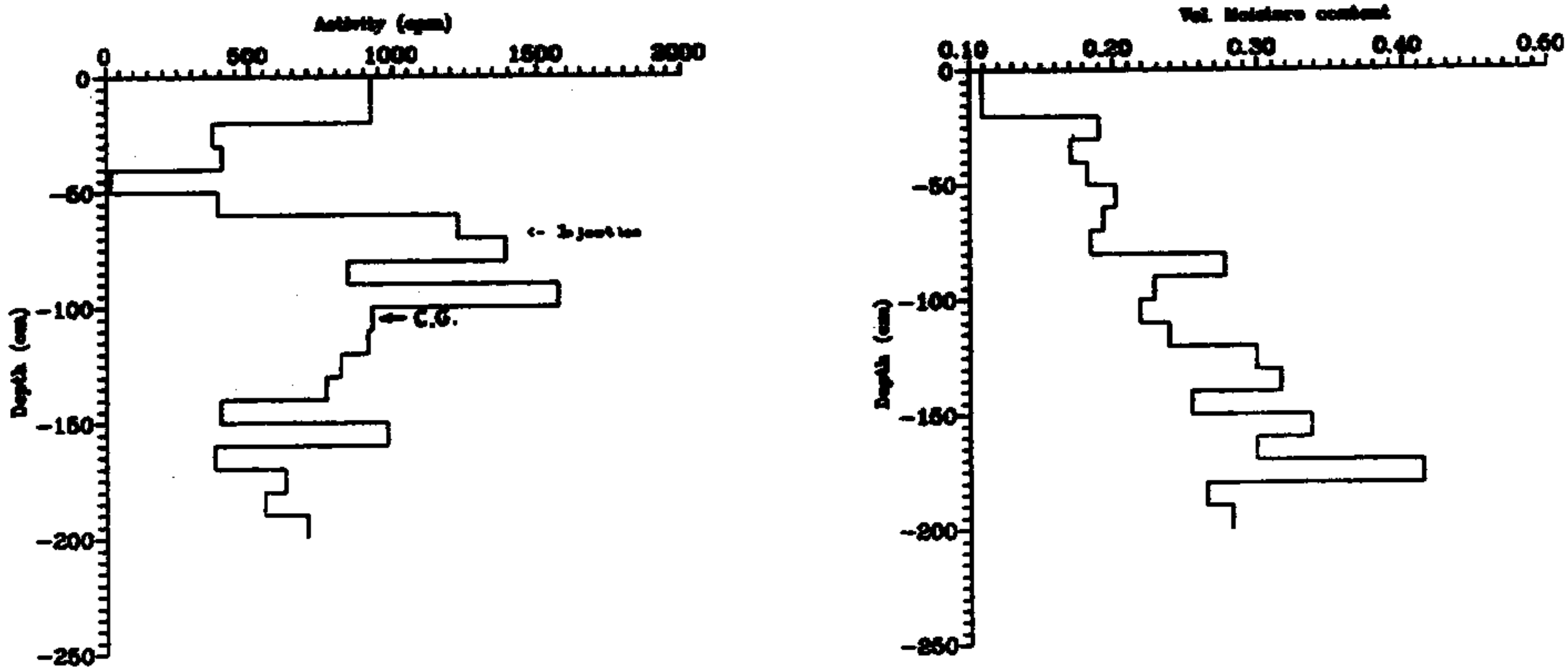


Fig. 6 : Movement of Injected Tritium and Soil Moisture at Supla site

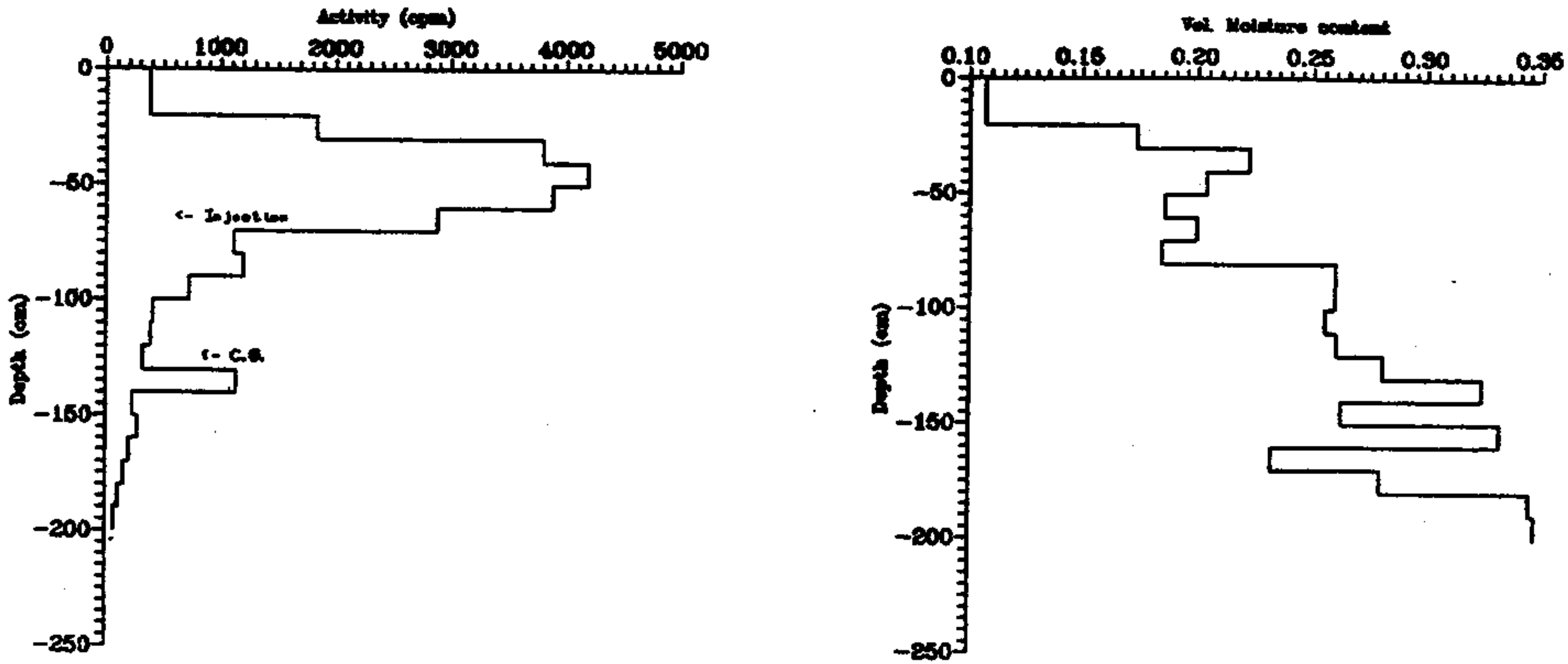


Fig. 7 : Movement of Injected Tritium and Soil Moisture at Bochhar site

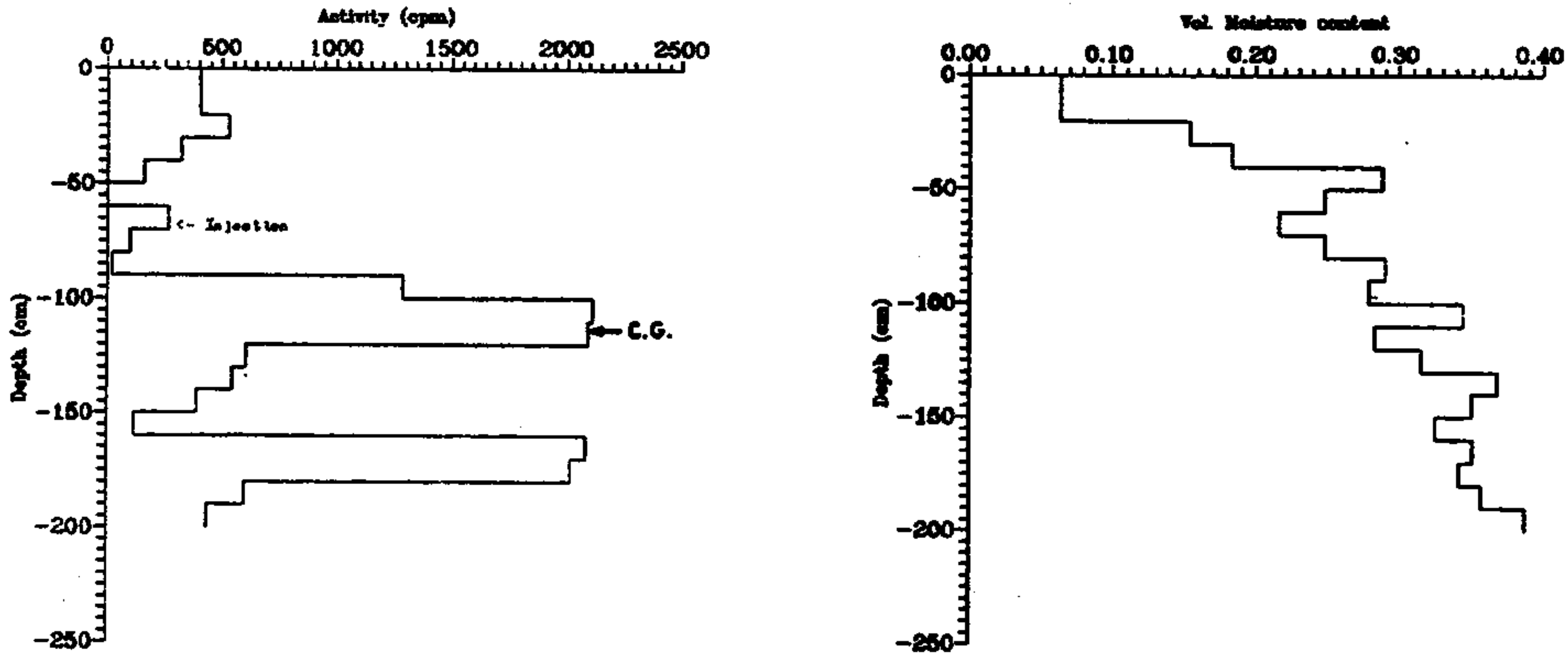


Fig. 8 : Movement of Injected Tritium and Soil Moisture at Mekh site

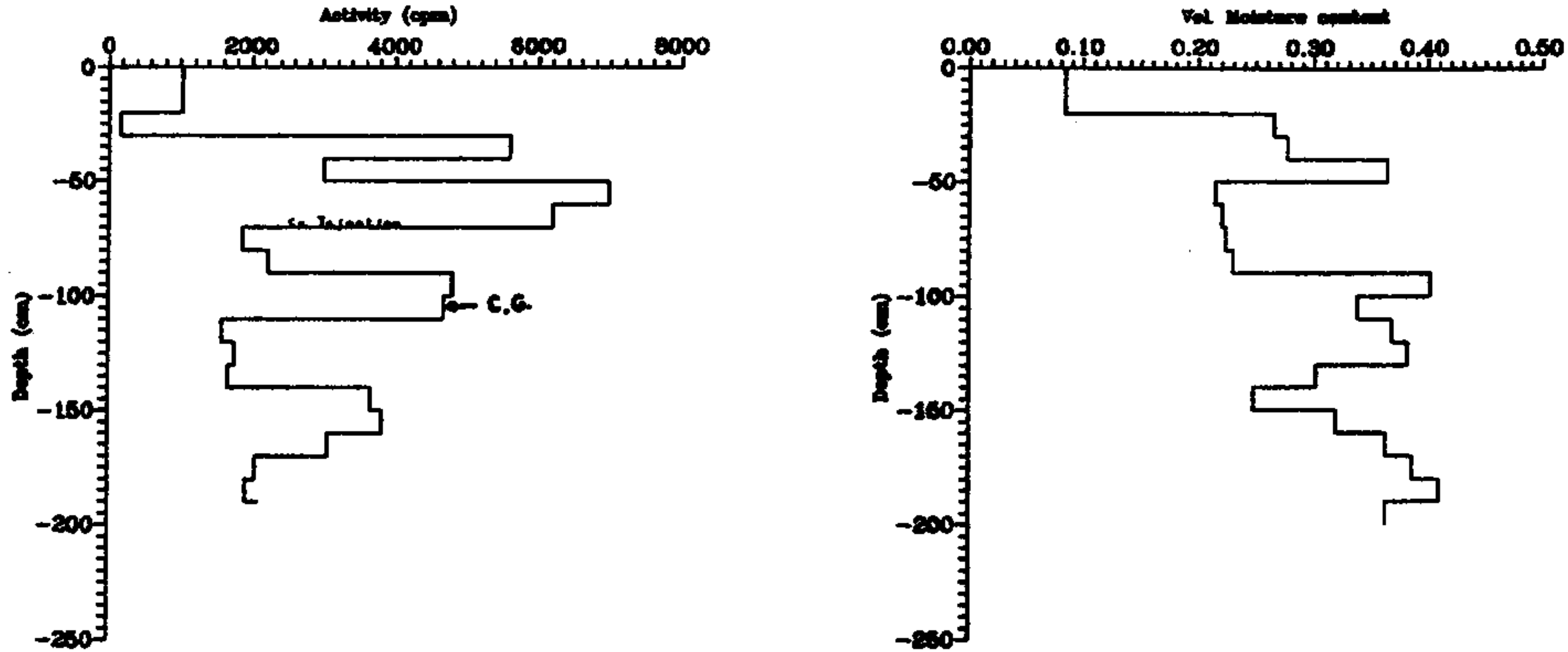


Fig. 9 : Movement of Injected Tritium and Soil Moisture at Surwari site

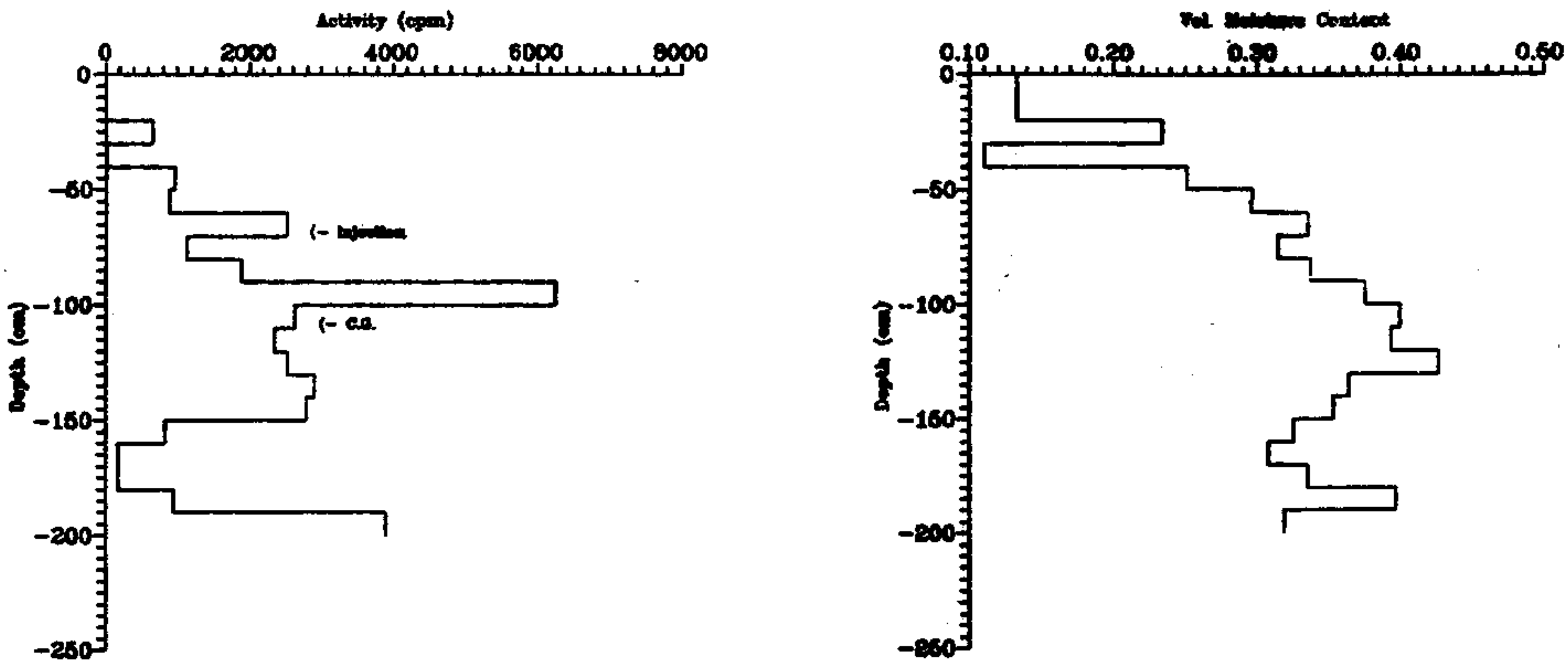


Fig.10: Movement of Injected Tritium and Soil Moisture at Berheta Site

