Engineering Hydrology
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Lecture – 47
Stream flow Measurement – 1

Hello all welcome back. In the previous couple of lectures, we were discussing about surface water. We have already seen whenever precipitation is occurring, some amount of water is lost as abstractions. Initially, whenever rainfall is occurring some amount of water will be pondered on the ground surface. After that the overland flow will be starting. Once the overland flow is started, it will be forming small, small channels and the water will be directed to the outlet of the basin. So, the runoff will be contributing to the outlet of the basin. So, how can it be measured? That is what we are going to see in this lecture.

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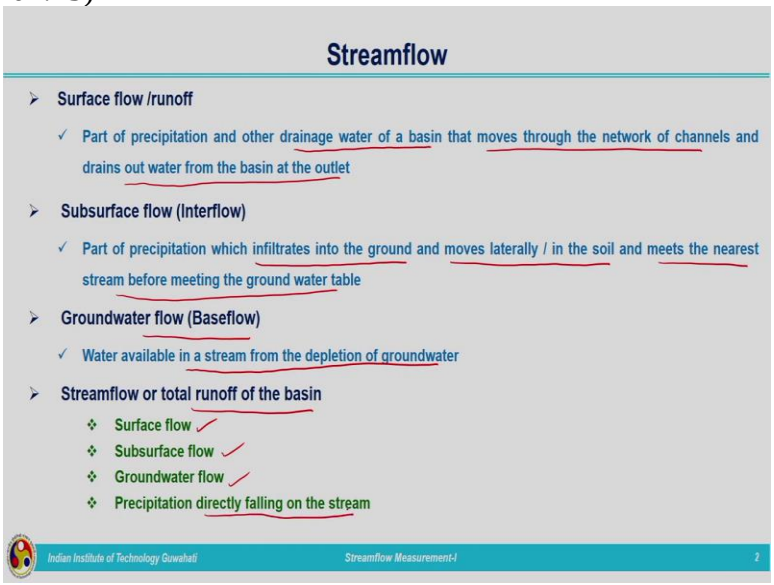

Surface flow or runoff, you know already what is meant by runoff. Part of the precipitation and other drainage water of a basin will be moving through the network of channels and drains out water at the basin outlet. Whenever this overland flow is occurring, after certain time some amount of water will be flowing through the channels or small, small channels will be produced and water will be directed to the outlet of the basin.

So, the water which is a part of precipitation, some part of precipitation and also other drainage water will be forming the runoff at the outlet of the watershed. Second one is subsurface flow or

interflow. In the case of subsurface flow what is happening actually, whenever precipitation is occurring, some amount of water will be infiltrating into the soil and the subsurface storage will be satisfied. After that the water starts flowing depending on the gradient. So, it will be flowing in the lateral direction and finally contributing to the streams. That is what is termed as the interflow. So, the part of precipitation which infiltrate into the ground and moves laterally in the soil and finally meets the nearest stream before meeting the groundwater table. This water is not again moving downward to meet the groundwater table. Before that itself, it is moving laterally based on the gradient and finally contributing to the stream, that is the contribution from the unsaturated zone is termed as the interflow. Next one is the groundwater flow or baseflow. This is the contribution to the stream coming from the groundwater. Some amount of water will be available in the stream from the depletion of groundwater. So, this is termed as baseflow.

So, when we talk about stream flow or total runoff of the basin, all these three components along with the precipitation comes into account that is surface flow, subsurface flow, groundwater flow and precipitation directly falling on the stream. So, the streamflow is consisting of the runoffs, subsurface flow, that is the interflow and groundwater flow that is the baseflow and also the precipitation which is directly falling on the channel together is termed as the streamflow.

So, the runoff for the surface flow is coming from the excess rainfall and the water which is coming as interflow is based on the infiltrated water and again it is percolating to meet the groundwater table that will be contributing towards the baseflow and in addition to that, rainfall is occurring on the watershed, it falls on the channels also. All these four components together termed as streamflow.

