# Module 1

# Principles of Water Resources Engineering

# Lesson 4

# Planning and Assessment of Data for Project Formulation

## Instructional Objectives

On completion of this lesson, the student shall be able to learn:

1. The range of water resources project and the general planning philosophy
2. Planning arrangements for drinking water supply project and related data requirement
3. Planning arrangements for irrigation water supply project and related data requirement
4. Planning arrangements for hydropower generation project and related data requirement
5. Planning arrangements for flood control project and related data requirement
6. Investigations for data assessment for constructing water resource engineering structures
7. Water availability computations
8. Data collection for environment, socio-economic and demographic informations
9. Data collection methods for topography, geology, rainfall and stream flow.

## 1.4.0 Introduction

A water resources systems planner is faced with the challenge of conceptualizing a project to meet the specific needs at a minimum cost. For a demand intensive project, the size of the project is limited by the availability of water. The planner then has to choose amongst the alternatives and determine the optimum scale of the project. If it is a multi-purpose project, an allocation of costs has to be made to those who benefit from the project. An important aspect of planning is that it has to prepare for a future date – its effects in terms of physical quantities and costs over a period of time spanning the useful life of project has to be evaluated. The return expected over the project period has to be calculated.

All this requires broader decisions, which affect the design details of the project. This chapter looks into the different aspects of preparing a project plan likely to face a water resources system planner, including the basic assessment of data that is primary to any project plan formulation.

## 1.4.1 Meeting the challenges

The major projects which water resources systems planner has to conceptualize are shown in Figure 1. Although the figure shows each project to be separate entity, quite a few real projects may actually serve more than one purpose. For example, the Hirakud or the Bhakra dams cater to flood control, irrigation and hydropower generation. On the other hand more than one project is necessary (and which actually forms a system of projects) to achieve a specific purpose.

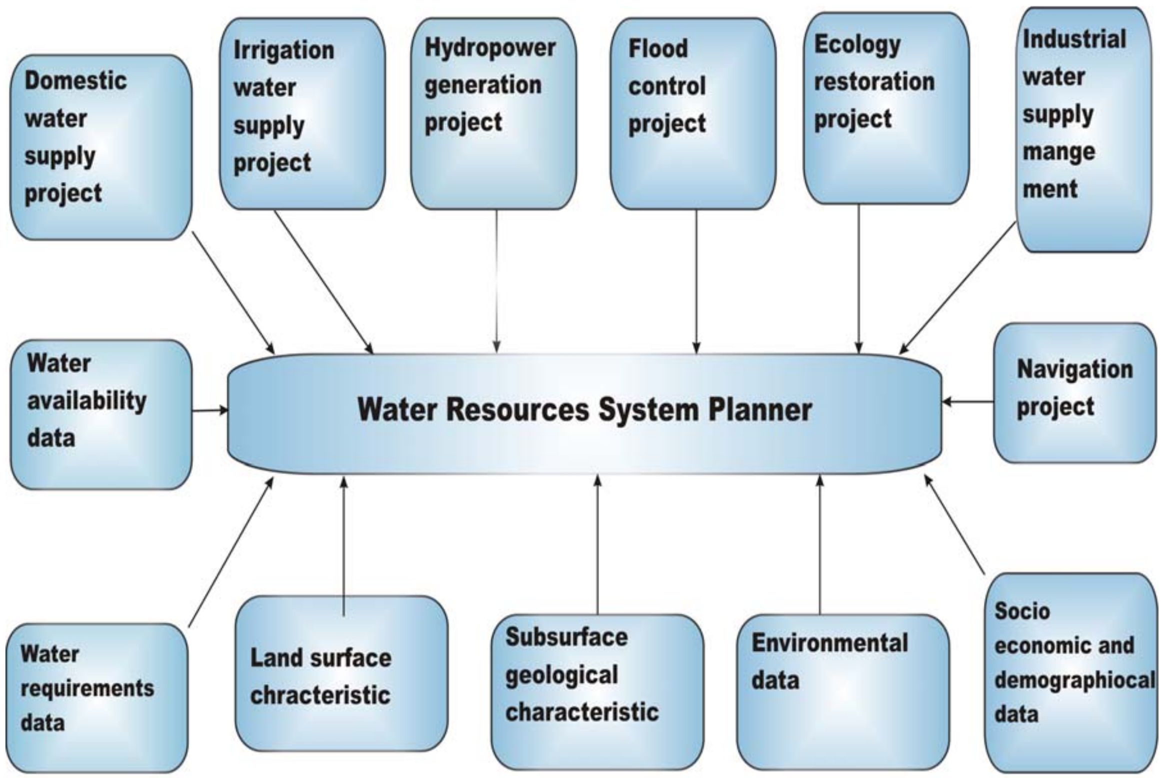



Figure 1 Possible water resources projects requiring planning and necessary data requirement

For example, to control the floods in the Damodar River, which earlier used to havoc in the districts of Bardhaman, Hooghly and Howrah in West Bengal, a number of dams were constructed on the Damodar and its tributaries between 1950s and 1970. For irrigation projects, a dam may be constructed across a river to store water in the upstream reach and a barrage may be constructed in the downstream reach to divert and regulate the water through an off taking canal.

### 1.4.2 Project planning for domestic water supply

The project for supplying drinking water to a township would usually consist of a network of pipelines to reach the demand area. The source of water could be underground or from a surface water body, usually a river. At times, it could be a judicious combination of the two. A water resources systems planner has to design the whole system from the source up to the distribution network. However, the scope of water resources engineering is generally be limited to the intake system design. The storage of water, its treatment and finally distribution to the consumers are looked after by the authorities of the township. Further details may be obtained in a course on Water and Waste Water Engineering.

Typical intake systems could possibly be one of the following, depending and the convenience of planning.

1. Construction of a water intake plant directly from the river
   Example: Water intake system at Palta for Kolkata from river Hooghly.

2. Construction of a dam across a river and drawing water from the reservoir behind.
   Example: Dam at Mawphlang on river Umiam for water supply to Shillong.

3. Construction of a barrage across a river and drawing water from the pool behind
   Example: Wazirabad barrage across river Yamuna for water supply to Delhi.

4. Construction of infiltration wells near a river to draw riverbed ground water
   Example: For water supply to IIT Kharagpur campus from river Kangsabati.

5. Construction of deep wells to draw water from lower strata of ground water
   Example: Water intake system for the city of Barddhaman.

A simple line sketch is shown in Figure 2 to show the processes for intake, storage, treatment and distribution of a typical drinking water project.

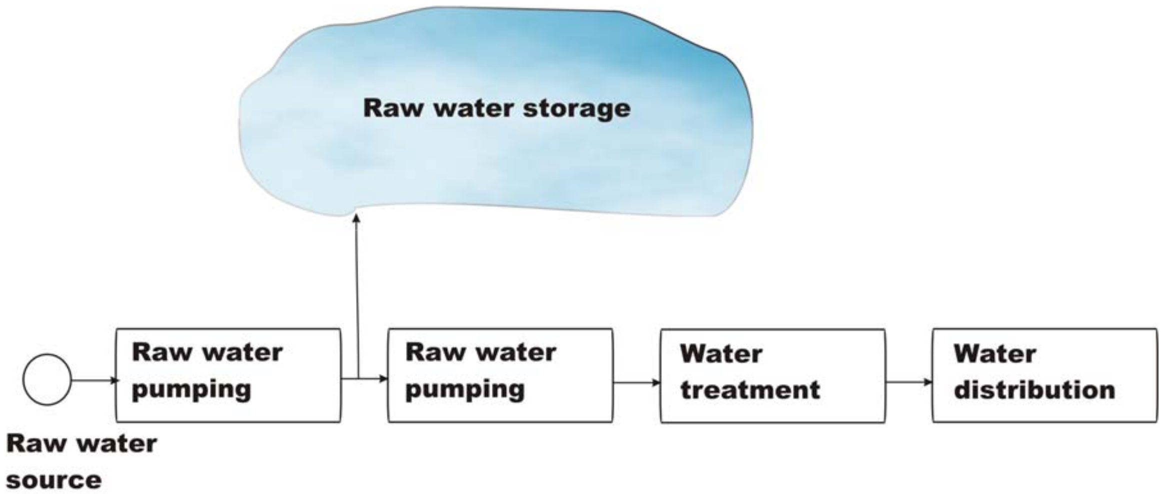



Figure . 2 A line diagram for intake, storage, treatment and distribution of a typical drinking water project

## 1.4.3 Data requirement for domestic water supply project

The following data is required for planning and designing a typical water supply system.

