Lab Manual
for
Engineering Hydrology
(BE05006021)

B.E. Semester 5th (Civil Engineering)

**Government Engineering College,
Dahod**

**Directorate of Technical Education
Gandhinagar, Gujarat**

Vision Statement of the Institute

To be a value-based engineering institute to disseminate globally acceptable education and nurturing research, innovation and entrepreneurship.

Mission Statements of The Institute

1. To provide quality education in the engineering disciplines through creative balance of academics and extracurricular programs.
2. To provide learning environment for innovation and entrepreneurship.
3. To disseminate ethical values, social values and sensitivity towards environmental issues.

Vision Statement of the Civil Engineering Department

To be a recognized department in the field of civil engineering education to produce professional civil engineers, innovators and entrepreneurs for the development of the society.

Mission Statements of the Civil Engineering Department

1. To provide quality education to civil engineering undergraduates through creative balance of academic, professional and extra-curricular activities.
2. To impart knowledge in the field of civil engineering for the development of infrastructure facilities with environmental concern for betterment of the society.
3. To contribute in the nation's development through innovative ideas in the field of civil engineering.

Knowledge and Attitude Profile

- **WK1**: A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.
- **WK2**: Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline
- **WK3**: A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
- **WK4**: Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
- **WK5**: Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area
- **WK6**: Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.

- **WK7**: Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development
- **WK8**: Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues
- **WK9**: Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes

Program outcomes (Pos).

- **PO1: Engineering Knowledge:** Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.
- **PO2: Problem Analysis:** Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4).
- **PO3: Design/Development of Solutions:** Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5).
- **PO4: Conduct Investigations of Complex Problems:** Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).
- **PO5: Engineering Tool Usage:** Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6).
- **PO6: The Engineer and The World:** Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).
- **PO7: Ethics:** Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9).
- **PO8: Individual and Collaborative Team work:** Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
- **PO9: Communication:** Communicate effectively and inclusively within the engineering

community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.

- **PO10: Project Management and Finance:** Apply knowledge and understanding of engineering management principles and economic decision-making and apply these in multidisciplinary environments.
- **PO11: Life-Long Learning:** Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8).

Program Specific Outcomes (Psos)

Program Specific Outcomes (PSOs) are what the graduates of a specific undergraduate engineering program should be able to do at the time of graduation.

Civil Engineering Graduates Shall Have

- **PSO 1:** Ability to analyze, design, construct, maintain and rehabilitate the infrastructural projects, using the knowledge of subjects related to planning, construction, structural analysis and design, surveying, geotechnical, transportation, environment and water resource engineering as well as project management.
- **PSO 2:** Ability to employ advanced civil equipments, software, and techniques, interact and work seamlessly in teams.
- **PSO 3:** Ability to apply gained knowledge to choose from the innovative career paths, to be an entrepreneur, and a zest for higher studies.

Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) describe the career and professional accomplishments that programs are preparing graduates to attain within a few years (3-5 years) of graduation.

Following are the PEOs of B.E Civil Engineering Program:

- **PEO 1:** Establish themselves as civil engineering professionals in government, public and private sectors.
- **PEO 2:** Manage infrastructural and sanitary facilities.
- **PEO 3:** Solve real world problems environmental concerns to serve society.
- **PEO 4:** Adapt to changing trends in analysis and design of civil engineering structures.
- **PEO-05:** To do testing, survey and planning of civil engineering structures using modern tools.

Government Engineering College, Dahod

Certificate

This is to certify that Mr./Ms. ____ ____________ Enrollment No. __________________ of B.E. Semester Civil Engineering of this Institute (GTU Code: ____) has satisfactorily completed the Practical/Assignment work for the subject **Engineering Hydrology (BE05006021)** for the academic year 2026-27.

Place: ___________

Date: ___________

Name and Sign of Faculty member

Head of the Department

Preface

The basic aim of laboratory/practical/field work is to enhance the required skills as well as creating ability amongst students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping this in view, GTU has designed competency focused outcome-based curriculum for engineering degree programs where sufficient focus is given to the practical work. It shows importance of enhancement of skills amongst the students and pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates interest and students can have basic idea prior to performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with industry relevant skills, course outcomes as well as practical outcomes (objectives). The students will also achieve safety and necessary precautions to be taken while performing practical.

This manual also provides guidelines to faculty members to facilitate student centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes. It also gives an idea that how students will be assessed by providing rubrics.

Civil Engineering
GTU Course Code: BE05006021

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Course Outcome matrix

CO-1	Comprehend hydrological cycle, precipitation processes, and measurement techniques.
CO-2	Analyze infiltration, evaporation, and runoff processes in a watershed
CO-3	Apply unit hydrograph and flood routing methods for hydrological analysis
CO-4	Estimate flood discharge using empirical and statistical methods.
CO-5	Evaluate groundwater flow and well hydraulics for sustainable usage.

Sr. No.	**Practical**	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
1.	Measurement and analysis of rainfall using Rain-gauges	√				
2.	Hydrograph plotting analytical and experimental (through rainfall simulator)			√		
3.	To determine rate of infiltration and infiltration capacity using double ring infiltrometer		√			
4.	Determination of Evaporation Rate Using a Pan Evaporimeter		√			
5.	To estimate Flood through simulation using software				√	
6.	To verify Dacy's law for groundwater flow using permeameter					√

Index
(Progressive Assessment Sheet)

S. No.	Name of Practical	Page No.	Starting Date	Date of completion	Marks	Sign. of Teacher with Date	Remarks
1.	Measurement and analysis of rainfall using Rain-gauges						
2.	Hydrograph plotting using rainfall simulator						
3.	To determine rate of infiltration and infiltration capacity using double ring infiltrometer						
4.	Determination of Evaporation Rate using a Pan Evaporimeter						
5.	To estimate Flood through simulation using software						
6.	To verify Dacy's law for groundwater flow using permeameter						
Total							

Practical 1: Measurement of rainfall

AIM OF THE EXPERIMENT: To measure rainfall from non-recording and recording rain gauges.

