Ethiopian TVET-System

Irrigation and Drainage Design and Construction

Level-III

Based on March 2017 G.C. Occupational Standard

Module Title: Monitoring and Scheduling Water Deliveries

TTLM Code: EIS IDC 3 TTLM 09 20v2

This module includes the following Learning Guides

LG 18: Schedule Water Deliveries

LG Code: EIS IDC3 M06 0920LO1-LG-18

LG 19: Monitor Water Delivery

LG Code: EIS IDC3 M06 0920LO2-LG-19

LG 20: Coordinate and Control Water Delivery

LG Code: EIS IDC3 M06 0920LO3-LG-20

LG 21: Compile Reports and Records of Water Delivery

LG Code: EIS IDC3 M06 0920LO4-LG-21

Instruction Sheet	Learning Guide 18: Schedule Water Deliveries

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Identifying and recording customer water orders
- Analyzing water orders to determine water delivery and flow rate requirements
- Scheduling water deliveries to meet flow rate requirements

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Identify and record customer water orders.
- Analyse water orders to determine water delivery and flow rate requirements.
- Schedule water deliveries to meet flow rate requirements and organizational standards for channel balance and capacity restraints.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information "Sheet 1, Sheet 2 and Sheet 3" in page 3, 6and 13respectively.
4. Accomplish the "Self-check 1, Self-check 2, and Self- check 3" -" in page 5, 12and 20respectively
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1in page21.
6. Do the "LAP test" in page 22

Information Sheet-1	Identifying and Recording Customer Water Orders

1.1 Customer water orders

Water ordering helps us understand and plan for variations in on-going water demand to ensure that sufficient water is always available and delivered from the river intakes. Irrigation water orders have some different purposes such as:

- **Improvement the productivity of irrigation water:** Irrigation managers and farmers are under increasing pressure to improve the productivity and sustainability of water use in the face of increasing scarcity and competition for water. Competition for available water resources arises from a combination of:
    - rapid population growth;
    - rapid and extensive urbanization and industrial development;
    - recognition of the environmental consequences of previous water development and the need to reserve or return water to natural systems;
    - climate changing in many areas, making dry periods even drier.
- **Improve the productivity of its irrigation sector:** Irrigation is supplemental in the dry season. There are significant supply limitations in the dry season, coupled with distribution problems in the canal networks. Crop yields remain low compared to potential. Better access to water is one contributing factor to raising yields. Larger scale and more intensive agriculture are also becoming increasingly important as a consequence of urban migration and industrialization and the pressure to increase farm size to generate a decent living
- **Help individual farmers improve access to water:** Farmers who have good access to water can satisfy their crop watering needs at a time and place of their choosing. Water ordering has the potential to improve farmers' access to water in canal and piped irrigation systems in the following ways:

✓ providing improved level of service through access to defined flows over a defined time period;

✓ enabling increased intensity and diversification in crop production, leading to higher productivity and income;

✓ reduction in user conflict;

- ✓ enabling system operators (at both the basin level and at a local level) to deliver water efficiently; and
- ✓ enabling effective rationing and management of scarce water resources when required.

1.2 Recording irrigation water orders

The irrigation management service allows farmers in a group or a scheme to order water from a stored repository and have visibility around remaining stored water (like a bank account). For the scheme operators, it saves time and provides better visibility and accuracy around the user's orders. For the users, it reduces the wait time between ordering and receiving water and gives them transparency and acknowledgement of their water orders.

There are four basic steps for customers water recording in the irrigation process:

- Set up account: All it takes is one simple phone call to. Once the customers have given one of irrigation management representatives their name and address, the operators will provide them with an account number, and explain how to activate their account for the calendar year.
- Learn the neighborhood system: The customers talk to their neighbors before their first scheduled delivery day about how irrigation is handled in their neighborhood. This should include whether individual property owners typically open and close gates or if a commercial irrigator is used. They should also check to make sure their berms are maintained and their property's irrigation valve is operating properly. On delivery day, the delivery gate will open to release water into their neighborhood. From there, it's carried to their property through a series of ditches, channels or pipelines that are owned, operated and maintained by them and their neighbors.
- Sign up for water:Order water or sign up for the Recurring Order Program online or by calling to the project .
- Receive water delivery:Take note of who is scheduled to receive water before and after them on their scheduled delivery date. About 30 minutes before their water is scheduled to arrive, look around their neighborhood and check all

stand boxes to make sure the gates are set properly. Any water listed as ditch time immediately prior to their scheduled time is their responsibility to manage.

Self-Check -1	Written Test

Directions 1: Say ‘‘True’’ if the statement is correct and ‘‘False’’ if the statement is incorrect and write the answer on the space provided. (2 pts each)

--------1. Water ordering used to save time for scheme operators.

--------2. Water ordering increases the wait time between ordering and receiving water for

users.

--------3. Water ordering is the cause for conflict between users.

--------4. Rapid population growth rises competition for available water resources

--------5. Water ordering decreases intensity and diversification in crop production

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Information Sheet-2	Analyzing water orders

2.1. Communication, information and governance water ordering

Effective water ordering relies on good, clear information flows, based on a sound recording and collation of water deliveries, requests and adjustments. It requires:

- an agreed system of water rights (this defines what farmers “can have”);
- good water measurement at the service point (these records what farmers use and when it is used);
- good water accounting (this reports how much a farmer has used to date, and how much water remains in their “account”); and
- the operators having the authority and skills to “govern” the system.

The type of infrastructure influences what is possible as the greater flexibility that is provided by ordering requires a high level of control over offtakes and regulating structures, which can be demanding. However modern communication devices (mobile phones, internet and “iPads”) provide opportunities to adopt simple systems in a way that were previously quite difficult. Therefore, careful assessment is required before attempting to adopt the appropriate water ordering system. This needs to address technical feasibility, cost and the ability to remove existing constraints.

2.2. Alternatives to water ordering

A number of alternatives can be employed to improve existing levels of service without having to resort to the complexity of water ordering. In canal systems, the most likely avenues for success are ones that allow greater flexibility and farmer control in accessing good water supply. This can be achieved by:

- converting to private groundwater systems;
- pumping directly from storages or rivers;
- constructing small on-farm storages;
- improving service delivery in channel networks which can be partially achieved by:
    - ✓ joint use of surface and groundwater;

- ✓ delivery from smaller communal sources managed by local Water User Group; and
- ✓ modernization of canal systems to improve storage and operational flexibility;

- providing continuous flow with strong governance systems to rotate rights of access to this flow – a common way for farmers to access water. This rarely provides a good level of service but, if well implemented, can be effective, especially for rice-based agriculture.

A high level of service can be delivered through:

- high capacity pipes that provide water on daily or shorter intervals – this may be appropriate in small scale developments producing high value crops.
- piped systems, allowing pressure to be adjusted for increased demand by reducing the flow rate and sharing available flows more equitably than under gravity in canals.

In summary, there may be feasible and cost-effective alternatives to introducing water ordering.

2.3. Water ordering in medium and large-scale public irrigation systems

Water ordering is essential in larger schemes if you want a high level of irrigation service, the flexibility to grow high value crops and significantly increase land and water productivity throughout the whole irrigation-area. Water ordering and associated metering also enables an improved operator understanding of an irrigation scheme's water balance, audit trail for scheme performance and ongoing targeting of enhancements to improve levels of service and scheme performance.

Water ordering is the best and most cost-effective option to improve the level of service and production from irrigated agriculture in large and medium scale public irrigation systems.

2.4. The principles behind water ordering

2.4.1 Levels of service (LoS)

Level of Service is a measure of the farmer's ability to access water. The highest level of productivity that can be attained by a farmer is when water is supplied on-demand at a time, flow rate and duration of the farmer's choosing. On-demand irrigation incurs high costs, as the capacity of supply must be sufficient – probably twice the capacity – to satisfy the possibility that many users on a reach of canal (or pipeline) may take water at the same time. In the case of canals, it is technically quite difficult to provide water on demand, especially if there is limited canal storage or if losses are to be minimized.

Therefore, the practical goal is to achieve an acceptable LoS that enables maximum production, without providing water on-demand.

A high LoS incorporates flexibility for the user to irrigate when they need according to changing circumstances on farm, e.g. rainfall, evaporative demand, changes in crop pattern and dates, and possible use of localized water supplies such as groundwater and runoff/stored water. Put simply, a desired LoS specifies how much water will be delivered to a user, when and where.

In practice, a more detailed specification of LoS may include:

- the annual volume to be delivered to a service point;
- the volume to be delivered per service point, at a specified time, maximumflow rate and duration of flow to complete an order or scheduled irrigation;
- the consistency of flow provided during supply (flow rate, supply head); and
- the reliability with which deliveries will be made on-time and at specified flow rate.

Water ordering allows users flexibility in choosing how much water they apply and when. It aims to achieve a LoS that approaches on-demand irrigation, at a more reasonable cost. When a farmer places a water order for a particular farm outlet, they specify:

- the desired start time;
- the desired finish time; and
- the desired flow rates.

If the capacity of the channel will be exceeded by trying to satisfy all orders simultaneously, the irrigation scheduling team will move one or more orders forwards or backwards. The change in timing is quite small, often a few hours in canals, and rarely reduces the LoS to the farmer.

After an order has been placed, it is confirmed by the operator. Alternatively, in some systems the farmer can use a touch pad telephone to find their starting time from an answering service. If a farmer wishes to stop an irrigation early, they can do so, but must advise the irrigation supplier before doing so.

Ordering allows farmers to access water with a Level of Service that is almost on-demand, but is cheaper. Mobile phones provide the perfect medium to place and confirm orders using data transfer, or simply text messages.

2.4.2 Water ordering – types and possibilities

The primary aim of water ordering is to enable the operator to deliver water to meet a customer request. The ability of any system to deliver depends upon:

- the time required from when the order is placed to when it can be delivered, which includes the transit time from higher up the canal network;
- the control mechanisms that enable delivery;
- how frequently the operator is able to regulate the system to adjust water supply;
- the communication system the operator uses to operate the system; and
- the communication system between the customer and the operator.

There are two broad categories of water ordering:

- Predictive: when the operator needs to 'predict' future demand patterns. This occurs when demand and supply are separated by long physical and time distances (e.g. >12 days)
- Customer request: when orders are placed by the customer for the amount of water required in the right place at the right time.

There are different conditions under which ordering might operate and these can be thought of as "drivers" for the ordering process used. Three such drivers can be identified:

- Scheduling: where orders are arranged in a queue so that:

- ✓ during peak demand, supply capacity is not exceeded within a service period;
- ✓ during off-peak, users would see few changes to the order schedule and farmers get water at the requested times; and
- ✓ if channel capacity is exceeded, the start times for one or more users are delayed or brought forward.

- Sharing/allocating resource: when there are limits on the water resources available to the system, then reduced water supply can be shared across all users. There are many ways to share water. The reductions in supply to any user would be proportional to the user's announced allocation, which is a percentage of the nominal annual water right or "entitlement".
- Predicting: prediction is always required for the timing of a release of water from a storage; the transit time from the storage to the system or user; the ability to control the release and the communication required to satisfy the order. The ability to predict is reliant on the water allocation process, an understanding of crops being irrigated and seasonal accounting and may sometimes require the use of computer models.

The system of canal/pipeline regulation is a key factor in the selection, design and implementation of an ordering system.

Figure 1: Overshot channel regulator

Figure 2: Manual drop bar adjustment of water level at tail regulator

c. Multibay flume gate regulator

Figure 4: Alternative canal regulation systems

Self-Check -2	Written Test

Directions 1: Choose the best answer for the following questions. Use the Answer sheet provided (2 pts each)

1. Which one of the following is **Not** true about water ordering?
   A. It requires an agreed system of water rights
   B. It allows farmers to access water
   C. It causes conflict between users
   D. It allows for users how much water they apply and when
2. Which condition of water ordering requires release of water from a storage?
   A. Scheduling
   B. Predicting
   C. Sharing resources
   D. allocating resource
3. The primary aim of water ordering is to enable the operator to deliver water to meet a customer request.
   A. True
   B. False
4. The ability of any system to deliver water depends upon:
   A. The time required from when the order is placed
   B. The control mechanisms that enable delivery
   C. the communication system the operator uses
   D. All

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3

3.1 Introduction to irrigation water deliveries

Water delivery refers to the process where the managers of the irrigation scheme operate the irrigation water delivery system to supply water to crops according to farmers' water orders, and it is mainly affected by the physical system and operational decision of canals.

The primary components are canals or pipelines, control structures in canals, and the field application systems, which are generally surface, sprinkler, or drip irrigation systems. This section covers all of these components.

Good water control is an essential requirement for an efficient irrigation system, both at the project level and at the farm level. Conveyance systems should be designed and maintained to minimize seepage losses, provide for adequate control by the operator, and allow for efficient irrigation. Generally, pipelines or lined ditches that provide for greater seepage control with low maintenance will have higher initial costs.

3.2 Methods of delivering water

The selection of a method of delivering water which will best serve is an important consideration in the design of the distribution system. Before the character and capacity or the system are finally determined upon, study can very profitably be devoted to the moisture requirements of anticipated crops, effective water-holding capacity of soils and the more readily ascertained factors of character of water supply and topography.

Water is delivered to the individual irrigator either in continuous flow or at intervals. Water delivered at intervals is served in turn to each of a group of irrigators or is delivered to the individual whenever he calls for it. According to this classification, there are three basic methods of water delivery, which are called

- Continuous: Delivery of water continuously to all users under a project thought out the irrigation season.
- Rotation: Delivery of water to users in turn, at regular or irregular intervals.

- Demand: Delivery of water to users whenever requested by them.

The water delivered to a farm depends upon the frequency with which the water is delivered, the duration of the delivery, and the size of head or stream delivered.

- **Frequency of delivery:** The frequency with which water is needed by the irrigator will depend upon his crop and soil requirements, an important factor being the capacity of the soil to retain moisture.
- **Duration of delivery:** The duration of the delivery is a factor in determining the completeness of the irrigation, and a delivery method which cuts the period short or which prolongs it unnecessarily is to that extent inefficient.
- **Heads or streams of water:** An element of the at most importance is the size of the irrigation head or stream. The capacity of the project distribution system, preparation of the land for irrigation, and methods of applying water to the land are made to depend upon the size of head selected. Hence a mistake is very difficult to correct.

These points are the principal elements of a mode of water delivery, and the degree of success with which they meet the requirements of the irrigators, taking into account the physical limitations of the project and without undue waste of water, is the measure of the efficiency of the method in question.

3.3 Preparing schedules for water deliveries from customer orders

The operation of an irrigation system, consists of acting upon two primary decisions:
First, the scheduling of water deliveries, this can describe as frequency, rate, and duration of water deliveries at all levels within an irrigation conveyance system.
Second, the determination of the interactive movement of various control structures to accomplish the desired schedule.

Water deliveries are made to each branch of a distribution system from the upstream branch. Main canals make deliveries to secondary canals, secondaries to tertiaries, and so on. Improved water control must begin with the main canals. Unless the unsteady flow in the main canals can be easily controlled, the flows in secondary canals will be erratic.

The water-delivery schedules are defined by the following characteristics:

- Frequency (How often the water arrives?);
- Rate (How much water flows per unit of time?);
- Duration (How long is the flow rate delivered?);
- Timeliness (Does the water arrive when the crop needs it or the farmer can use it?).

There are different types of water-delivery schedules:

- **Rotation schedules:** provide water with no flexibility in frequency, rate, or duration. In the simplest form of these schedules, a fixed flow rate arrives at a certain point on a calendar basis (for example, once every one or two weeks) for a fixed duration.This flow rate is rotated among various users (one at a time) on a lateral, distributaries, or tertiary canal until every user has received water for his turn.
- **Central scheduling:** is a "top-down" scheduling procedure. The schedule is not responsive; farmers do not order water. The central management determines when and how much water is to be delivered. In one sense, it is extremely simple because there is no need for farmer input. Justifications of this control logic often include the following:
  - ✓ Water is a scarce resource that has to be distributed equally over as wide an area as possible. In the absence of market mechanisms, such as price, water has to be allocated through central decision making.
  - ✓ It is difficult, if not impossible, to interact with a large number of farmers or farmer organizations.
  - ✓ The central command has more insight than the farmers in matters such as irrigation scheduling, cropping patterns, and plant water requirements.
- **Arranged schedule:** The most common water-delivery schedule to farms using modern on-farm irrigation technology is the arranged schedule. Water requests are made for a specific date, a specific flow and a specific duration. Sometimes restrictions on the maximum flow apply. The schedule requires good communication between the water user and the irrigation agency, and a flexible delivery system. Water requests are usually required 24 to 48 hours in advance to arrange delivery. Arranged schedules in a water-short situation require the allocation of volumetric water quotas to the individual farmers or &farmer groups. Arranged schedules are often linked to volumetric water charges. In that case

individual field turnouts must be metered, because each field may receive a different volume of water.

- **Limited rate demand:** refers to the schedule provided to urban homeowners for domestic water supply. There is no need to make any request for water; it is available at all times. The maximum flow rate is limited, however, by the size of the line servicing individual homes.

The operation of water delivery network may vary considerably depending on a number of water management factors, including but not limited to the:

- Climatic condition, particularly the rain fall pattern;
- Degree of regulation of the source of water;
- Quality of the water, particularly the silt content;
- Size of project;
- Number and type of farms;
- Number and category of other users;
- Type of conveyance and distribution facilities (open channels and/or buried pipes, etc.)
- Method of water distribution; e.g. on demand, or pre-arranged demand, under a rigid rotational system, or under continuous flow.

The actual distribution of water includes two distinct steps:

- The preparation of the irrigation system scheduling (indenting, ordering) at an interval to be determined;
- The operation of the delivery system.

3.4 System scheduling, indenting, ordering

The preparation of system scheduling depends on the method of water distribution and on the type of facilities. The water order for an individual farm or group of cultivator or other users can be placed by each farmer or group, or decided unilaterally by the agency according to a pre-established scheduling.

The preparation of water delivery schedule can be simplified or even eliminated when part of the system is operated on demand or is equipped with advanced water control facilities, such as for downstream control or centralized remote control. Difficult areas in preparing a delivery schedules are the estimation of water propagation time, water use efficiencies and effect of rain interruptions. Knowledge from prior operational experience should be used in refining estimates.

Standard forms should be prepared to facilitate the preparation of the system scheduling, such as forms for:

- Individual demand at lower level canals
- Aggregating water demand for lower level to headworks incorporating efficiency values at different levels of the system.

Instructions for operation of the canal systemshould be formulated regarding:

- System start-up and close-down;
- Range of discharges in each canal (minimum and maximum values);
- Authorized rate of change of discharge;
- Water level fluctuations at critical points of each canal (minimum, maximum, rate of fluctuation- normal and emergency);
- Operate during rainfall season;
- Operation of all water control structures (cross-regulators, offtakes, waste ways, pumps, etc.)

Depending up on the type of water control technology, forms should be prepared for recording flow and water levels at critical points of the irrigation system. This information is important for:

- Calculation of actual water delivered and used;
- Determination of actual water use efficiencies;
- Providing data for improvements in the system
- Longer term review and evaluation policy and operational practices.

3.5 Interaction and communication in water delivery

Communication is a critical component of irrigation water delivery. Unlike the pressurized systems found in homes, where the user can simply open a valve to deliver the desired amount of water. Most deliveries for farm irrigation are gravity-fed and require carefully controlled releases from canals, laterals, and reservoirs to deliver the desired volume of water to the user, without spilling water from the end of the system. Such agricultural deliveries require careful planning, to balance system contents, deliver the water at the desired time, and avoid operational spills.

3.5.1 Types of Communication

It is important to distinguish two basic types of communication:

- Internal communication within between the Management Committee and the individual farmers, members of the organization; and
- External communication between the project or organization and other agencies and organizations, including government agencies, local administration, financial institutions and/or private companies.

3.5.2 Main purposes of communication

One of the most important prerequisites for transparent and accountable management of the organization is an effective of internal communication between all levels and between all stakeholders, whereby communication is defined as the transmission of information, instructions, opinions and ideas from one person to another in order to enhance the understanding between these persons.

The main purposes of communication for the project/organization can be described as follows:

- To facilitate accountability and transparency as members of the Management Committee and the Control Committee have to inform, explain and justify their actions, decisions and behaviour with regard to the administrative and financial management of the project and the O&M of the irrigation system to the project as well as outside agencies Woreda Administration, Kebele administration, Social court, etc.);
- To facilitate the implementation of efficient and productive meetings by informing envisaged participants of meetings about the date, time, venue and agenda of planned meetings in a timely manner;
- To facilitate the collection of irrigation service fees (ISFs) by informing members how much, when and how they have to pay their due ISFs to the organization;
- To facilitate the operation of the irrigation systems by informing the members about the agreed annual operation plan, including the rules for the distribution of irrigation water;
- To facilitate the maintenance of the irrigation system by informing the members about the scope and timing of the planned maintenance works and their expected labour contributions;

- To facilitate individual farmers and/or group of farmers can submit information, questions and/or suggestions regarding the administrative and financial management of the project or organization and/or the O&M of the irrigation infrastructure directly to the elected members of the Management Committee.

3.5.3 Quality of Communication

The quality of communication is mainly determined by:

- Clarity of the message without missing and/or conflicting information.
- Method of communication, including:
- participatory presentation with active participation of all participants exchanging information, experiences and ideas (instead of long, classroom-like, one-way monologue/presentation with only one active provider of information and a passive group of receivers);
- use of non-verbal communication media, such as flip charts, pictures, drawings to illustrate presentation; publication of important information at public places.
- Attitude and behaviour of information provider and receiver, including:
- lack of patience to present and explain all information step-by-step and to answer questions;
- arriving too late at meeting and/or leaving too early;
- disturbing meeting by speaking during presentation and discussions and/or interrupting repeatedly;
- use of complicated language and/or speaking too fast and/or softly (not loud enough);
- shyness to express opinion in public;
- Lack of interest to listen to the opinions and ideas of others.
- Place and timing of meeting, including:
- No invitation sent and/or public announcement about the date, venue and time of meeting.
- Place selected that is difficult to find and/or too far away for most persons.
- Place selected that is too small, noisy and/or hot.
- Meeting is planned during daytime when most persons cannot participate, as they have to work in their fields or elsewhere.

Self-Check -3	Written Test

Directions 1: Choose the best answer for the following questions. Use the Answer sheet provided (2 pts each)

1. The most common water-delivery schedule to farms using modern on-farm irrigation technology is:
   A. Rotation schedules
   B. Arranged schedule
   C. Limited rate demand
   D. Central scheduling
2. The method of water delivery which is delivery of water to users whenever requested by them is:
   A. Central
   B. Demand
   C. Rotation
   D. Continuous
3. The characteristics of water-delivery schedules which indicates how much water flows per unit of time is ------
   A. Duration
   B. Frequency
   C. Timeliness
   D. Rate
4. -------- is the water delivery schedule in which the central management determines when and how much water is to be delivered:
   A. Arranged schedule
   B. Central scheduling
   C. Rotation schedules
   D. Limited rate demand
5. The main purposes of communication
   A. To facilitate the operation of the irrigation systems
   B. To facilitate the collection of irrigation service fees
   C. To facilitate the implementation of efficient and productive meetings
   D. Al

***Note:* Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3 4 5

Operation Sheet 1	Preparing Water Delivery Scheduling

Procedures for preparing water delivery scheduling:

1. Preparing materials
2. Determining frequencies of water deliveries.
3. Determining duration of water deliveries
4. Determining rate of water deliveries
5. Determining timeliness of water deliveries
6. Cleaning and restoring materials

LAP Test	**Practical Demonstration**

Name: _____________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 6 hours.

Task 1. **Prepare water delivery scheduling**

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Monitoring channel flow rate, regulation and delivery
- Maintaining delivery performance records
- Analyzing and recording system performance using system data

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

Monitor channel flow rate, regulation and delivery according to customer requirements.

- Maintain delivery performance records according to organizational requirements.
- Analyse and record system performance using system data to determine actual and planned performance.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information “Sheet 1, Sheet 2, and Sheet 3” in page 24, 54 and 58 respectively.
4. Accomplish the “Self-check 1, Self-check 2and Self- check 3” -” in page 52, 56and 63respectively
5. If you earned a satisfactory evaluation from the “Self-check” proceed to “Operation Sheet 1, Operation Sheet 2 and Operation Sheet in page 64
6. Do the “LAP test” in page 65

1.1 Important basic terminologies

- Head: is the energy in water (or other liquid) expressed in terms of the equivalent height of a water column above a given reference. Head at any point in the irrigation line is the sum of three components: static head, velocity head, and friction head.
- Static or Elevation Head(H_e): It is the vertical distance (e.g., ft) between the water inlet and the discharge point. It represents potential energy per unit mass of the water.
- Velocity Head (H_v): It is the energy (expressed in terms of head, ft) needed to keep irrigation water moving at a given velocity. It represents the kinetic energy per unit mass of water.
- Friction Head (H_f): Friction head (or loss) (H_f) is the energy needed to overcome friction in the irrigation pipes and is expressed in units of length (e.g., ft).
- Pressure: It is the force per unit area. It is expressed in pounds per square inch (psi), Pascals, or Newtons per square meter.

1.2 Monitoring channel flow rate, regulation and delivery

The term delivery system management refers to the management of the delivery system as a whole, and deals with matching the outgoing discharges with the inflowing discharges from the river. The main system management can be:

- Day-to-day system management, when regulation of the structures is not possible and/or required. It is applied in delivery systems under proportional control with a fixed splitting of the discharges, and in upstream controlled systems with standing orders for the water delivery during the whole irrigation season;
- Central system management, when a 'water operation center' has to match the incoming discharge from the river with the required delivery schedule. It is applied in upstream controlled delivery systems;

* Responsive system management, when the delivery system itself adjusts to the changing outflowing discharges. It is a feature of downstream, BIVAL and ELFLO control (as well as composite control).

The term regulation refers to the actions of the controller, and focuses on maintaining the water level or the discharge at the target value. Regulation can be done manually by a human operator, by the water forces on a hydro-mechanical gate, by a float with programmable logic controller (PLC) of an electro-mechanical gate, etc. Moreover, regulation can be done by a passive regulator, such as a long-crested weir.

1.2.1 Evaluation on operation and maintenance requirements

The operation and maintenance of smallholder irrigation schemes can be the responsibility of either the government, the irrigation agency, individual farmers or groups of farmers. It can also be a joint responsibility between groups of farmers and the government, depending on the size of the scheme. In large schemes or government-run schemes, the irrigation agency and the farmers often share the responsibility of operating and maintaining the irrigation infrastructure. In such cases, the operation and maintenance of the water delivery and storage system is normally the responsibility of the agency, while the farmers are responsible for maintaining field level infrastructure such as canals and small hydraulic structures.

The dividing line, however, is not very clear. Therefore, the agency and the farmers need to agree on their responsibilities and write them down in bylaws. Where irrigation projects are operated and maintained by farmers, as is the case for small community schemes, the farmers themselves bear all responsibilities for operation and maintenance. But even in this case, rules and regulation should be written down in bylaws.

Water operation centers are required for all upstream controlled irrigation systems where a 'flexible' supply of water should meet the changing demands. However, worldwide, it appears to be very difficult to create a well-functioning water operation center. The question may arise whether more efforts should be made to establish water operation centers, or whether they be avoided by selecting other operation methods.

Field staff for system operation are especially required in upstream controlled systems, where they play an essential role. The flow diversion through these systems is frequently adjusted by the water operation center, and the discharge regulators and the water level regulators have to be adjusted accordingly. The unsteady state of the system during the adjustments make proper gate settings a very time-consuming activity. Discharge measurement throughout the system appears to be a burden for the day-to-day management, and is rarely well achieved.

There are three main types of maintenance irrigation system namely:

- Special maintenance: Special maintenance includes work that is done to repair the irrigation system in response to unforeseen damages, such as those caused by floods or earthquakes. In this case no specific preventative measures would have been taken to circumvent the damage.
- Deferred maintenance: Deferred maintenance or rehabilitation includes any work that is done on the irrigation infrastructure in order to restore the capacity of the system. In this case, the system is allowed to deteriorate to a certain level, beyond which it would not operate well, before it is restored to its design operational level. Sometimes, deferred maintenance and rehabilitation are differentiated on the basis of the source of funds. The funds for deferred maintenance come from the operation and maintenance budget, while that of rehabilitation comes as an investment funded by loans or national development budgets.
- Routine maintenance:This includes all the work that is done in order to keep theirrigation system operating satisfactorily. It is normally doneannually.During the construction of the irrigation scheme, the futureirrigators should provide labour for construction activities.Besides the advantage of promoting scheme ownership byfarmers, farmer involvement in construction work teachesthem several aspects of repair and maintenance.Once the scheme is operational, the irrigation committeeshould mobilize the farmers for repair and maintenanceactivities.

1.2.2 Evaluation on economic, political and social aspects

The cost of the operation method will be a major determining factor in the selection. The creation of positive in-canal storage means that the embankments have to be raised above the design water level. This involves higher costs, especially for the longer distances between the regulators. The costs of the different control methods should be determined in the pre-design of the system, and have to be evaluated against the benefits and other aspects, such as organization, efficient water use, flexibility, and need for foreign currencies.

The political and social aspects might have an essential say in the ultimate selection of the operation method. Aspects may include: the robustness against water-theft and abuse, the equity of seasonable water distribution ('protective' irrigation), the equal distribution during disturbances in supply (upstream controlled systems), the flexibility of water delivery (downstream controlled systems), the use of 'dependable rainfall'.

1.3 Hydraulic structures of irrigation system

In hydraulics, as with any technical topic, a full understanding cannot come without first becoming familiar with basic terminology and governing principles as follows:

Flow Conveyance: Water travels downhill from points of higher energy to points of lower energy (unless forced to do otherwise) until it reaches a point of equilibrium, such as an ocean. This tendency is facilitated by the presence of natural conveyance channels such as brooks, streams, and rivers. The water's journey may also be aided by man-made structures such as drainage swales, pipes, culverts, and canals. Hydraulic concepts can be applied equally to both man-made structures and natural features.

Area, Wetted Perimeter, and Hydraulic Radius: The term 'area'refers to the cross-sectional area of flow within a channel. When a channel has a consistent cross-sectional shape, slope, and roughness, it is called a prismatic channel.

If the flow in a conveyance section is open to the atmosphere, such as in a culvert flowing partially full or in a river, it is said to be open-channel flow or free-surface flow. If a channel is flowing completely full, as with a water distribution pipe, it is said to be operating under full-flow conditions. Pressure flow is a special type of full flow in which forces on the fluid cause it to push against the top of the channel as well as the bottom and sides. These forces may result from, for example, the weight of a column of water in a backed-up sewer manhole or elevated storage tank.

A section's wetted perimeter is defined as the portion of the channel in contact with the flowing fluid.

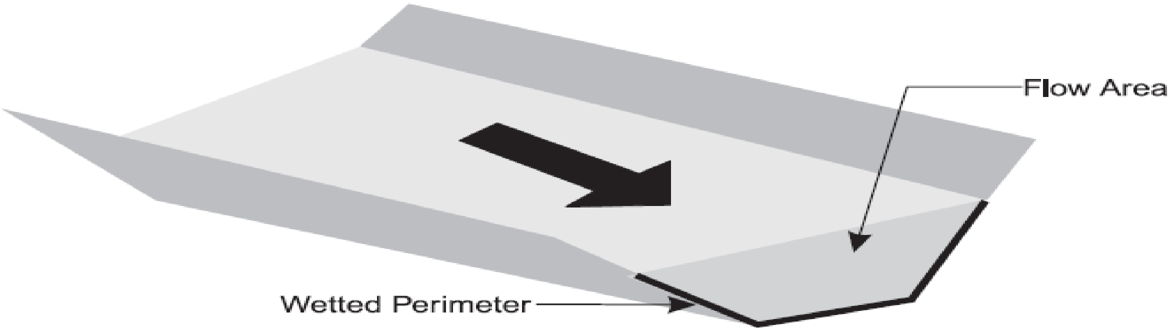


Figure 5: Flow area and water perimeter

The hydraulic radiusof a section is not a directly measurable characteristic, but it is used frequently during calculations. It is defined as the area divided by the wetted perimeter, and therefore has units of length.

