Surface Water Hydrology
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Lecture 17
Measurement of Flow Velocity

In this lecture, we will learn about the measurement of flow velocity. If we know the flow velocity then we can multiply with the respective flow cross-section to get the stream-flow volume. So, the flow velocity is the focus of this particular lecture.

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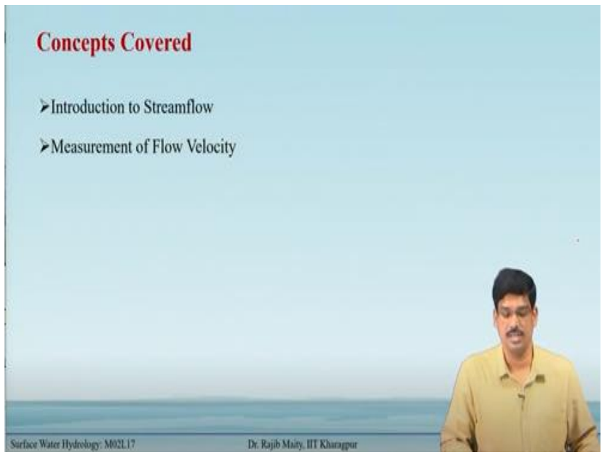

The two concepts that we will cover in this lecture, the first one is an introduction to stream-flow. And the measurement of flow velocity using different methods.

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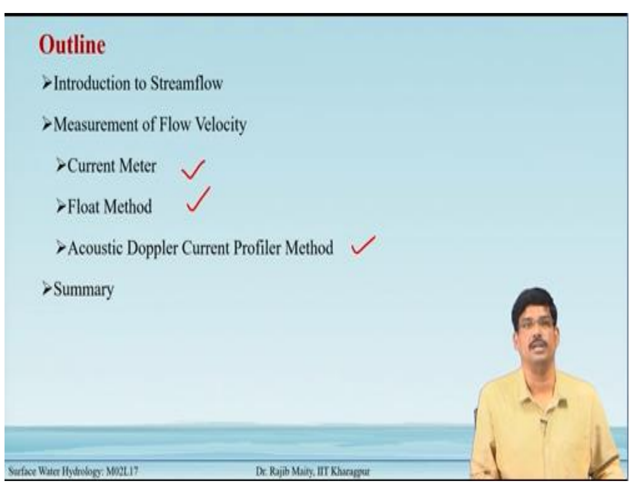

The outline goes like this. So, after the introduction to the stream-flow, different techniques to measure the flow velocity and we will specifically cover three different methods all are popular. The first one is the current meter method, then we will take the float method and then the Acoustic doppler current profile method. So, these are the three things that will we will cover. Also, their relative merits, demerits, their applicability, their suitability in different conditions of the gauging site will discuss.

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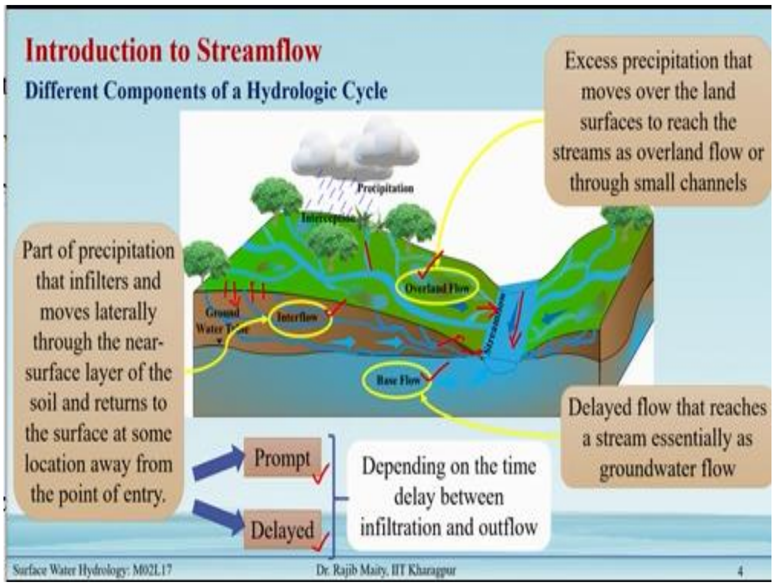

Introduction to Streamflow

Different Components of a Hydrologic Cycle

There are different processes of the hydrologic cycle. The ground surface receives the water from precipitation in the form of rainfall or snowfall or different other forms. The abstraction from the precipitation in different forms the interception is one of them, and after that, it goes to the different processes like overland flow, infiltration, then different processes. Now, so far as the stream-flow is concerned, there are three major components that we will discuss. The first one is overland flow, the second one is the interflow, and then base flow.