THEORY:

Rainfall may be measured by a network of rain gauges which may either be of non-recording or recording type. The non-recording rain gauge used in India is the Symon's rain gauge (Fig. 1). It consists of a funnel with a circular rim of 12.7 cm diameter and a glass bottle as a receiver. The cylindrical metal casing is fixed vertically to the masonry foundation with the level rim 30.5 cm above the ground surface. The rain falling into the funnel is collected in the receiver and is measured in a special measuring glass graduated in mm of rainfall; when full it can measure 1.25 cm of rain. The rainfall is measured every day at 08.30 hours IST. During heavy rains, it must be measured three or four times in the day, lest the receiver fill and overflow, but the last measurement should be at 08.30 hours IST and the sum total of all the measurements during the previous 24 hours entered as the rainfall of the day in the register. Usually, rainfall measurements are made at 08.30 hr IST and sometimes at 17.30 hr IST also. Thus, the non-recording or the Symon's rain gauge gives only the total depth of rainfall for the previous 24 hours (i.e., daily rainfall) and does not give the intensity and duration of rainfall during different time intervals of the day. It is often desirable to protect the gauge from being damaged by cattle and for this purpose a barbed wire fence may be erected around it.

Fig 1- Ordinary Symons Rain Gauge (Source: https://www.amazon.in)

Recording rain gauge

Self-recording, automatic or integrating rain gauge has an automatic mechanical arrangement consisting of a clockwork, a drum with a graph paper fixed around it and a pencil point, which draws the mass curve of rainfall. From this mass curve, the depth of rainfall in a given time, the rate or intensity of rainfall at any instant during a storm, time of onset and cessation of rainfall, can be determined. There are three types of recording rain gauges—tipping bucket gauge, weighing gauge and float gauge. The self-recording rain gauge is generally used in conjunction with an ordinary rain gauge exposed close by, for use as standard, by means of which the readings of the recording rain gauge can be checked and if necessary adjusted.

Float type rain gauge is usually used by the Indian Meteorological Department (IMD), as show in Fig 2. It consists of a cylinder with a funnel top, circular inner brass tube, and recording mechanism of a clock driven drum carrying the record sheet on which a pen draws the graph of rainfall against time. When the rainfall is collected in a float chamber, the float moves up which makes a pen to move on a chart wrapped round a clock driven drum. The X-axis of the chart (graph) is the rainfall (mm) with accuracy of 1 mm and Y-axis represents time When the float chamber fills up, the water siphons out automatically through a siphon tube kept in an interconnected siphon chamber. Water gets drained and pen drops to the zero position. The depth of rainfall recorded on the graph sheet is read for every half an hour to determine the variation in rainfall intensity for different durations of the storms. The clockwork revolves the drum once in 24 hours. The clock mechanism needs rewinding once in a week when the chart wrapped round the drum is also replaced.

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Fig 2- Recording Rain Gauge (Source: www.indiamart.com)

OBSERVATIONS AND CALCULATIONS

Non-recording rain gauge

Area of aperture of cylindrical gauge=

A	B	C
Time	Volume of water collected in cm^3	depth of rainfall = Volume of water collected /area of aperture of the gauge in cm^2

Amount of rainfall measured by cylindrical gauge at _____a.m./p.m = _____cm.

Recording rain gauge

Determine the depth of rainfall for each hour from graph = _____cm

Calculate the intensity of rainfall = ______cm/hr

RESULTS

1. **Non-recording rain gauge**

   Measure rainfall depth = ________cm

2. **Recording rain gauge**

   - Average depth of rainfall = _____cm
   - Intensity of rainfall = _______cm/hr

CONCLUSION:

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Practical 2: Hydrograph Plotting using Rainfall Simulator

AIM OF THE EXPERIMENT: To plot the hydrograph based on the observations for different rain conditions on a rainfall simulator.

APPARATUS:

- Rainfall simulator with Water supply tank, Spray nozzles
- Soil tray/test plot
- Stopwatch
- Measuring cylinders/Graduated beakers
- Rain gauges/collecting cans
- Scale/ruler
- Balance (optional)
- Thermometer (optional)

THEORY:

The experiment conducted on rainfall simulator in the lab is a process of observing rainfall distribution in a given space/area followed by infiltration (based on soil composition and moisture condition) and runoff. The experimental setup help to understand different scenarios of rainfall combined with other related parameters and the corresponding response of the soil.

In other words, the experiment is useful to simulate rainfall of known intensity on a soil surface, to determine the infiltration rate of the soil, to measure the runoff generated during simulated rainfall and to study the effect of rainfall intensity on runoff and infiltration.

A commonly used rainfall simulator in the lab is shown in Fig. 1.