The hydraulic radius can often be related directly to the geometric properties of the channel. For example, the hydraulic radius of a full circular pipe (such as a pressure pipe) can be directly computed as:

$$R = \frac{A}{P_w}$$

or

$$R_{circular} = \frac{\pi \cdot D^2/4}{\pi \cdot D} = \frac{D}{4}$$

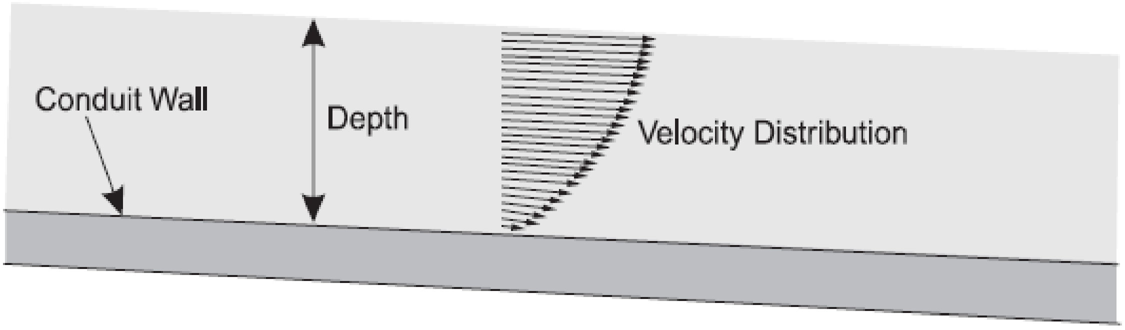
where R = hydraulic radius (m, ft)

A = cross-sectional area (m2, ft2)

Pw = wetted perimeter (m, ft)

D = pipe diameter (m, ft)

Velocity: As shown in Figure 6, the velocity of a section is not constant throughout the cross-sectional area. Instead, it varies with location. The velocity is zero where the fluid is in contact with the conduit wall.



Longitudinal Section (Profile)

Figure 6: Velocity distribution

The variation of flow velocity within a cross-section complicates the hydraulic analysis, so the engineer usually simplifies the situation by looking at the average (mean) velocity of the section for analysis purposes. This average velocity is defined as the total flow rate divided by the cross-sectional area, and is in units of length per time.

$$V = Q / A$$

where V = average velocity (m/s, ft/s)

Q = flow rate (m^3/s, ft^3/s)

A = area (m^2, ft^2)

Steady Flow: Speaking in terms of flow, the word steady indicates that a constant flow rate is assumed throughout an analysis. In other words, the flow velocity does not change with respect to time at a given location. For most hydraulic calculations, this assumption is reasonable. A minimal increase in model accuracy does not warrant the time and effort that would be required to perform an analysis with changing (unsteady) flows over time.

When analyzing tributary and river networks, storm sewers, and other collection systems in which it is desirable to vary the flow rate at different locations throughout the system, the network can often be broken into segments that can be analyzed separately under steady flow conditions.

Laminar flow, turbulent flow, and Reynolds number: Laminarflow is characterized by smooth, predictable streamlines(the paths of single fluid particles). An example of this type of flow is maple syrup being poured. In turbulentflow, the streamlines are erratic and unpredictable. Turbulent flow is characterized by the formation of eddies within the flow, resulting in continuous mixing throughout the section (see Figure 7).

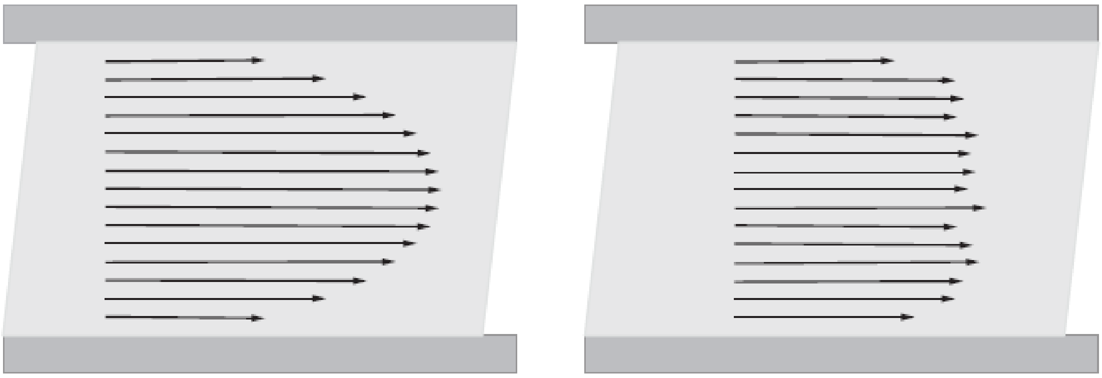


Figure 7: Instantaneous velocity distribution for Laminar and Turbulent Flow

Eddies result in varying velocity directions as well as magnitudes (varying directions not depicted in Figure 7 for simplicity). At times, the eddies contribute to the velocity of agiven particle in the direction of flow, and at other times detract from it. The result is that velocity distributions captured at different times will be quite different from one another, and will be far more chaotic than the velocity distribution of a laminar flow section.

By strict interpretation, the changing velocities in turbulent flow would cause it to be classified as unsteady flow. Over time, however, the average velocity at any given point within the section is essentially constant, so the flow is assumed to be steady.

The velocity at any given point within the turbulent section will be closer to the mean velocity of the entire section than with laminar flow conditions. Turbulent flow velocities are closer to the mean velocity because of the continuous mixing of flow, particularly the mixing of low-velocity flow near the channel walls with the higher-velocity flow toward the center.

To classify flow as either turbulent or laminar, an index called the Reynolds numberis used. It is computed as follows:

$$Re = \frac{4VR}{\nu}$$

where Re = Reynolds number (unitless)

V = average velocity (m/s, ft/s)

R = hydraulic radius (m, ft)

v = kinematic viscosity (m^2/s, ft^2/s)

If the Reynolds number is below 2,000, the flow is generally laminar. For flow in closed conduits, if the Reynolds number is above 4,000, the flow is generally turbulent. Between 2,000 and 4,000, the flow may be either laminar or turbulent, depending on how insulated the flow is from outside disturbances. In open channels, laminar flow occurs when the Reynolds number is less than 500 and turbulent flow occurs when it is above 2,000. Between 500 and 2,000, the flow is transitional.

The Energy Principle: The first law of thermodynamics states that for any given system, the change in energy (ΔE) is equal to the difference between the heat transferred to the system (Q) and the work done by the system on its surroundings (W) during a given time interval.

The energy referred to in this principle represents the total energy of the system, which is the sum of the potential energy, kinetic energy, and internal (molecular) forms of energy such as electrical and chemical energy. Although internal energy may be significant for thermodynamic analyses, it is commonly neglected in hydraulic analyses because of its relatively small magnitude.

In hydraulic applications, energy values are often converted into units of energy per unit weight, resulting in units of length. Using these length equivalents gives engineers a better "feel" for the resulting behavior of the system. When using these length equivalents, the engineer is expressing the energy of the system in terms of "head." The energy at any point within a hydraulic system is often expressed in three parts, as shown in Figure 1-4:

- Pressure head p/γ
- Elevation head z
- Velocity head $V^2/2g$

where p = pressure (N/m^2, lbs/ft^2)
γ = specific weight (N/m^3, lbs/ft^3)
z = elevation (m, ft)
V = velocity (m/s, ft/s)

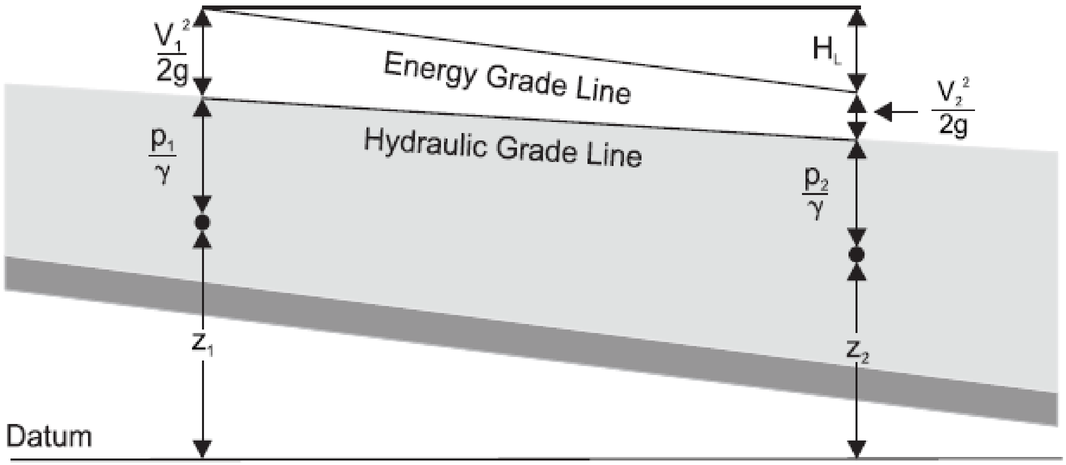


Figure 8: The energy principle

Note that a point on the water surface of an open channel will have a pressure head of zero, but will have a positive elevation head higher than that of a point selected at the bottom of the channel for the same station.

The Energy Equation: In addition to pressure head, elevation head, and velocity head, energy may be added to a system by a pump (for example), and removed from the system by friction or other disturbances. These changes in energy are referred to as head gains and head losses, respectively. Because energy is conserved, the energy across any two points in the system must balance. This concept is demonstrated by the energy equation:

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + H_G = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + H_L$$

where p = pressure (N/m^2, lb/ft^2)

γ = specific weight of the fluid (N/m^3, lb/ft^3)

z = elevation above a datum (m, ft)

V = fluid velocity (m/s, ft/s)

g = gravitational acceleration (m/s^{2,} ft/s^{2})

H_G = head gain, such as from a pump (m, ft)

H_L = combined head loss (m, ft)

Hydraulic Grade: The hydraulic gradeis the sum of the pressure head (p/γ) and elevation head (z). For open channel flow (in which the pressure head is zero), the hydraulic grade elevation is the same as the water surface elevation. For a pressure pipe, the hydraulic grade represents the height to which a water column would rise in a piezometer (a tube opens to the atmosphere rising from the pipe). When the hydraulic grade is plotted as a profile along the length of the conveyance section, it is referred to as the hydraulic grade line,or HGL.

Energy Grade: The energy gradeis the sum of the hydraulic grade and the velocity head ($V^2/2g$). This grade is the height to which a column of water would rise in a Pitot tube (an apparatus similar to a piezometer, but also accounting for fluid velocity). When plotted in profile, this parameter is often referred to as the energy grade line**,** or EGL. For a lake or reservoir in which the velocity is essentially zero, the EGL is equal to the HGL.

Energy Losses and Gains: Energy (or head) losses ($H_{L)}$ in a system are due to a combination of several factors. The primary cause of energy loss is usually the internal friction between fluid particles traveling at different velocities. Secondary causes of energy loss are localized areas of increased turbulence and disruption of the streamlines, such as disruptions from valves and other fittings in a pressure pipe, or disruptions from a changing section shape in a river. The rate at which energy is lost along a given length of channel is called the friction slope, and is usually presented as a unitless value or in units of length per length (ft/ft, m/m, etc.).

1.3.1 Orifices and Weirs

The energy equation serves as the foundation for calculating the flow through and over hydraulic structures based on the size of the opening associated with the structure and the difference in energy on either side of it. The flow exiting the structure can be calculated by solving the energy equation for velocity, V_2, and multiplying the resulting formula by the flow area and a coefficient to account for different hydraulic and physical variables. These variables include: head loss, the shape and nature of the opening, the contraction of the flow after it leaves the structure, and countless indefinable variables that are difficult to measure but produce quantifiable effects.

Two common devices for which equations are derived in this manner are weirs and orifices. They are important not only because of their widespread usage in the industry, but also because the equations that describe them serve as the foundation for mathematical descriptions of more complicated hydraulic devices such as drainage inlets and culverts.

a. Orifices

Orifices are regularly shaped, submerged openings through which flow is propelled by the difference in energy between the upstream and downstream sides of the opening. The stream of flow expelled from the orifice is called the jet. When the jet exits the orifice, adverse velocity components cause it to contract to a point after which the flow area remains relatively constant and the flow lines become parallel (see Figure 9). This point is called the vena contracta.

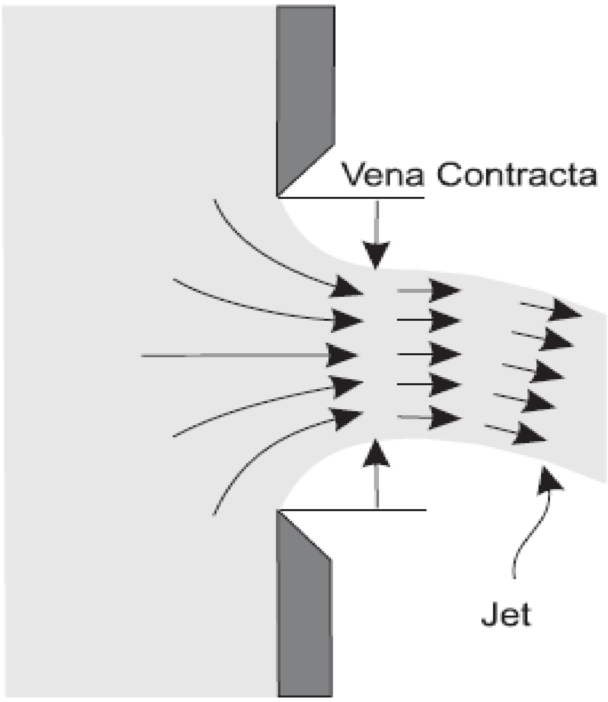


Figure 9: Cross-sectional view of typical orifice flow

Orifices and the orifice equations have the following applications:

- Regulating the flow out of detention ponds
- Regulating the flow through channels in the form of radial and sluice gates
- Approximating the interception capacity of submerged drainage inlets
- Approximating the flow allowed through a submerged culvert operating under inlet control
- Measuring flow

The Orifice Equation

For the structure in Figure 9, derive the orifice equation for an orifice of area A.

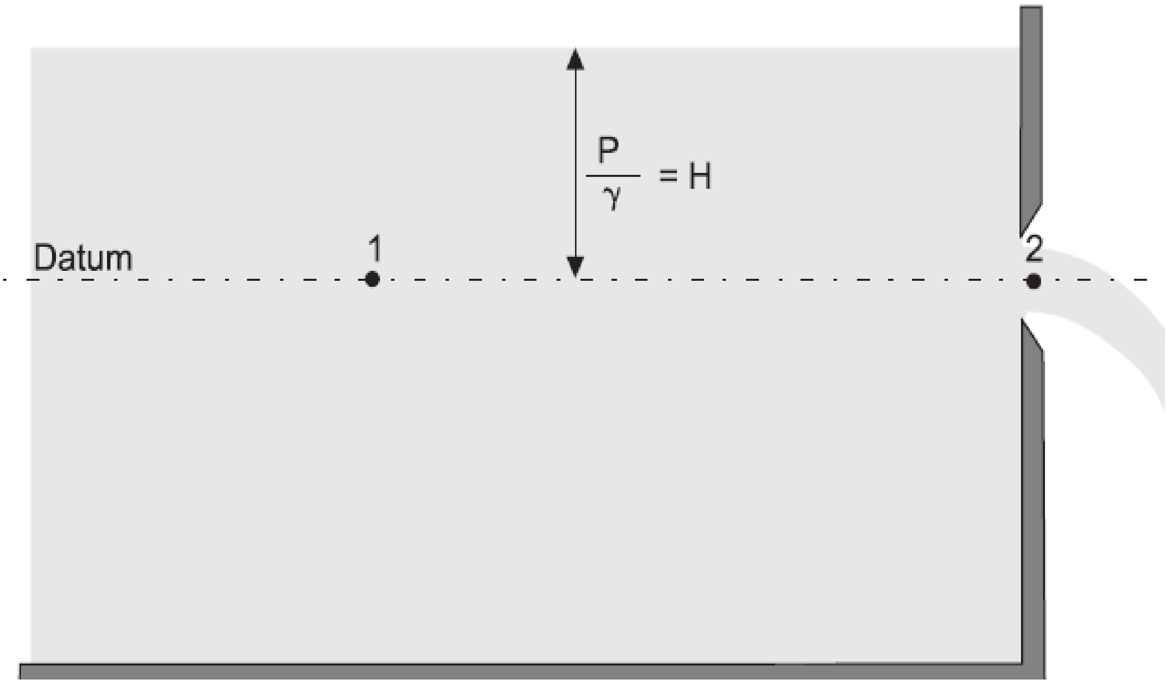


Figure 9: Orifice example

First, start with the energy equation

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + H_G = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + H_L$$

List known variables and assumptions:

- The datum is at the centerline/centroid of the orifice
- $p_1/\gamma = H$
- Point 2 occurs at the vena contracta
- Elevation heads, z_1 and z_2, are equivalent
- The velocity in the tank at point 1 is negligible
- The jet is open to the air, so the pressure at point 2 is 0

- There is no head gain

Taking these known variables and assumptions into account and solving for V_2, the energy equation becomes:

$$V_2 = \sqrt{2g(H - H_L)}$$

To find the flow exiting the structure at point 2, multiply both sides of the equation by the orifice area, A.

$$AV_2 = Q = A\sqrt{2g(H - H_L)}$$

where Q = discharge (m3/s, ft3/s)

The point of discharge is the vena contracta, where the flow area is usually contracted from the original orifice area. Also, computations can be simplified by eliminating the head loss term, HL. Both of these variables are accounted for by applying an orifice coefficient, C, to the right side of the equation. The final form of the orifice equation becomes:

$$Q = CA\sqrt{2gH}$$

where C = orifice coefficient

b. Weirs

Weirs are notches or gaps over which fluid flows. The lowest point of structure surface or edge over which water flows is called the crest, whereas the stream of water that exits over the weir is called the nappe. Depending on the weir design, flow may contract as it exits over the top of the weir, and, as with orifices, the point of maximum contraction is called the vena contracta.

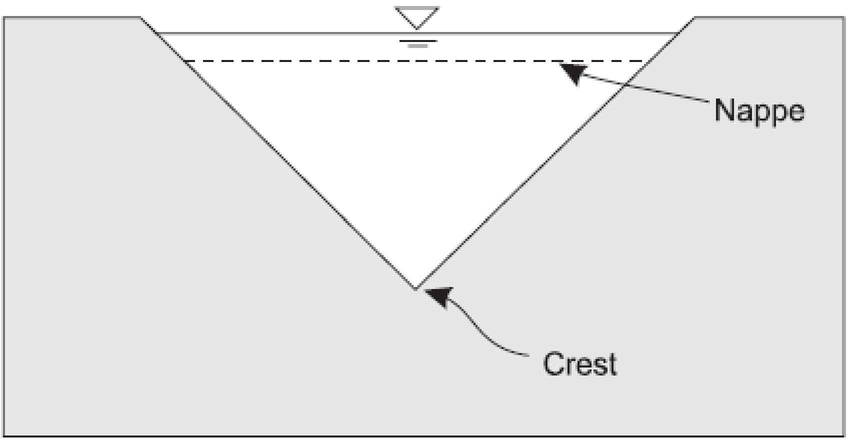


Figure 10: Front view of common weir

This contraction can be counteracted or suppressed by designing the weir such that its shape conforms to the shape of the channel. This type of weir is called a suppressed weir. With a contracted weir, the crest and nappe vary from the channel to such a degree that a significant contraction of flow area does occur.

In addition to suppressed and contracted weir types, weirs are also distinguished as either sharp-crested or broad-crested. A sharp-crested weir has a sharp upstream edge formed so that the nappe flows clear of the crest. Broad-crested weirs have crests that extend horizontally in the direction of flow far enough to support the nappe and fully develop hydrostatic pressures for at least a short distance.

Weirs can also be distinguished by their shapes. The most common shapes are shown in Figure 1-8. The effects of weir shape and other factors previously mentioned are accounted for with modifications to the weir equation, such as adjustments the weir coefficient.

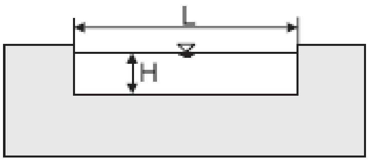
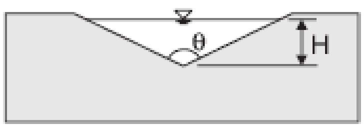
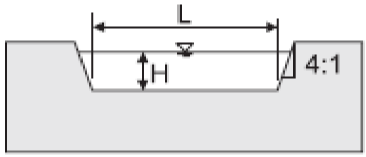
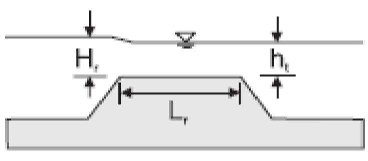
	Weir Type	Figure	Equation	Coefficients
Sharp Crested	Rectangular		Contracted $Q = C(L - 0.1iH)\ H^{3/2}$ Suppressed $Q = CLH^{3/2}$ i = Number of iterations	Metric C = 1.84 English C = 3.367
	V-Notch		$Q = C\left(\frac{8}{15}\right)\sqrt{2g}\tan\theta\left(\frac{H}{2}\right)^{3/2}$	C varies between 0.611 and 0.570 depending on H and Q*
	Cipolletti		Metric $Q = CLH^{3/2}$ English $Q = CLH^{3/2}$	Metric C = 1.86 English C = 3.367
Non-Sharp-Crested	Broad (Side View)		$Q = C_dLH_r^{3/2}$	C_d is a function of H_t, h_t and L_t ranging between 1.25 and 3.1*

Figure 11: Standard Weirs

Weirs have the following applications:

- Serving as emergency spillways for regulating high-return event flows overtopping dams and detention ponds

- Regulating the flow in channels
- Measuring flow
- Approximating the flow over roadways acting as broad-crested weirs when flow exceeds a culvert's capacity
- Approximating the interception capacity of unsubmerged drainage inlets in swales
- Approximating the flow allowed through an unsubmerged culvert operating under inlet control

The Weir Equation

Derive the weir equation for the rectangular weir with a crest of length L and head H, which discharges from a free outfall as shown in Figure 11.

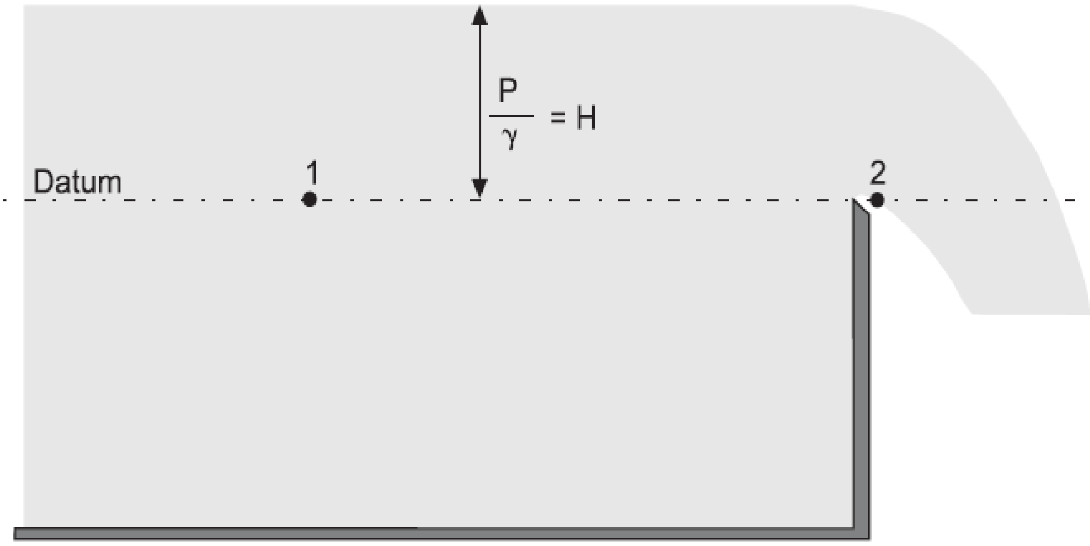


Figure 1-9: Weir Example

Figure 12: weir example

Solution

Begin with the energy equation:

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + H_G = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + H_L$$

List the known variables and assumptions:

- The datum is at the crest of the weir
- $P_1/\gamma = H$
- Point 2 occurs at the vena contracta
- The elevation heads, z_1 and z_2, are equivalent

- Assume the velocity in the tank is negligible
- The exiting stream pressure at point 2 is 0
- There is no head gain

After applying the known variables and assumptions and solving for $V_{2,}$ the energy equation becomes:

$$V_2 = \sqrt{2g(H - H_L)}$$

To find the flow, multiply both sides by the flow area, which in this case is the length of the weir, L, multiplied by the height of the head, H.

$$AV_2 = Q = LH\sqrt{2g(H - H_L)}$$

where L = length of weir (m, ft)

To account for head loss, contraction, and other variables, a weir coefficient, C, is applied. Unlike the orifice coefficient, the weir coefficient generally takes into account the constant 2g. Finally, the weir equation becomes:

$$Q = CLH^{3/2}$$

where C = weir coefficient ($m^{1/2}/s$, $ft^{1/2}/s$)

Unlike the orifice coefficient, the weir coefficient is not unitless. Care has to be taken that the correct coefficient is applied when using a specific unit system.

Friction Losses

There are many equations that approximate the friction losses associated with the flow of a liquid through a given section. Commonly used methods include:

- Manning's equation
- Chézy's (Kutter's) equation
- Hazen-Williams equation
- Darcy-Weisbach (Colebrook-White) equation

These equations can be described by a generalized friction equation:

$$V = kCR^x S^y$$

where V = mean velocity

C = flow resistance factor

R = hydraulic radius

S = friction slope

x, y = exponents

k = factor to account for empirical constants, unit conversion, etc.

The lining material of the flow channel usually determines the flow resistance or roughness factor, C. However, the ultimate value of C may be a function of the channel shape, depth, and fluid velocity.

i. Manning's Equation

Manning's equation is the most commonly used open channel flow equation. The roughness component, C, is typically assumed to be constant over the full range of flows and is represented by a Manning's roughness value, n. These n-values have been experimentally determined for various materials and should not be used with fluids other than water. Manning's equation is:

$$V = \frac{k}{n} R^{2/3} S^{1/2}$$

where V = mean velocity (m/s, ft/s)

k = 1.49 for U.S. customary units, 1.00 for SI units

n = Manning's roughness value

R = hydraulic radius (m, ft)

S = friction slope (m/m, ft/ft)

ii. Chézy's (Kutter's) Equation

The Chézy equation, in conjunction with Kutter's equation, is widely used in sanitary sewer design and analysis. The roughness component, C, is a function of the hydraulic radius, friction slope, and lining material of the channel. The Chézy equation is:

$$V = C\sqrt{RS}$$

where V = mean velocity (m/s, ft/s)

C = roughness coefficient (see following calculation)

R = hydraulic radius (m, ft)

S = friction slope (m/m, ft/ft)

The roughness coefficient, C, is related to Kutter's n through Kutter's equation. Note that the n-values used in Kutter's equation are actually the same as Manning's n coefficients.

U.S. Standard Units

$$C = \frac{41.65 + \frac{0.00281}{S} + \frac{1.811}{n}}{1 + \frac{\left(41.65 + \frac{0.00281}{S}\right)n}{\sqrt{R}}}$$

S.I. Units

$$C = \frac{23 + \frac{0.00155}{S} + \frac{1}{n}}{1 + \frac{\left(23 + \frac{0.00155}{S}\right)n}{\sqrt{R}}}$$

where C = roughness coefficient

n = Manning's roughness value

R = hydraulic radius (m, ft)

S = friction slope (m/m, ft/ft)

iii. Hazen-Williams Equation

The Hazen-Williams equation is most frequently used in the design and analysis of pressure pipe systems. The equation was developed experimentally, and therefore should not be used for fluids other than water (and only within temperatures normally experienced in potable water systems). The Hazen-Williams equation is:

$$V = kCR^{0.63}S^{0.54}$$

where V = mean velocity (m/s, ft/s)

k = 1.32 for U.S. customary units, or 0.85 for SI units

C = Hazen-Williams roughness coefficient (unitless)

R = hydraulic radius (m, ft) S = friction slope (m/m, ft/ft)

iv. Darcy-Weisbach (Colebrook-White) Equation

The Darcy-Weisbach equation is a theoretically based equation commonly used in the analysis of pressure pipe systems. It applies equally well to any flow rate and any incompressible fluid, and is general enough to be applied to open channel flow systems. The roughness component in the Darcy-Weisbach equation is a function of both the channel material and the Reynolds number, which varies with velocity and hydraulic radius.

$$V = \sqrt{\frac{8g}{f}RS}$$

where V = flow velocity (m/s, ft/s)

g = gravitational acceleration (m/s^2, ft/s^2)

f = Darcy-Weisbach friction factor (unitless)

R = hydraulic radius (m, ft)

S = friction slope (m/m, ft/ft)

The Darcy-Weisbach friction factor, f, can be found using the Colebrook-White equation for fully developed turbulent flow, as follows:

Free Surface

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{k}{12R} + \frac{2.51}{Re\sqrt{f}}\right)$$

Full Flow (Closed Conduit)

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{k}{14.8R} + \frac{2.51}{Re\sqrt{f}}\right)$$

where k = roughness height (m, ft)

R = hydraulic radius (m, ft)

Re = Reynolds number (unitless)

This iterative search for the correct value of f can become quite time-consuming for hand computations and computerized solutions of many pipes. Another method, developed by Swamee and Jain, solves directly for f in full-flowing circular pipes. This equation is:

$$f = \frac{1.325}{\left[\log_e\left(\frac{k}{3.7D} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$$

where f = friction factor (unitless)

k = roughness height (m, ft)

D = pipe diameter (m, ft)

Re = Reynolds number (unitless)

The irrigation network is equipped with hydraulic structures. Flow regulators are installed to control water level and flow rate in canals; water-conveying facilities (aqueducts, inverted siphons, tunnels) are installed to transport water over/through man-made and natural obstacles; and check drops and inclined drop structures are installed to connect lower and upper reaches.

The hydraulic structures are equipped with water metering, water level and flow rate controlling automatic devices as well as centralized remote monitoring and control devices. Network of observation wells is arranged to monitor groundwater level at an irrigated area.

1.3.2 Irrigation canals

The main canal and its branches deliver water from a water-intake structure to different-order distributors. Inter-farm distributors deliver water from the main canal to several farms, while farm distributors to a single farm.

Figure 13: Irrigation main canal

On-farm irrigation canals distribute water among production sites, crop-rotation plots, and irrigated fields within a farm. Lowest-order on-farm distributors that deliver water to irrigated plots are called delivery ditches.

The purpose of the regulation network is to distribute water over the field and transform water from the state of flow into the state of soil moisture.

At surface irrigation, the regulation network is composed of temporary ditches, field head ditches and furrow ditches, irrigation pipes, irrigating machines, irrigation ditches, furrows, and checks; at sprinkling irrigation, it is composed of sprinkling machines (sprinklers) and pipelines; at subsoil irrigation, it is composed of soil moisteners.

In order to exclude restricting the conditions for mechanical operations at agricultural fields, the regulation network is made temporary, portable or mobile, or fixed, i.e. put at a certain depth in the ground.

According to its design, the irrigation network can be broken down into three types as follows:

- open type consisting of unlined (earth) canals or lined canals if it is needed to reduce seepage or rise the flow velocity, or of flumes used in complex topographical and geological conditions;
- closed type consisting of pressure and free-flow pipelines laid in the ground; on the surface, water is supplied by means of hydrants;
- mixed type, in which the major large canals are made open, the major network is closed, or water from a water intake structure to a farm is delivered through pipes, and the on-farm network is made in the form of open canals and pipelines.

The water-collecting & escape network is meant for collecting and diverting excessive surface water and discharging water from irrigation canals. It consists of:

- emergency water removal and tail escapes,
- water-collecting canals of different orders, and
- interception drains that protect irrigated lands from inflowing surface water from upper areas.

The drainage network serves for diverting excessive ground water from the area commanded by the respective irrigation network. It consists of inter-farm and on-farm collectors and drains.

Irrigated lands with all their characteristics (relief, soil, hydrogeological conditions) are the key components of the irrigation system. They have a significant influence on the composition, number, and design of these components.

The composition of the irrigation system includes the lands of a single (on-farm irrigation system) or several (inter-farm irrigation system) farms, associations of farms and agricultural enterprises and even several administrative centers/towns.

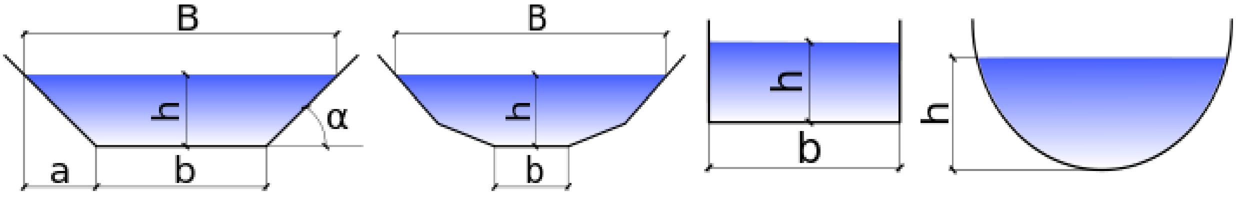
The area within the irrigation system's boundaries under agricultural crops and plants which are planned to be irrigated within the project implies the net irrigated area. The area under canals, structures, roads, forest belts, buildings, and small plots within an irrigated land which are not irrigated to ensure soil-reclamation and other conditions are called right-of-way zone.

1.3.2.1 Canal characteristics

The major characteristics of a canal are the form and size of its section, namely the flow area. The canal may have various forms. Often, trapezoidal and polygonal-shape canals are used. Also, its section may have rectangular, semicircular or parabolic form, delineated by a more compound curve or component.