Excess precipitation that moves over the land surfaces to reach the streams as overland flow or through small channels. So, it flows and joins to the nearest small streams, but sometimes there are some small temporary gully or channels are formed due to them depending on the amount of runoff.

Secondly, some parts of the precipitation penetrate the ground surface through the process called infiltration and after it infiltrates, the part of the precipitation that moves laterally through the near-surface layer of the soil and returns to the surface at some location away from the point of entry.

If there are some infiltration takes place in this zone and it follows a different path it can go downward to join the groundwater table or it can just flow approximately near the surface zone and then ultimately at some downstream it can again come up from to join the surface or the surface streams.

So, this comes in two different ways one is called the prompt, the prompt means it comes back quickly, and the other one is called the delayed depending on the time delay between the infiltration and the outflow that is coming out again on the surface. So that is why delayed flow reaches the stream essentially as that groundwater flow. So, these are the three main components that we are discussing the overland flow streamflow and the base flow that comes and join and flows as surface streamflow.

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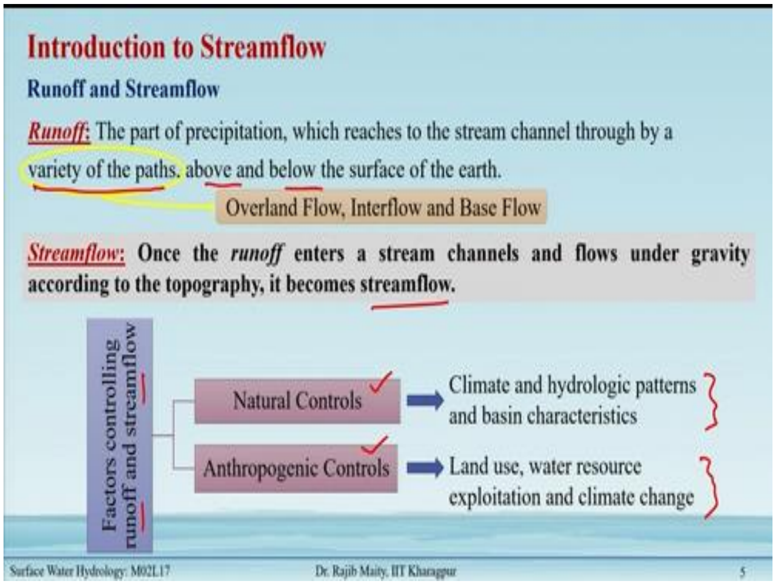

Runoff and Streamflow

Runoff: The part of precipitation, which reaches the stream channel through by a variety of paths, above and below the surface of the earth. The variety of paths through the different processes, the first one is overland flow or the interflow or the base flow.

Streamflow: Once the runoff enters a stream channel and flows under gravity according to the topography, it becomes streamflow.

Different factors control either runoff or stream-flow. There are two different groups, the first one is called the natural control and the second one is called the anthropogenic control. So, in the first one, the climate and the hydrologic pattern or the basin characteristics, these are the things that can be some of the things that we can categorize as the natural control. And under anthropogenic control, those are land use, water resource exploitation, and climate change. So, these are the most two broad controls that affect the variation of runoff and stream-flow.

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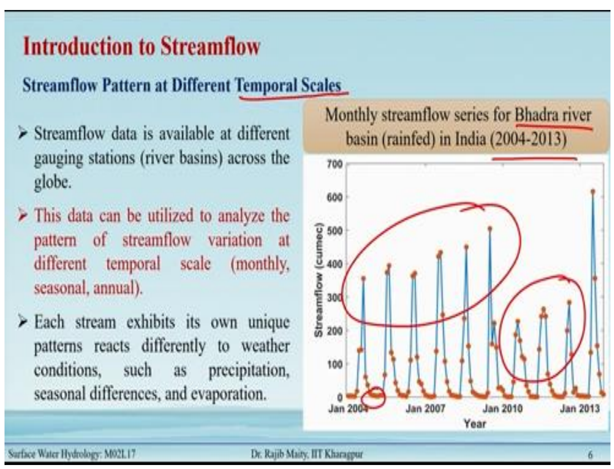

Streamflow Pattern at Different Temporal Scales

Temporal scale can be daily, it can be hourly or it can be weekly or monthly, or even seasonal, different temporal scales are possible. So, stream-flow data is available at different gauging stations across the river basin throughout the globe.