Following precautions are advised to be followed for effective performance of the practical:

1. Ensure the soil surface is level before testing.
2. Maintain constant water pressure throughout the experiment.
3. Use clean spray nozzles for uniform rainfall.
4. Prevent leakage from the apparatus.
5. Record readings at equal time intervals.
6. Use the same soil type and compaction for comparative tests.
7. Measure runoff accurately using graduated cylinders

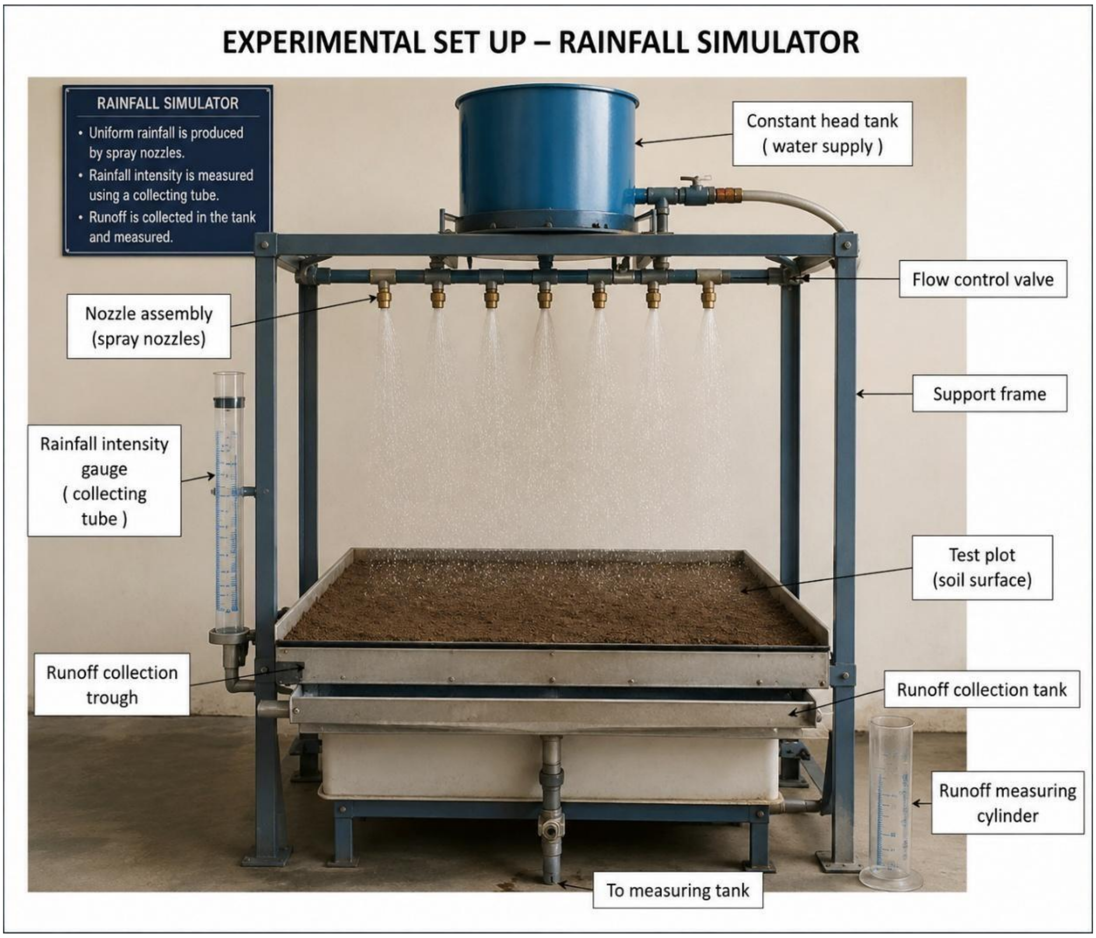


Fig.1

Rainfall Simulator

PROCEDURE:

The stepwise procedure to perform the practical is given below:

Step 1: Preparation of the Soil Bed

- Fill the experimental tray with the required soil.
- Level the soil surface uniformly.
- Compact the soil to the desired density.
- Measure and record the dimensions of the soil tray.
- If required, determine the initial moisture content.

Step 2: Setup of the Rainfall Simulator

- Ensure all nozzles are clean.
- Fill the overhead tank with water.
- Switch on the pump.
- Adjust the pressure to obtain uniform rainfall.
- Keep the rainfall simulator at the specified height above the soil tray.

Step 3: Calibration of Rainfall Intensity

- Place rain gauges or collecting cans uniformly on the test area.
- Operate the simulator for 5–10 minutes.
- Measure the amount of water collected in each gauge.
- Calculate rainfall intensity using following conceptual relationship (ensure homogeneity of units)

$$I = \frac{V}{A * t}$$

Where,

- **I** = Rainfall intensity (mm/hr)
- **V** = Volume collected (mm^3)
- **A** = Area of collector (mm^2)
- **t** = Time (hr)

Check that rainfall distribution is reasonably uniform.

Step 4: Conducting the Experiment

- Remove the rain gauges.
- Place the prepared soil tray below the simulator.
- Start rainfall.
- Simultaneously start the stopwatch.
- Observe the soil carefully.

Record:

- Time when infiltration begins.
- Time when runoff starts.
- Water infiltrated into soil.
- Runoff collected every **2 or 5 minutes**.

Continue rainfall for **20–30 minutes**.

Step 5: Collection of Runoff

- Collect runoff in measuring cylinders.
- Measure runoff volume at regular intervals.
- Record cumulative runoff.

Step 6: Completion

- Stop the simulator.
- Measure final runoff volume.
- Observe soil condition.
- Clean the apparatus.