So, now, we need to have mechanism for measurement of streamflow because this streamflow is very important whenever we are talking about any implementation of water resources projects. So, it is measured in terms units of discharge. What is the unit of discharge? It is in meter cube per second. Discharge is expressed in terms of meter cube per second, same unit is used for representing streamflow also.

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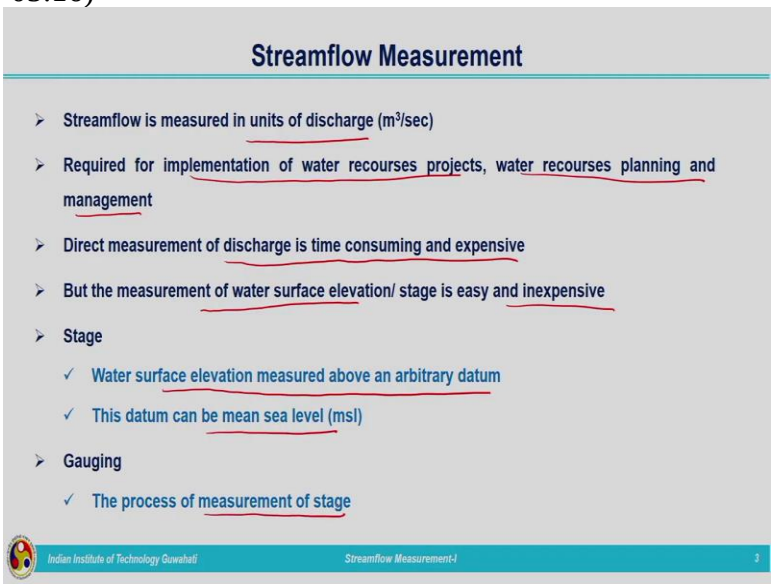

So, this is very important for the implementation of water resources projects: water resources planning and management, because whenever we are talking about the construction of a hydraulic structure, we need to have the quantification of streamflow. If we are going to provide some bank protection measures, in all these cases, we need to have the idea about the stream flow which is occurring at that particular location. So, direct measurement of discharge or streamflow is time consuming and expensive. Even though we need to have the stream flow measurement, the direct measurement is always very difficult and also time consuming. So, we will be going for indirect measurement of streamflow. It can be done by the measurement of water surface elevation, that is less time consuming and inexpensive.

Water surface elevation is also termed as stage. Stage measurement means water surface elevation, determination of water surface elevation. How much is the water depth prevailing in the particular stream, that is termed as stage. Stage is nothing but the water surface elevation measured above an arbitrary datum and this datum can be mean sea level. We need to have a datum based on that we will be measuring the water surface or water level. Water surface elevation is measured based on the datum, that datum usually we consider as the mean sea level and this process of measurement of stage is termed as gauging. So, when we talk about measurement of the streamflow, it is a difficult process and also time consuming. So, we will be always going for indirect measurement of streamflow by measuring the velocity and also water level measurement.

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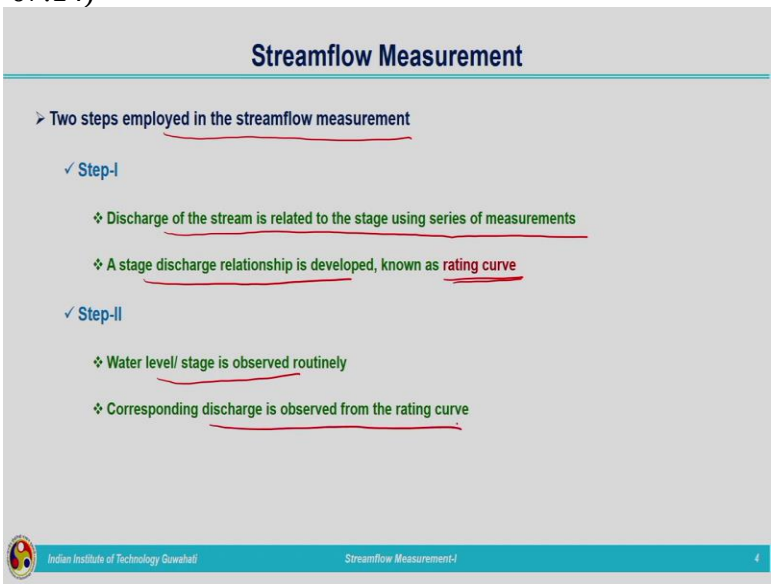