### 1.4.3.1 *Demand of water*

As discussed in lesson 1.2, according to the norms laid out in the National Building Code, and revised under National Water policy (2002), the following demand of domestic water consumption may be adopted:

***Rural water supply:***

- 40 litres per capita per day or one hand pump 250 persons within walking distance of 1.6 km or elevation difference of 100m in hills
- 30 lpcd additional for cattle in desert development programmed areas

***Urban water supply:***

- 40 lpcd where only sources are available
- 70 lpcd where piped water supply is available but no sewerage system
- 125 lpcd where piped water supply and sewerage system are both available.
- 150 lpcd for main cities

- Additional water for other demands like commercial, institutional, firefighting, gardening, etc.

Since the water supply project would serve a future population, a realistic projection has to be made based on scientific projection methods like

- ***Arithmetic increase method***.
- ***Geometric increase method***.
- ***Incremental increase method***.

Water supply projects, under normal circumstances, may be designed for a period of thirty years. This period may be modified in regard to certain components of the project, depending upon:

- The useful life of the component facility
- Ease in carrying out extensions, when required.
- Rate of interest.

### 1.4.3.2 Availability of water and other data

The availability of water has been discussed in a subsequent section of this lesson, which would be used to design the capacities of the intake by the water resources engineer, by comparing with the demand. The data for constructing the structures would usually be topography for locating the structure, geology for finding foundation characteristics and materials required for construction of the structure.

## 1.4.4 Project planning for irrigation water supply

The project may consist of supplying water to irrigate an area through a network of canals, by diverting some of the water from a river by constructing a barrage for water diversion and head regulator for water control. The water through canals mostly flows by gravity (except for pumped canal projects), the area under cultivation by the water of the canal is called the Command Area. This area is decided by the prevailing slope of the land. Although the main source of water for irrigating an area could be surface water, it could be supplemented with ground water. This combination of surface and ground water for irrigation is known as Conjunctive use.

The principal component of an irrigation scheme is a diversion structure – a weir or a barrage – though the latter is preferred in a modern irrigation project. Since the height of such a structure is rather small compared to that of a dam, the volume of water stored behind a barrage (the barrage pool) is small compared to that stored behind a dam (the dam reservoir). The elevated water surface of the barrage pool causes the water to be diverted into the canal, the entry of which is regulated through a ***canal head works***. If the river is perennial, and the minimum flow of the river is sufficient to cater to the flow through the canal, this arrangement is perfectly fine to irrigate a command area using a barrage and an irrigation canal system. However, if the river is non-perennial, or the minimum flow of the river is less than the canal water demand, then a dam may be constructed at a suitable upstream location of the river. This would be useful in storing larger volumes, especially the flood water, of water which may be released gradually during the low-flow months of the river.

A conceptual scheme of a diversion scheme for irrigation is shown in Figure 3.

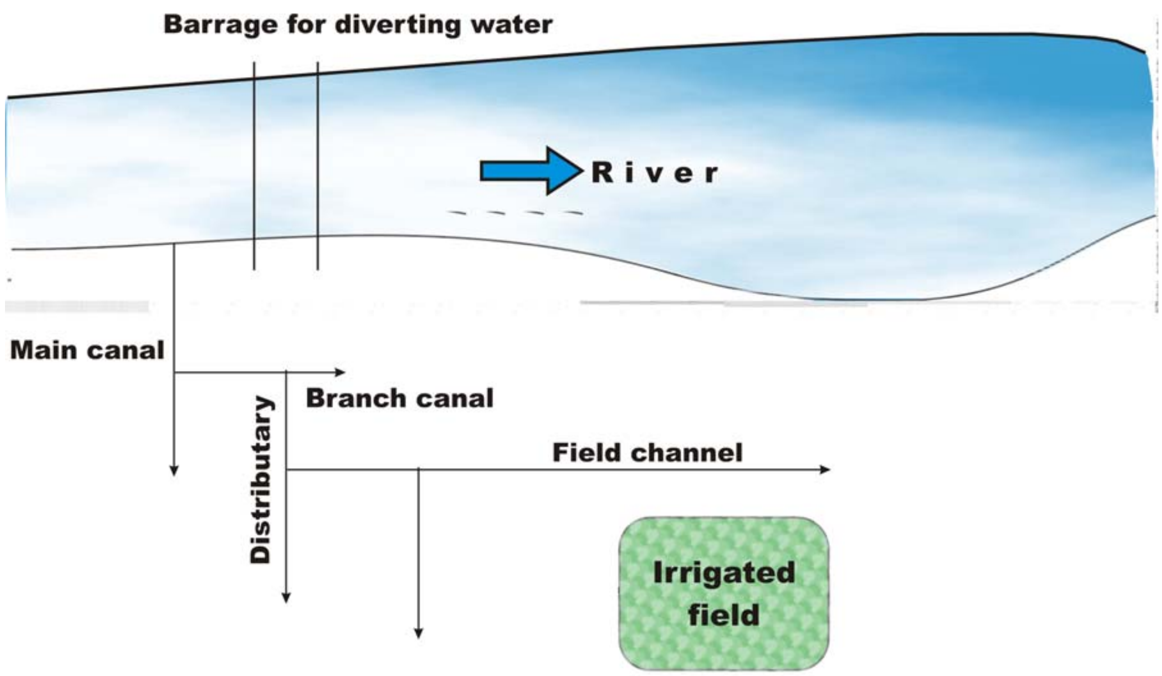



Figure 3 Diversion scheme for irrigation

## 1.4.5 Data requirement for water supply to an irrigation project

The following data is required for planning and designing a typical irrigation system.

### 1.4.5.1 *Demand of water for irrigation water supply*

The demand of water for an irrigation scheme is to be calculated from the cropping schedule that is proposed in the Command Area. Different crops have different water requirements and their demand also varies with the growth of the plants. Further, Command Area may be able to cultivate more than one crop within since many of the crops have maturity duration of few months.

The field requirement decides the design discharge for the distributaries and so on up to the canal regulator. Of course, most canals are prone to losses with water seeping through the canal sides. Exceptions are the lined canals, though in this case, the loss of infiltrating water is very small. Thus the net demand at the head of the canal system, as a function of time, is calculated. Lessons of Module 3 deal in detail about the irrigation system demand of water.

#### 1.4.5.2 Availability of water and other data

This has discussed in a subsequent section of this lesson. The data for demand and availability of water would be used to design the reservoir upstream of the dam for storage. This water, when released in a regulated way, would be diverted by a barrage and passed through a canal head regulator and water distribution network consisting of canals and other structures such as ***regulators*** and ***falls***. The data requirements for construction of the structures are usually: Topography, geology or riverbed soil characteristics, and materials.

## 1.4.6 Project planning for hydropower generation

A hydroelectricity generation project or a hydropower project in short, would essentially require water diversion form a continuous surface water source like a river. The diversion, as shown, could be using a dam or a barrage. A dam has the advantages of creating a high head and provides sufficient storage in the reservoir that is created behind. When the stream inflow to a reservoir is less, the stored water may be released to generate power.