OBSERVATIONS:

Observation Table 1: Rainfall Calibration

Trial	Duration (min)	Water Collected (ml)	Rainfall Intensity (mm/hr)
1			
2			
3			

Observation Table 2: Runoff Measurement

Time (min)	Rainfall Volume (Vr)	Runoff Volume (Ri)	Cumulative Runoff (R)	Infiltration (i)
0				
5				
10				
15				
20				
25				
30				

CALCULATIONS & RESULT:

Based on the observations made during repetition of practical, following parameters were calculated using standard relationships-

1. Rainfall Volume

$$Vr = I \times A \times t$$

Where,

- Vr = Rainfall volume
- I = Rainfall intensity
- A = Area of soil tray
- t = Duration

2. Infiltration

Infiltration=Rainfall−Runoff = Vr-Ri

3. Infiltration Rate

f=Infiltration/time

4. Runoff Coefficient

C=Run off Rainfall Coefficient = Cumulative Runoff /Rainfall Volume= R/Vr

CONCLUSION:

The rainfall simulator successfully reproduced controlled rainfall conditions. The infiltration rate, runoff volume, and runoff coefficient were determined from the experimental observations, demonstrating the relationship between rainfall intensity, infiltration, and surface runoff in the test soil.

Practical 3: To determine rate of infiltration and infiltration capacity using double ring infiltrometer

AIM OF THE EXPERIMENT: To determine the infiltration rate of water into the soil and infiltration capacity using double ring infiltrometer.

THEORY:

The rate of infiltration is determined by the amount of water that infiltrates into the soils per surface area, per unit of time Infiltration can be measured by either a single or double ring infiltrometer. The infiltrating water flows laterally and vertically away from the ring in single ring infiltrometer, and the effects of the lateral flow must be accounted for precise interpretation of the infiltration measurements and to estimate soil properties governing infiltration, such as the soil hydraulic conductivity. The outer ring of the double-ring infiltrometer is intended to reduce lateral flow from the inner ring, allowing the data from the inner ring to be analyzed as if the flow were one-dimensional. The double ring infiltrometer is a way of measuring saturated hydraulic conductivity of the surface layer. In the double ring Infiltrometer, measurement of infiltration rate can be carried out using two operational techniques -**constant head test and falling head test**. In the constant head test, the water level in the inner ring is maintained at a fixed level and the volume of water used to maintain this level is measured. In the falling head test, the time that the water level takes to decrease in the inner ring is measured. In both constant and falling head tests, the water level in the outer ring is maintained at a constant level to prevent leakage between rings and to force vertical infiltration from the inner ring. Numerical modeling has shown that falling head and constant head methods give very similar results for fine textured soils, but the falling head test underestimates infiltration rates for coarse textured soils.

APPARATUS:

The experimental setup consists of two concentric rings with a hammer, driving plate, for inner and outer rings, Float Pointer Gauge, a stainless steel hammering cross and a stopwatch. If a single-ring infiltrometer is desired, a ring of any one of the different sizes may be used. If a double-ring infiltrometer is desired, a small ring is installed, centered inside a larger ring. The 12- and 24-inch rings (inner ring diameter 30 cm and the outer ring of diameter 60 cm) are suggested for a double-ring infiltrometer installation.

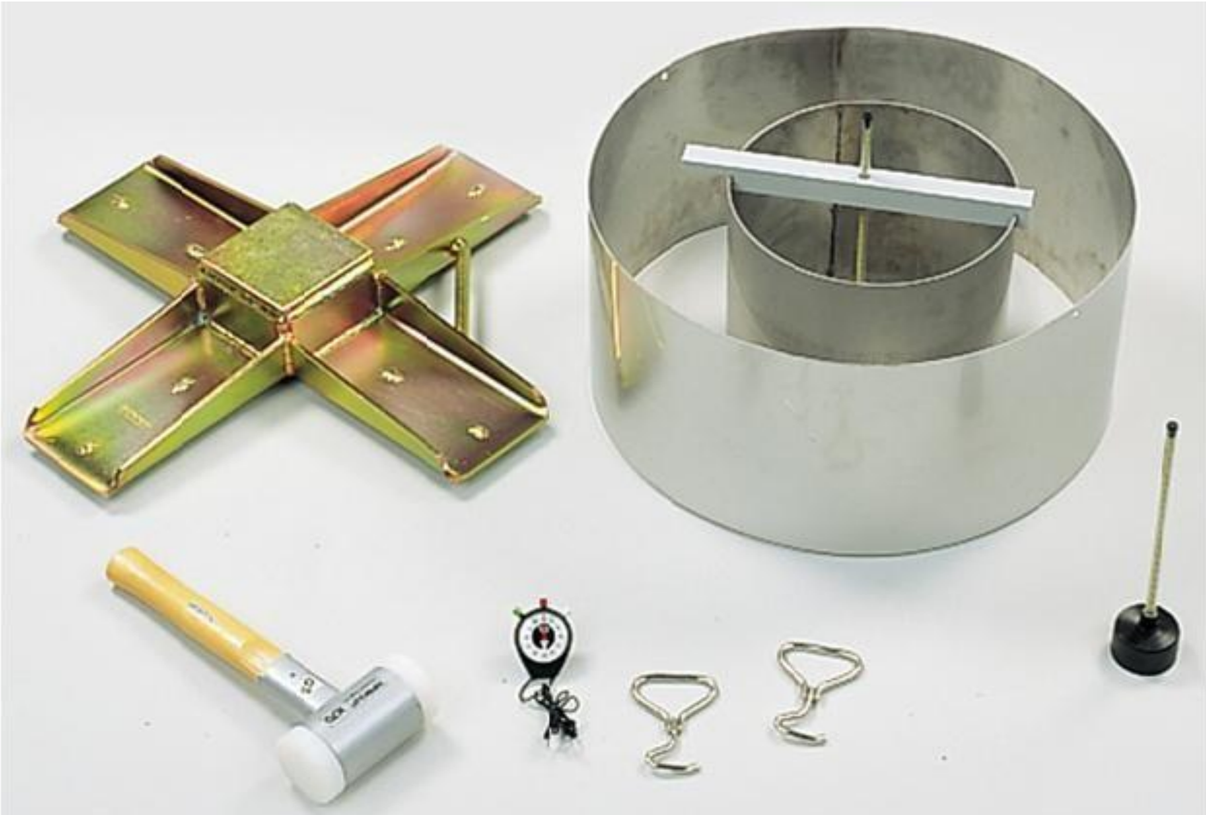


Fig 1.- Double Ring Infiltrometer
(Source:- 2830K1 Double Ring Infiltrometer Kit, operating instruction)