So, there are different places we play some gauging instruments to collect the data. And this data is generally utilized to analyze the pattern of the stream-flow variation at different temporal scales. Each stream exhibits its unique patterns that react differently to weather conditions, such as precipitation, seasonal differences, and evaporation.

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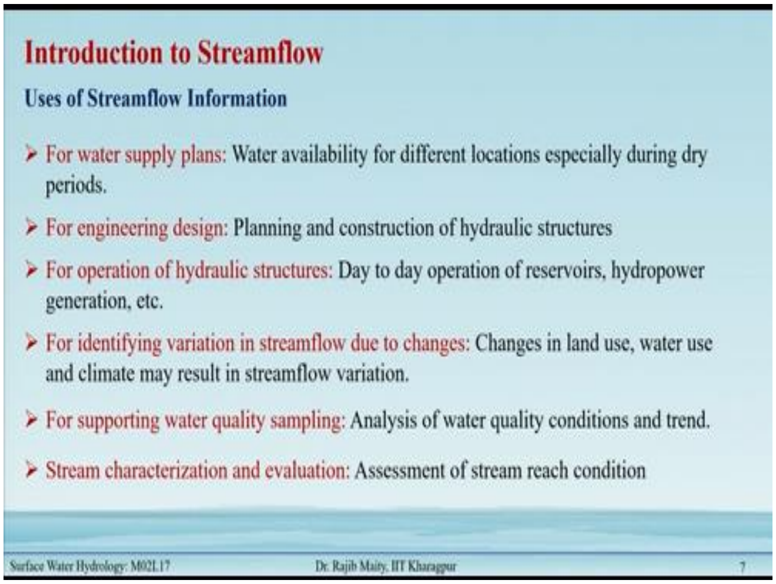

Uses of Streamflow Information

- For water supply plans: Water availability for different locations especially during dry periods.
- For engineering design: Planning and construction of hydraulic structures
- For the operation of hydraulic structures: Day to day operation of reservoirs, hydropower generation, etc.
- For identifying variation in streamflow
- Due to changes: Changes in land use, water use, and climate may result in streamflow variation.
- For supporting water quality sampling: Analysis of water quality conditions and trend.
- Stream characterization and evaluation: Assessment of stream reach condition

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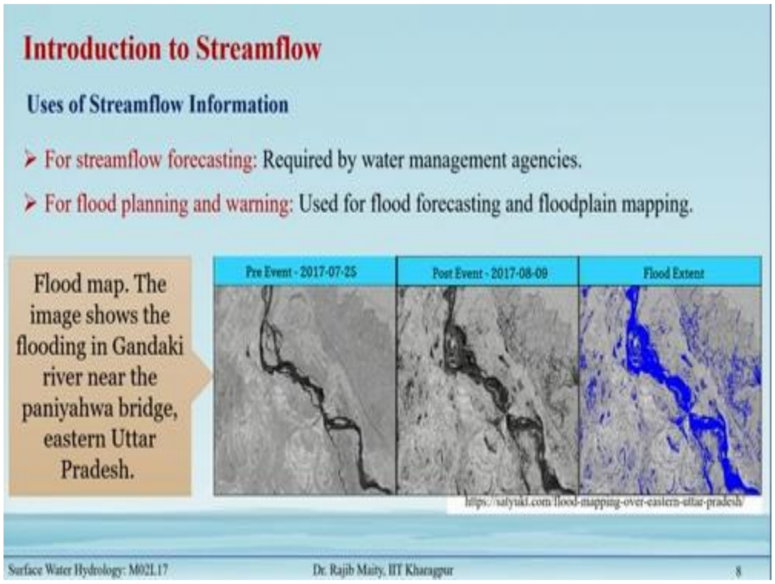

- ➢ For streamflow forecasting: Required by water management agencies.
- ➢ For flood planning and warning: Used for flood forecasting and floodplain mapping.