A barrage, on the other hand, does not store much water in the pool. Hence, the power generation would be according to the available flow in the river. It also does not create a high head and hence this type of arrangement is usually practiced in the hilly areas, where a long power channel ensures sufficient head for power generation. This is because the slope of the power channel would be rather small compared to the general slope of land. A system with no sufficient storage is called the run-of-the-river project.

Figure 4 shows a typical schematic diagram for a project with a dam for diverting water to generate hydropower.

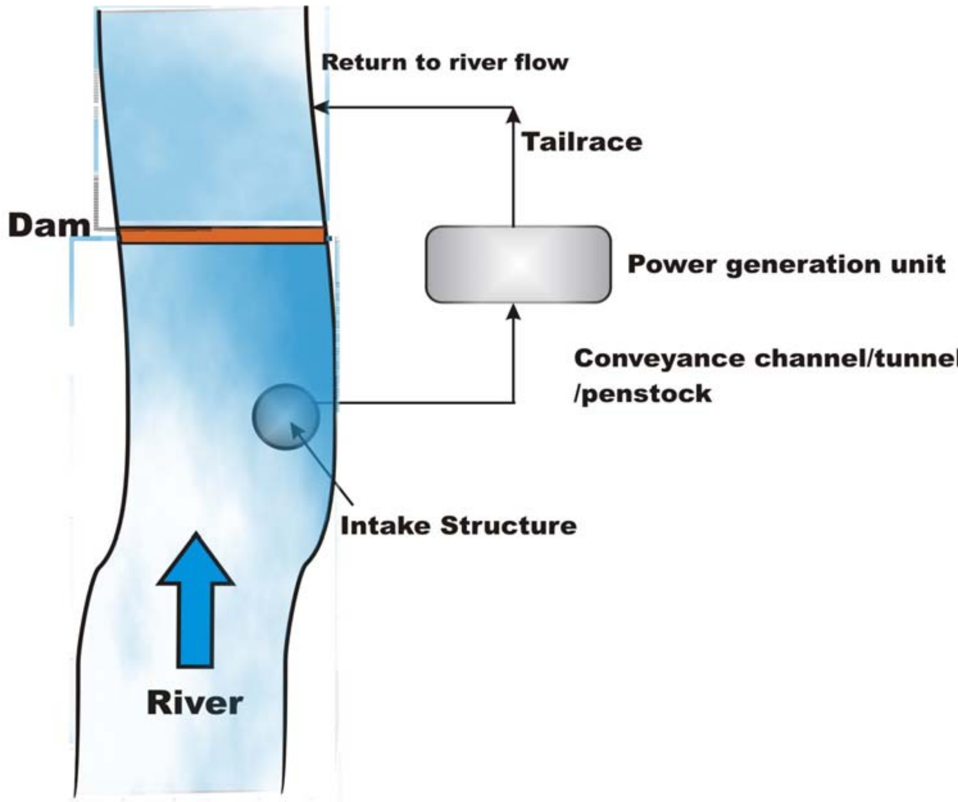



Figure 4 Diversion with a dam for power generation

Under some situation, a barrage may also be used to divert water through a power channel to generate hydropower. This is shown in Figure 5.

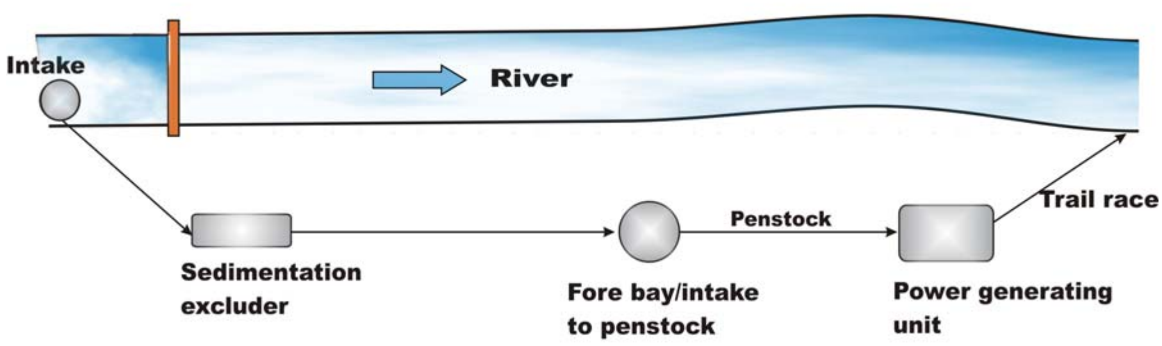



**Figure 5 Diversion with a barrage for power generation**

## 1.4.7 Data requirement for hydropower generation project

The following data is required for planning and designing a typical hydropower system.

### 1.4.7.1 *Demand of water*

Power generated 'P' is proportional to the discharge 'Q' passing through the turbine generator units and the piezometric head of water 'H'. Also, the demand of power varies with the time of the day (Figure 6) and some times on the days of the week. Hence the demand of water that is required to drive the turbines would vary too.

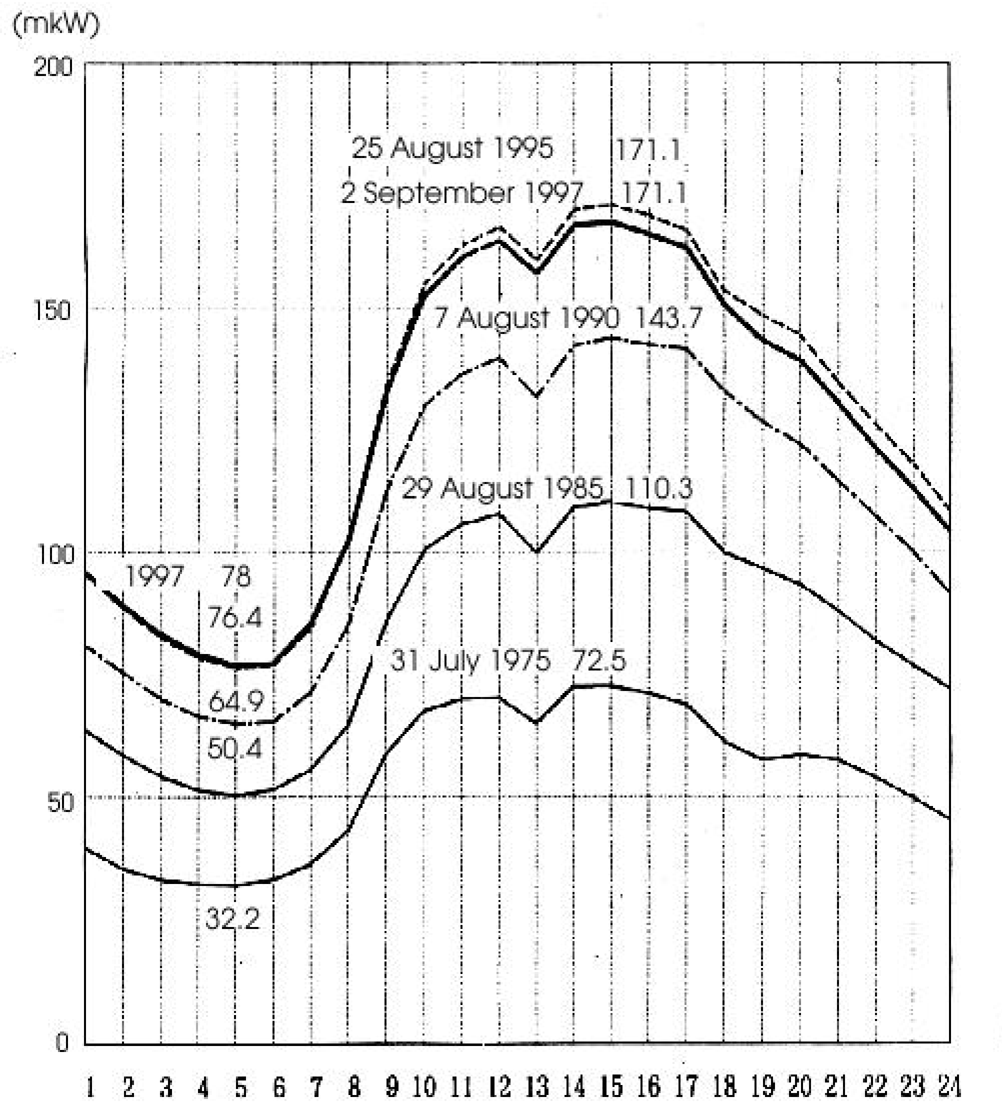



FIGURE 6 . Typical power demand curve variation over a month

However, when a hydropower plant is initially planned, the main constraint comes from the stream flow availability. Demand, on the other hand, is not really limited since more generation of power is always welcome. Hence, the maximum installed capacity of a hydropower plant would be limited to the reliable all-year-round available flow.