PROCEDURE:

1. Place the inner ring with the cutting edge facing down on the ground. Remove small obstacles such as stones or twigs. When measuring below the ground surface, a profiled pit should be made.
2. Put the driving plate on top of the inner ring. Depending on its diameter the ring will fit over, between or within the pins located on the bottom side of the driving plate.
3. Use the impact-absorbing hammer to insert the infiltration ring about 5 cm vertically into the soil. Keep the depth of placement as limited as possible so as not to disturb the top layer. Insert the rings in any case to below a particular top layer, such as a disturbed or crusted top layer or layer with macro-pores. Place the outer ring with the cutting edge facing down around the inner ring and put the driving plate on top of it.
4. Place the measuring bridge with measuring rod and float on the inner ring. Remove, without disturbing the soil structure, any vegetation that may hamper free movement of the float or affect the measuring.
5. Fill the outer ring with water, then the inner ring, to approximately 5 - 10 cm. Keep the water in the inner and outer ring at a similar level. A higher water level in the outer

ring will lead to a decreasing infiltration rate in the inner ring. A lower water level in the inner ring will cause the buffering against lateral spreading to decrease.

6. Start measuring by noting the time and the water level in the inner ring as indicated on the measuring rod (Column A and B Observation in Table 1). Determine the drop in the water level (infiltration) in the inner ring during a certain interval as in column C.
7. Stop measuring only if the infiltration rate has reached a constant value. A change of $< 10\%$ in a certain phase is often considered as constant. Depending on the type of soil this may occur within 1 or 2 hours, in exceptional cases only after a day. Determine infiltration capacity.
8. Remove the rings using the pull-out hooks, make sure no earth sticks and sets to the rings. The cumulative infiltration is the total amount of water infiltrating over a certain period of time.

OBSERVATIONS AND CALCULATIONS

Observation Table 1

A	B		C	D	E
Time	**Water Level, cm**		**Infiltration , cm**	**Infiltration rate,**	**Accumulated infiltration**
min	**Initial level**	**After filling**	**Fall in water level**	**cm/hr**	**cm**
0					
2					
5					
10					
20					
30					
45					
60					

RESULT:

Infiltration rate (I) = ___________________________________

Infiltration capacity= _________________________________

CONCLUSION:

____

____

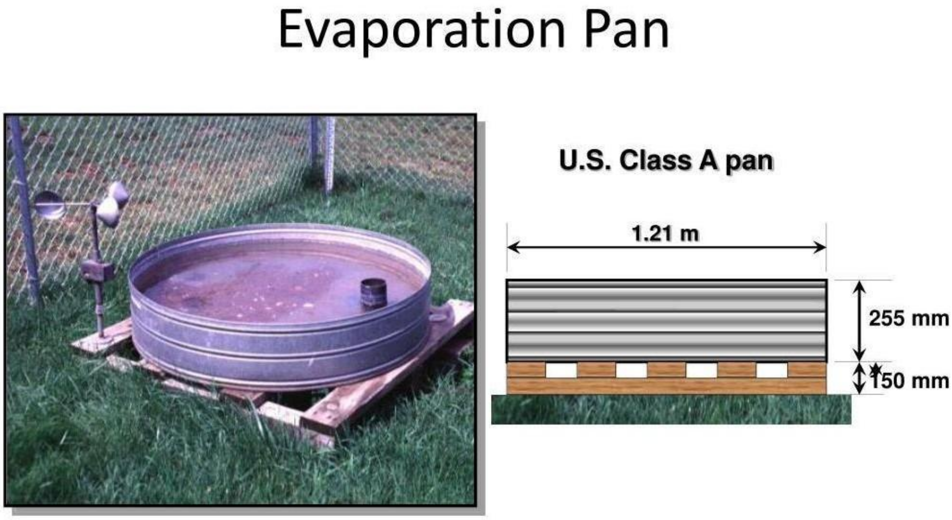
Practical 4: Evaporation study through PAN evaporimeter

AIM OF THE EXPERIMENT:

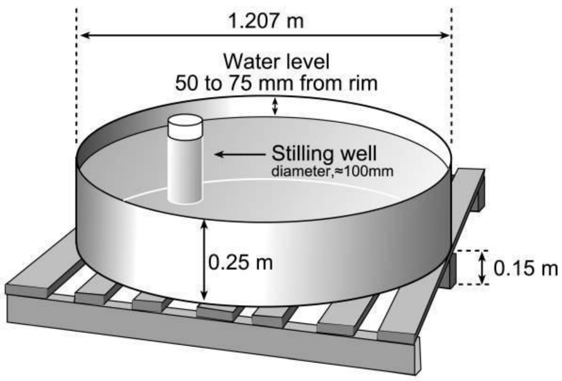
To measure the daily evaporation rate using a Class A PAN Evapometer and determine the amount of water evaporated under atmospheric conditions.