Canal sections

Trapezoidal Polygonal Rectangular Semicircular



The ratio of slope m given by

$$m = \operatorname{ctg} \alpha = a/h,$$

Depending on natural channels, it possible to make a hydraulically optimal size of the canal section (that is to pick up appropriate values, counterparts, of the canal width at the bottom and of the flow depth). With such section at given channel roughness, maximum delivery capacity at minimum section area will be provided. However, for the range of the most usual ratio of slope it turns out that such canals have deep depth and narrow width of the bottom, which is often unreasonable in terms of the practice of the organization and cost of works. In addition to that the flow erosive velocity rises. Therefore, the bottom width of canals is extended in comparison with the hydraulically optimal that.

1.3.2.2 Estimation of canal capacity

In the general case, small canals' capacity is calculated under the assumption of uniform motion of water. To determine flow velocity and rate, the Shezi formula is used:

$$V = C\sqrt{R \cdot I},$$

$$Q = \omega C\sqrt{R \cdot I},$$

Where

V stands for the average flow velocity, m/s;

C stands for the coefficient of friction resistance (Shezi coefficient), $m^{0.5}/s$, representing the integral characteristic of drag forces;

R stands for hydraulic radius, m;

Istand for the hydraulic gradient which at uniform open channel flow is equal to the bottom slope and water surface slope (hydraulic gradient); and

ω stands for cross-sectional wet area, m^2.

Canal water discharge is determined through water-management design. The problem consists in the calculation of the canal section and sizes at relatively narrow range of possible flow velocity. The flow velocity range narrowness is due to that the canal bed, on the one hand must, not be eroded and, on the other hand, must not become silted. Calculation of limiting velocity taking into account silting and erosion factors is a complex problem and is solved by approximate methods. For the majority of materials, the eroding velocity values are determined and are given in corresponding tables depending on hydraulic depth.

1.3.2.3 Canal regulation

The amount of water which can be directed from a river into the main canal depends on:

- the water available in the river,
- the canal capacity, and
- the share of other canals taking off from the river.

The flow in the main canal is diverted to various branches and distributaries. The distribution of flow, obviously, depends on the water demand of various channels. The method of distribution of available supplies is termed canal regulation. When there exists a significant demand for water anywhere in the command area of a canal, the canal has to be kept flowing.

The canal can, however, be closed if the water demand falls below a specified quantity. It is reopened when the water demand exceeds the specified minimum quantity. Normally, there always exists a demand in some part of the command area of any major canal. Such major canals can, therefore, be closed only for a very small period (say, three to four weeks in a year). These canals run almost continuously and carry discharges much less than their full capacity, either when there is less demand or when the available supplies are insufficient. If the demand is less, only the distributaries which need water are kept running and the others (including those which have very little demand) are closed.

In case of keen demand, but insufficient supplies, either all smaller channels run simultaneously and continuously with reduced supplies, or some channels are closed turn by turn and the remaining ones run with their full or near-full capacities. The first alternative causes channel silting, weed growth, increased seepage, water-logging, and low heads on outlets.

The second alternative does not have these disadvantages and allows sufficient time for inspection and repair of the channels. A roster is usually prepared for indicating the allotted supplies to different channels and schedule of closure and running of these channels. It is advantageous to have flexible regulation so that the supplies can be allocated in accordance with the anticipated demand. The allocation of supplies is decided on the basis of the information provided by the canal revenue staffs who keeps a close watch on the crop condition and irrigation water demand.

The discharge in canal is usually regulated at the head regulator which is usually designed as a meter. When the head regulator cannot be used as discharge meter, a depth gauge is provided at about 200 m downstream of the head regulator. The gauge reading is suitably related to the discharge. By manipulating the head regulator gates, the desired gauge reading (and, hence, the discharge) can be obtained.

1.3.2.4 Canal design types

Canal Design

- Drainage channel design
- Irrigation canal design

Design Parameters: -

- The design considerations naturally vary according to the type of soil.
- Velocity of flow in the canal should be critical.
- Design of canals which are known as ‘Kennedy’s theory’ and ‘Lacey’s theory’ are based on the characteristics of sediment load (i.e. silt) in canal water.

Figure 14: Canal Design

Terms associated with canal design: -

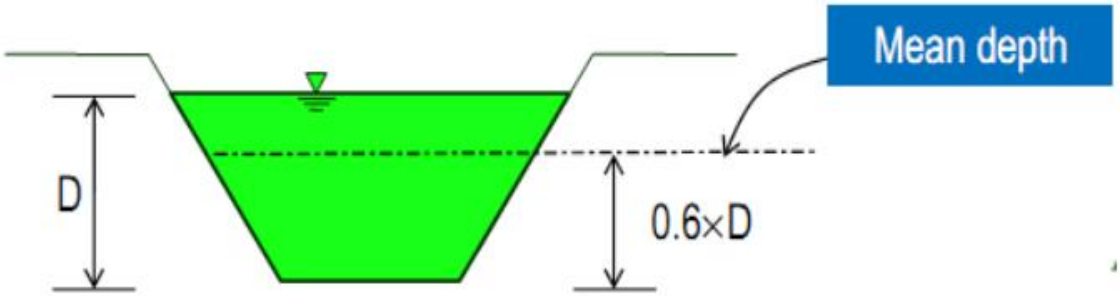
- Alluvial Soil: The soil which is formed by the continuous deposition of silt is known as alluvial soil.
- Non-alluvial Soil: The soil which is formed by the disintegration of rock formations is known as non-alluvial soil.
- Silt Factor: During the investigations works in various canals in alluvial soil, Gerald Lace established the effect of silt on the determination of discharge and the canal section. So, Lacey introduced a factor which is known as 'silt factor'. It depends on the mean particle size of silt. It is denoted by 'f'.

Silt Type	Particle Size (mm)	Silt Factor
Very Fine	0.05	0.40
Fine	0.12	0.60
Medium	0.23	0.85
Coarse	0.32	1.00

- Coefficient of Rugosity (n): The roughness of the canal bed affects the velocity of flow. The roughness is caused due to the ripples formed on the bed of the canal.

Material	**Value of 'n'**
Earth	0.0225
Masonry	0.02
Concrete	0.013-0.018

- Mean Velocity: It is found by observations that the velocity at a depth 0.6D represents the mean velocity (V), where 'D' is the depth of water in the canal or river.



- Mean Velocity by Chezy's expression:

$$V = C\sqrt{RS}$$

where V = mean velocity (m/s, ft/s)

C = roughness coefficient (see following calculation)

R = hydraulic radius (m, ft) S = friction slope (m/m, ft/ft)

- Mean Velocity by Manning's expression:

$$V = \frac{k}{n} R^{2/3} S^{1/2}$$

where V = mean velocity (m/s, ft/s)

k = 1.49 for U.S. customary units, 1.00 for SI units

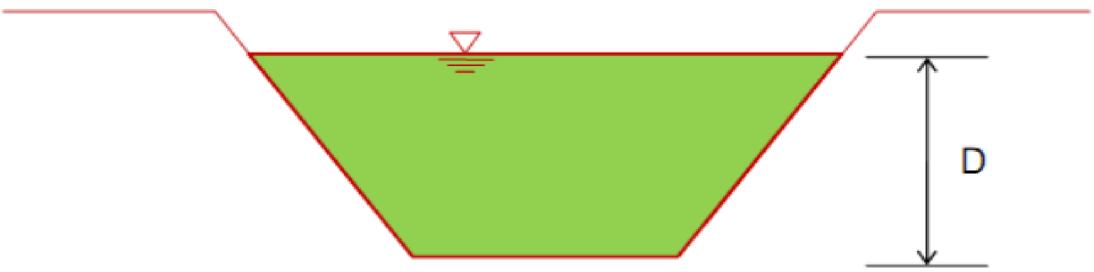
n = Manning's roughness value

R = hydraulic radius (m, ft)

S = friction slope (m/m, ft/ft)

- Critical velocity: When the velocity of flow is such that there is no silting or scouring action in the canal bed, then that velocity is known as critical velocity. It is denoted by 'Vo'. The value of V0 as given by Kennedy according to the following expression,

  Where D = Depth of water



- Critical velocity ratio (C.V.R): The ratio of mean velocity 'V' to the critical velocity 'Vo' is known as critical velocity ratio (CVR). It is denoted by m i.e. When m = 1, there will be no silting or scouring. When m > 1, scouring will occur When m < 1, silting will occur So, by finding the value of m, the condition of the canal can be predicted whether it will have silting or scouring.
- Regime Channel: When the character of the bed and bank materials of the channel are same as that of the transported materials and when the silt charge and silt grade are constant, then the channel is said to be in its regime and the channel is called regime channel. This ideal condition is not practically possible.

$$V = 10.8R^{2/3}S^{1/3}$$

- Hydraulic Mean Depth/Ratio: The ratio of the cross-sectional area of flow to the wetted perimeter of the channel is known as hydraulic mean depth or radius. It is generally denoted by R.

1.4 Impact of the principles of hydraulics on the operation of flows

Hydraulics is defined as the study of the movement of fluids. In our case, that means the movement of water as it passes through the irrigation structures and backflow-prevention devices of a typical irrigation system.

A hydraulic analysis accounts for changes in energy as water moves from one point to another within an irrigation system. Water has three forms of energy: velocity (how fast the water moves), elevation (the vertical elevation difference between two locations in a system) and pressure.

Velocity: The velocity is how fast the water moves within a canals or pipe and is usually expressed as the distance water travels in a second (feet per second). For example, we might talk about a velocity of 4.5 feet per second. The amount of energy in the water as a result of velocity is small compared to pressure and elevation.

Elevation: There are several ways to look at or track the energy that results from changes in elevation. One approach is to determine the elevation of specific points that are above a reference point you choose. "Sea level" is probably the most common reference point. Elevations are expressed in feet above the average sea level. In developing your own topographic map, you can use any conspicuous point at your site as the reference elevation. Then, when referring to the elevations of other points on the site, you would describe them as so many feet above that reference. An increase in elevation means a decrease in pressure. A drop in elevation represents a gain in pressure. An easy way to keep this straight is to ask, "Does it take more effort to push a loaded wheelbarrow uphill or downhill?" Elevation is generally expressed in units of feet. However, you also can convert it to units of psi.

Pressure: Pressure is the force in pounds per unit of area in square inches. The force is the weight of the water in the system vertically (above the location at which you're making the measurement) divided by the area upon which the weight sits.

Dynamic conditions: For every flow rate (in gallons per minute), you have a different dynamic pressure. The difference is caused by friction, which you'll often hear referred to as friction losses. Don't take this description literally. It is not a loss of friction but a loss of energy, which results from friction. Another way to think of friction is as a resistance to the flow of water through pipes, valves, fittings and backflow-prevention devices. It simply takes energy to overcome this resistance to flow. What are the factors that influence the amount of friction? They include the length of pipe, the pipe material, flow rate and the diameter of the pipe.

Friction loss:You can compute the friction loss in pipe, or you can use a reference table that has computed that value for you. These charts-typically supplied by sprinkler and pipe manufacturers-offer the friction loss for various flow rates for a 100-foot length of pipe, according to standard pipe sizes and various pipe materials.

Flow rate: The amount of friction is more sensitive to increases in flow rate than increases in pipe length.

Self-Check -1	Written Test

Directions 1: Choose the best answer for the following questions. Use the Answer sheet provided (2 pts each)

1. The vertical distance between the water inlet and the discharge point is:
   A. Pressure Head
   B. Friction Head
   C. Static or Elevation Head
   D. Velocity Head
2. What types of maintenance of irrigation system done annually?
   A. Special maintenance
   B. Routine maintenance
   C. Deferred maintenance
   D. Corrective maintenance
3. In which types of flow the streamlines are erratic and unpredictable?
   A. Turbulent flow
   B. Steady Flow
   C. Laminar flow
   D. Unsteady flow
4. The sum of the pressure head (p/γ) and elevation head (z) is:
   A. Hydraulic Radius
   B. Energy Grade
   C. Hydraulic Grade
   D. Energy Losses
5. Notches or gaps over which fluid flows are -----
   A. Orifices
   B. Weirs
   C. Canals
   D. Dams
6. Which one of the following is **Not** the application of Orifices?
   A. Regulating the flow through channels in the form of radial and sluice gates
   B. Approximating the interception capacity of submerged drainage inlets
   C. Serving as emergency spillways for regulating high-return event flows
   D. Regulating the flow out of detention ponds

***Note:* Satisfactory rating - 6 points** **Unsatisfactory - below 6 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3 4 5

2.1. Water delivery performance indicators

Four water delivery performance indicators, namely adequacy, efficiency, equity and reliability were used. These indicators could be evaluated for a single offtake, a group of offtakes in a sub-system, or for a whole irrigation scheme. Adequacy is an indicator for a water delivery system whether it attained a target or required water delivery over a certain period of time. The time frame to be considered could be daily, per irrigation turn, monthly, seasonally or annually as required. In this case, a period of three months is considered. It is given by:

$$P_A = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R p_A\right)$$

Where $PA$is adequacy indicator aggregated over a region *R* and time *T*,

$pA$is a ratio of delivered to required flows at a point (offtake).

However, in the conventional adequacy indictor it could be observed that when the delivered amount is in excess of the required, the adequacy indicator takes a maximum value of 1.0. Hence, this indicator cannot capture performance in cases of excess water delivery. If not well addressed, in addition to the apparent inefficiency in water use, excess delivery can result in serious environmental concerns like waterlogging.

Water delivery performance indicators are selection guidelines or criteria to select the appropriate structure and needs to review the states of established objectives of the scheme. It is stressed again that in this study the selection of structures is based purely upon the best hydraulic performance. In order to assess the performance of the irrigation water delivery, the hydraulic performance indicators such as adequacy, equity, dependability and efficiency of water supply are used'

The water delivery performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied and by the adequacy and uniformity of the application in each field on the farm to evaluate the irrigation system. Improvement need for in hydraulic performance of conveyance system, equity, adequacy and efficiency of water supply suitable to crop production system.

2.2. Internal water delivery performance

Adequacy, efficiency, dependability and equity are performance objectives considered when evaluating irrigation water delivery. Adequacy can be defined as the ability of an irrigation system to meet the required amount of water .

Adequacy is a measure of the degree to which water deliveries meet soil-plant water requirements. It can be managed by matching cropping plans and calendars with estimated seasonal water availability before the start of the season or by adjusting operational targets in reaction to actual demand during the season.

Supply adequacy is influenced by water availability at the source, delivery capacity and the operational situation of the scheme predictable water demand in relation to supply and type of division system. Efficiency embodies the ability to conserve water by matching water deliveries with water requirements.

Dependability expresses the ability to find water at the right time and in the place desired in the system. In this respect, dependability comes to mean that the water can be delivered at promised flow rate and duration. The major reason for the low performance of irrigation systems is undependable water distribution. Water that is supplied undependably is comparable to rainfall, which cannot be controlled.

The uncertainty and undependability in the delivery may cause confusion and conflict among farmers. Dependability of water supply is an appearance of confidence in the irrigation system to deliver water as promised and is indicative of the timeliness and adequacy of decided deliveries.

2.3. Water supply indicators

Relative water supply (RWS) and relative irrigation supply (RIS) relates supply to demand, and give some indication as for the condition of water abundance or scarcity, and how tightly supply and demand are matched.

To determine the annual water supply and the annual irrigation supply the values of four parameters of water supply/demand were determined which include:

- annual water supply;
- annual crop water demand,
- annual irrigation supply and
- annual irrigation demand.

Annual irrigation supply is the volume of irrigation water delivered to the head of the command. Annual water supply is the sum of delivered irrigation water and rainfall. The Annual crop water demand is determined using FAO CROPWAT model for a given cropping pattern and irrigation intensity.

Self-Check -1	Written Test

Directions 1: Match column 'A' with column 'B' and write the answer on the space provided. (2 pts each)

A

-------1. Adequacy

-------2. Annual irrigation demand

-------3.Annual irrigation supply

-------4. Annual crop water demand

-------5. Annual water supply

B

A. Determined using FAO CROPWAT model

B. Sum of delivered irrigation water and rainfall

C. Amount of water needed to the command

D. Uncertainty and undependability in the delivery

E. Volume of irrigation water delivered to the head of the command

F. Confusion and conflict among farmers

G. Water delivery performance indicator

H. Insufficient water supply

I. Receive water delivery

Answer Sheet

Score = ___________

Rating: ____________

Information Sheet-3	Analyzing system performance

3.1. Performance monitoring

To properly monitor and encourage the improvement of water service provision, the Water Sector Regulatory Council (WSRC) is continuing a program for monitoring the performance of water service providers through key performance indicators.

A performance monitoring system can be of use to many stakeholders in the water sector and is a necessary step for effective regulation. Key performance indicators offer a sound and internationally accepted form of measure of the quality of services provided and allow transparent, objective comparisons between different providers.
A performance monitoring system can be used to many actors in the water sector and is a necessary first step for effective regulation. Such as:

I. For the water sector regulatory council

A performance monitoring system allows the WSRC to gauge the performance of water service providers against national benchmarks. This not only provides an overall view of sector development but also provides an in-depth look into key areas of underdevelopment. Key Performance Indicators used in the annual monitoring assessments signal to problem areas in water service delivery and allow the WSRC to pinpoint deficiencies and develop mitigation needed. Publication of performance monitoring reports offers a means for communication with customers and increases transparency in water and wastewater services. The WSRC monitors compliance of water service providers to national policies and standards and reports directly to the Palestinian Cabinet of Ministers.

II. For water service providers

A performance monitoring system provides managers of water service providers with a measure of performance and allows the development of improved operational methodologies. Results of performance assessments can be used as a common basis for comparing performance indicators between service providers and for benchmarking with other institutions in the water industry thus inducing self-motivation for improvement of the quality of services offered. Performance indicators assist managers in efficient planning, decision making and allocation of financial resources targeted to improve performance where needed. Furthermore, this encourages sharing of good practices among service providers.

III. For policy makers

A performance monitoring system helps to inform policy makers about the water and wastewater sector with accurate, specific and transparent information. Policy makers make use of trends in sector performance to formulate and develop sector policies. Performance monitoring results will support sector planning, resource allocations, investments planning, and the development of national regulations and standards.

IV. For the customers

A transparent performance indicator system will offer a measure of the quality of services provided to customers by translating complex processes into simplified, presentable information. Monitoring water services helps to fulfill and protect customers' interests and needs and protects customers from monopolistic practices. It will also promote accountability and maintain a balance between the level of service and its price, thus ensuring that customers are receiving water services in accordance with national standards.

3.2. Factors affecting performance water use efficiency (WUE)

The WUE of irrigated agriculture are affected by a range of factors which may be broadly categorized as shown in Figure 14. Engineering and technological factors include improvement of water distribution networks and on-farm irrigation development, irrigation scheduling, real-time control and optimisation, remote sensing and sensor and communication networks. These factors improve irrigation WUE mainly by reducing water losses. In the recent past, a variety of hardware and software gadgets has become commercially available and is used to enhance irrigation WUE. Advancements in plant genetics have led to the development of high-yielding and disease-resistant varieties with higher WUE. There has been greater environmental awareness, leading to some governments around the world funding water-saving initiatives with the understanding that the water saved is released as environmental flows. Socio-economic factors are also important drivers of WUE. This will be covered in this section, with a focus on technology adoption and the decision-making processes of irrigation water users.

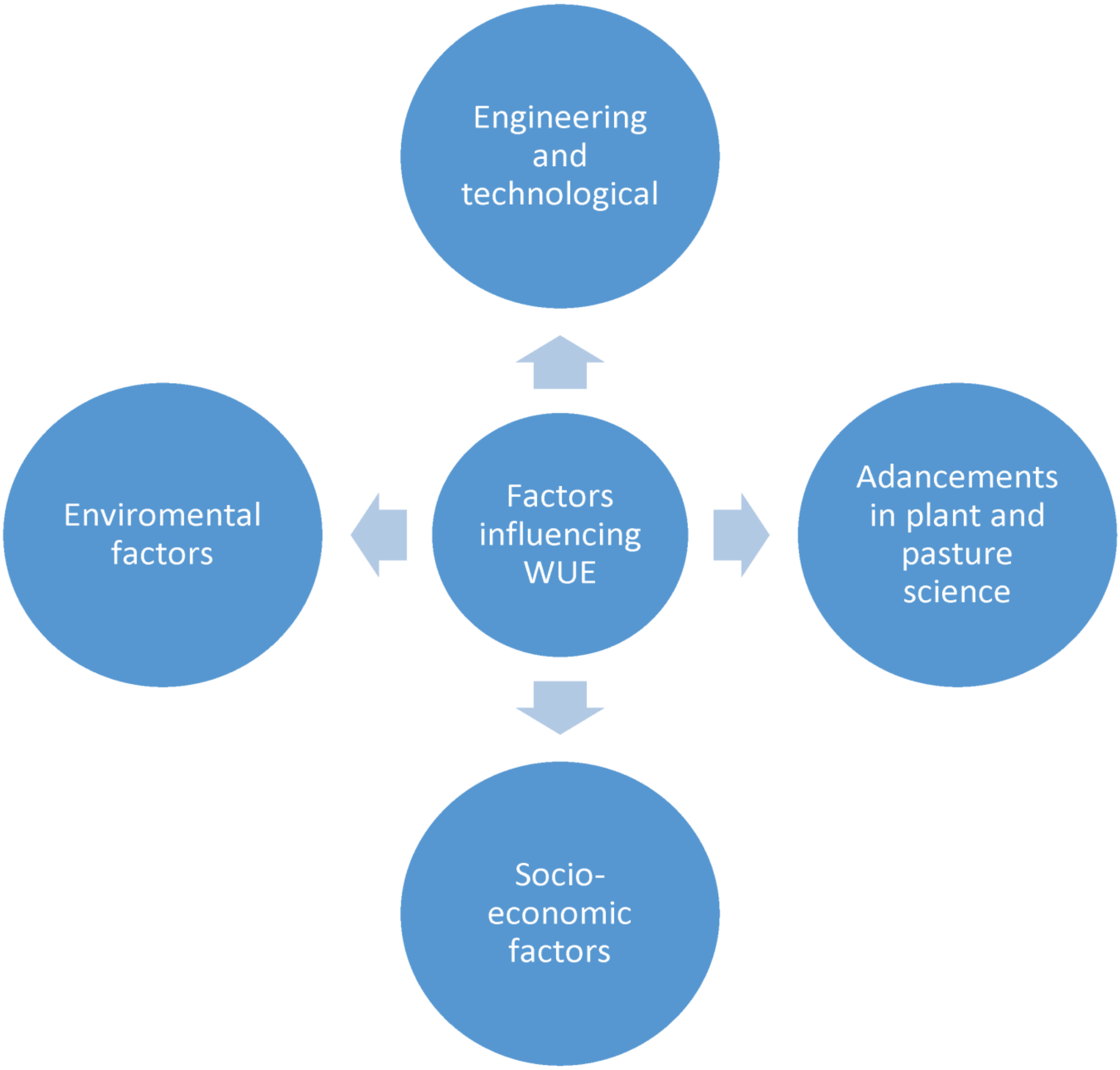


Figure 15:Factors influencing water use efficiency

3.3. Ethiopian water resources Management Policy (EWRMP)

The overall objective of the irrigation policy is to develop the huge irrigated potential for the production of food crops and raw materials needed for agro-industries, on efficient and sustainable basis and without degrading the fertility of the production fields and water resources base.

The policy sets the following detailed objectives:

- Development and enhancement of small-scale irrigated agriculture and grazing lands for food self-sufficiency at household level
- Development and enhancement of small, medium and large-scale irrigated agriculture for food security and food self-sufficiency at national level including export earnings and to satisfy local agro-industrial demand.
- Promotion of irrigation study, planning and implementation on economically viable, socially equitable, technically efficient, environmentally sounds basis as well as development of sustainable, productive and affordable irrigation farms.
- Promotion of water use efficiency, control wastage, protection of irrigation structures and appropriate drainage systems.
- Ensuring that small-scale, medium-scale and large-scale irrigation potential projects are studied and designed to stage ready for immediate implementation by private and/or the government at any time.

3.4. Irrigation development strategy

The irrigation development strategy is one of the sub-sectors dealt in the water sector strategy. The principal objective of the irrigation development strategy is to exploit the agricultural production potential of the country to achieve food self-sufficiency at the national level, including export earnings, and to satisfy the raw material demand of local industries, but without degrading the fertility and productivity of country's land and water resources base.

More specific objectives of the strategy are:

- Expand irrigated agriculture
- Improve irrigation water-use efficiency and thus the agricultural production efficiency
- Develop irrigation systems that are technically and financially sustainable
- Address water logging problems in irrigated area

Main elements of the irrigation strategy technical and engineering aspects:

- Initiate the planning and implementation of a comprehensive, well-coordinated and targeted-irrigation development program

- Design appropriate irrigation schemes by taking into account the physical conditions, hydraulic characteristics, irrigation engineering, management capacity of users, and detailed agronomic and agricultural considerations.
- Implement measures to secure long-term viability and sustainability of irrigation schemes.
- Adopt improved and affordable systems and tools for water harvesting and pumping, for reducing seepage losses in canals, for water control, storage and retention systems and measurement structures.
- Undertake measures to improve water conveyance efficiency, especially the irrigation water use efficiency by implementing agronomic, engineering, demand management, and economic measures based on detailed studies and analysis of these measures.
- Develop standards, guidelines, manuals and procedures for the sustainable operation and maintenance of irrigated schemes and systems, while ensuring their successful application, monitoring and improvement
- Develop and promote simple designs and standards for construction and operation and maintenance of irrigated schemes.
- Establish water allocation and priority setting criteria, as well as fair and transparent management system.
- Pursue integrated planning approach in the development and implementation of irrigation projects.
- Consider development of groundwater resources as supplementary means of irrigation in drought-prone areas, where rainfall duration is less than the length of growing season, as it is the only insurance against crop failure.
- Develop necessary technical guidelines and standards for mechanisms, systems, materials and technologies to be used for improving water use efficiency in small, medium and large scale agriculture, so as to avoid both shortage (stress) and excesses (loss).
- Give emphasis to water harvesting methods for small-scale irrigation development in areas where wet season runoff can be stored and used for crop production.
- Create conditions conducive to the implementation/construction of medium and large-scale irrigation schemes.

- Give appropriate consideration to past performance and technical capacity while selecting contractors and consultants for implementation/construction of irrigation projects because, in general the list bidder principle had not proven successful in construction works.
- Implement a sequential framework for project authorization for the planning (studies and design), implementation and management phases. Analyze and outline the operation and maintenance as well as management requirements with respect to the beneficiary skills, and availability of materials, budgets and technical capacities.

Self-Check -3	Written Test

Directions: Choose the best answer for the following questions. Use the Answer sheet provided (2 pts each)

1. A performance monitoring of water delivery system can be used for:
   - B. The customers
   - C. Policy makers
   - D. Water service providers
   - E. All
2. One of the following is an engineering and technological factor which affect performance of water delivery:
   - A. Disease-resistant varieties
   - B. Irrigation scheduling
   - C. Climate
   - D. Rainfall
3. The more specific objectives of the irrigation development strategy are:
   - A. Develop irrigation systems
   - B. Expand irrigated agriculture
   - C. Improve irrigation water-use efficiency
   - D. All
4. Technology adoption and the decision-making processes of irrigation water users focused on:
   - A. Advancements in plant
   - B. environmental
   - C. Socio-economic factors
   - D. Engineering and technological factors

Note: **Satisfactory rating - 4 points Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3. 4.

Operation Sheet 1	Monitoring channel flow rate, regulation and delivery

Procedures for monitoring channel flow rate:

1. Prepare materials
2. Visit the site
3. Identify some problems from channel flow
4. Record the problems
5. Prepare feedback and recommendation

Operation Sheet 2	Maintaining delivery performance records

Procedures for maintaining water delivery structures:

1. Identify the structure to be maintained
2. Prepare materials for maintenance
3. Calculate quantity of materials
4. Carry out maintenance
5. Finalize the work

Operation Sheet 3	Analyzing system performance

Procedures for analyzing water delivery system performance:

1. Prepare materials for maintenance
2. Observe the system
3. Check and record system performance
4. Analyze the system performance
5. Give feedback and recommendation
6. Prepare reports and documentation

LAP Test	Practical Demonstration

Name: _________________________________ Date: ________________

Time started: ___________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 8 hours.

Task 1. Monitor channel flow rate, regulation and delivery

Task 2. Maintain delivery performance records

Task 3. Analyze system performance

Instruction Sheet	**Learning Guide 20: Coordinate and control water delivery**

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Calculating system adjustments
- Coordinating flow regulation, channel levels, security of flow devices and settings

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Calculate system adjustments according to demand and organizational requirements.
- Coordinate flow regulation, channel levels, security of flow devices and settings according to demand and organizational requirements.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information “Sheet 1 and Sheet 4” in page 66 and 83 respectively.
4. Accomplish the “Self-check 1and Self- check 2” -” in page 82 and 92 respectively
5. If you earned a satisfactory evaluation from the “Self-check” proceed to “Operation Sheet 1in page 93.
6. Do the “LAP test” in page 94.

Information Sheet-1	Calculating system adjustments

1.1. Calculating delivery discharge

The properties of irrigation structures of significance to the operation process are:

- firstly, the freedom and precision that can be exerted in the adjustment of the output;
- secondly, the effort required for manipulation and control; and finally, the hydraulic stability based on sensitivity of the structure. These properties lead to identification of the following criteria for operation.

The properties, freedom of adjustment and precision of control can be analyzed through the classification of structures:

- Fixed: no adjustment is possible, e.g. weirs, orifices, dividers, ...
- Open/closed: generally, gates for minor canal either fully open or closed
- Stepwise adjustment: regulation by steps, modules or stoplogs
- Gradual adjustment: gated orifices, movable weirs.
- Automatic: hydraulically adjusted gates.

For fixed structures, freedom of adjustment is nil, since output is directly imposed by ongoing discharge (input), and precision is meaningless.For open/closed structures, freedom, and precision are not relevant. For stepwise adjustment, freedom and precision are limited by the number of discrete steps in the adjustment between zero and full capacity.

Figure 16: Stepwise regulator

Most devices measure flow indirectly. Flow measuring devices are commonly classified into those that sense or measure velocity and those that measure pressure or head. The head or velocity is measured, and then charts, tables, or equations are used to obtain the discharge. Some water measuring devices that use measurement of head, h, or pressure, p, to determine discharge, Q, are:

- Weirs
- Flumes
- Orifices
- Venturi meters
- Runup measurement on a flat "weir stick"

Head, h, or depth commonly is used for the open channel devices such as flumes and weirs. Either pressure, p, or head, h, is used with tube-type flowmeters such as a venturi.

Pressure, p, is the force per unit area as shown on figure 16 that acts in every direction normal to containing or submerged object boundaries. If an open vertical tube is inserted through and flush with the wall of a pipe under pressure, water will rise to a height, h, until the weight, W, of water in the tube balances the pressure force, Fp, on the wall opening area, a, at the wall connection.

These tubes are called piezometers. The volume of water in the piezometer tube is designated ha. The volume times the unit weight of water, γha, is the weight, W.

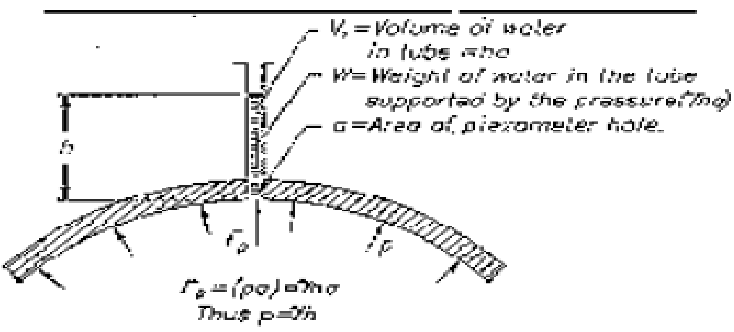


Figure 17: Pressure definition

The pressure force, F_p, on the tap connection area is designated *pa*. The weight and pressure force are equal, and dividing both by the area, *a*, gives the unit pressure on the wall of the pipe in terms of head, *h*, written as:

$p = \gamma h$(1-1)

or:

$h = \gamma / p$(1-2)

Thus, head is pressure, *p*, divided by unit weight of water, γ, or 62.4 pounds per cubic foot (lb/ft3). Pressure is often expressed in **psi** or pounds per square inch (lb/in2), which may be converted to feet of water by multiplying the (lb/in2) value by 2.31. For example, 30 lb/in2 is produced by 69.3 feet of water. When the head principle is used, the discharge, *Q*, is computed

from an equation such as the one used for a sharp-crested rectangular weir of length, *L*:

$Q = CLh^{3/2}$**(1-3)**

A coefficient, *C*, is included that accounts for simplifying assumptions and other deficiencies in deriving the equation. The coefficient can vary widely in nonstandard installations, but is well defined for standard installations or is constant over a specified range of discharge.