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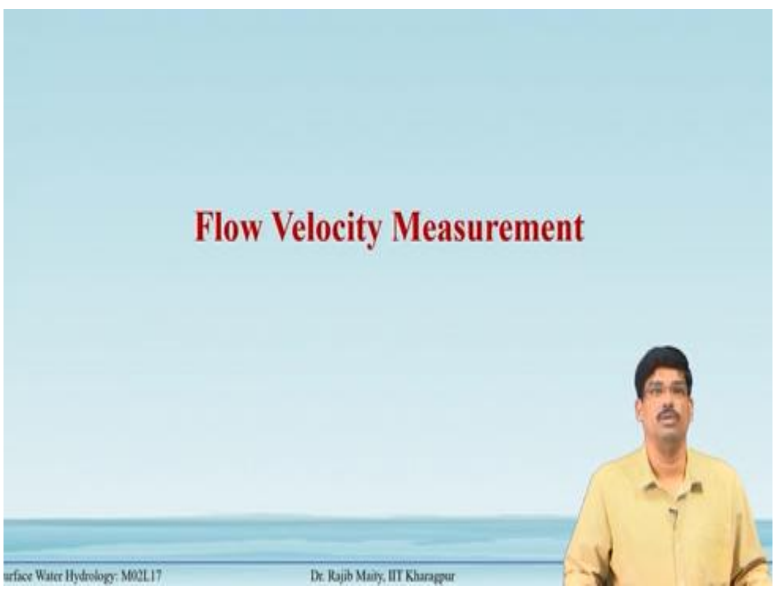

So, coming to our topic today is that flow velocity measurement

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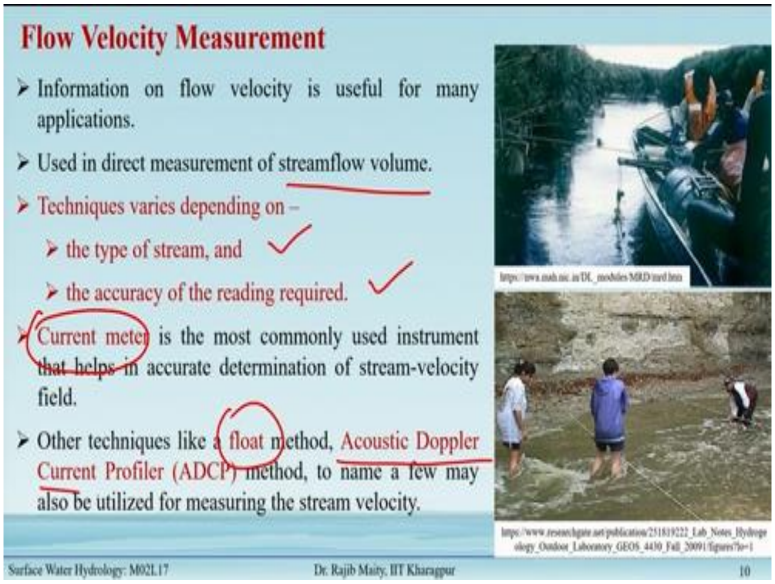

Flow Velocity Measurement

The information for the flow velocity is useful for many applications. The velocity assessment can be used in the direct measurement of streams of volume. So, if we know the flow cross-sectional area, then that information can be utilized for this temporal volume which is essential.

Then, there are different techniques, depending on the different site conditions, the first one is the type of stream and the accuracy of the reading that is required sometimes, it always depends on the two things as how much accuracy we need and how much economically it is viable. So, these are the two things always we decide, before we proceed to any specific technique that we need to adopt for the flow velocity measurement.

The current meter is one of the instruments that are the most commonly used instrument that helps in the accurate determination of stream velocity field and there are other instruments are also there. Other techniques like a float method, Acoustic Doppler Current Profiler (ADCP) method, to name a few may also be utilized for measuring the stream velocity.

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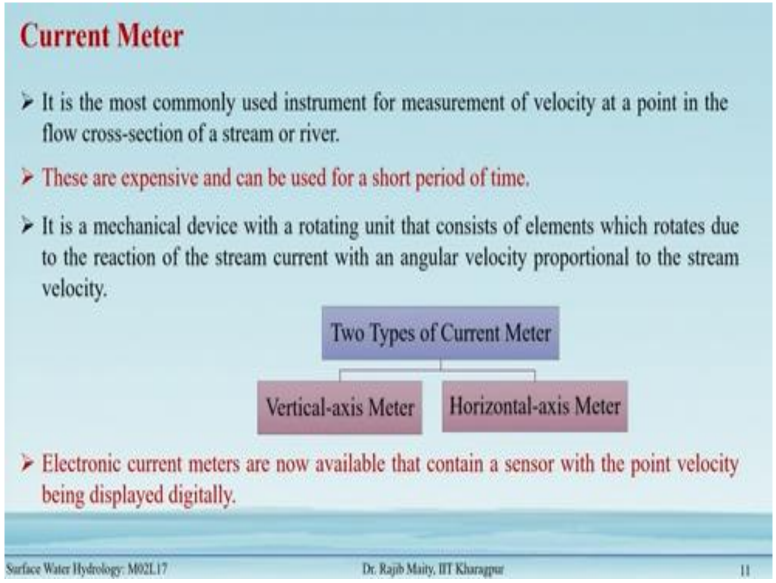

The current meter is the most commonly used instrument for measuring the velocity at a point in the flow cross-section of a stream or river but these are expensive and can be used for a short period of time.