APPARATUS:

- Class A PAN Evapometer (A **Class A PAN Evapometer** is a standardized circular pan made of galvanized iron or stainless steel. It’s approximate Diameter = **120.7 cm** and Depth = **25 cm**
- Stilling well
- Hook gauge or point gauge
- Measuring cylinder
- Clean water



(a) Pan Setup



(b) Base and Pan

(c) Gauge

Fig. 1 US Class A Pan Evapometer and its components (a-c)

THEORY:

Evaporation is the process by which liquid water changes into water vapour due to solar radiation, wind movement, air temperature, and atmospheric pressure. The Class A PAN Evapometer is an effective instrument for measuring open water evaporation. Evaporation increases with higher temperature, stronger winds, and greater solar radiation, while high humidity reduces evaporation. PAN evaporation data are widely used in irrigation scheduling, crop water requirement estimation, reservoir management, and hydrological studies.

The pan is filled with water up to a specified level. The fall in water level over 24 hours indicates evaporation. If rainfall occurs, suitable correction is applied.

Water Balance Formula

$$E = I + R - F$$

Where,

- **E** = Evaporation (mm/day)
- **I** = Initial water level (mm)
- **R** = Rainfall during observation period (mm)
- **F** = Final water level (mm)

If no rainfall occurs,

$$E = I - F$$

Calculating evaporation rate in millimetres (mm/day) by measuring daily evaporation loss from an open water surface and study the influence of climatic factors such as temperature, humidity, wind speed, and sunshine on evaporation can provide useful insight about changes in climate over short and long periods.

PROCEDURE:

Following procedure should be followed to observe and record the evaporation rate at any place using pan evaporimeter:

1. Install the PAN Evapometer on a wooden platform in an open area.
2. Fill the pan with clean water up to the reference level.
3. Record the initial water level using the hook gauge.
4. Leave the pan exposed for 24 hours.
5. Record the final water level after 24 hours.
6. Measure rainfall, if any.
7. Calculate evaporation using the formula.
8. Repeat observations daily for several days.

OBSERVATIONS:
(with sample data)

Day	Initial Water Level (mm)	Final Water Level (mm)	Rainfall (mm)	Evaporation (mm/day)
1	200	194	0	6
2	200	193	0	7
3	200	195	2	7
4	200	192	0	8
5	200	194	1	7

`

CALCULATION:

Sample calculation:

Given

Initial water level = **200 mm**

Final water level = **194 mm**

Rainfall = **0 mm**

$$E = I + R - F$$
$$E = 200 + 0 - 194$$
$$E = 6 \text{ mm/day}$$

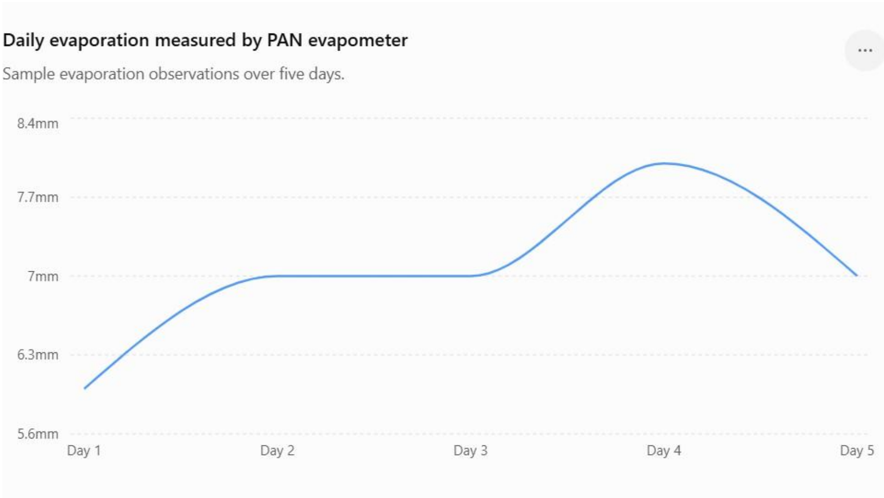
Therefore, Daily Evaporation = **6 mm/day**

Average Evaporation Rate= **__________**mm/day (Total evaporation rate per day/no. of days)

Sample Graph (for assumed data)

Sample evaporation observations over five days.

Day 1	Day 2	Day 3	Day 4	Day 5
5.6mm	6.3mm	7mm	7.7mm	8.4mm



RESULT:

The daily evaporation from the Class A PAN Evapometer was successfully measured. The observed evaporation ranged from **6 to 8 mm/day**, with an average evaporation of:

$$\frac{6+7+7+8+7}{5} = 7.0 \text{ mm/day}$$

Hence, the average daily evaporation during the observation period was **7.0 mm/day**.

CONCLUSION:

___

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Practical 5: Flood estimation through Simulation

AIM OF THE EXPERIMENT: The objective of this experiment is to assess the flooding in river basin using simulation.

SOFTWARE TOOLS REQUIRED:

Any hydrological and hydraulic software with capability of integrating georeferenced terrain of the river basin area and both surface and sub-surface properties including soil and natural cover. Some of the suitable software for estimating flood are HEC-HMS, HEC-RAS, RIBASIM, MIKE11, etc.

THEORY:

Flood estimation through simulation experiments involves building hydrological and hydraulic models to predict flood behavior. By inputting rainfall and terrain data into software like HEC-HMS or HEC-RAS, these experiments allow engineers to simulate runoff, visualize inundation depths, and estimate peak discharges to design safer infrastructure.