#### 1.4.7.2 *Availability of water*

This has been discussed in a subsequent section of this lesson. The data for demand and availability would decide the height of dam or a barrage and the size of the appurtenant structures required for conveying water up to the power generation unit and the corresponding exit channel. The data requirement for construction of the structures is the same as mentioned before, that is, Topography, Geology and Materials.

## 1.4.8 Project planning for flood control

Truly speaking, controlling a flood is generally not possible, but with different combinations, it can be managed in such a way that the resulting damages are minimized. There are several options, but broadly, these may be classified as being structural or non-structural. Construction of a large dam across a river to hold the incoming flood and the release of the regulated flow would fall under structural measures. On the other hand, if the residents of the flood prone area are warned before hand by making suitable predictions of the impending flood using a flood forecasting technique, then it falls under a non-structural measure.

Lesson 6.2 deals with different types of flood management techniques, but presently, the discussion is limited to the construction of dams for management of floods, as illustrated in Figure 7.

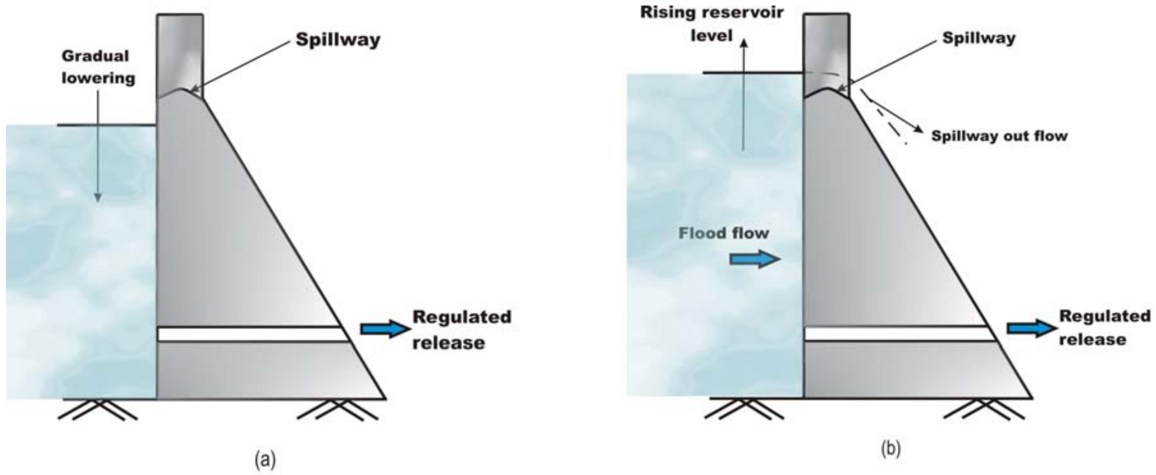



Figure 7 Section of dam a) Showing level of water before inflow of flood
b) Showing reservoir storage for flood inflow and regulated release

## 1.4.9 Data requirement for flood control project

Theoretically a dam constructed to reduce a flood peak should require the maximum possible stream flow ***hydrograph***.

However, this is neither possible to be determined exactly, nor is desirable as it would too costly to build a huge dam. Rather, a flood of a certain probability of occurrences (say 1 in 100 years) is estimated from past peak stream flow records and a corresponding hydrograph constructed. This is generally used to design the height of the dam (which determines the size of the reservoir) and the ***spillway***.

Hence, if a dam is used to moderate the flood of a river, then the data collection should be aimed at that required for constructing a dam. They usually concern topography, geology and materials. If other structural measures like embankment are constructed, then also the above mentioned parameters appropriate to the construction of embankment would be required to be collected.

## 1.4.10 Planning for other miscellaneous projects

Other major types of water resources project include those for

- Ecology restoration

- Industrial water supply
- Navigation

In each of the above, a certain demand of water is first estimated, for example.

- How much water is required for restoration of a marshy or aquatic habitat and how is it spread overtime.
- How much water is required to be supplied to an industry (relatively larger demands being required for the cooling of thermal energy producing plants).
- How much water is required to flush out sediment from a navigable channel or to what height the river water level should be raised to increase the draft necessary for moving vessels.

Accordingly, a dam or a barrage and possibly a water conveying canal would be required, to achieve the above objectives. The construction details for each of these components have been dealt with in the lessons of Module 4. We shall look now into the data requirement and its source.

## 1.4.11 Investigations for data assessment

The main structural components that are proposed for any water resource project include the following:

- A storage structure like Dams
- A diversion structure like Barrages
- A water conveyance structure like Canals

The primary job of the water resources engineer would be to locate or site the structure and for that the land surface elevation, or topography, is required. Once a structure is sited (or a few alternatives sited), then the next phase would be investigate the suitability of the foundation. Thus, geological characteristics determination forms an important data requirement.

For demand intensive projects, where the demand is more than the supply, the maximum possible flow that can be diverted for useful function is limited by the stream flow availability. Hence, the water availability studies form the third set of important data assessment

In the national level, the survey and investigation wing of the ***Central Water Commission (CWC)*** takes up these assessment jobs for surface water projects in concurrence with concerned state governments or central government. The CWC monitors most of the country's ***Major and Medium Projects*** and the detailed project reports (DPRs) have been prepared and submitted to concerned authorities.

## 1.4.12 Topographic details

These are the elevation contour maps the area where a project is proposed to be executed. The ***Survey of India*** has the responsibility to prepare and publish such maps for the nation. The maps (called ***toposheet***) in the scale of 1:50,000 have been completed for almost all regions the country. The contour interval in these maps is 20 meters and each sheet covers 15 minutes of latitude and longitude. Some areas have been surveyed in greater detail in the scale of 1:25000 in which the contour interval is 5 meters.

The survey of India also conducts specific surveys for particular project sites to serve the needs of project authorities. The scale and contour interval depends upon the nature of the terrain (country) and the purpose of the survey. The ***National Remote Sensing Agency*** has also acquired a ***Lidar*** for precision survey work with a topographic precision of 0.01m.

The elevation contour map of a region is useful to decide among others

- Height of storage structures (dam) and elevation of its spillway.
- Extent of inundation due to reservoir formation behind a dam.
- Amount of storage possible in the reservoir.
- Alignment of canals and their branches.

## 1.4.13 Geological characteristics

Usually hydraulic structures like dams or barrages for major water resources projects are massive. Unless the foundation properties are correctly found from geologic features and their interpretation, chances of structural failure would increase. Even for barrages, which are comparatively lighter structures, the underlying foundation strata of the river bed needs to be properly investigated. The ***Geological Survey of India*** has produced maps showing geological structure of the country. However, whenever a project is planned, a detailed geological investigation is carried out by drilling ***Bore Holes*** at required number of places and taking a ***Boring Log***. The ***Strength Parameters*** of the underlying rock/soil layers are investigated by extracting cores of samples and taken to laboratory for ***Strength Tests***. Sometimes, ***In-situ Laboratory Tests*** are conducted that avoids disturbing the foundation material in its original form.