The current meter is a mechanical device, it has some rotating unit that consists of elements that rotate due to the reaction of the stream current with an angular velocity proportional to the stream velocity.

There are two major types of this current meter there one is called the vertical axis meter another one is the horizontal axis meter. There are some other recently developed instruments like the electronic current meters. These electronic current meters attach to an additional sensor with the point velocity being displayed digitally they are themselves so, that it is calibrated and that sensor helps to use that rotational speed and convert it to the velocity at that particular point.

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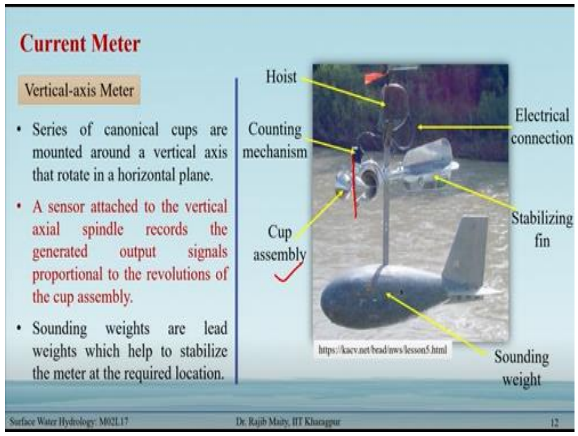

Vertical-axis Meter

In the vertical axis meter, a series of canonical cups are there mountain around a vertical axis and that rotates in a horizontal plane depending on how much is the velocity of this one. It rotates once we immerse it below the water surface and there is a sensor attached to this vertical axial spindle that records the generated output signal proportional to the revolution on the curve assembly.

And there are some sounding weights are also there, those sounding weights help to stabilize it in a particular location. Other parts are also there like this is the host pipe where it helps to hold it in a position there are some electrical connections are also required, then the stabilizing fin is there on the backside of the cup assembly so, that it directs towards the flow.

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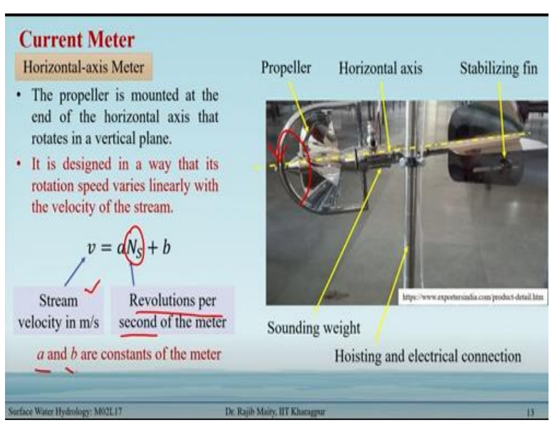

Horizontal-axis Meter

In the horizontal axis meter, the propeller is mounted at the end of the horizontal axis that rotates in a vertical plane. It is designed in a way that its rotation speed varies linearly with the velocity of the stream.

And there are other parts are also there, for example, the stabilizing fin is also there at the end and there is a sounding weight is there hosting and electrical connections are also there below the to hold it in a position. Now, for both this current meter is there is calibration is needed initially.

$$v = aN_S + b$$

So, this v is the velocity of the stream in meter per second and it is related to the revolution per second that is there in $N_{S;}$ a and b are the constant of the meter. So, that needs to be ascertained first before we use it.