Key Simulation Methodologies

- Continuous Simulation: Uses long-term continuous historical or stochastically generated rainfall data to evaluate how catchment soil moisture and varying precipitation create complex flood peaks.
- Monte Carlo Simulation: A statistical approach utilizing probability distributions (like the Joint Probability Approach) to generate thousands of synthetic flood events. This helps capture rare, extreme flood probabilities without relying on short observational records.
- Rainfall-Runoff Modeling: Transforms meteorological input (hyetographs) into water discharge (hydrographs) using catchment parameters such as curve numbers and concentration time.

Primary Simulation Tools

- HEC-HMS: Developed by the US Army Corps of Engineers, this program is the industry standard for simulating the precipitation-runoff processes of watershed systems.
- HEC-RAS: Used to perform one- and two-dimensional hydraulic routing of water through rivers and floodplains to map inundation limits.
- GIS Platforms: Used alongside hydraulic models to translate exported water surface elevations into usable, grid-based depth maps.

Educational and Technical Resources

Several highly authoritative resources detail the exact methodologies and physics behind these simulation experiments:

- Review the Continuous Simulation Modelling for Design Flood Estimation paper for insight into catchment-scale rainfall-runoff experiments.
- Examine the USGS Estimation of Flood Volumes and Simulation of Floods report to understand the practical equations and datasets required for volumetric analysis.
- Download the UK Centre for Ecology & Hydrology's Flood Estimation Handbook Volume 3 for complete academic and practical guidance on continuous simulation modeling.

PROCEDURE:

Flood modeling incorporates several core elements like *Catchment Parameters* (Inputting static data like the Digital Elevation Model (DEM) and channel geometry to represent the physical terrain), *Dynamic Variables* (Simulating inputs like rainfall intensity, soil moisture, and infiltration rates by Horton, Green-Ampt, or SCS-CN methods), *Hydrodynamic Routing* (Solving flow equations such as Saint-Venant equations, to predict how water moves through channels and overflows onto floodplains) and *Visualization* (generating flood risk and inundation maps, often integrating GIS frameworks).

Flood estimation through simulation involves modeling how a catchment converts rainfall into runoff using mathematical and hydrological processes. It involves using hydrological and hydrodynamic models to compute flood hydrographs, water depths, and inundation extent based on parameters like rainfall, terrain elevation, and soil infiltration. It is typically carried out by following specific, sequential steps within specialized software.

1. **Data Collection & Preparation:** Gather topographical data (DEMs), land use/soil maps, and continuous hydro-meteorological records (rainfall, evaporation, and streamflow) for the basin
2. **Loss & Transformation Modeling:** Apply a loss method (like the SCS-Curve Number or initial/continuing loss) to determine how much rain is absorbed, and a transform method (e.g., Unit Hydrograph) to calculate direct surface runoff.
3. **Routing:** Route the resulting runoff through the river network and floodplains using hydraulic models (like 1D/2D hydrodynamic engines) to predict water depth, velocity, and extent.
4. **Calibration & Validation:** Adjust model parameters (e.g., roughness coefficients) until simulated flows match historical, observed flood events.
5. **Scenario Simulation:** Input design storms (e.g., 100-year return period) to estimate and map the resulting flood extents and risks.

RESULTS

The result of simulation depends on input values of hydrological and hydraulic parameters for an area. It will also depend on the ability of software and the relationship used for calculating parameters like runoff and stream flow. Other environmental factors like wind, rainfall, existing moisture content, etc. can also affect the result to some extent.

CONCLUSION

The prediction of flood in any area is a challenging prediction as it involves complex dynamic modelling to simulate a possible scenario having many factors affecting the net outcome. It is important to have thorough understanding of physical phenomenon involved. The correctness of the result depends on the accuracy of measured data, minimum error in generating the real scenario and relating the input values with the model. The experience of analyst combined with adequate knowledge of the software is important in correctly inferencing from the obtained results.

Practical 6: Groundwater analysis (Darcy's law)

AIM OF THE EXPERIMENT: To measure the hydraulic conductivity (K) of a porous medium (like sand or gravel) and validate the Darcy's Law by observing water flowing through it under a known hydraulic gradient.

APPARATUS REQUIRED:

- Constant-head permeameter cylinder (transparent tube to hold soil).
- Porous discs or mesh screen filters (placed at both ends of the sample).
- Two manometers / piezometers (to measure water levels h_1 and h_2).
- Water supply reservoir (with an overflow mechanism to keep the head constant).
- Graduated cylinder and stopwatch (to measure the outflow volume over time).
- Soil sample (clean, uniform sand is ideal).
- Vernier caliper / ruler (to measure cylinder diameter and sample length).

THEORY:

The experiment determines the soil's **hydraulic conductivity (K)** by tracking the volume of water passing through a known sample geometry over time. A linear relationship between the flow rate and the pressure gradient validates the core premise of Darcy's Law.

- Sand & Gravel (Constant-Head Setup): High permeability allows water to flow quickly. This keeps volume and time measurements highly accurate.
- Silt & Clay (Falling-Head Setup): Extremely low permeability makes constant-head tests impractical because water moves too slowly. For these materials, track the falling speed of a water column instead of collecting volume in a cylinder.