The flow cross-sectional area, *A*, does not appear directly in the equation, but an area can be extracted by rewriting this equation:

$Q = CLhh^{1/2}$(1-4)

in which:

$A = Lh$(2-5) (1.5)

In this form, *C* also contains a hidden square root of 2*g*, which, when multiplied by (*h*)1/2, is the theoretical velocity. This velocity does not need to be directly measured or sensed. Because the weir equation computes velocity from a measuring head, a weir is classified as a head measuring device.

Some devices that actually sample or sense velocities, *v*, are:

- Float and stopwatch
- Current and propeller meters
- Vane deflection meters

These devices generally do not measure the average velocity, *V*, for an entire flow cross section. Thus, the relationship between sampled velocities, *v*, and the mean velocity, *V*, must be known as well as the flow section area, *A*, to which the mean velocity applies. Then, the discharge, *Q*, sometimes called the flow rate, is the product, *AV*.

Discharge or rate of flow has units of volume divided by unit time. Thus, discharge can be accurately determined by measuring the time, *t*, to fill a known volume, V_o:

$$Q = V_o/t \quad (1\text{-}6)$$

Water measurement devices can be calibrated using very accurate volumetric tanks and clocks. More commonly, weight of water in the tanks is used by converting the weight of water per unit volume. The weight of water per cubic foot, called unit weight or specific weight, γ, is 62.4 lb/ft^3 at standard atmospheric conditions.

1.1.1 Discharge-area-velocity relationships

Flow rate or discharge, *Q*, is the volume of water in cubic feet passing a flow section per unit time, usually measured in cubic feet per second (ft^3/s). The distance, d_v, in feet that water will travel at a given velocity in a pipe of constant diameter is velocity, *V*, in feet per second (ft/s) multiplied by time, *t*, in seconds, or:

$$d_v = Vt \quad \textbf{(1-7)}$$

The volume, V_o, in cubic feet passing from the upstream to the downstream ends of this distance is the distance, d_v, in feet times area, *A*, in square feet of the flow section. Thus:

$$V_o = d_v A = AVt \quad (1\text{-}8)$$

To get the time rate of flow or discharge, *Q*, in cubic feet per second, divide the right and left sides of equation 1-8 by time, *t*, in seconds, resulting in:

$$Q = AV \quad (1\text{-}9)$$

Flow in open channels of rectangular cross section is often expressed in terms of unit discharge, *q*, in cubic feet per second per foot of width which is discharge, *Q*, in cubic feet per second divided by cross-sectional width, L_b, in feet or:

$$q = Q/L_b = VA/L_b = VD \quad (1\text{-}10)$$

The area, *A,* is L_bD, where *D* is the depth of flow. The continuity concept is an important extension of equation 2-9. On the basis that water is incompressible and none is lost from a flowing system, then as the cross-sectional area changes, the velocity must adjust itself such that the values of *Q* or *VA* are constant:

$$Q = A_1V_1 = A_2V_2 = \dots\dots = A_nV_n \qquad (1\text{-}11)$$

where the subscript denotes any number of arbitrarily selected positions along the flowing

system. This principle, known as continuity, is especially useful in the analysis of tube flowmeasurement devices such as the venturi meter.

1.1.2 Velocity Head Concept

The velocity of water leaving an opening under a given head, h, is the same as the velocity that would be attained by a body falling that same distance.

The equation that shows how velocity changes with h and defines velocity head is:

$$V = \sqrt{2gh} \qquad (1\text{-}12)$$

which may also be written in velocity head form as:

$$h = V^2/2g \qquad (\mathbf{1\text{-}13})$$

1.1.3 Orifice Relationships

Equations 1-9 and 1-13 can be used to develop an equation for flow through an orifice, which is a sharp-edged hole in the side or bottom of a container of water (figure 17). To find the velocity of flow in the orifice, use equation 2-13, then multiply by area to get AV, or discharge,

Q, resulting in:

$$Q1 = A\sqrt{2gh} \qquad (1\text{-}14)$$

The subscript t denotes theoretical discharge through an orifice. This equation assumes that the water is frictionless and is an ideal fluid. A correction must be made because water is not an ideal fluid. Most of the approaching flow has to curve toward the orifice opening. The water, after passing through the orifice, continues to contract or curve from the sharp orifice edge. If the orifice edges are sharp, the jet will appear as shown on figure 18. The maximum jet contraction occurs at a distance of one-half the orifice diameter (d/2) downstream from the sharp edge. The cross-sectional area of the jet is about six-tenths of the area of the orifice. Thus, equation 2-14 must be corrected using a contraction coefficient, Cc, to produce the actual discharge of water being delivered. Thus, the actual discharge equation is written as:

$$\boldsymbol{Qa = C_c A\sqrt{2gh}} \qquad (1\text{-}15)$$

For a sharp-edged rectangular slot orifice where full contraction occurs, the contraction

coefficient is about 0.61, and the equation becomes:

$$\boldsymbol{Qa = 0.61A\sqrt{2gh}} (1\text{-}16)$$

A nonstandard installation will require further calibration tests to establish the proper contraction coefficient because the coefficient actually varies with the proximity to the orifice edge with respect to the approach and exit boundaries and approach velocity.

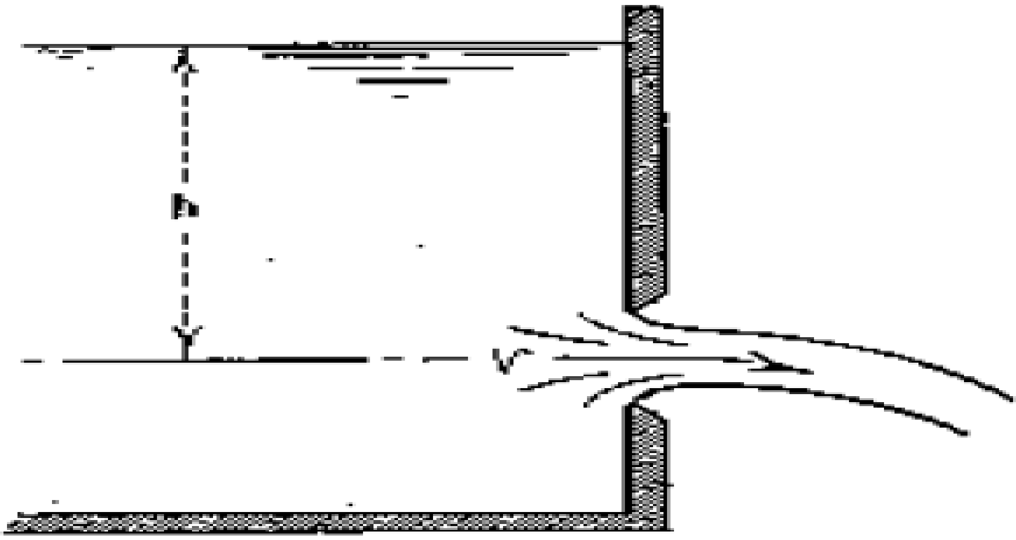


Figure 18: Orifice flow.

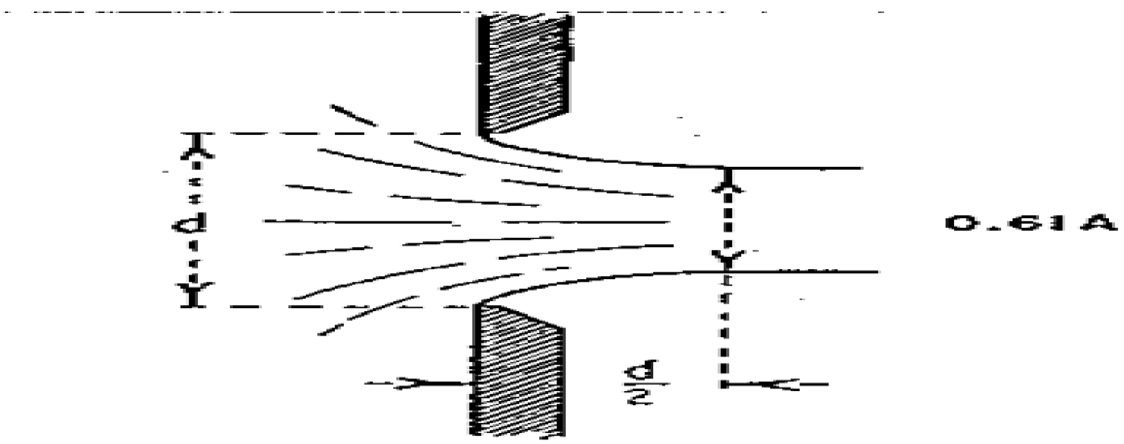


Figure 19: Contraction at an orifice

1.1.4 Thin plate weir relationships

Most investigators derive the equation for sharp-crested rectangular weirs by mathematical integration of elemental orifice strips over the nappe (Bos, 1989). Each strip is considered an orifice with a different head on it.

The resulting rectangular weir equation for theoretical discharge is:

$$\boldsymbol{Qt} = \frac{2}{3}(\boldsymbol{2g})^{\boldsymbol{1/2}}\boldsymbol{L_b h^{3/2}} \quad (1\text{-}17)$$

A correction factor is needed to account for simplifications and assumptions. Thus, a discharge coefficient, Cd, is added to obtain actual discharge, expressed as:

$$\boldsymbol{Qa} = \boldsymbol{C_d}\frac{2}{3}\sqrt{\boldsymbol{2g}}\boldsymbol{L_b h^{3/2}} \quad (1\text{-}18)$$

This relationship is the basic weir equation and can be modified to account for weir blade shape and approach velocity. However, Cd must be determined by analysis and calibration tests. For standard weirs, Cd is well defined or constant for measuring within specified head ranges.

1.1.5 Energy balance flow relationships

Hydraulic problems concerning fluid flow are generally handled by accounting in terms of energy per pound of flowing water. Energy measured in this form has units of feet of water. The total amount of energy is that caused by motion, or velocity head, $V^2/2g$, which has units of feet, plus the potential energy head, Z, in feet, caused by elevation referenced to an arbitrary datum selected as reference zero elevation, plus the pressure energy head, h, in feet. The head, h, is depth of flow for the open channel flow case and p/γ defined by equation 1-2 for the closed conduit case. This summation of energy is shown for three cases on figure 19.

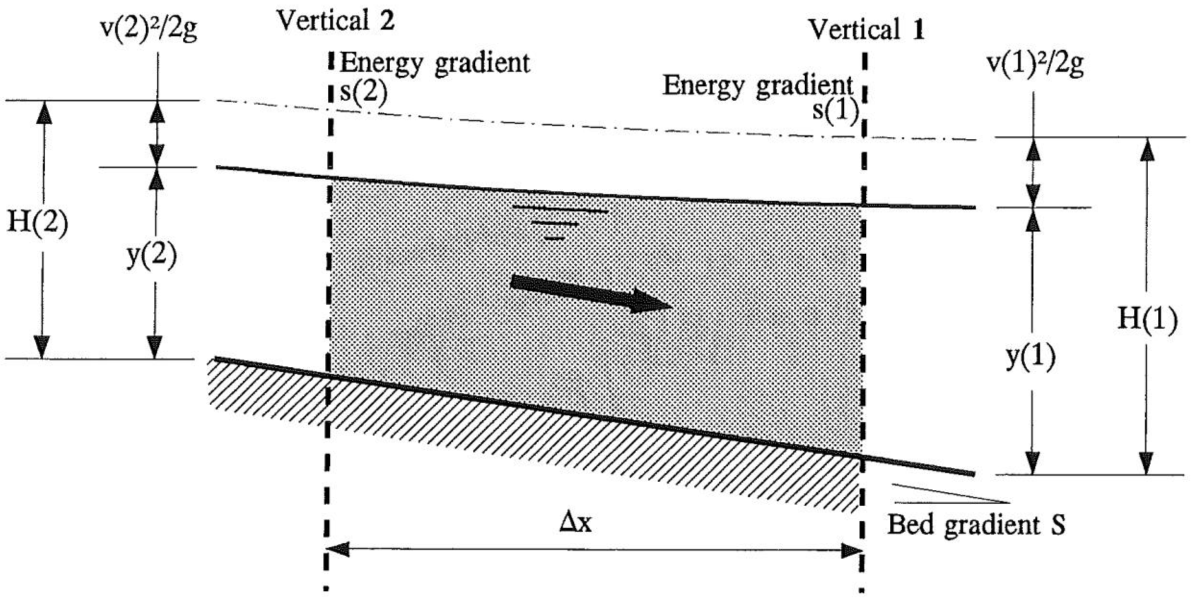


Figure 20: Energy balance

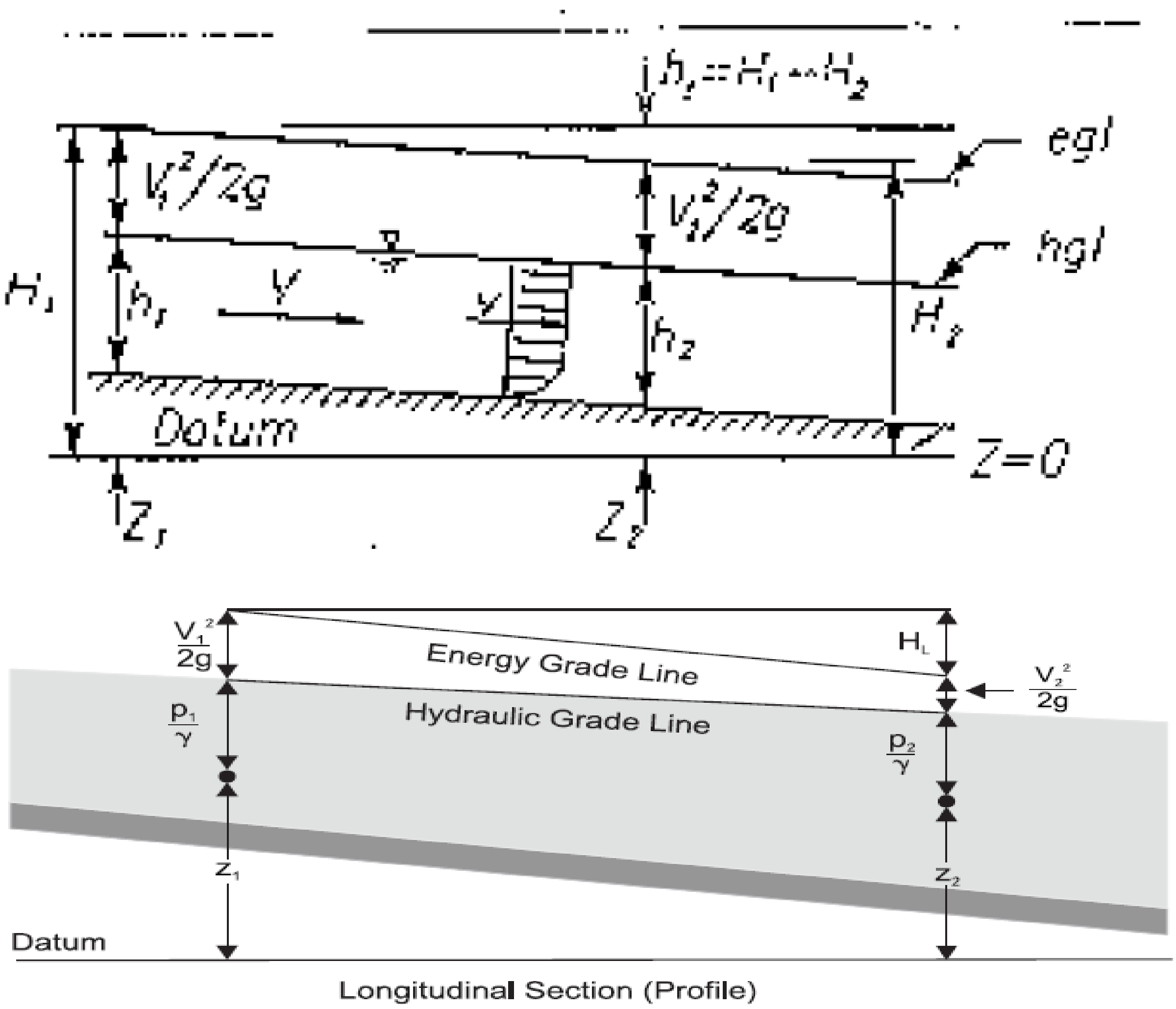


Figure 21: Energy balance in open channel flow.

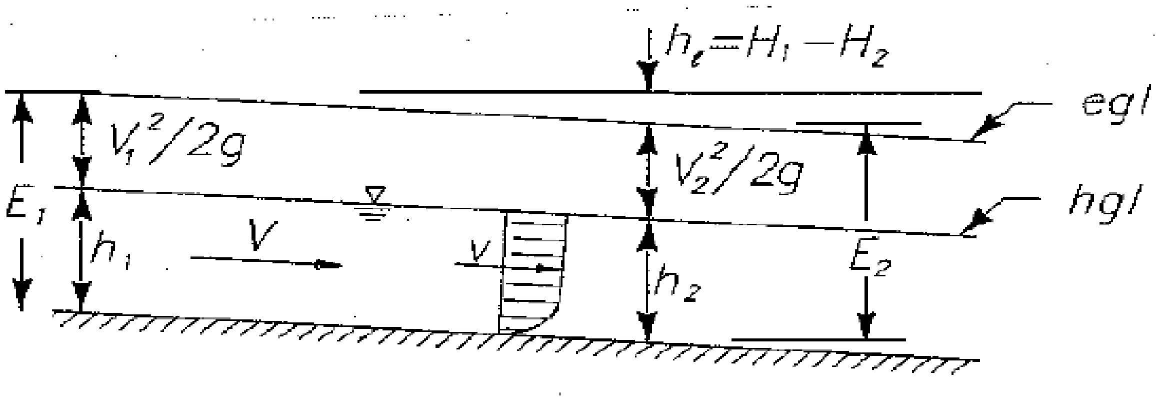


Figure 22: Specific energy balance

Figures 21 and 22 show the total energy head, H1; for example, at point 1, in a pipe and anopen channel, which can be written as:

$$\boldsymbol{H1} = \boldsymbol{h1} + \frac{\boldsymbol{V^2}_{\boldsymbol{1}}}{\boldsymbol{2g}} + \boldsymbol{Z_1} \text{(1-19)}$$

At another downstream location, point 2:

$$\boldsymbol{H2} = \boldsymbol{h2} + \frac{\boldsymbol{V^2}_{\boldsymbol{2}}}{\boldsymbol{2g}} + \boldsymbol{Z_2} \text{(1-20)}$$

Energy has been lost because of friction between points 1 and 2, so the downstream point 2 has less energy than point 1. The energy balance is retained by adding a head loss, $hf(_{1-2})$. The total energy balance is written as:

$$\boldsymbol{h1} = \frac{\boldsymbol{V^2}_{\boldsymbol{1}}}{\boldsymbol{2g}} + \boldsymbol{Z_1} = \boldsymbol{h2} + \frac{\boldsymbol{V^2}_{\boldsymbol{2}}}{\boldsymbol{2g}} + \boldsymbol{Z_2} + hf(_{1-2}) \text{(1-21)}$$

The upper sloping line drawn between the total head elevations is the energy grade line, egl. The next lower sloping solid line for both the pipe and open channel cases shown on figure 23 is the hydraulic grade line, hgl, which is also the water surface for open channel flow, or the height to which water would rise in piezometer taps for pipe flow.

A special energy form is commonly used in hydraulics in which the channel invert is selected as the reference Z elevation (figure 24). Thus, Z drops out, and energy is the sum of depth, h, and velocity head only. Energy above the invert expressed this way is called specific energy, E. This simplified form of energy equation is written as:

$$\boldsymbol{Specific\,energy} = \boldsymbol{E} = \frac{\boldsymbol{V^2}}{\boldsymbol{2\,g}} + \boldsymbol{h} \qquad \text{(1-22)}$$

In a fairly short pipe that has little or insignificant friction loss, total energy at one point is essentially equal to the total energy at another point. If the size of the pipeline decreases from the first point to the second, the velocity of flow must increase from the first point to the second. This increase occurs because with steady flow, the quantity of flow passing any point in the completely filled pipeline remains the same. From the continuity equation (equation 1-11), when the flow area decreases, the flow velocity must increase.

The second interesting point is that when the velocity increases in the smaller section of the pipeline, the pressure head, h, decreases. At first, this decrease may seem strange, but equation 1-21 shows that when $V^2/2g$ increases, h must decrease proportionately because the total energy from one point to another in the system remains constant, neglecting friction loss. The fact that the pressure does decrease when the velocity in a given system increases is the basis for tube type flow measuring devices.

In open channel flow where the flow accelerates, more of its supply of energy becomes velocity head, and depth must decrease. On the other hand, when the flow slows down, the depth must increase.

1.1.6 Hydraulic mean depth and hydraulic radius

There is irregular flow cross section with different methods for defining depth offlow. In terms of frictional head losses, the perimeter is important. Hydraulic radius, Rh, isdefined as the area of the flow section divided by the wetted perimeter, Pw, which is shown on figure 24 and is written as:

$\boldsymbol{Rh} = \frac{\boldsymbol{A}}{\boldsymbol{P_w}}$(1-23)

Thus, wetted perimeter times the hydraulic radius is equal to the area of irregular section flow as shown on figures 1-4a and 1-4c.

For use in Froude number and energy relationships in open channel flow hydraulics, mean depth, hm, is defined as the depth which, when multiplied by the top water surface width, T, is equal to the irregular section area, A, shown on figures 1-4a and 1-4b, of the flow section and is commonly used for critical flow relationships. The equation for hydraulic mean depth, hm, is:

$\boldsymbol{h_m} = \frac{\boldsymbol{A}}{\boldsymbol{T}}$ (1-24)

In rectangular channels, hydraulic radius, Rh, does not equal depth, but approaches depth as the channel becomes very wide. However, the hydraulic mean depth, hm, is the same as the depth of the rectangular flow section.

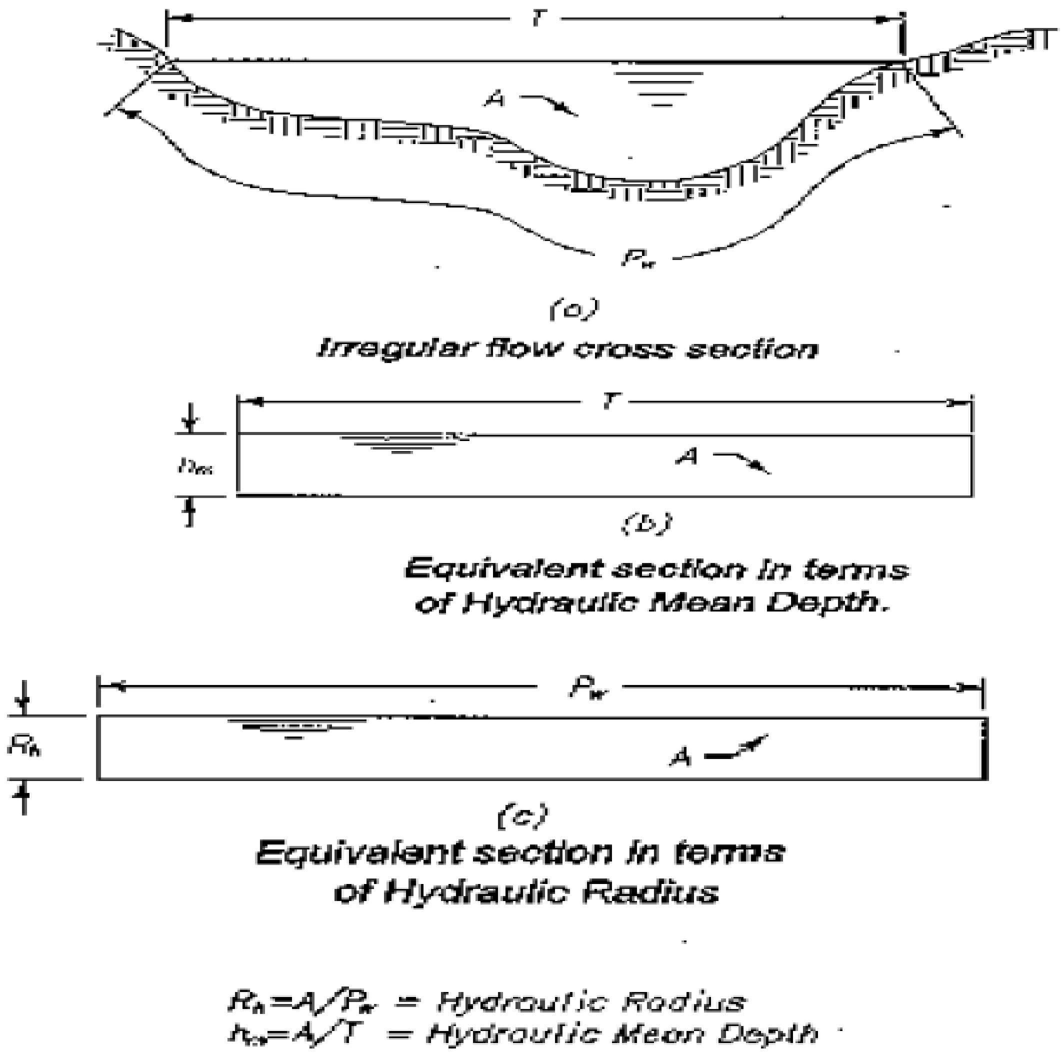


Figure 24: Definitions of hydraulic radius and hydraulic mean depth (area is the same for all three cases).

1.1.7 Froude number, critical flow relationships

In open channel hydraulics, the Froude number is a very important non-dimensional parameter.

The Froude number, F, is the ratio of inertia force to gravity force, which simplifies to:

$$F = \frac{V}{\sqrt{gh_m}} \quad (1\text{-}25)$$

where the subscript m denotes hydraulic mean depth.

For open channel modeling, the Froude number of a model is made equal to the Froude number of the actual full-size device. The length ratio is set and the scale ratios for velocity and discharge are determined from the equality. However, the modeler must make sure that differences in friction loss between the model and the actual device are insignificant or accounted for in some way.

Open channel flow water measurement generally requires that the Froude number, F, of the approach flow be less than 0.5 to prevent wave action that would hinder or possibly prevent an accurate head reading.

When the Froude number is 1, the velocity is equal to the velocity of wave propagation, or celerity. When this condition is attained, downstream wave or pressure disturbances cannot travel upstream. A Froude number of 1 also defines a very special hydraulic condition. This flow condition is called critical and defines the critical mean depth and critical velocity relationship as:

$$\boldsymbol{F_c} = \frac{\boldsymbol{V_c}}{\sqrt{\boldsymbol{g}\boldsymbol{h}_{\boldsymbol{cm}}}} \quad (1\text{-}25)$$

The subscript c denotes critical flow condition. The critical hydraulic mean depth, h_{cm},is the depth at which total specific energy is minimum for a given discharge. Conversely, h_{cm}, is the depth at which the discharge is maximum for a given total specific energy. When depth is greater than critical, the resulting velocity is considered streaming or tranquil and is called subcritical velocity. Conversely, when the depth is less than critical, the flow is rapid or shooting and is called super-critical velocity.
Water measurement flumes function best by forcing flow to pass through critical depth; then discharge can be measured using one head measurement station upstream. Also, for weirs and flumes, one unique head value exists for each discharge, simplifying calibration. This flow condition is called free flow. However, if the downstream depth submerges critical depth, then separate calibrations at many levels of submergence are required, and two head measurements are needed to measure flow.

Designing flumes for submerged flow will always decrease accuracy of flow measurement. Flumes and weirs can be submerged unintentionally by poor design, construction errors, structural settling, attempts to supply increased delivery needs by increasing downstream heads, accumulated sediment deposits, or weed growths.

Important critical flow relationships can be derived using equation 1-26 and rewriting in the form:

$$Vc = \sqrt{gh_{cm}} \qquad (1\text{-}27)$$

Solving for head in equation 2-27 results in:

$$h_{cm} = \frac{V_c^2}{g} \qquad (1\text{-}28)$$

Dividing both sides of this equation by 2 gives critical velocity head in terms of critical mean depth written as:

$$\frac{V_c^2}{2g} = \frac{h_{cm}}{2} (1\text{-}29)$$

The total energy head with Z equal to zero for critical flow using equation 2-19 is:

$$H_c = h_c + \frac{V_c^2}{2g} \qquad (1\text{-}30)$$

Squaring both sides of equation 2-27 and replacing velocity with Q/A and h_{cm} with A/T according to equation 2-24 and rearranging results in:

$$\frac{Q_c^2}{g} = \frac{A_c^3}{T_c} \qquad (1\text{-}31)$$

1.2. Discharge equation for broad-crested rectangular weirs

The discharge equation for the rectangular broad-crested weir will now be derived similar to Bos (1989). The width, Lb, of a rectangular flow section is the same as T, the top water surface width.

Also, h_c is the same as h_{cm}, and using equation 1-29 for velocity head, equation 1-30 can be rewritten as:

$$H_c = h_c + \frac{h_c}{2} \qquad (1\text{-}32)$$

Or

$$H_c = \frac{3}{2} h_c \qquad (1\text{-}33)$$

Conversely:

$$h_c = \frac{2}{3} H_c \qquad (1\text{-}34)$$

Multiplying both sides of equation 2-27 by the area, Ac, of the flow section, which is $L_b h_c$, results in discharge expressed as:

$$Q = L_b h_c \sqrt{g h_c} = L_b \sqrt{g h_c}^{\,3/2} \qquad (1\text{-}35)$$

To get unit discharge, *q*, this equation is divided by the width of flow, L_b, resulting in:

$$q = \frac{Q}{L_b} = \sqrt{g h_c}^{\,3/2} \qquad (2\text{-}36)$$

Solving for h_c:

$$h_c = \sqrt[3]{\frac{q^2}{g}} \qquad (2\text{-}37)$$

Using equation 2-34 to replace *hc* with *Hc* in equation 2-35 results in theoretical discharge, *Qt*:

$$Q_l = L_b \sqrt{g} \left(\frac{2}{3} H_c\right)^{3/2} \qquad (2\text{-}38)$$

Because specific energy is constant in a fairly short measuring structure with insignificant

friction losses, specific energy, H_c, at the critical location can be replaced with specific energy, H_1, at a head measuring station a short distance upstream. However, some friction loss, possible flow curvature, and non-uniform velocity distribution occur. Thus, a coefficient of C_d must be added to correct for these effects, resulting in an expression for actual discharge:

$$Q_a = C_d L_b \frac{2}{3} \sqrt{\frac{2}{3}} g H_1^{3/2} \qquad (1\text{-}39)$$

For measurement convenience, the total head, *H*1, is replaced with the depth, *h*1. To correct for neglecting the velocity head at the measuring station, a velocity coefficient, *C*v, must be added, resulting in:

$$Q_a = C_d C_v L_b \frac{2}{3} \sqrt{\frac{2}{3} g} h_1^{3/2} \quad (2\text{-}40)$$

(1-40)

Self-Check -1	Written Test

Directions: Choose the best answer for the following questions. Use the Answer sheet provided (2 pts each).

1. In which structure freedom of adjustment is nil?
   - A. Open/closed structure
   - B. Fixed structure
   - C. Stepwise adjustment
   - D. Gradual adjustment

2. One of the following water measuring devices use measurement of head or pressure.
   - A. Vane deflection meters
   - B. Current and propeller meters
   - C. Float and stopwatch
   - D. Venturi meters

3. Which parameter of water delivery system does not measure by using water measuringdevices or structures?
   - A. Velocity
   - B. Head
   - C. Discharge
   - D. Pressure

4 When the Froude number is 1, which condition will occur?
   - A. There is no movement of water in the channel
   - B. Velocity is equal to the velocity of wave propagation
   - C. Downstream wave or pressure disturbances travel upstreamdisturbances travel upstream
   - D. The velocity is zero at the downstream

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3. 4.

Information Sheet-2	Coordinating flow regulation, channel levels, security of flow devices and settings

2.1. Water delivery system layout

Layout system design has great role on the overall sustainability of the schemes. It is impossible to design an effective conservation irrigation system without complete understanding by both irrigator and planner. There should be mutual understanding of the water supply needed. The planner must know the farmer's wishes. He must consider the entire farm even if only one field is to be planned for irrigation at any one time.

A well-designed conservation irrigation system delivers the required amount of water to all parts of the area to be irrigated at the require rate without damage to the soil or excessive loss of water. It is accessible and easy to operate without obstructing other farming operations. To plan such an irrigation system, you must know the many factors that affect design in the area to be irrigated. Study such factors as soils topography, crop to be irrigated, water supply, existing facilities, and available construction and farm equipment.

When we design the layout of water delivery system, the following considerations should be taken:

- A primary concern in the layout of the system is that it serves the purpose of conveying and distributing water to key locations in the area of service
- The excavation and earthen fill volumes not be excessive
- When large volume of excavation and or fill are required, the construction costs can increase tremendously
- In fill areas, compaction of the soil material is very important to avoid settlement problems and possible structural failure
- In reaches constructed over fill, the seepage losses tend to be high, even if the canal is lined

- For these reasons, canals are often designed to follow the existing topography for the design bed slop, which often means routing the canals indirectly so that earth moving work can be minimized, or at least held to an acceptable level
- The selection of longitudinal bed slope should also take in to account the existing slopes of the train so as to minimize deviations in canal routing
- Curves in canals should not be to sharp.