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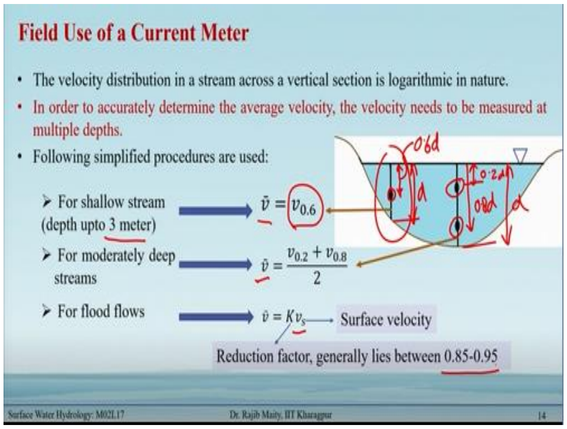

Field Use of a Current Meter

There is different field use of the current meter. The velocity distribution in a stream across the vertical section is in the logarithmic that we know that is not uniform from the surface to the bottom of the stream. To accurately determine the velocity profile, we need to measure this velocity at multiple depths. So, we need to emerge it below the surface and record that what is the depth and what is the velocity there. So, it helps to get the velocity profile.

For practical purposes sometimes, there are some simplified methods are also utilized. Three cases are possible.

One is the shallow stream up to 3 meters for example, in this case, the mean velocity is considered as $v_{0.6}$. So, if this total depth is d, then this one is 0.6 d. At this location, the current meter is placed and recorded we get that record as a mean velocity for that section.

$$\bar{v} = v_{0.6}$$

Now, if it is even deeper, so, greater than 3 meters, then place the current meter in two different locations; one is from 20% of the total depth to and then another location is 0.8d. Then measure it in these two locations and then take an arithmetic average of this to get the average velocity for that section.

$$\bar{v} = \frac{v_{0.2} + v_{0.8}}{2}$$

Sometimes for the flood flows the average velocity is taken as a surface velocity. Here v_s is the velocity at the surface and then we multiply it with respect to some reduction factor K and this reduction factor depends on the local condition that can vary from 0.85 to 0.95.

$$\bar{v} = Kv_s$$

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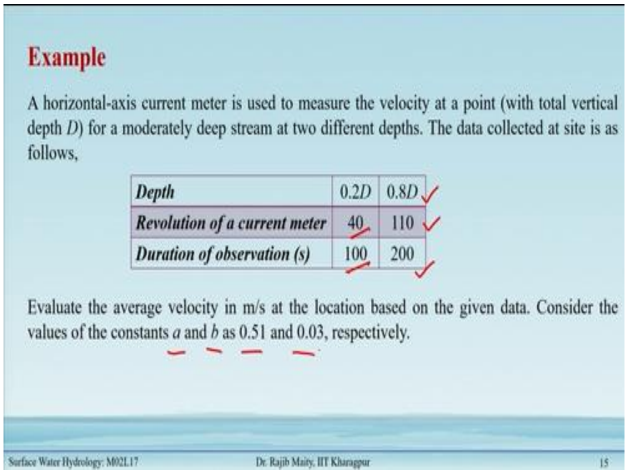

Example

A horizontal-axis current meter is used to measure the velocity at a point (with total vertical depth D) for a moderately deep stream at two different depths. The data collected at the site is as follows,

Depth	0.2*D*	0.8*D*
Revolution of a current meter	40	110
Duration of observation (s)	100	200

Evaluate the average velocity in m/s at the location based on the given data. Consider the values of the constants a and b as 0.51 and 0.03, respectively.

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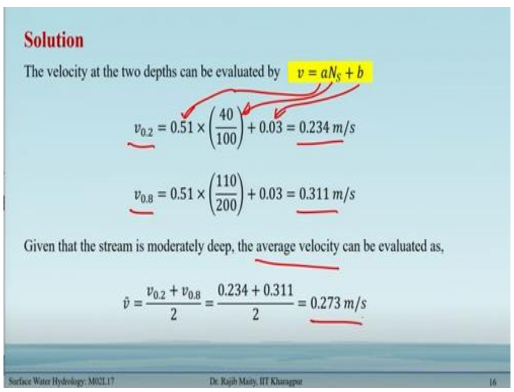

Solution

The velocity at the two depths can be evaluated by

$$V = a\ N_s + b$$

$$v_{0.2} = 0.51 \times \left(\frac{40}{100}\right) + 0.03 = 0.234\ m/s$$

$$v_{0.8} = 0.51 \times \left(\frac{110}{200}\right) + 0.03 = 0.311\ m/s$$

Given that the stream is moderately deep, the average velocity can be evaluated as,