The geological tests of the foundation material of the proposed project allow the determination of the following major parameters.

- Base width of a dam or a barrage so that the ***Bearing Pressure*** is within safe limits.
- Degree of protection required for prevention of seepage below the hydraulic structure. ( grout holes for dams and sheet piles for barrages)

## 4.1.14 Water availability data

Lesson 1.1 gives details about the average water availability of the country in general for a specific project dependant on surface water sources, however more detailed data of the amount of water availability needs to be established. In fact, the success of a water resources project depends on how accurate has been the estimation of the total quantity of water available and its variation with time – over days, weeks, months and years. This would require collection of data and its analysis by suitable methods.

| Project | Dependable water availability* |
|---|---|
| Irrigation | 75% |
| Drinking water | 100% |
| Hydro power project | 90% |

*n% dependable availability means that the minimum water required for the project would be available for 'n' units of time (say days or weeks, 10 day period, monthly) from within 100 equivalent units.

***Database***:
For computations of water availability, the following rainfall and stream runoff data should be collected in order of preference as given below. Daily observed data collected for ten consecutive days is more commonly used and mentioned here as ten-daily data

- Runoff data at the proposed site for at least 40 – 50 years.

Or

- Rainfall data of the catchment for 40-50 years and Runoff data for at least 5-10 years.

Or

- Rainfall data of the catchment for 40-50 years and Runoff data and concurrent rainfall data at existing project on upstream or down stream of the proposed site for at least 5-10 years.

Or

- Rainfall data of the catchment for 40-50 years and Runoff data concurrent rainfall data at existing project of a nearby river for at least 5 to 10 years provided ***Orographic*** conditions of the catchment at the work site are similar to that of the proposed site.

## 4.1.15 Water availability computations

Depending on the type of data available, the water availability can be computed from the following methods:

**Direct observation method:**
This method is applied when observed runoff data at the proposed site is available for the last 50 years or so. The method has been discussed in Lesson 2.4.

**Rainfall-Runoff series method:**
The method consists in extending the runoff data with the help of rainfall data by means of rainfall-runoff relationships (Lessons 2.2 and 2.3**)**.Depending upon the availability of rainfall and runoff data, following three cases arise

- Long term precipitation record along with a stream flow data for a few years is available.
- Long term precipitation record is available for the catchment along with a few years of stream flow data at a neighboring site on the same river.
- Long term precipitation record is available for the catchment rainfall-runoff data on a nearby river.

**Langbein's log-deviation method:**
This method is used when short term runoff data is available at the proposed site along with long term runoff at a nearby gauging station.

There are other methods which are discussed in the advanced texts, as the following:

Mutreja, K N (1995) *Applied Hydrology*, Tata McGraw Hill.

## 4.1.16 Environmental data

Any water resources project would be affecting the environment in one way or other. Construction of a dam or barrage may not allow free movement of fish along the river, the ponded water behind may cause submergence of valuable forest and even human habitation. Construction of flood protection environment may cause water logging in the area behind the embankment unless proper drainage is provided, thus leading to breeding of mosquitoes and other disease carrying vectors.

It is, therefore, always mandatory to check the impact on the environment due to construction of a water resource project. For this purpose, the relevant data on environment and ecology has to be collected for analysis.

## 4.1.17 Socio-economic and demographic data

Dam and barrage projects constructed at one point on a river benefits people downstream largely. However, the construction affects the people residing on the upstream as the ponded water causes submergence of villages and force people to migrate. It is pertinent, therefore, to study the effect of the project on the people and impact on the socio-economic fabric of the region benefited or affected by the project.

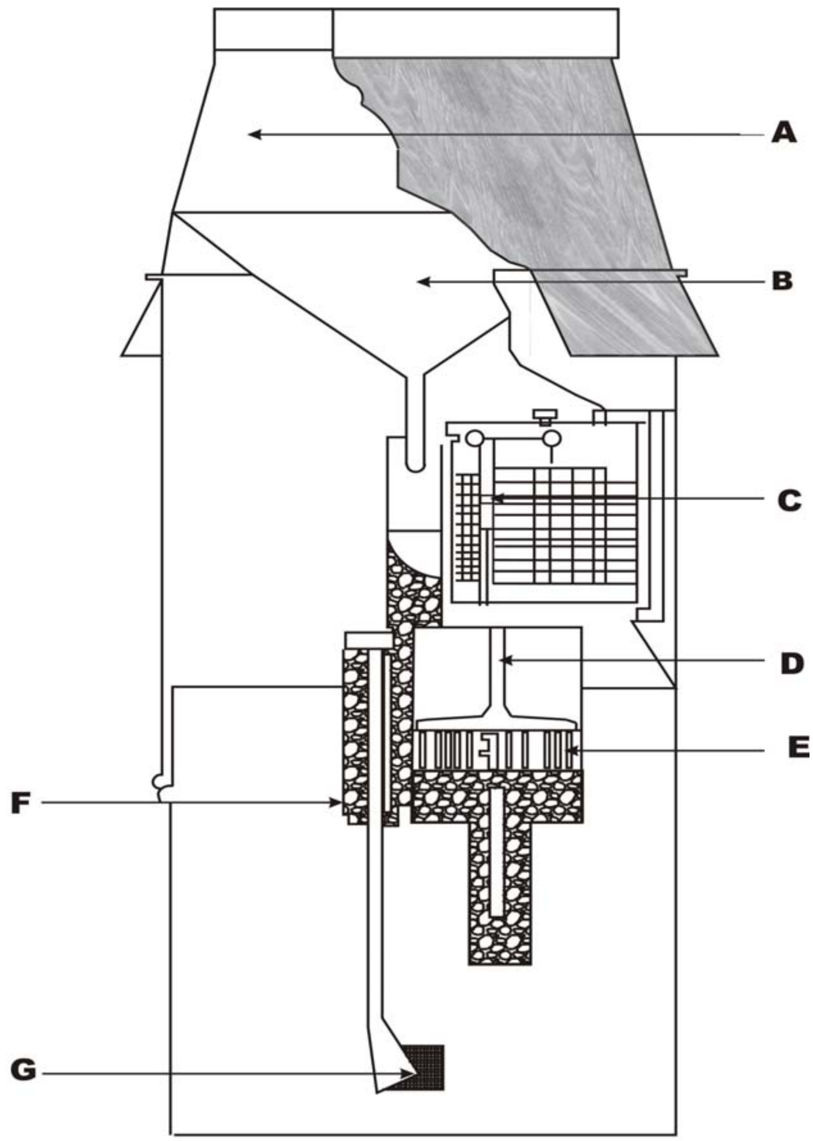
## 4.1.18 Data collection methods

**Rainfall:**
This is measured with rain gauges, which may be of ***Recording*** (Figure 8) ***or Non-Recording*** (Figure 9) types. The specifications regarding these gauges may be found in the following Indian Standard codes of practices:

- ***IS: 5225*** (1998) - Specifications for non-recording rain gauges.
- ***IS: 4986*** (2002) - Installation of non-recording rain gauges and rain measurement
- ***IS: 5235*** (1998) - Specifications for recording rain gauges.
- ***IS: 8389*** (2003) - Installation and use of recording rain gauges.