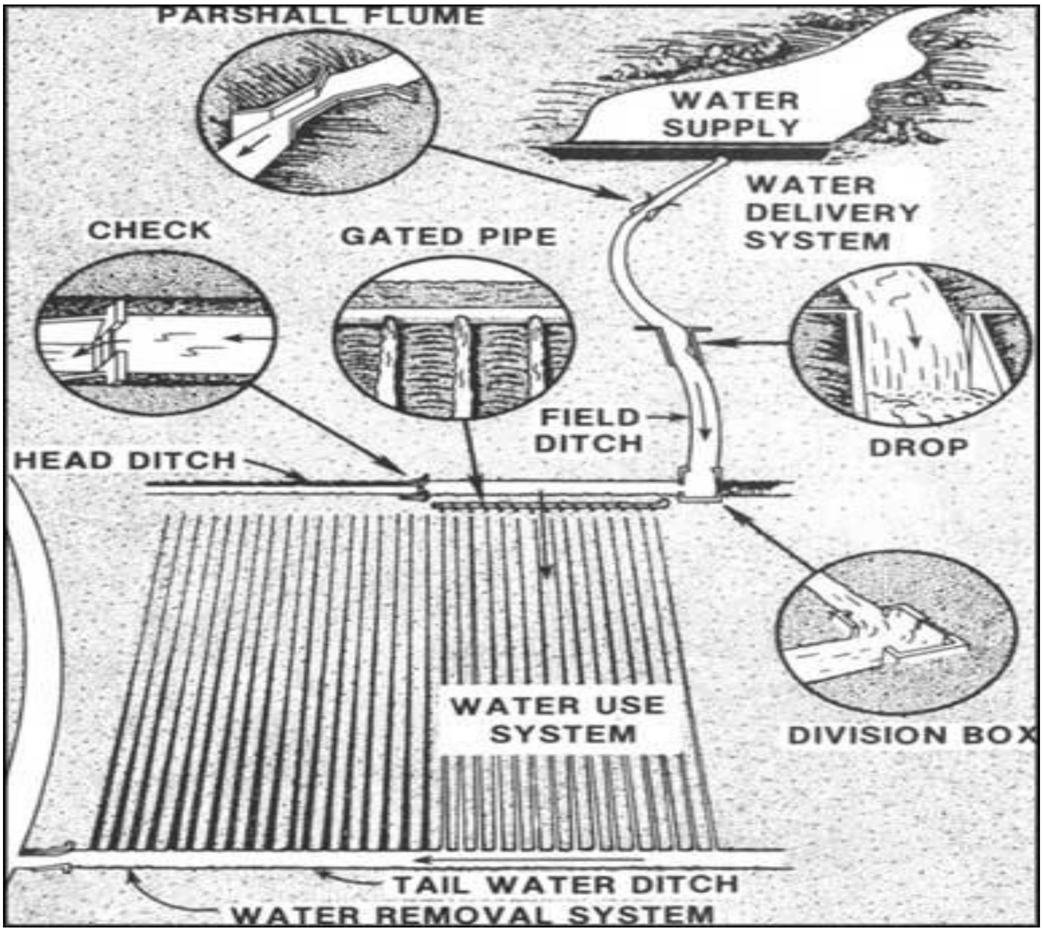
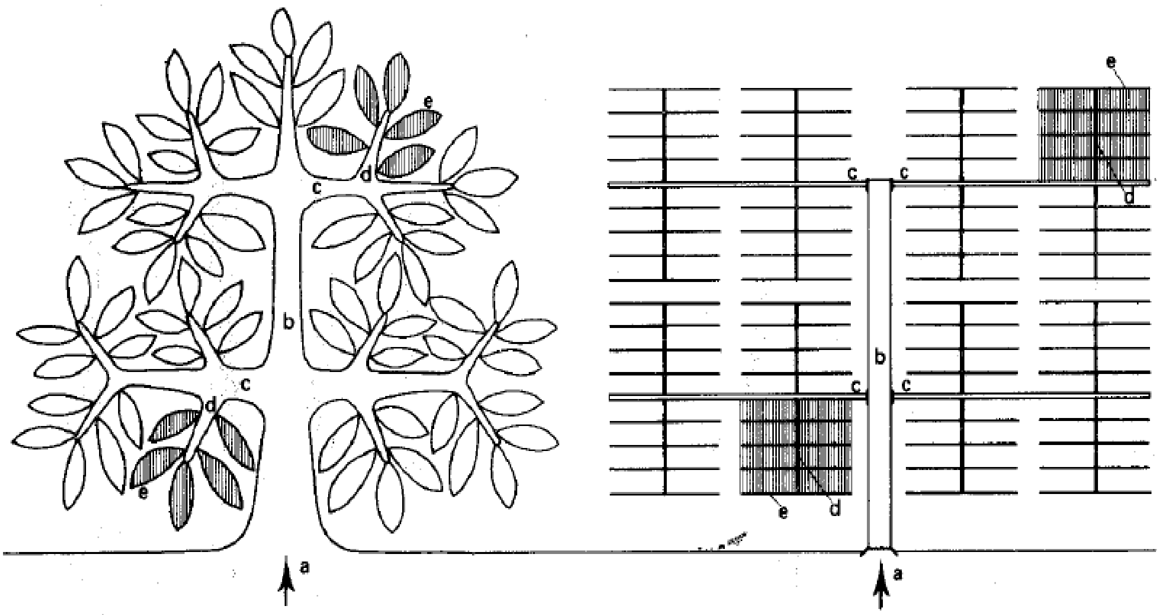


Figure 25: Water delivery layout

2.2. Canal Irrigation Network

Usually it is desirable that a canal off taking from a river or storage should be able to irrigate as much an area as possible. The general layout concept can be explained when studied in respect of the off-take point of the canal and the surrounding contours. A system of irrigation canals, also known as a 'canal network', transports water from its source to the fields, and is made up of many canals.

An irrigation canal network compared to a tree



2.2.1 Irrigation canal layout

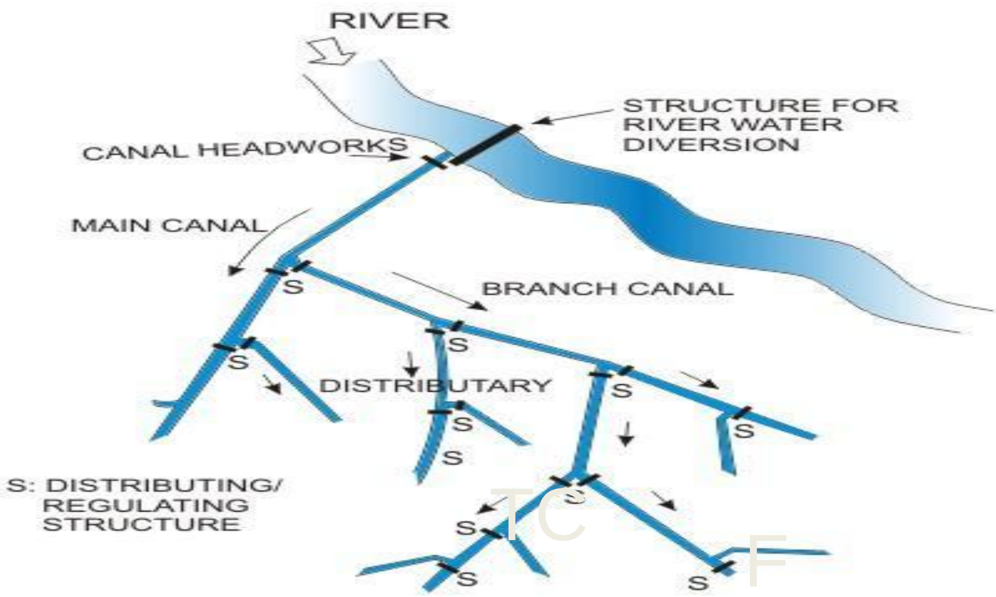


Figure 26: Irrigation canal layout

Before designing a canal network, a topographical survey of the area should be done and a topographical map of the area drawn. On this map the layout of the canal system is planned so that water delivery will be as efficient as possible. This map is called the irrigation plan/layout. Figure next shows an example of topographic map and such an irrigation plan.

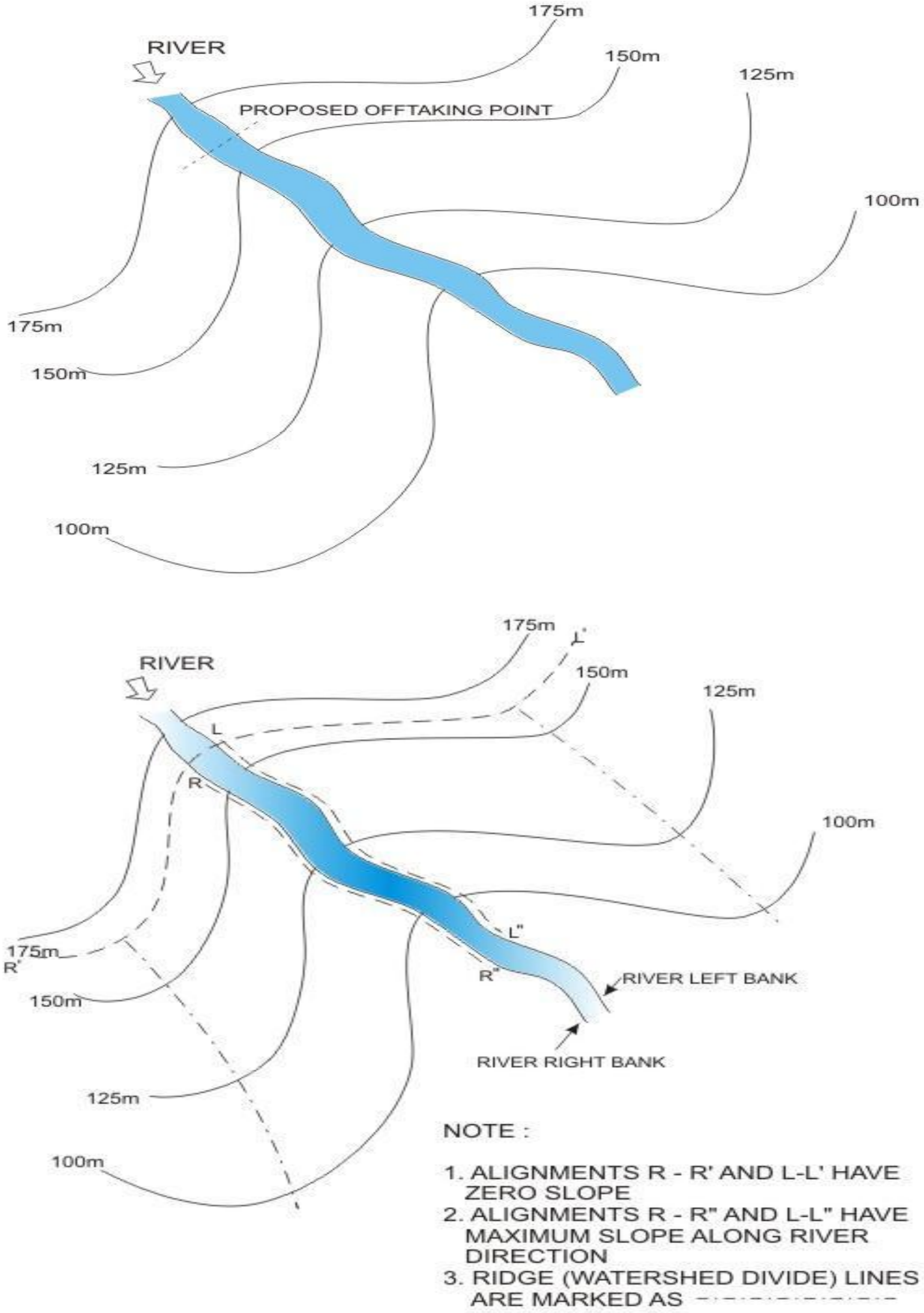


Figure 28: Topographic map for an irrigation plan

2.2.2 Principles of canal layout

Points to be considered during canal layout:

• A primary concern in the layout of the system is that it serves the purpose of conveying and distributing water to key location in the area of service

• Another concern is that the excavation and earthen fill volumes not excessive

• When large volumes of excavation and or fill are required, the constructions costs can increase tremendously

• In fill area, compaction of the soil material is very important, to avoid settlement problems and possible structural failure

• In reaches constructed over fill, the seepage losses tend to be high, even if the canal is lined.

For these reasons, canals are often designed to follow the existing topography for the design bed slope, which often means routing the canals indirectly so that earth work can be minimized, or at least held to an acceptable level. The selection of longitudinal bed slope should also take into account the existing slopes of the terrain, so as to minimize deviations in canal routing. Curves in canals should not be too sharp; following are some recommended limits. In bends the radius of curvature should usually be between 3 and 7 times the top width of flow at maximum design discharge (larger radius for larger canals).

The alignment should be such that the canal crosses the natural stream at its narrowest point in the vicinity. The alignment of channels should be marked on topo-sheets, until an optimum is reached.

2.2.3 Longitudinal profile of canals

In practice the main and secondary canals are usually aligned following the natural topography. However, canals do not always follow contours, depending on the topography of the land it might be necessary to cross the contours.

As a result of this mild slope of the canals will either float above the natural ground surface which demands excessive fill and at the same time it needs additional facility to lower if it is going to supply water to the nearby land.

To the contrary if the canal (earthen canal) is forced to follow the topography, the resulting canal slope will be steep and thus eroding velocity.

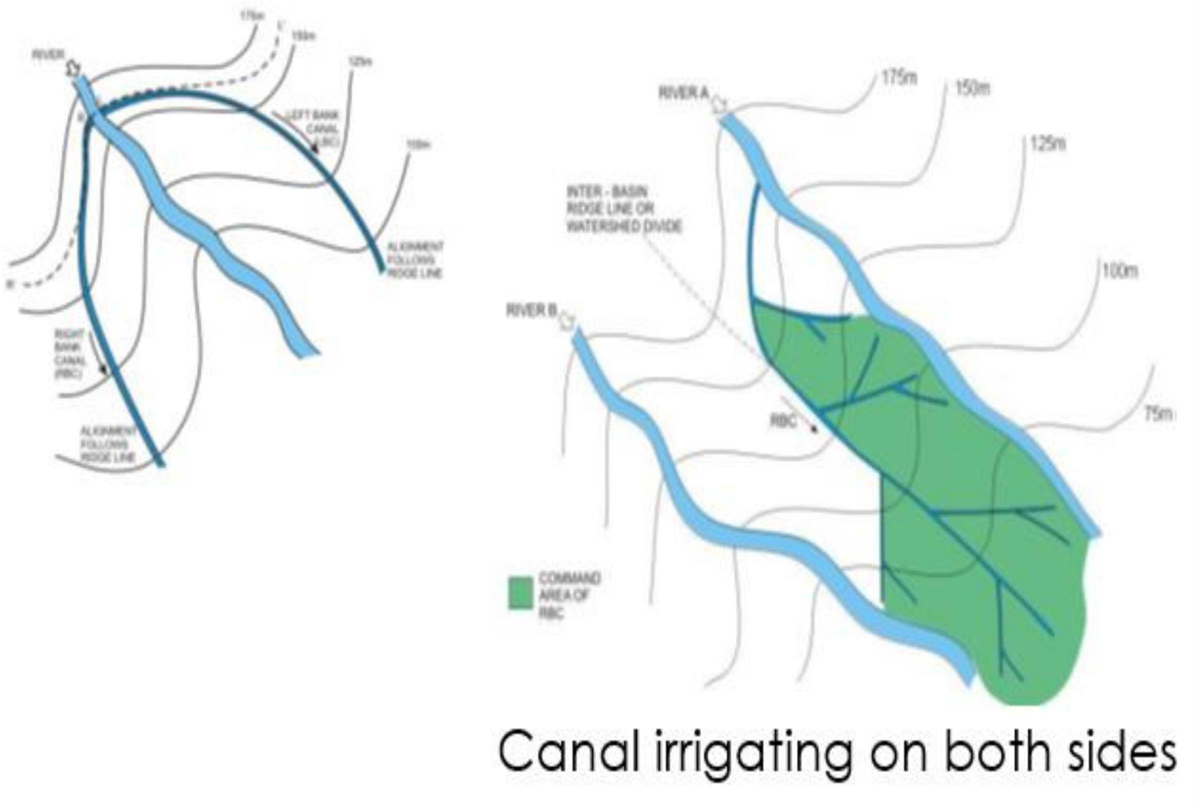


Figure 29: Canal irrigation on both sides

Thus, in order to avoid the above mentioned two problems it is necessary to:

- Follow the contour where possible
- Select mild slope to avoid canal erosion
- Provide necessary structures i.e. canal falls/ drops or chute channel
- The inclusion of drop/canal falls should consider balancing cut/fill and required
  water head for irrigating the adjacent land

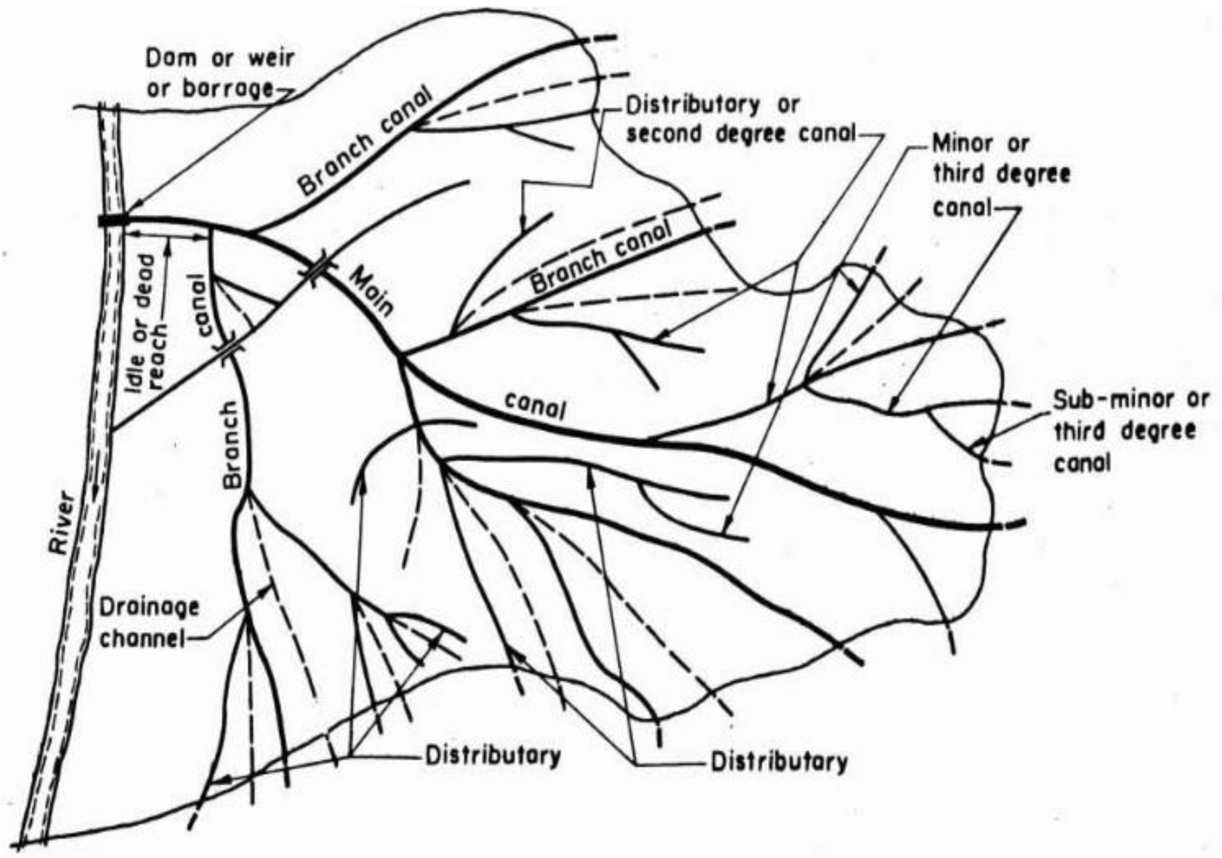


Figure 30: Sketch of a typical irrigation system

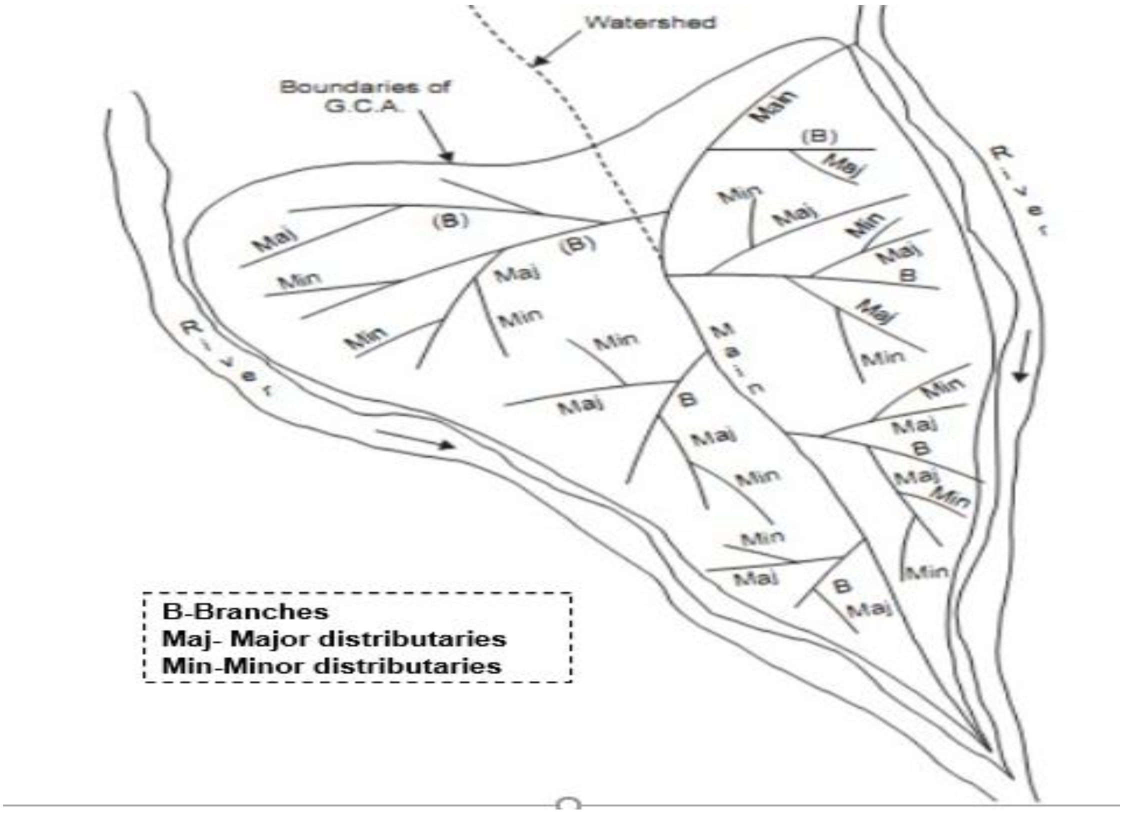


Figure 31: Layout of an irrigation canal network

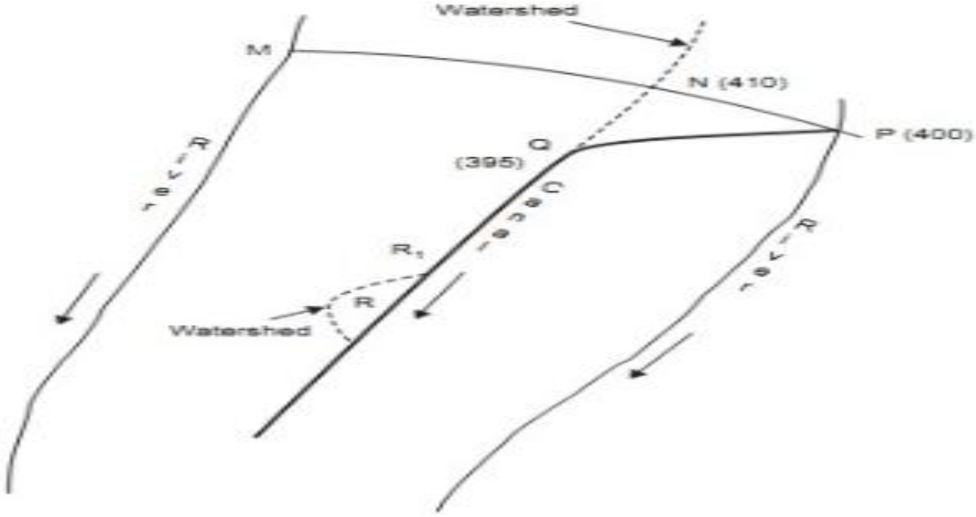


Figure 32: Head reach of a main canal in plains

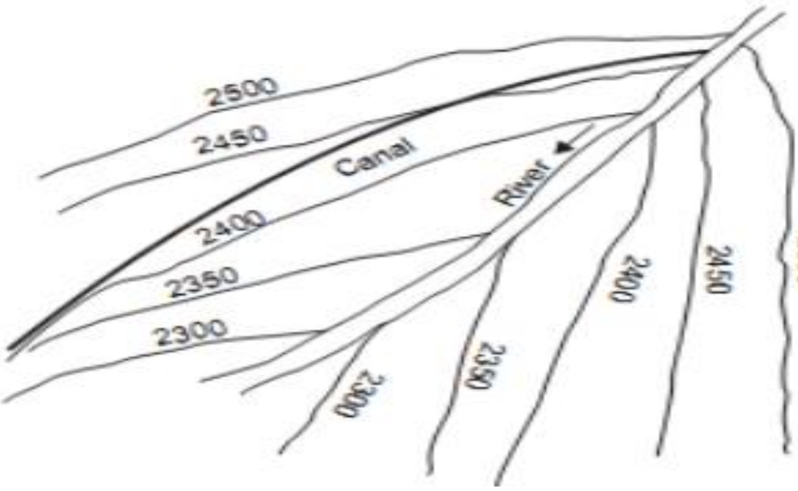
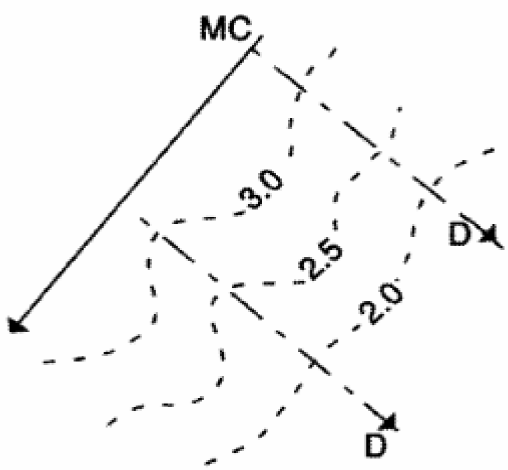


Figure 33: Alignment of main canal in hills

Non irrigated area between canals should be avoided. The first and foremost principle for a proper layout is that drains will be located in the lower parts of the area.



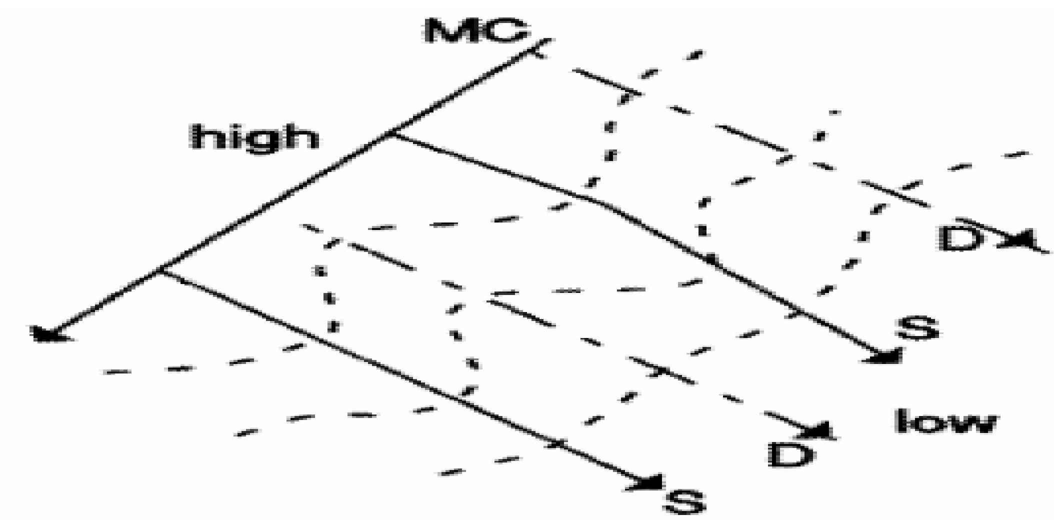
The layout process is, therefore, started with the layout of main drains for which existing drainage channels or valley bottoms form an alignment. Additional secondary drains will be located between the natural ones.

The alignment of the main canal forms in many instances the boundary of the command area. At first estimate of the design water level near the intake point and of the required bed slope is made in order to be able to proceed with the layout in case such a canal is a contour canal. Otherwise the main canal can be projected right away. The area to be irrigated from a contour canal can be estimated directly from the map in case the available quantities of water do not permit to irrigate the whole command area. Two possibilities exist in such a case:

- The whole command area will be included in the scheme but each farmer will receive water only for the part of his holding, at least during periods of peak demand; (deficient irrigation) or
- The command area will be irrigated fully and will

A decision, whether to irrigate the whole command area or not, should be based on economic and social consideration. Example: the upstream and downstream condition and water use for other purpose.

Existing canals and structures, and other infrastructure, will have to be taken in to account, certainly in rehabilitation and modernization projects. In general, the horizontal alignment of the irrigation and drainage canals follows the topology of the terrain. Alignments are further strongly influenced by soil conditions.



Secondary and tertiary supply canals are preferably located on high grounds, such as ridges. Tertiary outlets will be located on only one side of the canal in case the secondary canals are contour canals.

Depending on the project nature all canal types and infrastructures may not found in one system. For most small-scale irrigation schemes, tertiary canals take off water from the main canals. Access road along or in between drain and supply canals should be designed. Road cross, Division boxes, gully crosses and other structures should be laid out on the horizontal alignment system.