This experiment is designed to illustrate the validity of Darcy's law according to the equation:

$$Q = -K * A * (\Delta h / L)$$

Where:

- Q is the volumetric flow rate (m^3/s)
- K is the hydraulic conductivity (m/s)
- A is the cross-sectional area of the soil sample (m^2)
- Δh is the hydraulic head difference (h_1 - h_2) across the sample (m)
- L is the length of the soil sample (m)

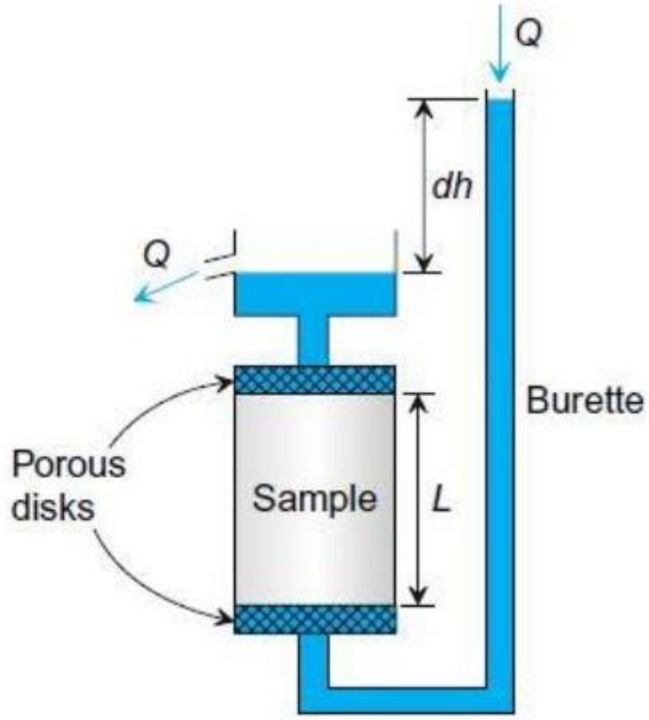

Fig. 1 Constant Head Permeameter

The experiment requires following attentions:

a) *Setting Up the Permeameter*

- Measure the internal diameter of the cylinder to calculate the cross-sectional area:

$$A = (\pi * D^2) / 4.$$

- Pack the soil sample uniformly into the cylinder to prevent artificial void spaces or channeling.
- Measure the length (L) of the packed soil sample.
- Connect the piezometer tubes to the pressure ports located at the inlet and outlet boundaries of the sample.

b) *Establishing Steady State Flow*

- Saturate the soil sample slowly from the bottom up to expel any trapped air bubbles.
- Connect the water supply to the top inlet and adjust the overflow pipe to maintain a fixed water level.
- Allow water to drain through the sample until the outflow rate becomes steady and the piezometer levels stop fluctuating.

c) *Potential Error Sources*

- Air entrapment: Bubbles inside the soil artificially reduce the available cross-sectional area, leading to undercalculated K values.

- Preferential flow pathways: Poorly compacted soil along the cylinder walls creates boundary leakage channels where water bypasses the soil matrix.
- Fines migration: Small silt particles moving with the water flow can clog the porous discs and alter the soil permeability during the experiment.

PROCEDURE:

Given Ls and A in cm and cm2 respectively

1. Measure the distance between the marks outlining the potential locations of the constant-head tank
2. Divide this distance to about 10 intervals
3. For the current location of the tank, adjust the flow to the tank and open the outflow valve wide open. Make sure water will not overflow from the constant head tank
4. Make sure that tubes are void of air bubbles
5. When the flow stabilizes, measure the difference in the head level between the two manometers (h)
6. Measure the flow rate Q a few times by collecting a volume of water and measuring the time for collection. You will use the average Q for calculations. Keep an eye also on h
7. Calculate the ratio Q (average)/h
8. Carefully change the height of the constant head tank and repeat steps 3 and 7 for the 10 or so intervals. Close the in- and out-flow valves before the change. Open the valves and wait for the flow to stabilize before measuring Q and h
9. Check if the ratio Q (average)/h is roughly constant

OBSERVATIONS:

Fixed System Variables:
- Sample Diameter (D): _________cm
- Sample Cross-Sectional Area ($A = (\pi * D^2) / 4$): _________cm²
- Sample Length (L): _________cm

Trial #	Head h_1 (cm)	Head h_2 (cm)	Head Loss Δh (cm)	Volume V (cm^3)	Time t (s)	Flow Rate Q (cm^3/s)	Hydraulic Conductivity K (cm/s)
1							
2							
3							
4							
Average							

** Reference Values for Common Porous Materials

Material Type	Hydraulic Conductivity K (m/s)	Hydraulic Conductivity K (cm/s)	Drainage/Permeability Description
Clean Gravel	10^{-3} to 1.0	10^{-1} to 100	Very High / Rapid drainage
Coarse Sand	10^{-4} to 10^{-3}	10^{-2} to 10^{-1}	High / Quick drainage
Fine Sand	10^{-5} to 10^{-4}	10^{-3} to 10^{-2}	Medium / Moderate drainage
Silt / Loess	10^{-9} to 10^{-5}	10^{-7} to 10^{-3}	Low / Poor drainage
Unweathered Clay	10^{-12} to 10^{-9}	10^{-10} to 10^{-7}	Practically Impermeable

CALCULATIONS:

Calculating Hydraulic Conductivity

- Rearrange Darcy's Law to solve for the hydraulic conductivity: $K = (Q * L) / (A * \Delta h)$
- Repeat the collection process at different water head heights to verify that Q scales linearly with $\Delta h/L$, confirming laminar flow conditions.

RESULT: Plot the flow rate (Q) against the hydraulic gradient ($\Delta h/\Delta L$) to verify the linear relationship. The slope of this line is used to experimentally determine the **hydraulic conductivity (K)** of the sand sample.

CONCLUSION:

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** The practical can be performed on Virtual Lab for better understanding: https://smfe-iiith.vlabs.ac.in/exp/permeability/simulation.html