5. RESULTS AND DISCUSSION

The percentage of recharge to groundwater at each experimental site namely, Nayagaon, Supla, Bochhar, Mekh, Surwari and Berheta due to monsoon rains of 1996 is given in table 9.

From the results obtained it is observed that the percentages of recharge at sites Nayagaon, Bochhar, Mekh and Berheta due to monsoon rains are 15.59, 21.88, 18.08 and 22.4% respectively. The particle size of the soil samples collected from these sites reveals that the total percentages of silt and clay are 89.7, 88.1, 85.0 and 77.4% with percentage of gravel as 4.9, 1.6, 1.0 and 2.4% respectively at these sites. Therefore the results are well comparable at these sites. While the percentages of recharge to the groundwater at sites Supla and Surwari due to monsoon rains are comparatively low i.e. 12.22 and 13.02% respectively corresponding to the total percentage of silt and clay i.e. 91.1 and 94.0% at these sites. However, if we consider the percentage of gravel at these sites, the values of groundwater recharge seem to be justified at these sites.

Table 9: Tritium peak shift, Average volumetric moisture content, recharge, rainfall, irrigation, and % of recharge for various experimental sites

Name of site	Tritium peak-shift (cm)	Average volumet. moisture content	Recharge (cm)	Rainfall (cm)	Irrigation (cm)	Recharge (%)
Nayagaon	28.61	0.345	9.87	63.31	0.00	15.59
Supla	33.8	0.229	7.74	63.31	0.00	12.22
Bochhar	54.5	0.249	13.625	62.25	0.00	21.88
Mekh	41.76	0.290	12.11	66.95	0.00	18.08
Surwari	30.55	0.285	8.72	66.95	0.00	13.02
Berheta	41.2	0.364	14.997	66.95	0.00	22.40

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