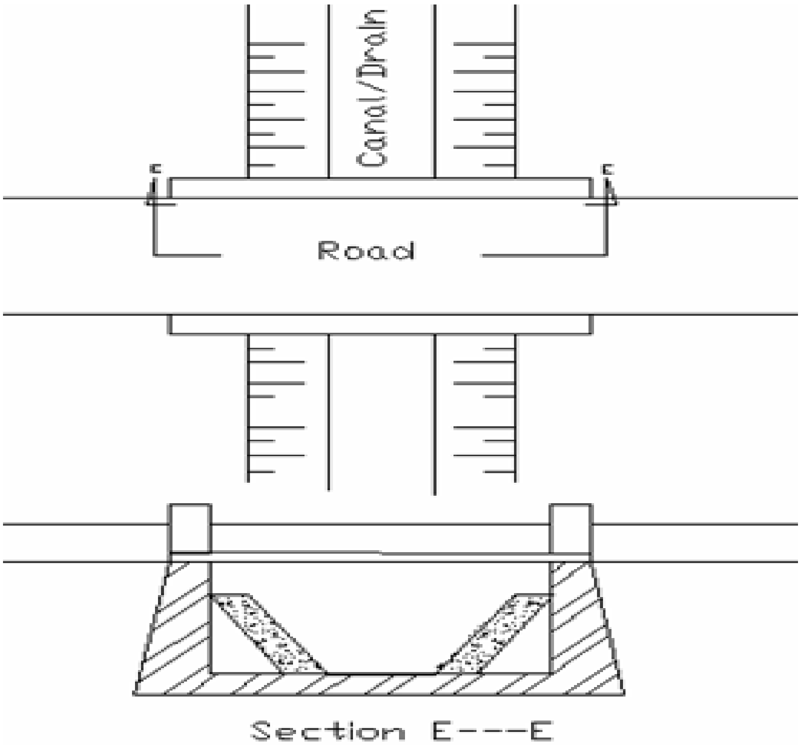


Figure 34: Canal section view

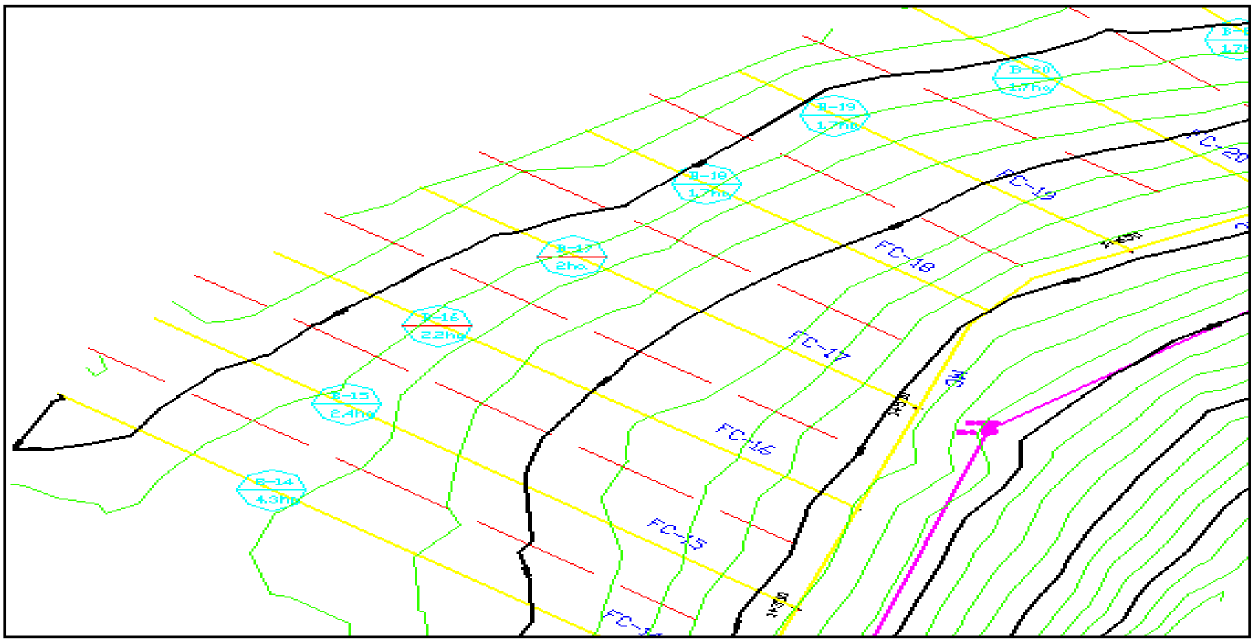


Figure 35: Simple layout system (Chacha Diversion Irrigation Project, Debre Berhan)

2.2.4 Vertical Canal Design

The vertical alignment is a compromise between the following conditions:

- the water level in supply canals should be sufficient high to irrigate the highest areas for which irrigation is envisaged;
- in drains the water level should be low enough to drain the lowest areas that area to be drain;
- maintenance costs should be as low as possible: they are lower when the water level in the canal is below the ground surface; it is then also more difficult to divert water illegally from supply canals; and
- a balance between cut and fill is economical for construction but canals in high fill are difficult to construct and would in general lose more water by seepage; this would certainly to be so when also the bottom of the canal is above the original ground surface: at least the bottom of the canal – but preferably the whole canal should be in cut after stripping 0.10 to 0.15m of the topsoil; seepage could also lead to slides and water logging problems in fields along the canal.

It is clear from the above that the water level and the ground surface elevation along the alignment are important parameters. Ground surface elevations are from the map or a survey along the proposed alignment of the canal.

Self-Check -2	Written Test

Directions: Choose the best answer for the following questions. Use the Answer sheet provided (2pts each).

1. In well-designed irrigation delivers system, one of the following is true.

A. Damage to the soil occur
B. Excessive loss of water
C. Accessible and easy to operate
D. Irrigation canal eroded

2. In order to avoid the eroded of earthen canal it is necessary to:
   A. Follow the contour where possible
   B. Select steep slope to avoid canal erosion
   C. Construct across the contour
   D. Stope the water flow in the canal
3. In the well design layout of water delivery system, one the following event is occurred.
   A. The excavation and earthen fill volumes be excessive
   B. Conveying and distributing water to key locations
   C. Settlement problems and possible structural failure
   D. Curves in canals should be to sharp
4. One of the following is true about irrigation canal layout.
   A. Non irrigated area between canals should be avoided
   B. Drains will be located in the upper parts of the area
   C. The command area will not be fully irrigated
   D. Canals always follow contours

***Note:* Satisfactory rating - 4 points Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3. 4.

Operation Sheet 1	Coordinating flow regulation, channel levels, security of flow devices and settings

Procedures for preparing irrigation canal layout:

1. Prepare materials for maintenance
2. Measure the elevations of the site
3. Prepare contour map of the site
4. Design the canal on the contour map
5. Prepare canal layout

LAP Test	Practical Demonstration

Name: _______________________________ Date: _________________

Time started: _________________________ Time finished: _________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 8 hours.

Task 1. Prepare irrigation canal layout

Instruction Sheet	Learning Guide 21: Compile reports and records of water Delivery

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Maintaining appropriate measurements and delivery records
- Compiling reports from system performance data

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Maintain appropriate measurements and delivery records according to organizational requirements.
- Compile reports from system performance data according to organizational requirements.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 1 to 6.
3. Read the information written in the information "Sheet 1and Sheet 2" in page 96 and 120 respectively.
4. Accomplish the "Self-check 1and Self- check 2" -" in page 119 and 129 respectively
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1" in page 130.
6. Do the "LAP test" in page 133.

Information Sheet-1	Maintaining appropriate measurements and delivery records

1.1 Units of Measuring Water

There are many ways to express water volume and flow. The volume of water applied is usually expressed in acre-inches or acre-feet for row crops or gallons per tree in orchards. Flow rate terminology is even more varied. Flow rate is expressed as cfs (cubic feet per second), gpm (gallons per minute) and in some areas, miner's-inches. Below is a description of each.

Acre-inch (ac-in.): An acre-inch is the volume of water required to cover an acre of land with one inch of water. One acre-inch equals about 3,630 cubic feet or 27,154 gallons.

Acre-foot (ac-ft): An acre-foot is the volume of water required to cover an acre of land with 1 foot of water. One acre-foot equals about 43,560 cubic feet, 325,848 gallons or 12 acre-inches.

Cubic feet per second (cfs): One cubic foot per second is equivalent to a stream of water in a ditch 1- foot wide and 1-foot deep flowing at a velocity of 1 foot per second. It is also equal to 450 gallons per minute, or 40 miner's-inches.

Gallons per minute (gpm): Gallons per minute is a measurement of the amount of water being pumped, or flowing within a ditch or coming out of a pipeline in one minute.

Miner's inches: Miner's-inches was a term founded in the old mining days. It is just another way of expressing flow. Some areas in the West still use this measurement unit. Caution needs to be taken because there are Arizona miner's-inches, California miner's-inches and probably some that are locally used. Approximately 40 Arizona miner's- inches equals 1 cfs or 450 gpm.

Pressure or Head (H): People often use the phrase "head of water." A foot of head usually implies that the water level is one foot above some measuring point. However, head can also mean pressure. For example, as the level of water rises in a barrel, the pressure at the bottom of the barrel increases. One foot of water exerts 0.43 pounds per square inch (psi) at the bottom of the barrel. Approximately 2.31 feet of water equals 1 psi. Thus, if a tank of water were to be raised 23.1 feet (2.31 x 10) in the air with a hose connected to it, the pressure in the hose at the ground would be about 10 psi.

Area: The cross-sectional area of a ditch is often required to calculate flow. Some ditches are trapezoids and others or more like ellipses. To find the area of a trapezoid (Figure 34), measure the width of the bottom (b) and the width of the ditch at the water surface (s) and add them together. Divide that number by 2 and then multiply by the height (h) of the water. If the ditch is more elliptical in shape (Figure 34b), take the depth of the water (h), multiply it by the width of the ditch at the surface (s), divide by 4 and then multiply by PI (3.14). To calculate the cross-sectional area of a pipe, the formula is PI x r2, where PI is 3.14 and "r" is the radius of the pipe. NOTE: All measurements should be in feet.

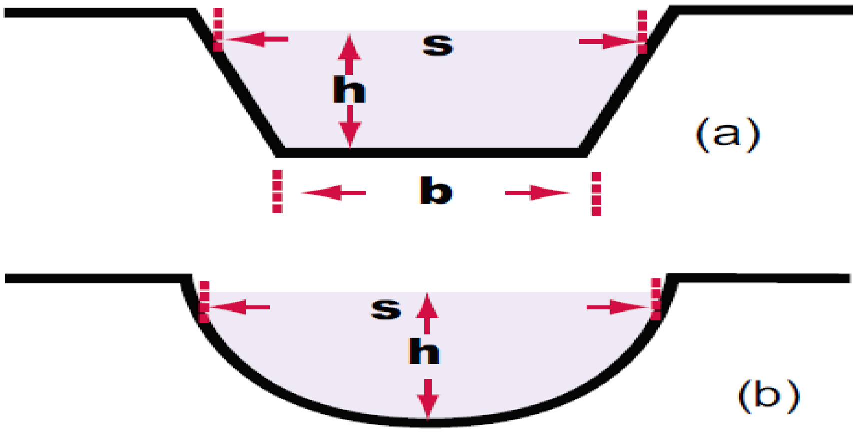


Figure 35: Cross-sectional dimensions for trapezoidal (a) and elliptical (b)ditches.

Table1. Coefficients to correct surface float velocities to mean channel velocities

Average Depth (ft)	Coefficient
1	0.66
2	0.68
3	0.70
4	0.72
5	0.74
6	0.76
9	0.77
12	0.78
15	0.79
20	0.80

1.2 Basic principles of water measurement

Knowing how much water is flowing in a ditch can help determine if there is enough water and when to turn it off. Rate of flow in an irrigation ditch is measured in cubic feet per second (cfs), corresponding to a cubic foot volume of water (1-foot wide, 1-foot high, and 1-foot long) passing a given point every second. This is equivalent to approximately:

- gallons per minute (gpm).
- 1 acre-inch per hour (1 inch of water covering 1 acre).
- acre-feet per day (24 hours) (2 feet of water covering 1 acre).

Open ditch flows are typically measured using a weir, flume, or a submerged orifice installed in a channel. Water flows over a notch (weir), through a channel (flume), or through a submerged hole (submerged orifice) of predetermined size, and a depth reading is taken. Flows are determined using a table or graph. Each has advantages and disadvantages and specific conditions in which it will operate correctly. Cost, ease of measurement, and maintenance are other considerations for determining which type is best.

Some general guidelines to obtain accurate results include:

- The ditch or canal must have a shallow grade with a relatively straight segment upstream and uniform cross-section with little turbulence.
- Weirs require more slope than flumes or submerged orifices.
- The location must not cause excessive sediment loading, debris build-up, or flooding of surrounding areas.

1.3 Measuring water flow in ditches

There are a number of good ways to measure the amount of water in a stream or a canal. What method of measurement you should use will depend on several factors?

- The accuracy of the result needed;
- The quantity of water present in the stream or canal you will measure;
- The equipment you have available to use.

1.3.1 Quick rough estimate

This is a very simple method to measure approximate water flow in very small streams. You do not need any special equipment for this estimate.

Drop a leaf in the water flow of the stream you want to measure. Walk in the direction the leaf is floating at a normal pace for about 30 meters or 35 paces. See how far the leaf floats during the time you are walking and estimate the water flow as shown in the examples.

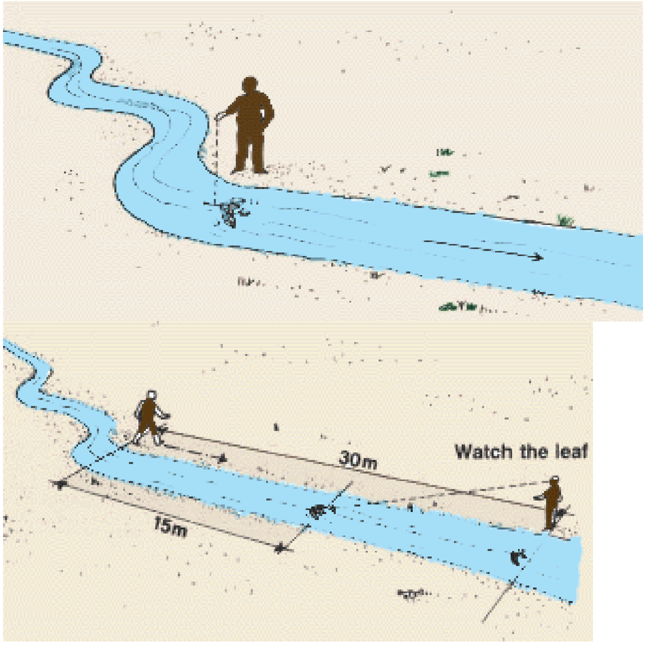
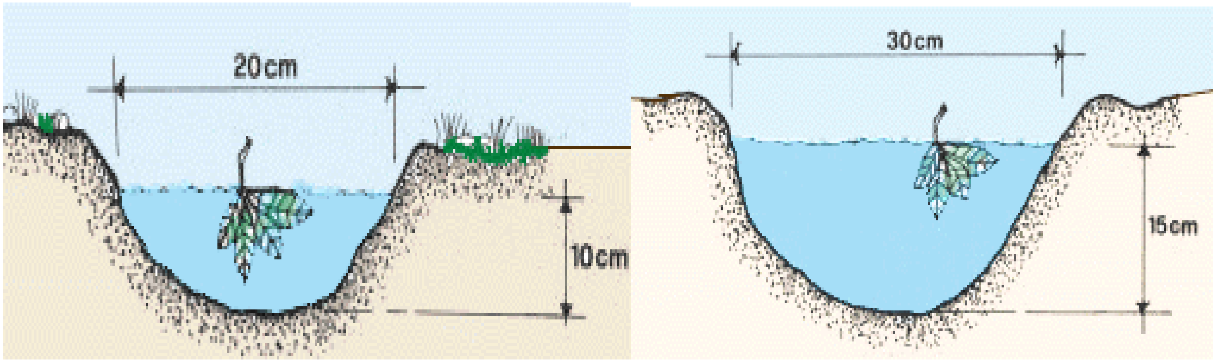
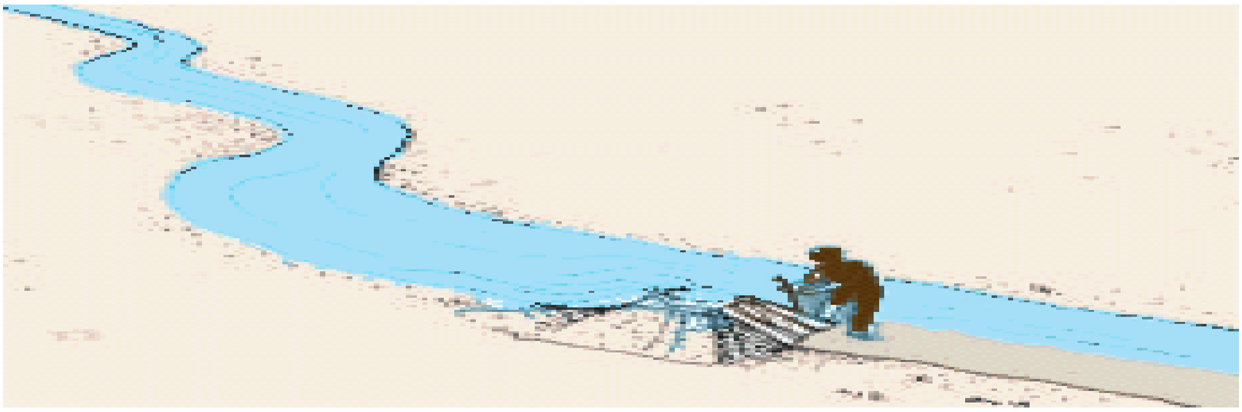


Figure 35: Quick rough measurment

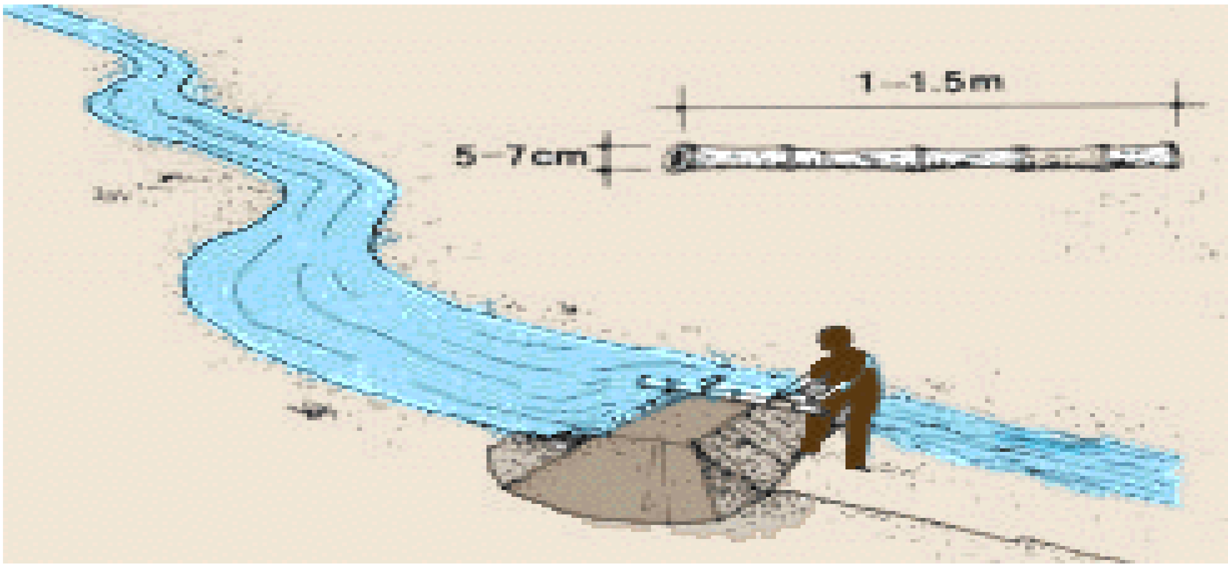


1.3.2 Bucket method

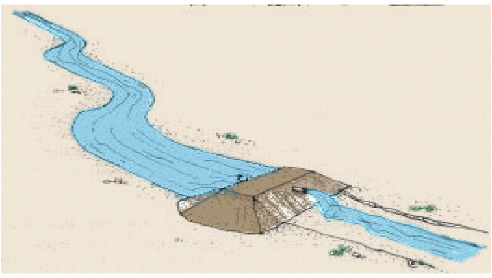
This is a simple method for measuring a very small flow of less than 5 l/s with very high accuracy.

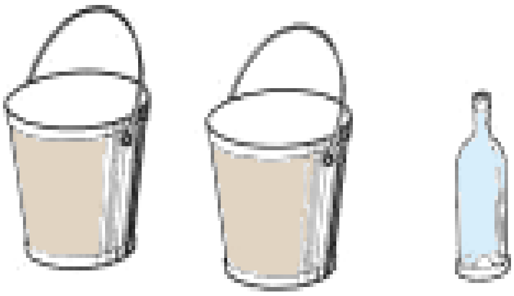


Begin to build a small dam of earth across the stream to stop the flow. You can use wood poles, bamboo or tree branches to hold the earth in place while you build the dam.

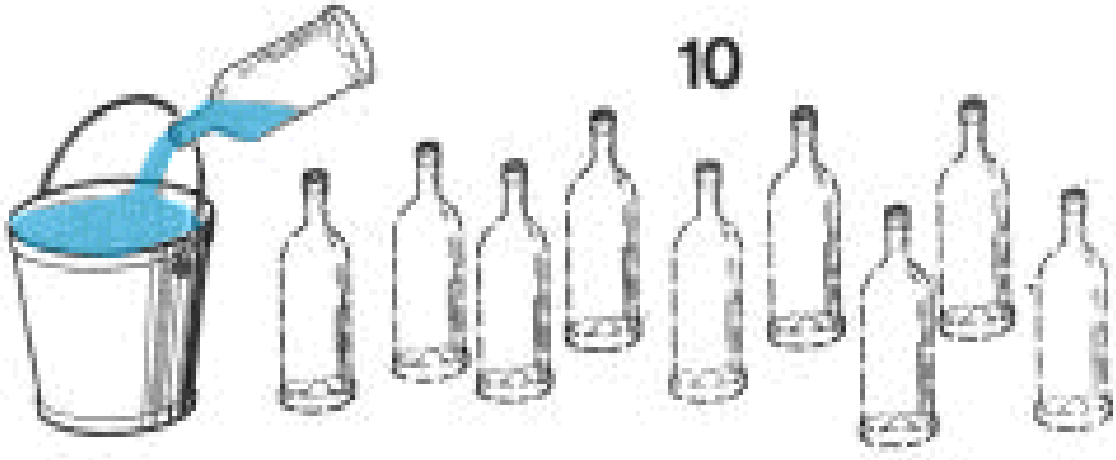


When the dam is about half built, put in a pipe about 5-7 cm in diameter and about 1-1.5 m long. This pipe can be made of bamboo. Finish building the dam across the stream so that all the water flow passes through the pipe. Find at least two buckets or other, similar containers which you can use to catch the water flowing through the pipe. You will also need a bottle or other, smaller 1-litre container.





Using the 1-litre container, count the number of liters needed to fill the buckets with water, in order to find how much each bucket will hold.Example You need 10 1-litre containers to fill a bucket, so it holds 10 litres.



Using one bucket after the other, catch all the water flowing through the pipe for 1 minute (60 seconds). Count how many buckets you can fill during that time. Calculate the total water flow (in l/s).

1.3.3 Float method

This is a method for measuring small to large water flow with medium accuracy. This method is best used in streams with calm water and during periods of good weather for if there is too much wind and the surface of the water is rough the float may not travel at the normal speed.

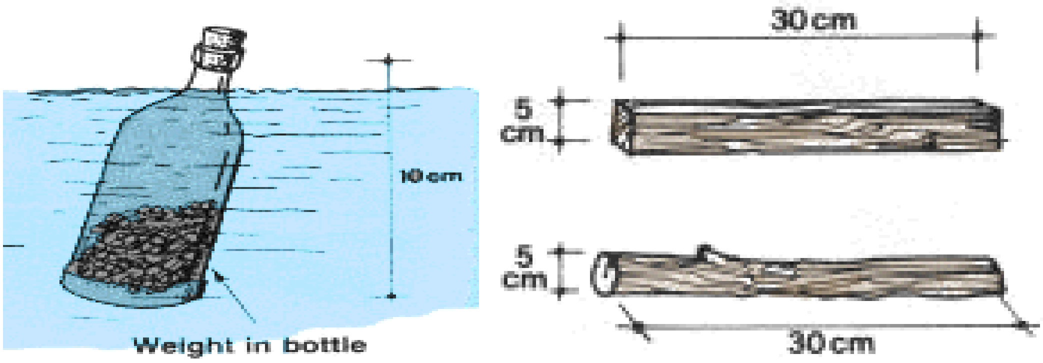
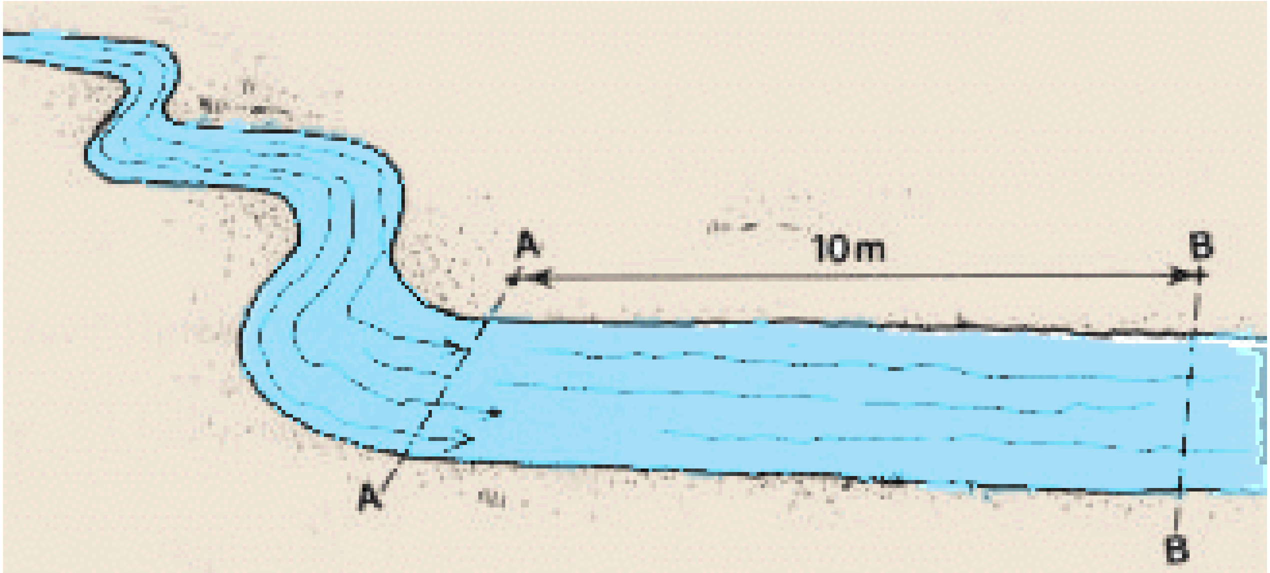


Figure 36: Float measurement equipment

Prepare a float: A good float may be a piece of wood or a smooth tree branch about 30 cm long and 5 cm wide or a small well- capped bottle 10 cm tall, containing enough matter (such as water, soil or pebbles) so that, when it floats in the stream, the top of the bottle is just above the surface.



Where to measure:Find and mark a length AA to BB along the stream, which is straight for a distance of at least 10 meters. Try to find a place where the water is calm and free from water plants so the float will flow easily and smoothly.

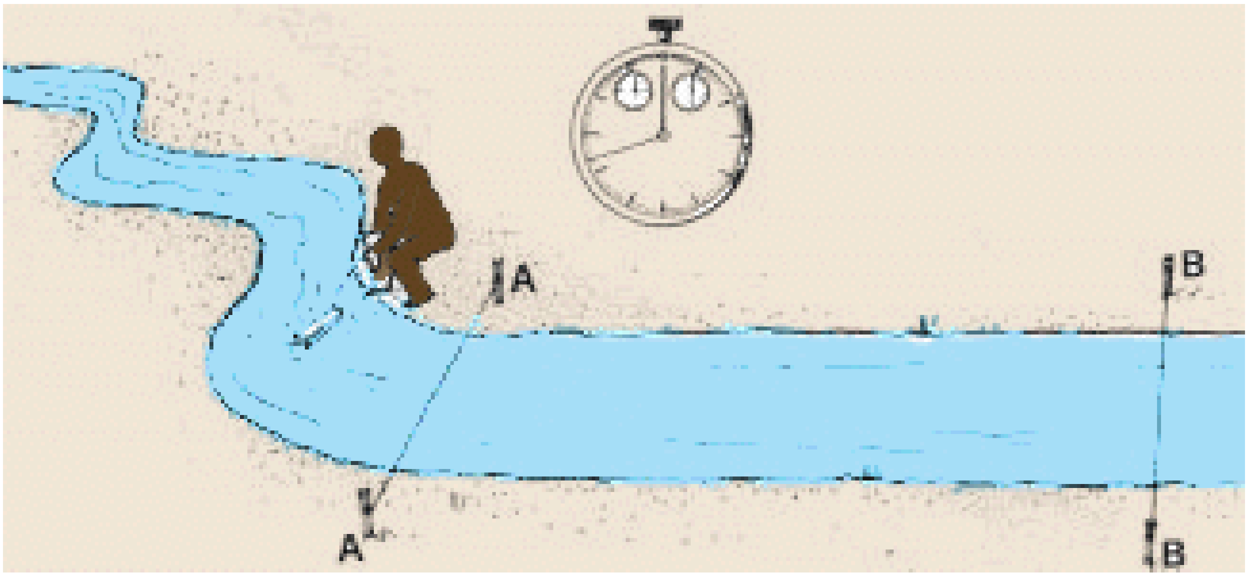


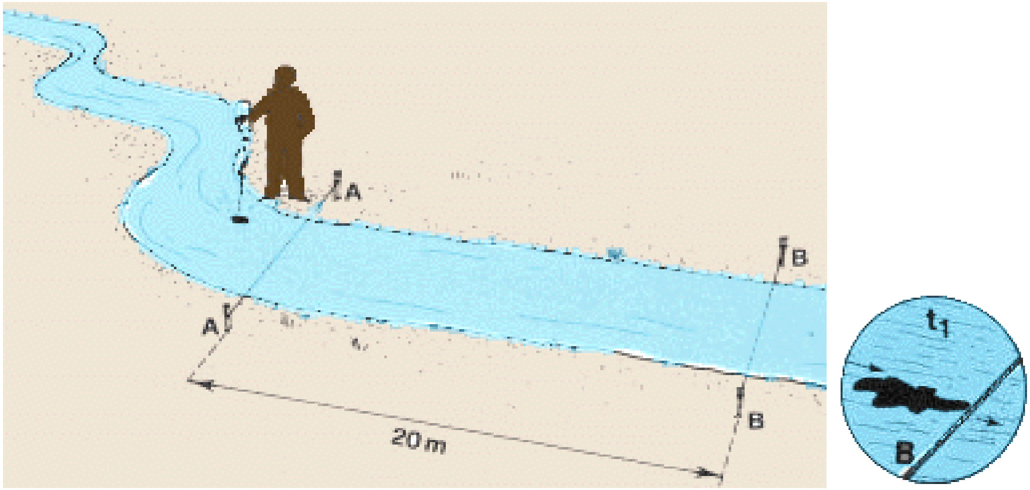
Figure 36: Floating measurement methods

Find the average water velocity: Ask a friend to place the float in the middle of the stream, a few meters upstream from line AA, and to release it gently into the current. Stand at line BB and using a watch, measure exactly the time (in seconds) it takes the float to travel the distance from AA to BB. Repeat this measurement three times. Place the float in the water and note how long it takes to travel the distance from AA to BB three different times.

Note: if one of the three measurements is greatly different from the other two, take a fourth measurement and use this one.

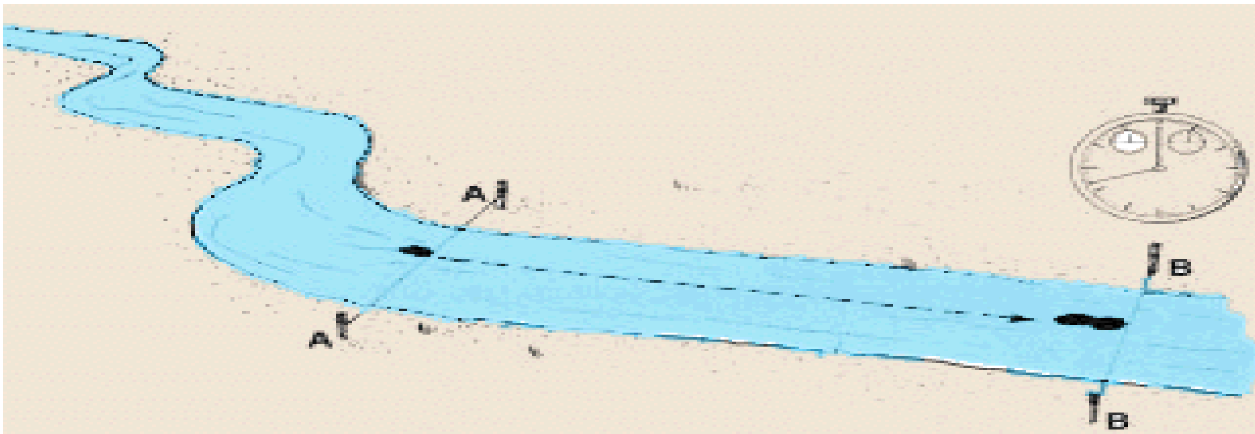
1.3.4 Dye stain and cross-section method

This is a method for measuring small and large water flow with medium accuracy. In this method, water-staining dye is used instead of a float to measure the water flow. Measure the time (t1, in seconds) it takes for the front of the dye stain to reach line BB.

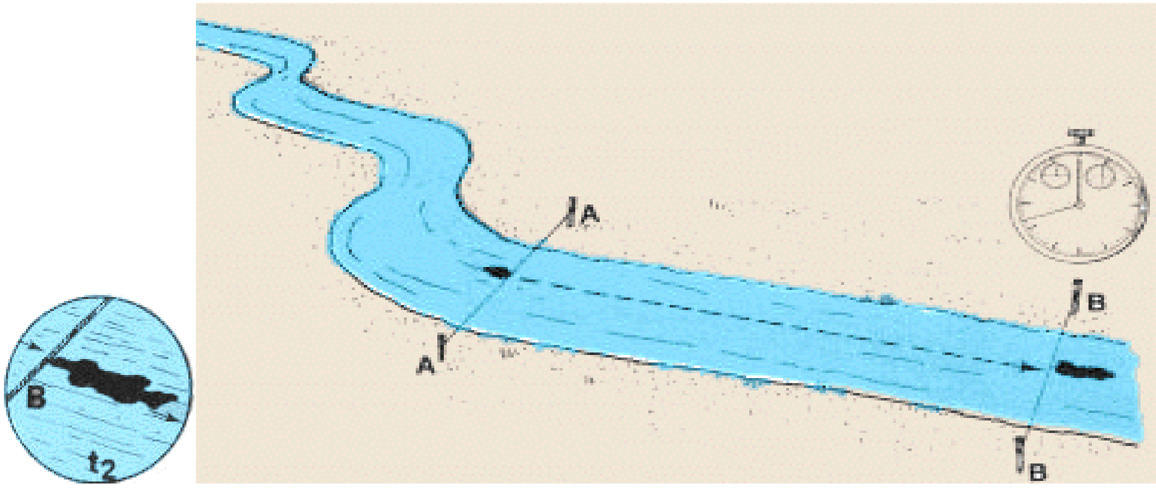


Drop a small amount of dye in the middle of the stream a little above line AA. This will form a dye stain in the water.