$$\bar{v} = \frac{v_{0.2} + v_{0.8}}{2} = \frac{0.234 + 0.311}{2} = 0.273\ m/s$$

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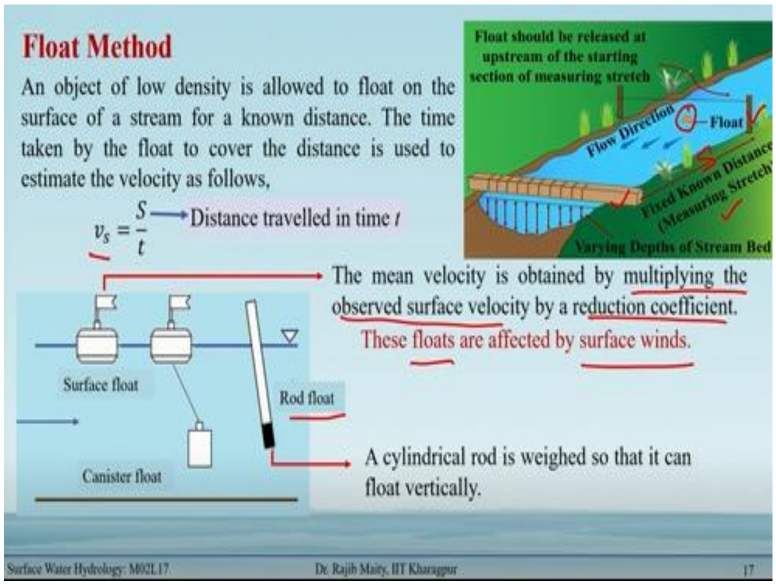

Float Method

A float is an object of low density and it is allowed to float on the surface of a stream for a known distance the time taken by the flow to cover the distance is used to estimate the velocity as follows

$$v_s = \frac{S}{t}$$

The S is the distance that traveled by that is traveled in time t and there are two sections are there this is one section where it starts from and there is another section total fixed-length distance and this is the measuring stretch.

Now, there are different types of floats are there. The mean velocity is obtained by multiplying the surface velocity by a reduction factor that is when the fluid is coming in, it will give approximately the surface velocity only, but the surface velocity does not reflect the average velocity of the section. So, generally multiply with some reduction factor, reduction coefficient.

However, as these floats are generally affected by the surface wind, so, we take different measures, for example, we put some weight below or there are some rod float kinds of thing, it is a cylindrical rod weight, so, that it can float vertically and it takes some sort of estimate from the lower side also.

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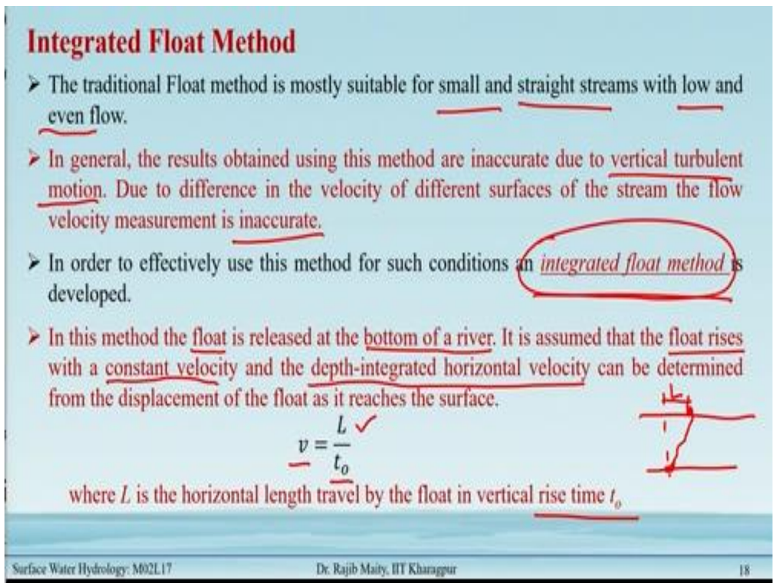

Integrated Float Method

The traditional Float method is mostly suitable for small and straight streams with low and even flow. In general, the results obtained using this method are inaccurate due to vertical turbulent motion. Due to differences in the velocity of different surfaces of the stream the flow velocity measurement is inaccurate. To effectively use this method for such conditions, an integrated float method is developed.