The rain gauges may be distributed within the catchment as specified in the following IS code:

- ***IS: 4987*** (1994) - Recommendations for establishing network of rain gauge stations




**LEGEND**

**A . COLLECTOR**
**B . FUNNEL**
**C . RECORDING DRUM**
**D . FLOAT AND FLOAT ROD**
**E . FLOAT CHAMBER**
**F . SIPHON CHAMBER**
**G . DISCHARGE TUBE**

**NATURAL -SIPHON RAIN GAUGE**

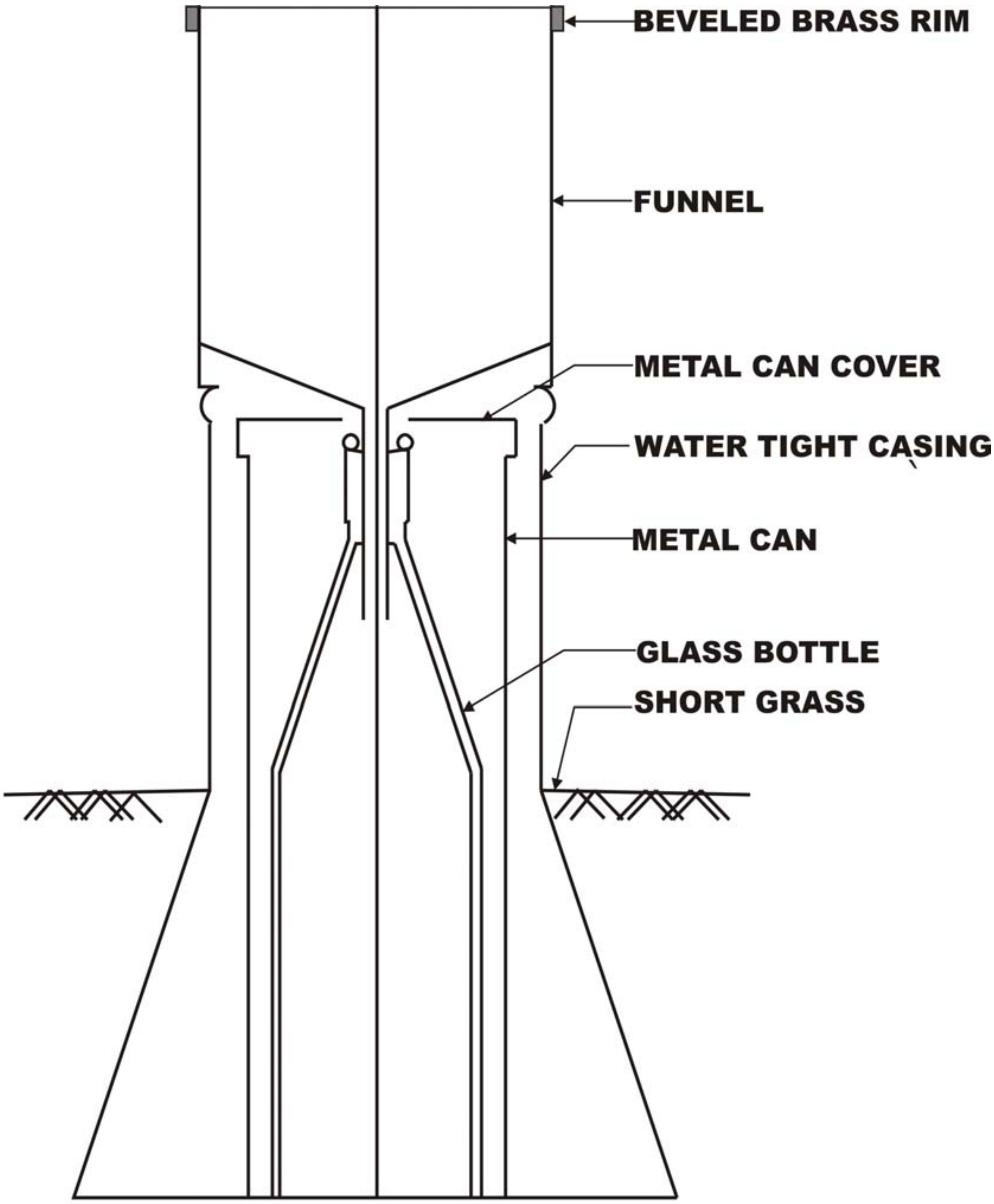
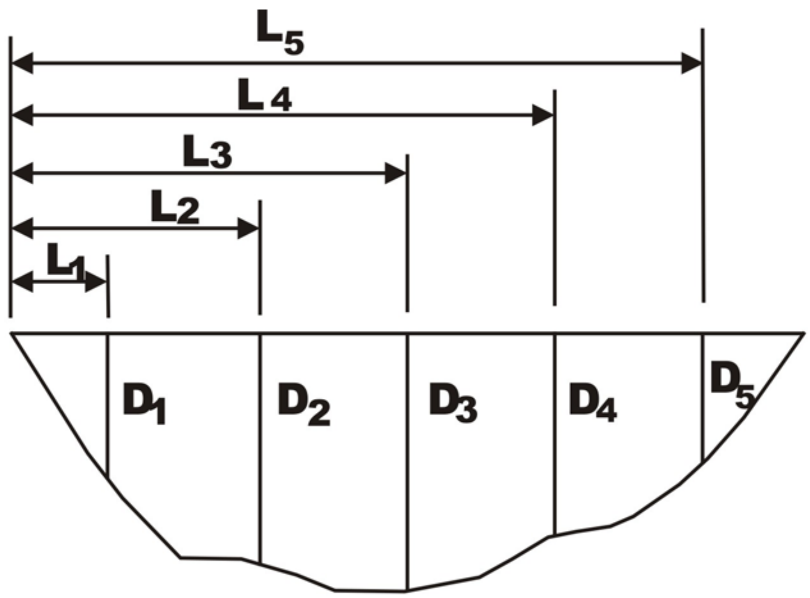



Figure 9. Non-recording rain gauge

**Stream Runoff (Discharge):**

The discharge of a stream or a river at a point varies with time. Usually, the discharge is measured by calculating the average velocity of the stream and multiplying by the cross sectional area. Since the velocity of a stream varies across the cross section, it is usual to divide the cross section hypothetically into several vertical strips (Figure 10).




**Typical cross- section**

Figure 10. Division of river into strips

Calculation of the discharge passing through each strip is then done by multiplying the average velocity of the strip by the area of the strip (approximated as a trapezium). The velocity is measured with a ***current meter*** (Figures 11 and 12) which dipped in the flowing water to a distance of 0.6 times the depth of water at that point, since the velocity at this point is seen to represent the average velocity well for most streams. There are many different types of current meters, of which the "Price" cup-type current meter attached to a round wading rod is illustrated in Figure 8. Discussions on the principles of measurement of stream flow, including the types of current meters may be obtained from the United States Bureau of Reclamation online document "Water measurement manual" which may be found in the following web-site:

http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/indexframe.html

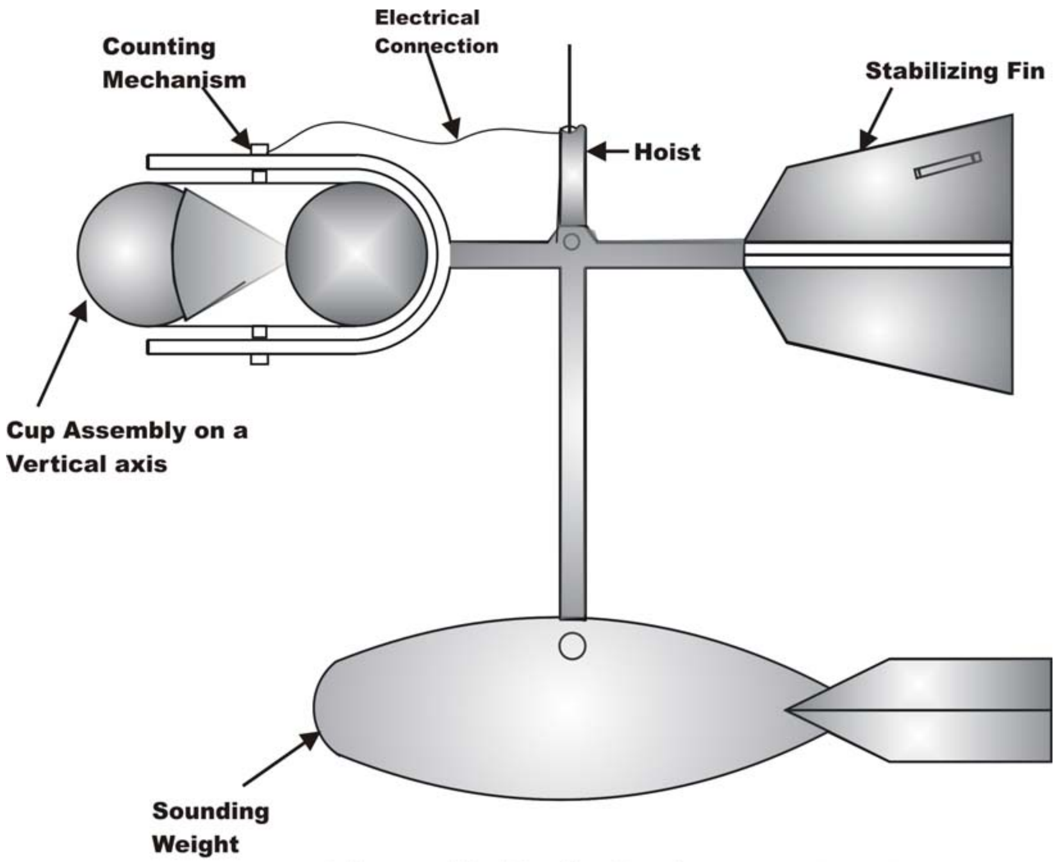



Figure 11. Vertical axis current meter

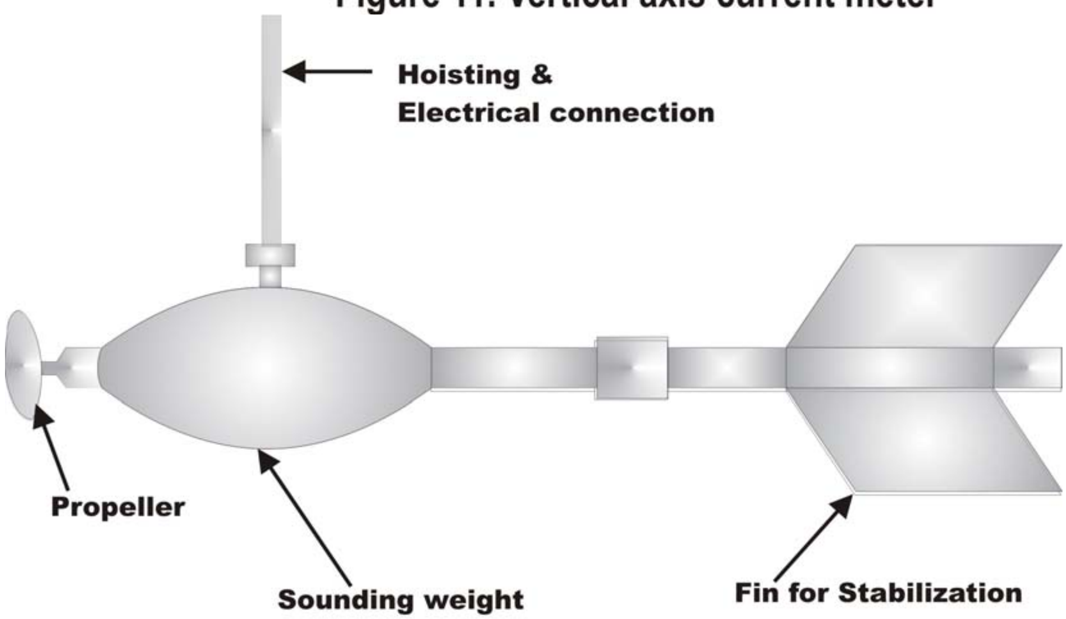



Figure 12. Horizontal- axis current meter

## 4.1.19 Important terms

**Arithmetic increase method**

In this method it is assumed that, the population increases at constant a rate. Therefore, population after *n* decades $P_n = P_O + n\bar{x}$

Where,

$P_O$ → Present population.

$P_n$ → Forecasted population after *n* decades.

$\bar{x}$ → Arithmetic mean of population increase in the known decades.

*n* → No of decades.

**Geometric increase method**

In this method, the decade wise percentage increase or percent growth rate is assumed to be constant. Thus, population after *n* decades $P_n = P_O\left(1+\frac{r}{100}\right)^n$

Where,

$P_O$ → Present population.

$P_n$ → Forecasted population after *n* decades.

$r$ → Percent of increase in population in the known decades.

*n* → No of decades.

**Incremental increase method**

In this method it is assumed that per decade growth rate is not constant, but is progressively increasing or decreasing. Hence, population after *n* decades $P_n = P_O + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$

Where,

$P_O$ → Present population.

$P_n$ → Forecasted population after *n* decades.

$\bar{x}$ → Average increase in the known decades.

$\bar{y}$ → Average incremental increase in known decades.

*n* → No of decades.

***Hydrograph:*** This is a plot of the discharge of a stream versus time.

***Spillway:*** Spillway is the sluiceway/passage that carries excess water from the water body over a dam or any other obstructions.

***Major, Medium and Minor Projects:*** This is a classification of the irrigation projects in India according to the area of land cultivated.

***Toposheet:*** The Survey of India has published maps of the entire country in different scales. Usually, the ones in scale 1:25,000 or 1:50,000 have the elevation contours marked out in meters. These maps are called topography sheets, or toposheets, in short.

***Lidar:*** LIDAR is an acronym for Light Detection and Ranging. This instrument can:

- Measure distance
- Measure speed
- Measure rotation
- Measure chemical composition and concentration of a remote target where the target can be a clearly defined object, such as a vehicle, or a diffuse object such as a smoke plume or clouds

For more information, one may visit: www.lidar.com

***Bore Holes***

The sub-soil investigation report will contain the data obtained from boreholes. The report should give the recommendations about the suitable type of foundation, allowable soil pressure and expected settlements. All relevant data for the borehole is recorded in a boring log. Depending upon the type of soil the purpose of boring, the following methods are used for drilling the holes.

- Auger drilling
- Wash boring
- Rotary drilling
- Percussion drilling
- Core boring

***Boring Log***

It is essential to give a complete and accurate record of data collected. Each borehole should be identified by a code number. All relevant data for the borehole is recorded in a boring log. A boring log gives the description or classification of various strata encountered at different depths. Any additional information that is obtained in the field, such as soil consistency, unconfined compression strength, standard penetration test, cone penetration test, is also indicated on the boring log. It also shows the water table. If the laboratory tests have been conducted, the information about the index properties, compressibility, shear strength, permeability, etc. should also be provided in this log.