Note: potassium permanganate and fluorescein are suitable dye solutions that may be available from chemical suppliers.



Measure the time (t2, in seconds) it takes for the end of the dye stain to reach line BB.



Calculate the average time it takes the front and back of the dye stain to reach line BB by adding t1 and t2 and dividing the result by 2.

1.3.5 Weirs Method

Weirs are simplest to install and use. They can provide very accurate flow measurements when properly designed, installed, and maintained. There are square, trapezoidal, and v-notch weirs, with the v-notch being especially good at handling a wide range of flows. Flow is measured using a staff gauge placed in the channel far enough above the structure so it is unaffected by the curve of the water over the weir. The depth of the water is measured where the water surface touches the gauge.

Weirs do have limitations. They require enough ditch slope so water can flow freely over the structure to the downstream water surface, and a pool, or stilling area, above to slow water velocity. Both can be an issue with silt-laden water or in an earthen ditch, as the pool may silt up and the drop may cause excessive erosion below the weir.

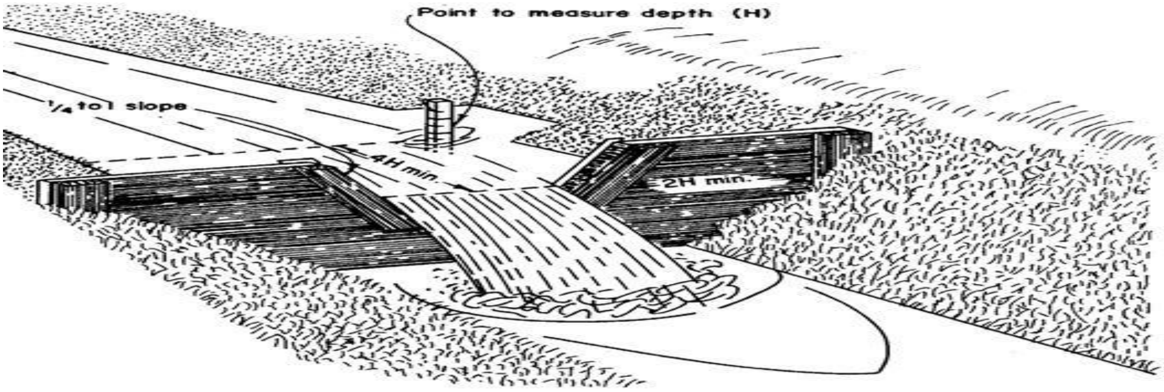


Figure 37: Cipolletti weir

A weir is an obstruction placed across a stream that forces all the water to flow through a notch in the weir. There are weirs of many types and designs. In this section we will discuss two types, the triangular weir and the rectangular weir.

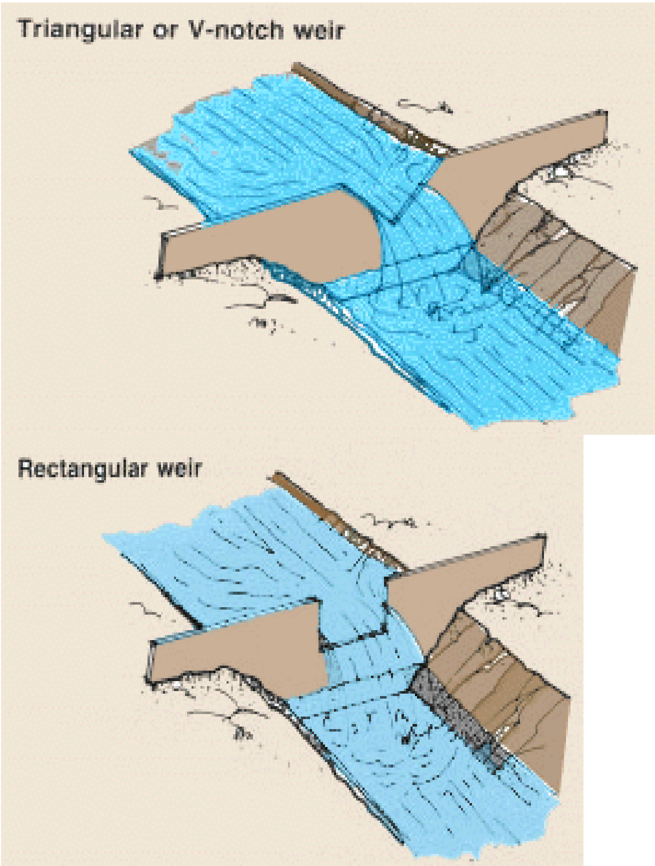


Figure 38: Types of weirs

In both the triangular and the rectangular weir, the notch used has sharp edges so the water flowing over the weir will touch only a fine line and the notch width is smaller than the stream width (contracted weir).

When a weir is in place across the stream it raises the upstream water level. To be efficient, a weir should create a sufficient vertical drop between the notch bottom and the downstream water surface. In such a case, the water will fall free, and air can circulate beneath the water as it overflows.

The crest of a weir is the bottom edge of the weir notch. In a rectangular weir the crest length is the width of the notch. In a triangular (or V-notch) weir the crest length is zero.

The head of the weir is the vertical distance from the weir crest to the undisturbed upstream water surface.

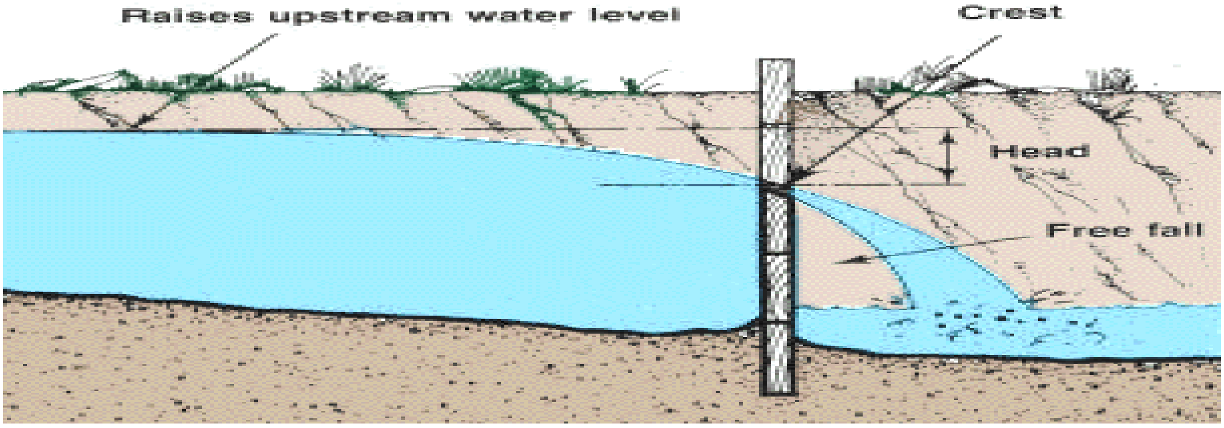


Figure 39: Components of weir

Weirs have advantages and disadvantages

Advantages:

- They allow for easy and accurate flow measurement;
- They are easy to build and require only little maintenance; small, floating debris will easily pass through the notch;
- They are durable.

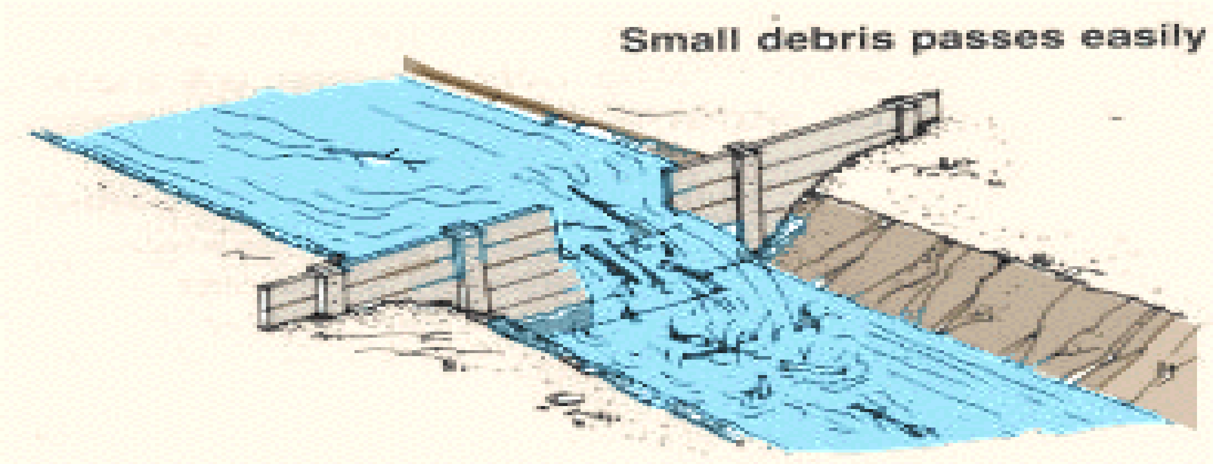


Figure 40: Debris passes through weirs

Disadvantages**:**

- They require considerable head-loss for proper operation;
- Large pieces of floating debris can become caught in the notch and change the water flow;
- Changes in flow can occur, for example, if debris becomes caught in the weir, silt builds up behind the weir, etc.

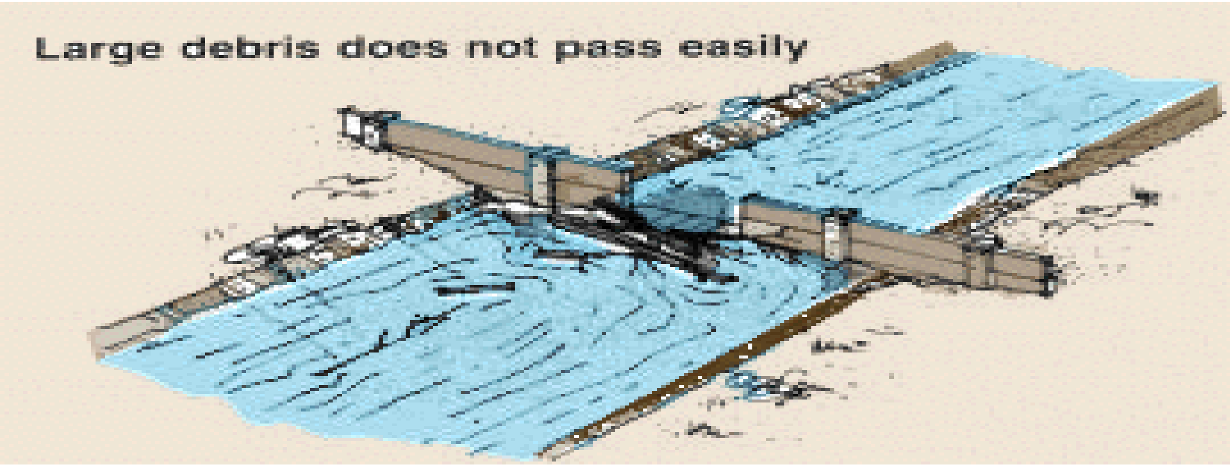


Figure 41: Large debris blocks the weirs

For accurate measurement it is essential that your weir:

- Be built at a right angle (90°) to the direction of the water flow;
- Be placed exactly vertical at a 90° angle to the surface of the water.

A weir is used to determine water flow by measuring the head, or the difference between the level of the crest of the weir and the water level upstream from the weir. The level of the water actually passing over the crest of the weir will not be as high as the water level upstream because, as water flows closer to the weir, the level begins to drop before it flows over the crest.

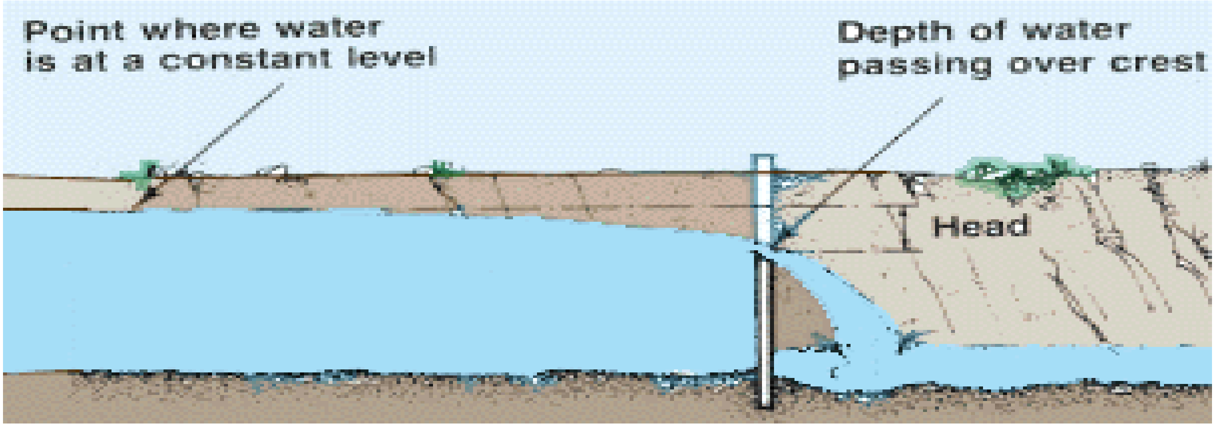


Figure 42: Weirs used to determine water flow

To measure the head, or the constant upstream water level equivalent at the weir, you will have to transfer a point equal to the crest height at the weir to another point upstream where the water level will be constant.

1.3.6 Flumes Methods

Parshall flumes are the most common type of structure used and can provide very accurate flow measurements. They have a channel of predetermined shape and size. Flumes can provide accurate measurement with less drop needed between the upstream and downstream water surface than weirs. Other advantages include:

- Can carry sand/silt through the flume (so less opportunity for build-up) with no effect on accuracy.
- Requires about one-fourth the loss of head (see description below*) compared to a weir, meaning the water won't be slowed as much.
- Can obtain accurate measurements with varying water velocity or flow rates. Wide range of capacity: a flume with a 1-foot throat will measure from 1/3 cfs to 10 cfs.
- Can be made from wood, metal, or concrete, but they must be fabricated to precise dimensions and properly installed to measure irrigation water accurately.

The trapezoidal flume is another style. This structure can be easy to install, as its shape conforms well to the shape of the ditch. Other advantages include:

- Water is not slowed as much, which results in very little backwater and less scouring of the earthen ditch around the structure.
- Does not clog easily.
- Flume will operate under greater submergence (when the downstream water level is high enough to inhibit free flow through the channel) without having to make necessary corrections to determine actual discharge.

A disadvantage is a small change in head (*difference in elevation between the water above the orifice and the water below the orifice), or reading on the measuring gauge, can cause drastic changes to flow measurements.Accurate depth readings are critical to obtain accurate flow measurements. A flume should be in a straight section of the ditch where flow is unimpeded in its approach to the structure. Flow should be smooth with no turbulence. The measuring device is mounted to the side of the flume, at the top and bottom of the structure.

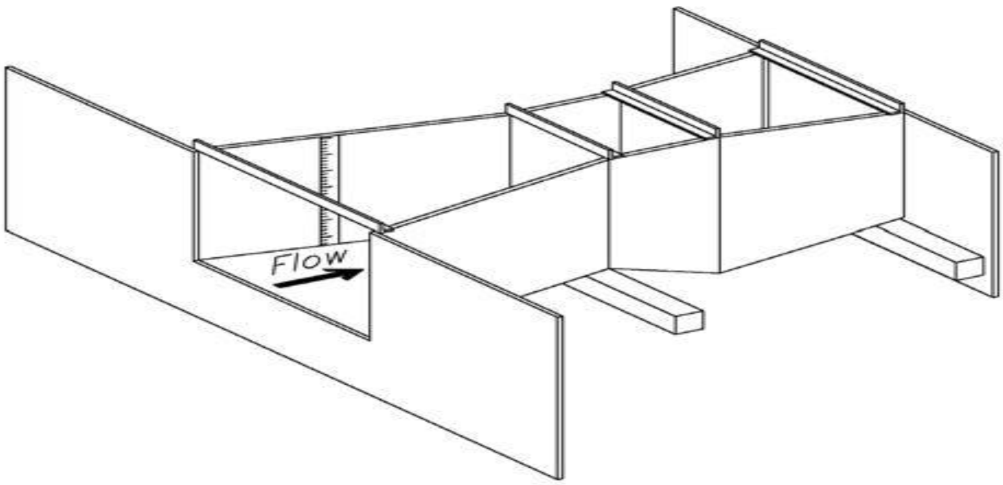


Figure 43: Parshall flume

Figure 44: Parshall flume in action

1.3.7 Submerged orifice

A submerged orifice measures water flowing through an opening of predetermined size. The opening must be fully submerged to be an accurate measure of water flow in the ditch. This works well with very little change in head, or in flat ditches. The essential components of a submerged orifice include:

- A smooth, vertical face of sufficient size.
- An orifice with smooth, sharp edges and of accurate dimensions.
- A provision for measuring the head.

To measure head, two stakes are set, with the tops at the same elevation one above the orifice, one below. Measurements are made from the top of each stake to the water surface. Stakes should be placed where the water is calm. The head, in feet, is then compared to an appropriate chart for that orifice to determine flow.

Submerged orifices typically cost less than weirs and can fit into smaller spaces. A meter gate, a type of submerged orifice, can be used to let water from a main ditch into a field, as the gate can be opened/closed or partially opened to set a specific flow.

A disadvantage of the submerged orifice is the potential for clogging if water is carrying lots of silt or debris.Most irrigation systems work most efficiently when run at correct capacity. Accurately measuring water flowing to the field can assure maximum efficiency and help determine how long to run an irrigation set, if you are meeting crop water needs, or if there is a leak or other issue. Ensure all structures are installed and maintained properly, including cleaning out any debris build-up each spring. Take time to learn accurate management and measurement techniques for any structures in use.

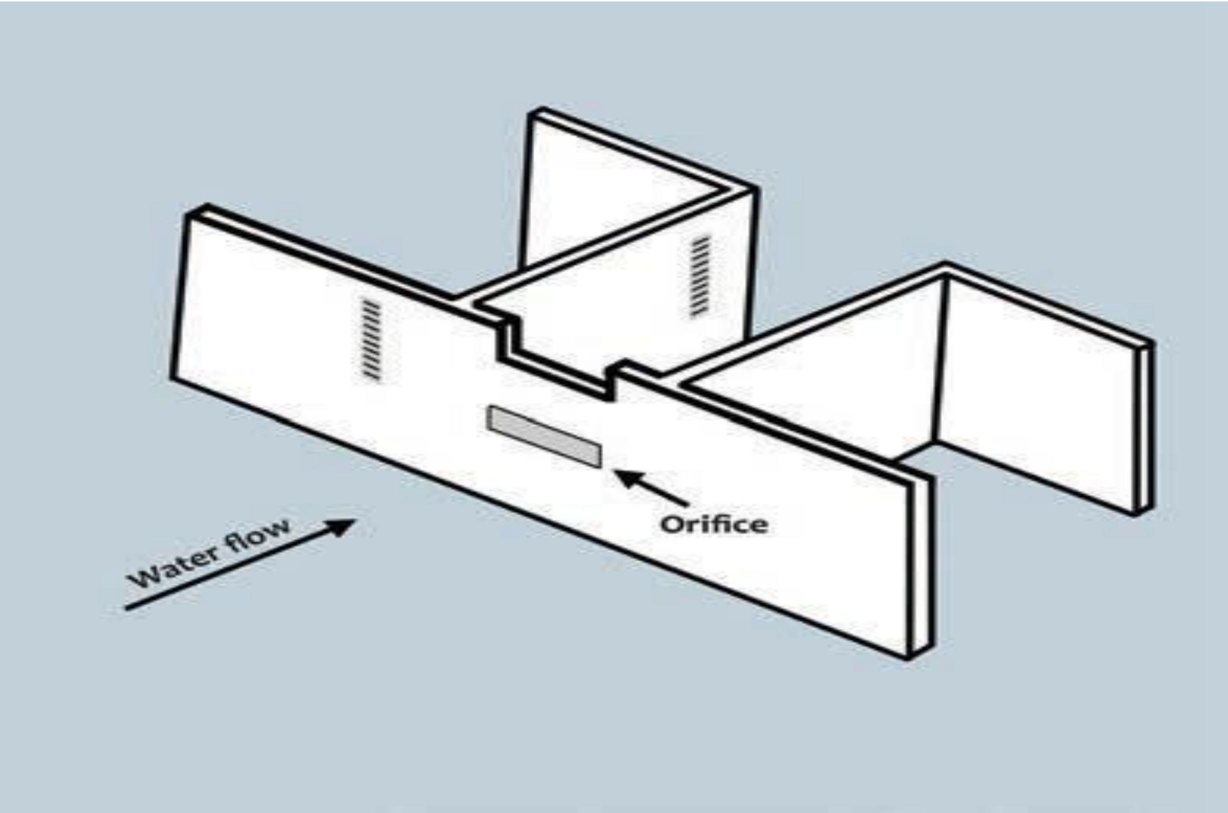


Figure 46: Submerged orifice

The equation for calculating flow through an orifice is:

$$Q = K\sqrt{H}$$

Where

Q = flow in gallons per minute.

K = a constant dependent upon a combination of pipe size,

orifice size and orifice shape, and discharge conditions.

H = Head in inches.

Measuring irrigation flow contributes to better management and scheduling of irrigation events, thus improving profitability. Such measurements are needed to evaluate the performance of an irrigation pumping plant. Irrigation flow measurements also are a tool for quantifying irrigation water use and are useful in evaluating the effects of management changes or conservation measures. This publication will help irrigators learn to select, install and use irrigation flow meters, as well as estimate flow manually using simple hydraulic formulas. In almost all cases, for flow meters to be accurate, pipes must be full of water (full pipe flow).

Measuring water in surface irrigation systems is critical for peak efficiency management. Without knowing the amount of water being applied, it is difficult to make decisions on when to stop irrigating or when to irrigate next. A good irrigation manager should know the flow rate of the irrigation water, the total time of the irrigation event and the acreage irrigated. From this, the total amount of water applied can be determined, which will help determine whether the irrigation was adequate and when the next irrigation should be. Irrigation management decisions should be made based on the amount of water applied and how this relates to the consumptive use demands of the plants and the soil water holding capacity.

1.3.8 Velocity head rod method

The velocity head rod is used to measure the velocity of water in a ditch and is relatively inexpensive and fairly accurate. The rod is in actuality a ruler used to measure the depth of the water. The water height is first measured with the sharp edge of the ruler parallel with the flow and the again with the ruler turned 90 degrees (Figure 47). The difference in the height of water is the head differential and using Table 2, an estimate of the velocity (feet per second) can be made. From there, follow the same formula as with the float or tracer method, i.e., multiply the velocity by the cross-sectional area of the ditch to get cubic feet per second. The velocity head rod method works only for velocities greater than 1.5 ft/sec and less than about 10 ft/sec.
The procedure is:

- Place the rod with the sharp edge upstream. Record the depth of the water (normal depth).
- Place the rod sideways. This will cause some turbulence and the water level will "jump" causing the water level to rise. Record the level again (turbulent depth).
- Subtract the normal depth from the turbulent depth and this will be the jump height.
- Find the corresponding velocity from Table 2.
- Multiply the velocity by the cross-sectional area of the ditch to get the flow rate (cfs).

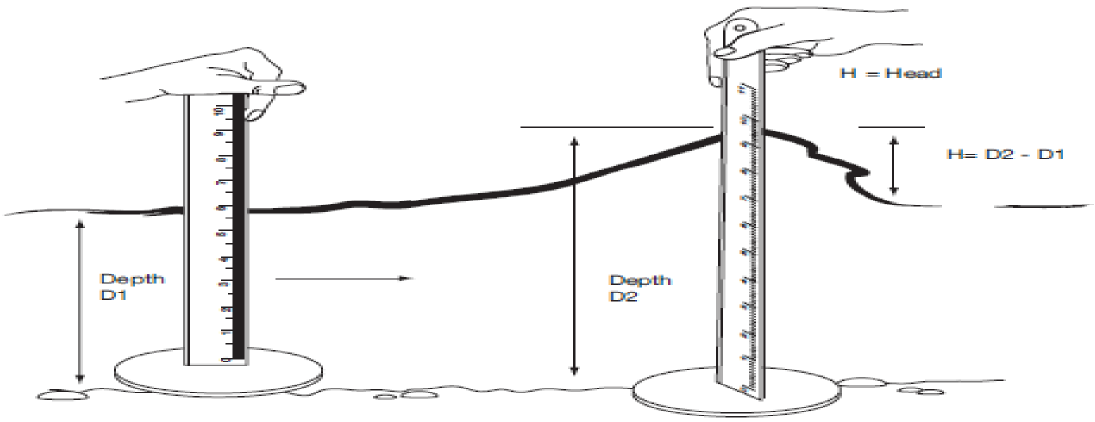


Figure 47: Velocity rod measurement

1.3.9 Counting Tubes

If siphon tubes are used to irrigate out of an open ditch, an estimate of the flow rate can be obtained by counting the number of tubes. The size of the siphon tube and the distance from the water level in the ditch to the water level in the field (the drop) is needed to estimate the flow rate. Figure 48 shows two possible conditions. In condition I (free flowing) the drop is the distance from the water level in the ditch to the end of the tube on the field side (usually level with the field). In Condition II (submerged), the drop is the distance from the water level in the ditch to the water level in the field. The larger the tube size or the greater the drop, the higher the flow rate. Table 3 shows some typical sizes and drops used for irrigation.

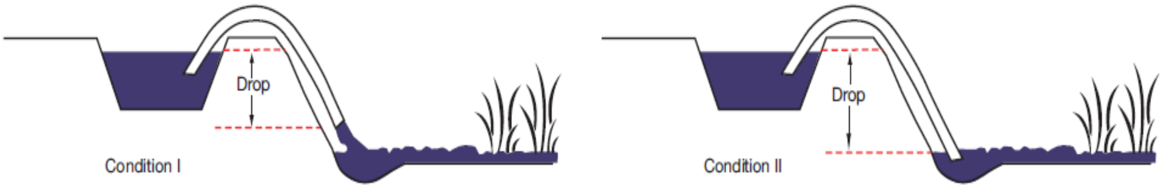


Figure 48: Measure the drop distance for siphon tube

Table 3 Approximate flow rate in gallons per minute for siphon tubes

Pipe Size (in.)	Flow Rate (gallons per minute)				
	Drop (in.)	4"	6"	8"	10"
¾"		3.6	4.4	5.0	5.6
1"		6.4	7.9	9.0	10.0
1 ¼"		10.4	12.7	14.6	16.2
1 ½"		14.3	17.5	20.2	22.5
2"		25.6	31.8	35.9	40.0
3"		57.2	70.0	80.8	90.0

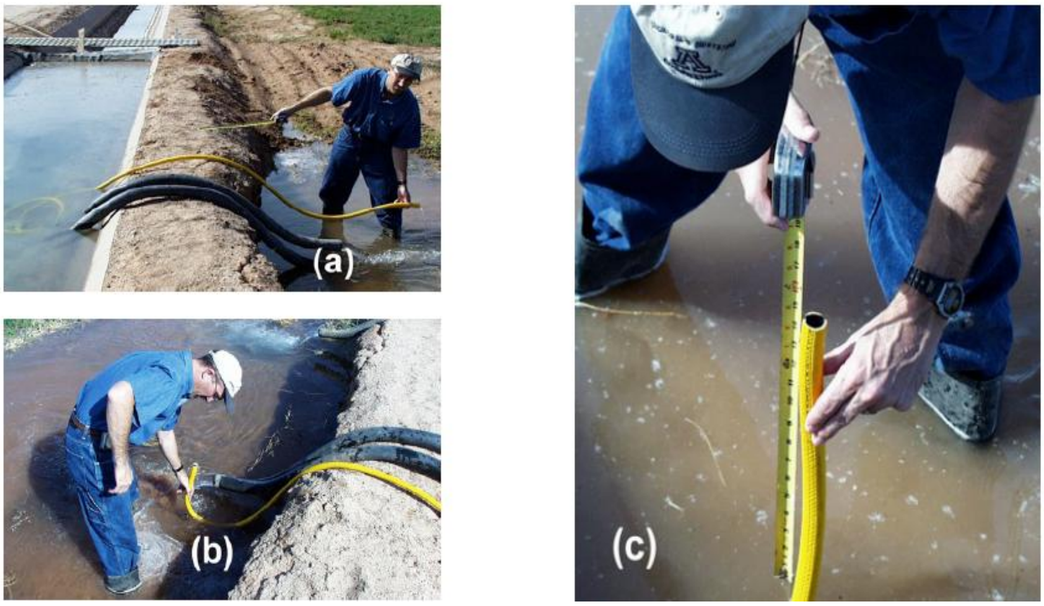


Figure 49: Demonstrating how to measure the ‘’drop’’ in a surface system (a) Use the hose to siphon water out of the ditch; (b) Raise the hose up until water stops flowing out of the hose end; (c) Measure the distance between the end of the hose and the water level in the field.

It is often difficult to measure the difference in water levels between the ditch and the field. One easy way is to do this is to get a piece of hose and a tape measure. Put the hose in the ditch and use it to siphon water into the field. Next, slowly raise the hose in the field until the water stops coming out. Now, use your measuring tape to measure the distance between the end of the hose and the water level in the field or the outlet of an irrigation siphon tube .

Make sure to keep the end up just at the level where the water stops coming out. This distance is your drop.

1.3.10 Measuring flow in gated pipe

Measuring water flow in gated pipe can be accomplished many different ways. Probably the most commonly used method is the propeller meter. These meters are normally installed inside a section of pipe at the distributor's shop.The buyer then simply buys a meter section for whatever diameter pipe used. There are some other methods that can be used but for convenience and ease of measurement, the propeller is a simple and accurate method.

Table 4. Typical range of flows for different size propeller meters

Meter size (inches)	Minimum flow (gpm)	Maximun flow (gpm)
4	50	400
6	90	900
8	100	1200
10	125	1500
12	150	2000


Figure 50: Measuring the head (ft)in a gated pipe system.

Table 5. Approximate flow capacities in gallons per minute (gpm) for some commercially available gates.

Head (ft)	Flow Capacities (gpm)			
	Rite-Flow™	Epp™ Snap-Top Boot Gate	Epp™ Fly Gate	Tex-Flow™ Yellow Top
0.25 (4")	11	12	15	22
0.50 (6")	16	17	21	32
1.00	22	24	30	46
2.00	32	35	42	67
3.00	39	42	52	82

Propeller meters are permanent pipeline devices that measure and record the volume and flow of water moving through a pipe. The pipe must be running at full flow for the meters to operate properly. Also, there must be a straight length of pipe upstream from the meter at least 10 times the diameter of the pipe. This is to reduce the turbulence in the water as it enters the meter section. The meters are usually placed inside a length of aluminium pipe that is inserted into the gated pipe system. If poly-type plastic pipe is being used, there are connectors that will allow a meter section to be put in place. If you don’t want to pay the expense for the meter, you can use a piece of tubing, similar to the tube method for ditches.

Find a piece of tubing (preferably clear) that either fits tight inside a gate or even better, can be attached tightly to the outside of the gate. Raise the tubing into the air until the water stops flowing out. Measure the distance from the water level in the tubing to the centre of the gated pipe. If clear tubing is used, then you can raise the tube well above the point when the water stops coming out and it makes for an easier measurement. Most manufacturers should be able to supply this information.

1.3.11 Current meter method

In the area velocity method current meters are generally used to measure the velocity of flow at the different sections. The current meter consists of a small revolving wheel or vane that is turned by the movement of water. It may be suspended by a cable for measurements in deep streams or attached to a rod in shallow streams. The propeller is rotated by the flowing water and speed of propeller is proportional to the average velocity of flow. Corresponding to the number of revolutions, the velocity can obtain from calibration graphs or tables.

Figure 51: Current meter.

Procedure for velocity measurement using the current meter: Stretch a tape across the channel cross-section. Divide the distance across the channel to at least 25 divisions. Use closer intervals for the deeper parts of the channel.

- Stretch a tape across the channel cross-section. Divide the distance across the channel to at least 25 divisions. Use closer intervals for the deeper parts of the channel.
- Start at the water's edge and call out the distance first, then the depth and then the velocity. Stand downstream from the current meter in a position such that the velocity is least affected by the meter. Hold the rod in a vertical position with the meter directly into the water.
- To take a reading, the meter must be completely under water, facing the current, and free of interference. The meter may be adjusted slightly up or downstream to avoid boulders, snags and other obstructions. The note taker will call out the calculated interval, which the meter operator may decide to change (e.g., taking readings at closer intervals in deep, high-velocity parts of the channel). Record the actual distance called out by the meter operator as the center line for the subsection.
    - ✓ Take one or two velocity measurements at each subsection.