In this method, the float is released at the bottom of a river. It is assumed that the float rises with a constant velocity and the depth-integrated horizontal velocity can be determined from the displacement of the float as it reaches the surface.

$$v = \frac{L}{t_o}$$

Where L is the horizontal length travel by the float in vertical rise time t_o

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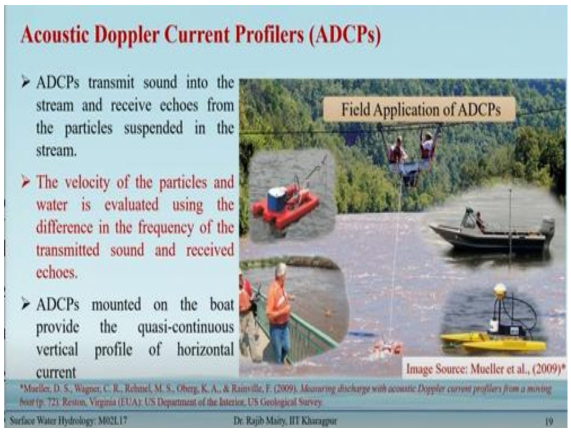

Acoustic Doppler Current Profilers (ADCPs)

Next comes another method which is very expensive and it required some very expertise. Then, it is called the Acoustic Doppler Current Profilers, ADCPs. ADCPs works based on the principle that it transmits the sound into the stream and receive the echoes from the particle suspended in the stream and the velocity of the particle and the water is evaluated using the difference in the frequency of the transmitted sound and the received echoes.

There is a different setup on the ground that is needed, and they are depending on the site condition, there are different possibilities are there whether it is at a location near the bridge or it is just like a virgin River or it is the hilly terrain. One of the very interesting features of this kind of measurement is that it gives a quasi-continuous vertical profile of the horizontal current. This is very important to get an accurate estimate of the total flow quantity.

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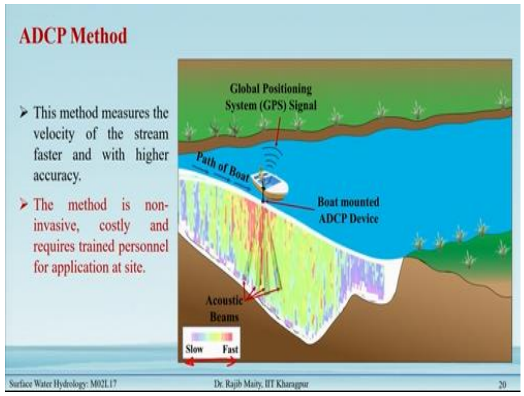

The ADCPs method measures the velocity of the stream faster and with higher accuracy. The method is non-invasive, costly, and requires trained personnel for application at the site.

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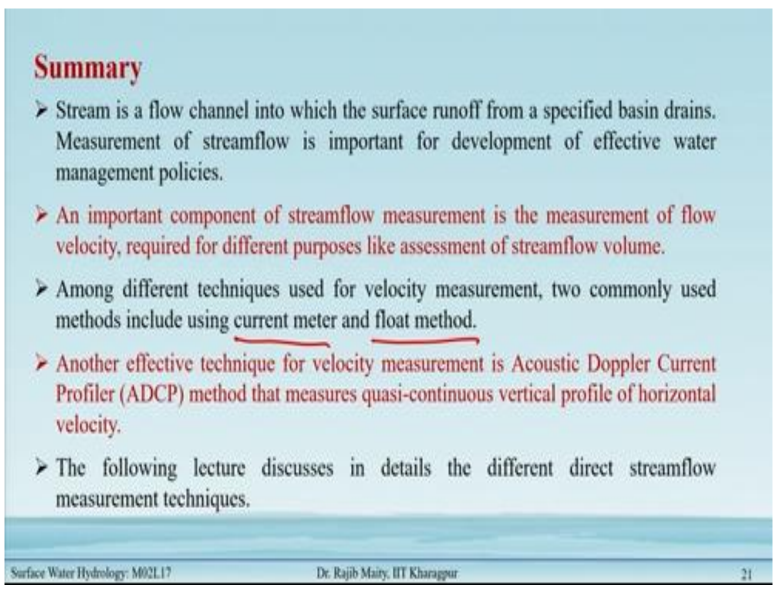

Summary

In summary, we learned the following points from this lecture:

- Stream is a flow channel into which the surface runoff from a specified basin drain. Measurement of streamflow is important for the development of effective water management policies.
- An important component of streamflow measurement is the measurement of flow velocity, required for different purposes like the assessment of streamflow volume.
- Among different techniques used for velocity measurement, two commonly used methods include using the current meter and float method.
- Another effective technique for velocity measurement is the Acoustic Doppler Current Profiler (ADCP) method that measures the quasi-continuous vertical profile of horizontal velocity.
- The following lecture discusses in detail the different direct streamflow measurement techniques.