***Strength Parameters:*** These are the physical strength characteristics of soils and the important ones are:

- Shear strength ($\tau$)

- Internal angle of friction or angle of shearing resistance (Φ)
- Cohesion intercept (c)
- Effective stress (σ')

Shear strength (τ) of a soil is its maximum resistance to shear stresses just before the failure. Shear failure occurs of a soil mass occurs when the shear stresses induced due to applied compressive loads exceed the shear strength of the soil. Soils are seldom subjected to direct shear. However the shear stresses develop when the soil is subjected to direct compression. Shear strength is the principal engineering property which controls the stability of soil mass under loads. It governs the bearing capacity of the soils, the stability of slopes in soils, and the earth pressure against retaining structures.
Shear strength of a soil at a point on a particular plane was expressed by coulomb as a linear function of normal stress an that plane, as

$$\tau = c + \sigma \tan\phi$$

Where,

$c$ = cohesion interception

$\phi$ = angle which the envelop makes with σ–axis called angle of internal friction

Effective stress (σ') at any point in the soil mass is equal to the total stress minus pore water pressure. Total stress (σ) on the base of a prism is equal to the force per unit area which is given

$$\sigma = P/A = \gamma_{sat} h$$
$$(\sigma') = \sigma - u = \gamma_{sat} h - \gamma_w h$$
$$\sigma' = (\gamma_{sat} - \gamma_w) h = \gamma' h$$

***Strength Tests:*** The following tests are used to measure the shear strength of soil.

- Direct shear test.
- Triaxial compression test
- Unconfined compression test
- Vane shear test

Direct shear test: This test is performed to determine the consolidated-drained shear strength of a sandy to silty soil. The shear strength is one of the most important engineering properties of a soil, because it is required whenever a structure is dependent on the soil's shearing resistance. The shear strength is needed for engineering situations such as determining the stability of slopes or cuts, finding the bearing capacity for foundations, and calculating the pressure exerted by a soil on a retaining wall.

The direct shear test is one of the oldest strength tests for soils. Direct shear device will be used to determine the shear strength of a cohesionless soil (i.e. angle of internal friction (f)). From the plot of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress. After the experiment is run several times for various vertical-confining stresses, a plot of the maxi mum shear stresses versus the vertical (normal) confining stresses for each of the tests is produced. From the plot, a straight-line approximation of the Mohr-Coulomb failure envelope curve can be drawn, f may be determined, and, for cohesionless soils (c = 0), the shear strength can be computed from the following equation:

S = S*Tan (f)

- Direct shear device
- Load and deformation dial gauges
- Balance

Triaxial compression test: Trial test is used for determination of shear characteristics of all types of soils under different drainage conditions. The test has been explained in the Indian standard code (IS: 2720-1997).

Unconfined compression test: The unconfined compression test is a special form of a triaxial test in which the confining pressure is zero. The test can be conducted only on clayey soils which can withstand confinement. The test is generally performed on intact, saturated clay specimens.

Vane Shear Test: The undrained shear strength of soft clays or rocks can be determined in the laboratory by vane shear test. The test can also be conducted in the field on the soil at the bottom of the borehole. The field test can be performed even without drilling a bore hole by the direct penetration of the vane from the ground surface.

### *In-situ Laboratory Tests*

The strength parameters of soil or rock layers are investigated by extracting cores of samples and taken to the laboratory for testing. Insitu laboratory tests are conducted to avoid disturbing of foundation material. These Insitu laboratory tests mainly include plate jack test for soils and hydro fracture test for rocks.

The hydro-fracture test is done to determine the strength of underlying strata, in case of site where huge structures, such as dams, etc are built. In this test, water is injected into the soil at huge pressures and checked if the soil is able to bear the pressure and even the magnitude of fractured rock can be estimated. In the hydro-fracture test the magnitude of the minimum principal stress is determined and back analysis is done from monitored deformations, when suitable excavations are made for other purposes and economical monitoring can be used. D5607-02 gives standard test method for performing laboratory direct shear strength tests of rock specimens under constant normal force. The Insitu shear test or the plate jack test for the soils is explained in IS: 2720-Part39/sec2.

### *Bearing Pressure*

Foundations for structures are generally classified as deep and shallow. Deep foundations generally refer to piled foundations, whereas shallow foundations include pad foundations, raft foundations, and strip footings. The performance and functional viability of a foundation depends on the interaction between the structure which is supported and on the founding material. The behavior of the soil depends on the bearing pressure and width of the foundation, hence the bearing capacity is not simply a function of the soil, but rather is also a function of the specific foundation arrangement. Bearing pressure is the maximum pressure at which the supporting ground is expected to fail in shear.

***Orographic:*** Denotes effects that are related to the presence of mountains or high ground on, say, rainfall. Orography is the study of the physical geography of mountains and mountain ranges.

### *Non- Recording and Recording rain gauges*

The **non-recording rain gauge** that is extensively used in India is the *Symon's gauge*. It essentially consists of a circular collecting area connected to a funnel. The rim of the collector is set in a horizontal plane at a suitable height above the ground level. The funnel discharges the rainfall catch into a receiving vessel. The funnel and receiving vessel are housed in a metallic container. Water contained in the receiving vessel is measured by a suitably graduated measuring glass, with accuracy up to 0.1mm. Recently India Meteorological Department (IMD) has changed over to the use of *fiberglass reinforced polyester raingauges*, which is an improvement over the Symon's gauge. These come in different combinations of collector and bottles.

**Recording rain gauges** produce a continuous plot against time and provide valuable data of intensity and duration of rainfall for hydrologic analysis of storms. Following are some of the commonly used recording rain gauges.

1. Tipping bucket type
2. Weighing bucket type
3. Natural siphon type
4. Telemetering Rain gauges.

For a detailed list of commercial rain gauges usually manufactured, one may refer to the web-site of one of the manufacturers Nova Lynx at the following web-site:
http://www.novalynx.com/products-rain-gauges.html

***Current meter***

Current meters are velocity measuring devices that that are used to measure the velocity of a stream at a point. Each point velocity measurement is then assigned to a meaningful part of the entire cross section passing flow. Several classes of current meters are used in water measurement.

- Anemometer and propeller velocity meter
- Electromagnetic velocity meters
- Doppler velocity meters
- Optical strobe velocity meters

One may consult the United States Bureau of Reclamation online document "Water measurement manual" for more information which may be found in the following web-site:
http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/indexframe.html

## 4.1.19 Important organizations

**Central Water Commission**

Central Water Commission is a premier Technical Organization in the country in the field of Water Resources since 1945 and is presently functioning as an attached office of the Ministry of Water resources. The Commission is charged with the general responsibilities of initiating, coordinating and furthering in consultation of the State Governments concerned, schemes for control, conservation and utilization of water resources throughout the country, for purpose of Flood Control, Irrigation, Navigation, Drinking Water, Power Development & water supply. It also undertakes the investigations, construction and execution of any such schemes as required.
Web-site: http://cwc.nic.in/

**Survey of India**

Survey of India, The National Survey and Mapping Organization of the country under the Department of Science & Technology, is the oldest scientific department of the govt. of India. It was set up in 1767 and has evolved rich traditions over the years. In its assigned role as the Nation's principal mapping agency, Survey of India bears a special responsibility to ensure that the country's domain is explored and mapped suitably to provide base maps for expeditious and integrated development and ensure that all resources contribute their full measure to the progress, prosperity and security of our country now and for generations to come.
Web-site: http://dst.gov.in/scservices/soi.htm

**National Remote Sensing Agency**

National Remote Sensing Agency (NRSA) is an autonomous organization under Department of Space, Govt. of India engaged in operational remote sensing activities. The operational use of remote sensing applications is in the fields of

water resources, agriculture, soil and land degradation, mineral exploration, groundwater targeting, geomorphologic mapping, coastal and ocean resources monitoring, environment, ecology and forest mapping, land use and land cover mapping and urban area studies, large scale mapping, etc.
The chief activities are satellite data and aerial data reception, data processing, data dissemination; applications for providing value added services and training.
Web-site: http://www.nrsa.gov.in/

**Geological Survey of India**

This is the premier organization of Earth Science Studies in the sub-continent with strength of 2900 geoscientists and technical professionals. The GSI has a network of Offices located in all the states of India. It is the custodian of Geoscientific database developed over a period of 150 years and is capable of handling time-bound jobs in different sub disciplines of earth science: from geological mapping to deposit modeling. It is also equipped with modern laboratories run by professionals. It possesses organizational setup to impart training in the fields of earth science and holds the key to mineral exploration.
Web-site: www.gsi.gov.in