- ✓ If depth (d) is less than 60 cm, measure velocity once for each subsection at 0.6 times the total depth (d) measured from the water surface.
- ✓ If depth (d) is greater than 60 cm, measure velocity twice, at 0.2 and 0.8 times the total depth. The average of these two readings is the velocity for the subsection.

- Allow a minimum of 40 seconds for each reading. The operator calls out the distance, then the depth, and then the velocity. The note taker repeats it back as it is recorded, as a check.
- Calculate discharge in the field. If any section has more than 5% of the total flow, subdivide that section and make more measurements.

Current meters are designed in a manner such that the rotation speed of the blades varies linearly with the stream velocity. This can be expressed by the following equation:

$$v = a N_s + b \qquad (1.1)$$

Where,

v = stream velocity at measuring site in m/s

N_s = revolutions per second of the meter

a, b = constants of the meter.

To determine the constants, which are different for each instrument, the current meter has to be calibrated before use. This is done by towing the instrument in a tank at a known velocity and recording the number of revolutions N_s. This procedure is repeated for a range of velocities.

It has to be kept in mind that for shallow streams the measurement can be taken at a depth= 0.6 of the total depth, whereas for deeper streams two measurements are needed at 0.2 and 0.8 of total depth and then averaged to get the actual velocity.

Example:

Data pertaining to a stream-gauging operation at a gauging site are given below. The rating equation of the current meter is $v = 0.63N_s + 0.08$m/s. where N_s = revolutions per second. Calculate the discharge in the stream.

Distance from the left water edge (m)	0	5.0	8.0	11.0	14.0	17.0	20.0	24.0

Depth (m)	0	1.8	3.4	4.6	3.7	2.6	1.5	0
Revolutions of a current meter kept at 0.6 depth	0	42	55	93	87	48	28	0
Duration of observation (s)	0	120	120	125	135	110	100	0

Solution:

$$\bar{W} = \frac{\left(W_1 + \frac{W_2}{2}\right)^2}{2W_1}$$

For the last and first section using equation

Average width, $= \frac{\left(5 + \frac{3}{2}\right)^2}{2\ X\ 5} = 4.225\ \text{m}$

For the rest of the segments,

$$\bar{W} = \left(\frac{W_i}{2} + \frac{W_{i+1}}{2}\right) = \left(\frac{3}{2} + \frac{3}{2}\right) = 3.0\ \text{m}$$

Since the velocity is measured at 0.6 depth the measured velocity is the average velocity at that vertical

The calculation of discharge is shown below:

Distance from the left water edge (m)	**Average width (m)**	**Depth *y* (m)**	**N_s = rev. /sec**	**Velocity (m/s)**	**Segmental discharge (m^3/s)**
0	0	0			0.0000
5	4.225	1.8	0.350	0.3005	2.2853
8	3	3.4	0.458	0.3688	3.7613
11	3	4.6	0.744	0.5487	7.5723
14	3	3.7	0.644	0.4860	5.3946
17	3	2.6	0.436	0.3549	2.7683
20	4.225	1.5	0.280	0.2564	1.6249
24	0	0			0.0000
				Sum	= 23.4067

∴ Discharge in the stream = 23.40 m^3/s **Ans**

Self-Check -1	Written Test

Directions: Choose the best answer for the following questions. Use the Answer sheet provided (2pts each).

1. Which method is very accurate flow measurements when properly designed, installed, and maintained?

A. Bucket method
B. Weirs Method
C. Float method
D. Quick rough estimate method

2. One of the following is a disadvantage of the submerged orifice.

A. A smooth, vertical face
B. Measurements are made from the top
C. Potential for clogging
D. Can fit into smaller spaces

3. Which one of the following is the limitation of weir measurement method?

A. Require enough ditch slope
B. Flow is measured using a staff
C. Simplest to install and use
D. A staff gauge placed in the channel

4. One of the following is the disadvantage of flume measurement.

A. Can carry sand/silt through the flume
B. Requires about one-fourth the loss of head
C. A small change in head
D. Water is not slowed as much

Note: **Satisfactory rating - 4 points Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Answers

1. 2. 3. 4.

Information Sheet-2	Compiling reports from system performance data

2.1 Water recording

Records of stage are important in stream gaging because the rate of flow is plotted against stage in preparing discharge curves. After a curve has been established for a stable channel, rate of flow can be directly determined from stage reading. Reliability of the stage reading is, therefore, of great importance. Head measurements in all types of water measurement structures, including various flumes, weirs, and gates, are equally important.

Records of gage height may be obtained from a series of systematic readings on nonrecording gages or from automatic water-stage recorders. Laser, satellite, microwave, and electronic systems can be used to transmit gage readings from either nonrecording or recording gageslevel from some other characteristic, such as the head read by a pressuretransducer.

2.1.1 Nonrecording Gages

Two general types of nonrecording gages are in use:

- staff gages, on which readings of stage are made directly; and
- chain, wire weight, float-type, and hook gages, with which measurements are made from fixed points.

Staff gages may be either vertical or inclined. The inclined type should be carefully graduated and accurately installed to ensure correct stage readings. Most permanent gages are enameled steel plates bolted in sections to the staff. Care should be taken to install the gages solidly to prevent errors caused by changes in elevation of the supporting structure.

A chain gage is a substitute for the staff gage and consists of a horizontal scale and a chain that passes over a pulley to attach to a hanging weight (figure 51). Chain gages may be mounted on a bridge that spans (or any other structure that overhangs far enough) over the stream. Water stage is indicated by raising or lower the weight until it just touches the water surface and reading the position of the chain index mark on the horizontal scale.

2.1.2 Recording Gages

Water-stage recorders consist of a group of instruments that produce a record of water surface elevation with respect to time. The output can be analog (providing a graphical result) or digital(punched paper tape or stored or transmitted values). Important advantages of recorders overnon recording staff gages are:

- In streams having daily fluctuations, continuous records provide the most accurate means of determining the daily average gage height.
- Maximum and minimum stage are recorded, and the time they occurred can be noted.
- Records can be obtained at stations where observers are not always available.

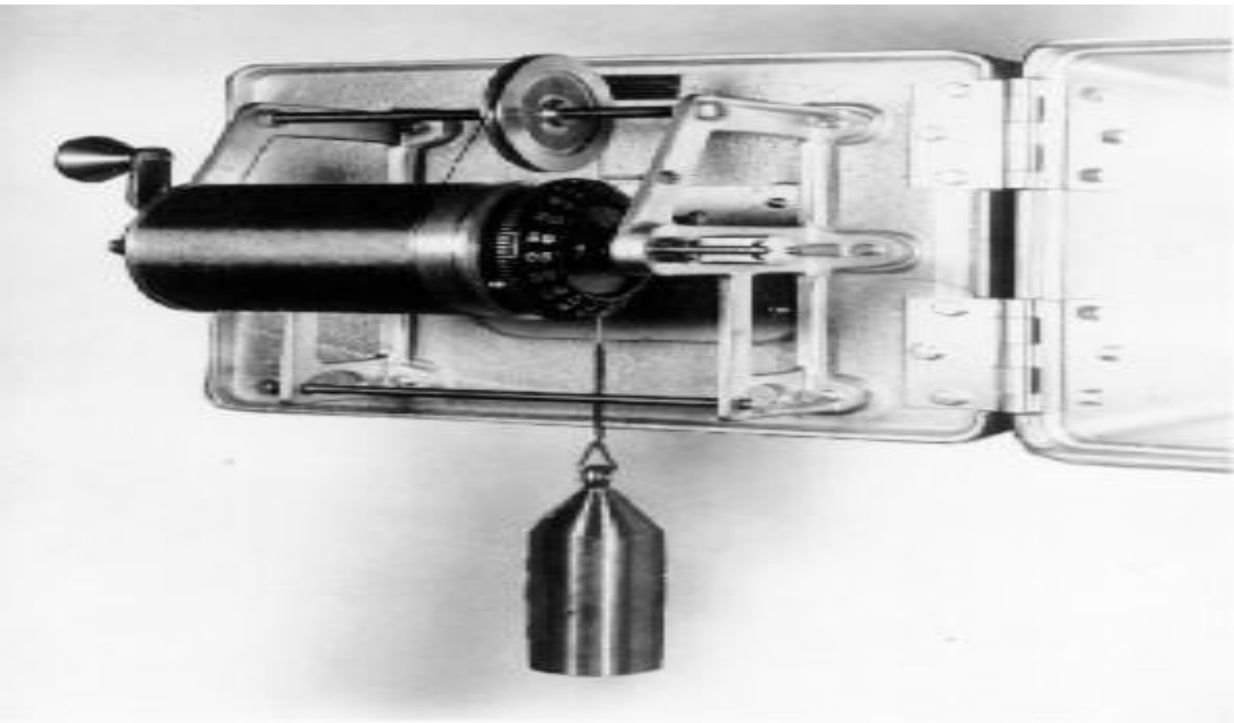


Figure 52: Non recording wire and weight-type gage

(a) Analog-Graphical Recorders

In general, analog or graphical recorders consist of two main elements: a clock mechanism actuated by a spring, weight, or electric motor and a gage height element actuated by a float, cable or tape, and counterweight. Four basic types of recorders use these elements. Figure 53 shows a horizontal drum recorder, in which the clock positions the pen along the drum axis, and the gage height element rotates the drum. This recorder is also available with a vertical drum.

Another type of recorder also has a vertical drum, but the time and height elements have been reversed so that the clock mechanism rotates the drum.

Figure 53: Horizontal drum water-stage recorder. The time element records parallel to the axis of the drum.

These types of recorders usually operate using 8-day, spring-driven clocks. Electrical drives could also be used if a reliable source were readily available. The stylus, usually either a capillary pen or a pencil of proper hardness, must be capable of operation for the full 8 days without attention. To accommodate various water-stage differentials, ratios of water-stage change to recorder-chart change are available from 1:1 to 10:1 and should be specified at the time the recorder is ordered. The standard width of recorder paper is 10 inches (in), and all recorders come equipped with metal covers.

The fourth type of graphic recorder consisting of a compensated, balanced, weight-driven clock, drives two parallel rolls, one of which holds the supply paper. The paper unrolls from the supply roll at a uniform rate and with constant tension and is taken up on the receiving roll. Speed of travel may be adjusted from 0.3 to 9.6 in per day on any standard instrument, and other chart speeds are available on special order. The normal chart length is 75 feet (ft).

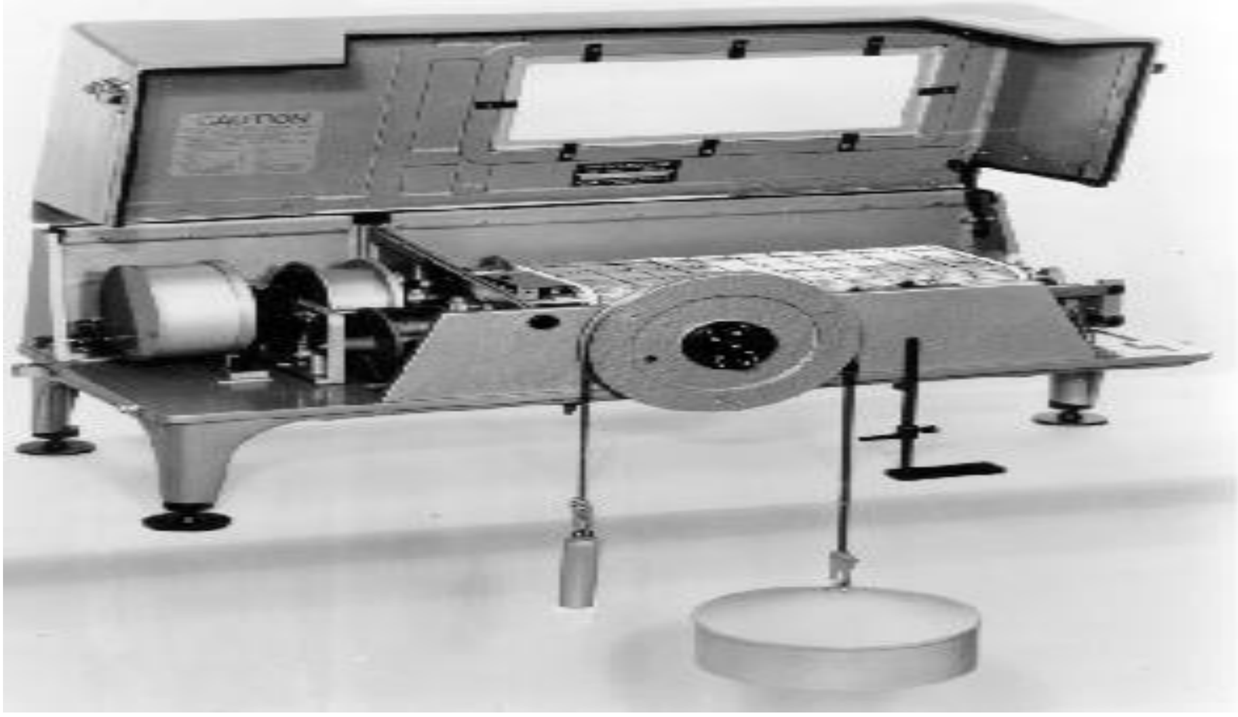


Figure 54: Continuous recording water-stage recorder with cover raised. The time element rotates the rolls, and the height element records parallel to the axis of the rolls.

(b) Digital Recorders

Digital recorders used in water stage measurements usually include two types: punched-papertape and analog-to-digital data loggers. Both types are electrically operated (usuallyby batteries) and record numbers either on the paper tape or in memory at selected time intervals.

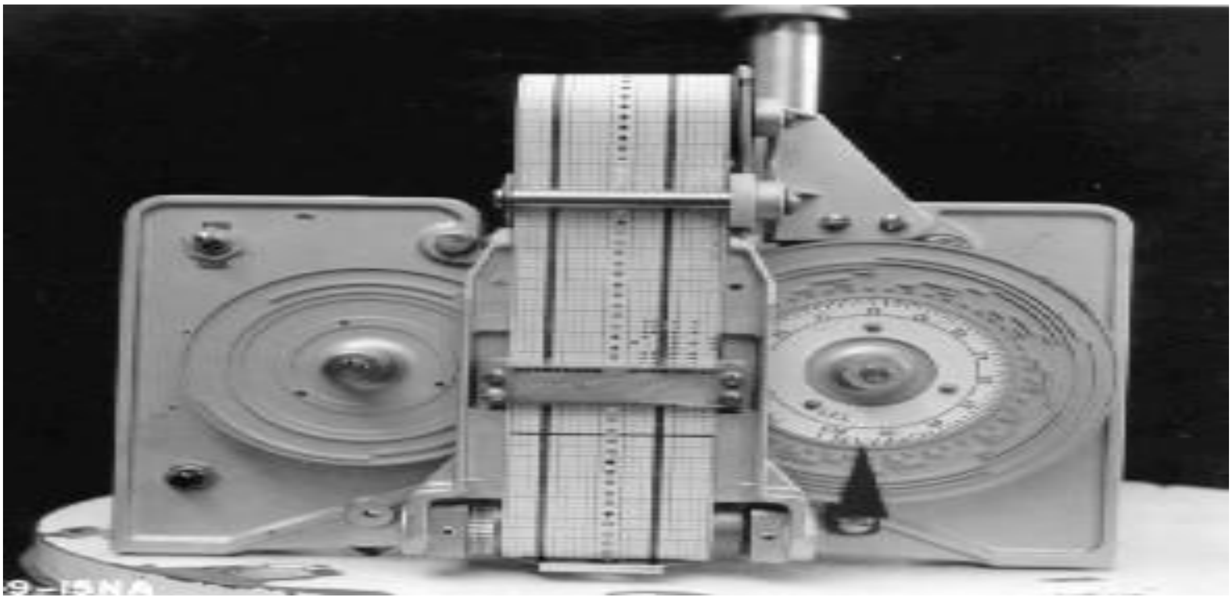


Figure 55: Digital recorder

Water stage is transmitted to the punched-paper tape recorder, usually through shaft rotation on a float and pulley arrangement. Shaft rotation is converted by the recorder into coded punch-tape

records. The code consists of four groups of four punches each. In each group, the first punch represents "1"; the second, "2"; the third, "4"; and the fourth, "8." Thus, a combination of 1, 2, or 3 appropriate punches in a given group represents digits from 1 to 9. A blank (no punch) represents zero. Together, the four groups of punches represent all numbers from 0 to 9999.

2.1.3 Installation of Water-Stage Recorders

Important considerations in the installation of a water-stage recorder are the proper sizing and installation of a stilling or float well (if used) and the establishment of the reference datum forthe site. The gage must be accessible at all times and substantially constructed for security and reliability. The recorder should be protected from the environment. The reference datum should be below the lowest stage of the stream or structure, and the instrument used to measure the stage must have the capability to cover the full range of water surface changes.

2.2 Reporting and recording

Operation of an irrigation system is facilitated by the use of standard forms for reporting activities and keeping permanent records. The most valuable forms contain space for all essential information, simplified as much as possible.

The record should be complete in order that management and water users may be informed of what is going on, that unnecessary trouble over quantities of water delivered may be averted, and that data be provided on which to base desirable changes and economies. Typical forms used in connection with the several functions of water delivery are shown below.

Date --------------------------------

Turned on----------------------------Sec, -Feet at -----------------------------M

Turned off ---------------------------------- Sec, -Feet at ---------------------M-------------------- 2012

Remarks

Ditch Tender

A record of the time and quantity of water delivered to each irrigator is of prime importance to an irrigation manager, particularly where deliveries are charged for on a quantity basis. Every delivery report should be signed and dated by the ditch tender before being turned in to the office, in case the matter should be brought into court. ceases are on record in which users have disclaimed their signatures to applications for water, but are extremely rare, for a water user confronted with his own signature or with the ditch-tender's record of delivery to him seldom makes further protest.

A written report of each break or flood is valuable. Such report should give the location, description, and cause of the break, with full information as to damage done to land, crops, or roads, and time the water was turned out of the canal and estimated time it may be turned back again. Ample space should be provided for all descriptive matter and notes.

2.3 Risk Management

The expansion and intensification of agriculture made possible by irrigation has the potential for causing: increased erosion; pollution of surface water and groundwater from agricultural biocides; deterioration of water quality; increased nutrient levels in the irrigation and drainage water resulting in algal blooms, proliferation of aquatic weeds and eutrophication in irrigation canals and downstream waterways. Poor water quality below an irrigation project may render the water unfit for other users, harm aquatic species and, because of high nutrient content, result in aquatic weed growth that obstructs waterways and has health, navigation and ecological consequences. Elimination of dry season die-back and the creation of a more humid microclimate may result in an increase of agricultural pests a plant disease.

Large irrigation projects which impound or divert river water have the potential to cause major environmental disturbances, resulting from changes in the hydrology and limnology of river basins. Reducing the river flow changes flood plain land use and ecology and can cause salt water intrusion in the river and into the groundwater of adjacent lands. Diversion of water through irrigation further reduces the water supply for downstream users, including municipalities, industries and agriculture. A reduction in river base flow also decreases the dilution of municipal and industrial wastes added downstream, posing pollution and health hazards.

The potential direct negative environmental impacts of the use of groundwater for irrigation arise from over-extraction (withdrawing water in excess of the recharge rate). This can result in the lowering of the water table, land subsidence, decreased water quality and saltwater intrusion in coastal areas.

Upstream land uses affect the quality of water entering the irrigation area, particularly the sediment content (for example from agriculture-induced erosion) and chemical composition (for example from agricultural and industrial pollutants). Use of river water with a large sediment load may result in canal clogging.

The potential negative environmental impacts of most large irrigation projects described more in detail below include:

- waterlogging and salinization of soils,
- increased incidence of water-borne and water-related diseases,
- possible negative impacts of dams and reservoirs,
- problems of resettlement or changes in the lifestyle of local populations.

2.3.1 Waterlogging and salinization

About 2 to 3 million ha are going out of production worldwide each year due to salinity problems. On irrigated land salinization is the major cause of land being lost to production and is one of the most prolific adverse environmental impacts associated with irrigation. However, very limited research has yet been conducted to quantify the economic impact of irrigation induced salinization. Quantitative measurements have generally been limited to the amount of land affected or abandoned. Estimates of the area affected have ranged from 10 to 48% of worldwide total irrigated area. Especially the arid and semi-arid areas have extensive salinity problems.

Waterlogging and salinization of soils are common problems associated with surface irrigation. Waterlogging results primarily from inadequate drainage and over-irrigation and, to a lesser extent, from seepage from canals and ditches. Waterlogging concentrates salts, drawn up from lower in the soil profile, in the plants' rooting zone. Alkalization, the build-up of sodium in soils, is a particularly detrimental form of salinization which is difficult to rectify.

Irrigation-induced salinity can arise as a result of the use of any irrigation water, irrigation of saline soils, and rising levels of saline groundwater combined with inadequate leaching. When surface water or groundwater containing mineral salts is used for irrigating crops, salts are carried out into the root zone. In the process of evapotranspiration, the salt is left behind in the soil, since the amount taken up by plants and removed at harvest is quite negligible. The more arid the region, the larger is the quantity of irrigation water and, consequently, the salts applied, and the smaller is the quantity of rainfall that is available to leach away the accumulating salts.

Excess salinity within the root zone reduces plant growth due to increasing energy that the plant must expend to acquire water from the soil. The tolerance of crops to salinity is variable: clover and rice are more sensitive to salts than barley and wheat. Comprehensive studies of farm-level effects of irrigation-induced salinity indicate that the yields of paddy and wheat are around 50% lower on the degraded soils and net incomes in salt-affected lands are around 85% lower than the unaffected land.

Irrigation-related salinity has adverse effects not only on the production areas, but also on areas and people downstream. The rivers, particularly in arid zones tend to become progressively more saline from their headwaters to their mouths. The aquifers interrelated with the river are highly saline and the salts discharged to the river system from saline aquifers adversely affect downstream water users, particularly irrigated agriculture and, in some special cases, wildlife.

2.3.2 Water-borne and water-related diseases

Water-borne or water-related diseases are commonly associated with the introduction of irrigation. The diseases most directly linked with irrigation are malaria, bilharzia (schistosomiasis) and river blindness (onchocerciasis), whose vectors proliferate in the irrigation waters. Other irrigation-related health risks include those associated with increased use of agrochemicals, deterioration of water quality, and increased population pressure in the area. The reuse of wastewater for irrigation has the potential, depending on the extent of treatment, of transmitting communicable diseases. The population groups at risk include agricultural workers, consumers of crops and meat from the wastewater-irrigated fields, and people living nearby. Sprinkler irrigation poses an additional risk through the potential dispersal of pathogens through the air.

The risk that one or more of the above diseases is introduced or has an increased impact is most likely in irrigation schemes where:

- soil drainage is poor, drainage canals are either absent, badly designed and/or maintained;

- rice or sugar cane is cultivated;
- night storage reservoirs are constructed;
- borrow pits are left with stagnant water;
- canals are unlined and have unchecked vegetation growth.

The control of the water-related diseases can be affected in a number of ways, some of which are mutually reinforcing. Three types of measures are distinguished:

- measures aimed at the pathogens: immunization, prophylactic or curative drugs;
- measures aimed at reducing vector densities or vector lifespan: chemical, biological and environmental controls;
- measures to reduce human/vector or human/pathogen contact: health education, personal protection measures and mosquito proofing of houses.

Self-Check -2	Written Test

Directions: Choose the best answer for the following questions. Use the Answer sheet provided (2pts each).

1. One of the following is **Not** the risks in irrigation system?

A. Water logging
B. Salinization of soils
C. Reduce crop production
D. Water related diseases

2. Which one of the following is the potential negative environmental impacts of most large irrigation?

A. Increase incidence of water-related diseases
B. Positive impacts of dams and reservoirs
C. Increase farm production
D. Changes in the lifestyle of local populations

3. Waterlogging results primarily from-------------

A. Inadequate drainage system
B. Efficient irrigation
C. Less water application
D. High soil infiltration

4. What is the problem of salinity in irrigation system?

A. Reduces plant growth
B. Affect people at downstream
C. Salts discharge ground water
D. All

Note: **Satisfactory rating - 4 points Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Answers

1. 2. 3. 4.

Operation Sheet 1	Maintaining appropriate measurements and delivery records

1.1 Procedures for floating measurement method:

Step 1- Choose a suitable straight reach with minimum turbulence (ideally at least 3 channel widths long).

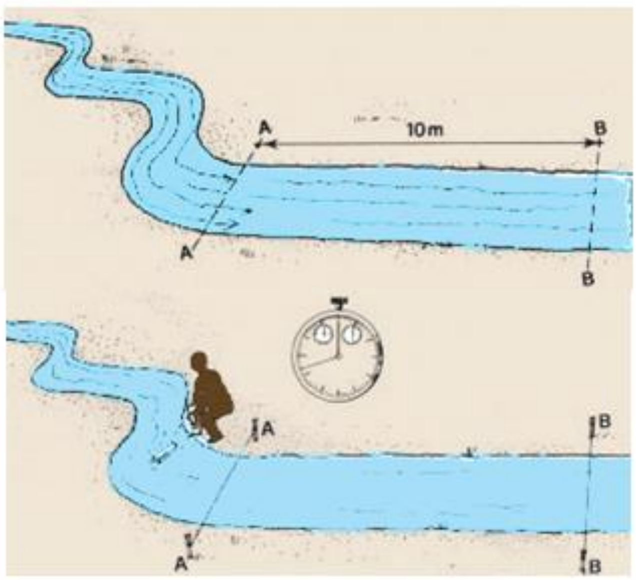
Step 2 - Mark the start and end point of your reach.

Step 3 - If possible, travel time should exceed 20 seconds.

Step 4 - Drop your object into the stream upstream of your upstream marker.

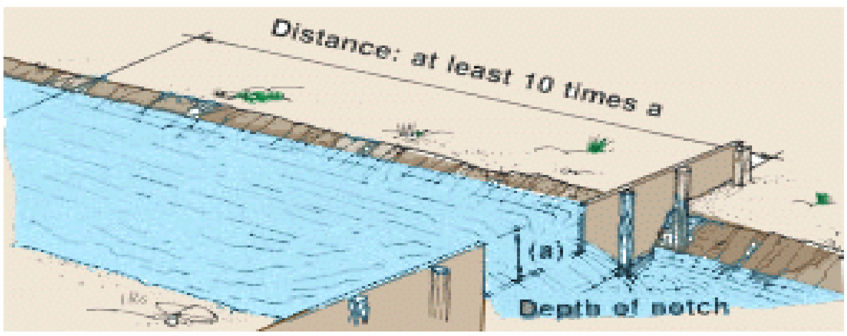
Step 5 - Start the watch when the object crosses the upstream marker and stop the watch when it crosses the downstream marker.

Step 6 -You should repeat the measurement at least 3 times and use the average velocity in further calculations.

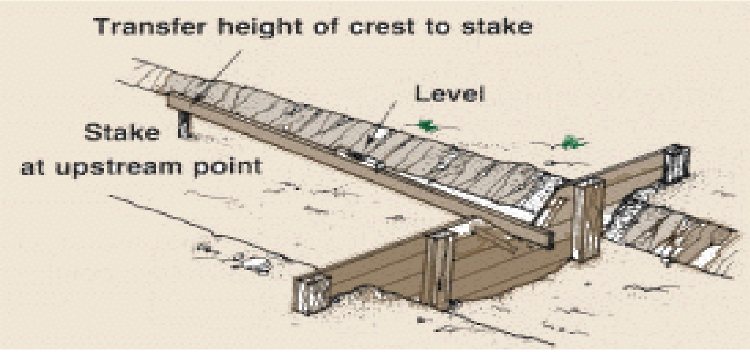


1.2 Procedures for weir measurement method:

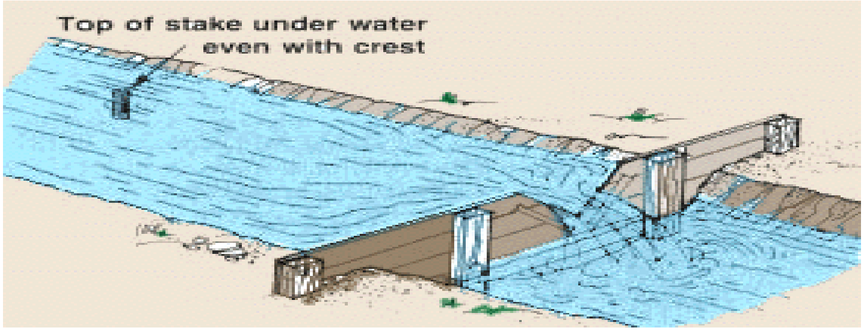
1. Measuring a distance above the weir that is a least 10 times the depth of the weir notch.



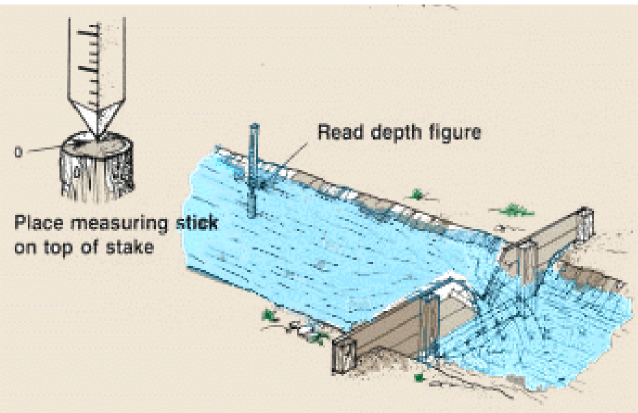
2. Preparing an upstream point to measure the head



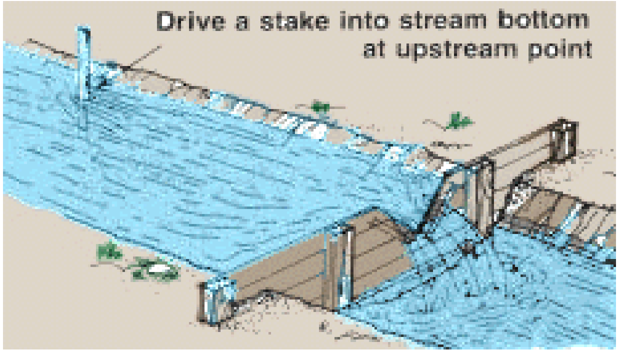
3. Drive a stake into the stream bottom near the bank at the upstream point you have selected.



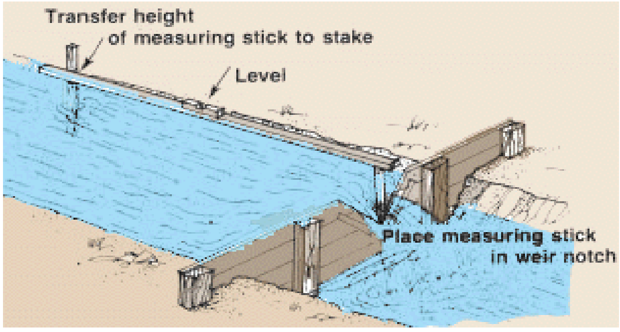
4. Now let the water flow back into the channel.
5. Find the head by placing a measuring stick, with the zero mark at the bottom, on top of the stake and reading the depth figure at the surface of the water.



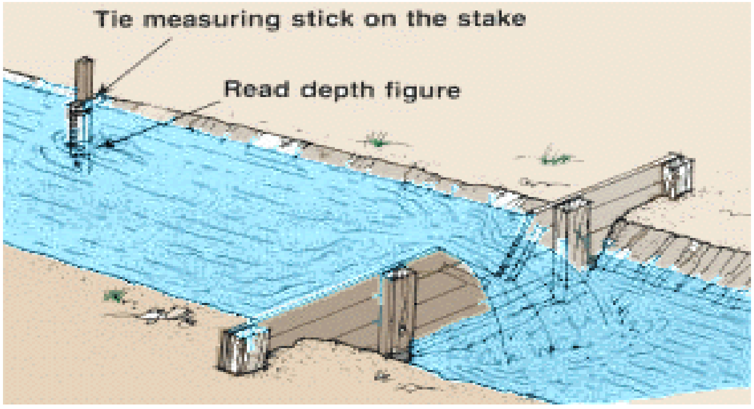
6. Preparing an upstream point to measure the head when you have not diverted the water flow:



7. Hold a measuring stick, with the zero mark at the bottom, in the weir notch.



8. Remove the measuring stick from the notch, place it beside the stake and tie the top of it to the stake, even with this mark.
9. Check to see that the weir is built properly and all requirements have been met, either for the triangular weir or for the rectangular weir.
10. Find the head by reading the depth figure on the measuring stick at the surface of the water.



11. Finalize the work

LAP Test	Practical Demonstration

Name: _______________________________ Date: _________________

Time started: __________________________ Time finished: _________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 6 hours.

Task 1: **Maintain appropriate measurements and delivery records**

1.1 Floating measurement method

1.2 Weir measurement method

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