There are two steps involved in the stream flow measurement: step 1 and step 2. In step 1 discharge of the stream is related to the stage using series of measurement. We will be measuring the stage at a particular gauging station and corresponding velocity at that particular gauging station measured. Based on the stage and width of the river and also the velocity measured we can calculate the discharge at that particular gauging station.

After that a stage discharge relationship is developed which is known as well-known rating curve. This rating curve is very important. How this rating curve is formed? We will be plotting the data corresponding to water level and the corresponding discharge. So, for a particular gauging station we will be measuring the stage or the water level and the corresponding discharge will be calculated and that will be plotted in a graph. That is the rating curve. So, if rating curve is available to us for a particular river, that can be utilized for getting the discharge at different water levels. So, in the first step what we are doing, we are finding out the relationship between the stage and the discharge, that is the formation of stage discharge rating curve will be done. Then in step 2, after formulating the rating curve, after certain time period, maybe in different season, we will be measuring the water level or stage and corresponding to that stage what will be the discharge that will be noted from the rating curve.

So, every time there is no need to go for measurement of discharge that is measurement of stage and velocity. Only stage is required if rating curve is already formed for a particular gauging station. So, second step what we are doing water level or stage is observed routinely and

corresponding discharge is observed from the rating curve. The water level observation is done routinely by certain agencies. So, always discharge measurement would not be done. Water level measurement will be done and corresponding to that water level we can get the discharge from the rating curve. So, this is the way which we look forward to get the streamflow in a particular gauging station rather than directly measuring the streamflow.

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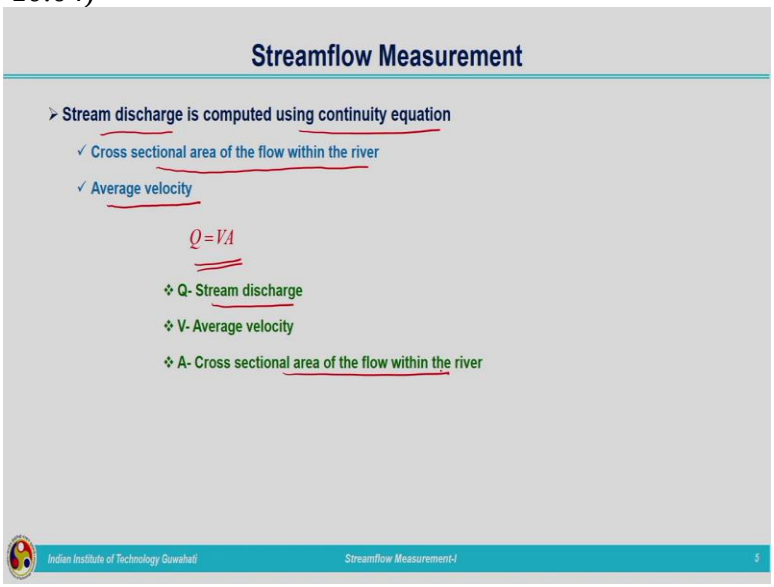

So, after the getting the stage at a particular location, how can we determine the stream discharge? That can be obtained by making use of the continuity equation. We all are very much familiar with the continuity equation, that continuity equation will be utilized for the stream discharge or streamflow calculation. For that we need to have the cross-sectional area of the flow within the river. Once this cross-sectional area and average velocity is known to us we can calculate the stream discharge by using the formula

$$Q = VA$$

Q is the stream discharge, V is the average velocity, A is the cross-sectional area of the flow within the river.

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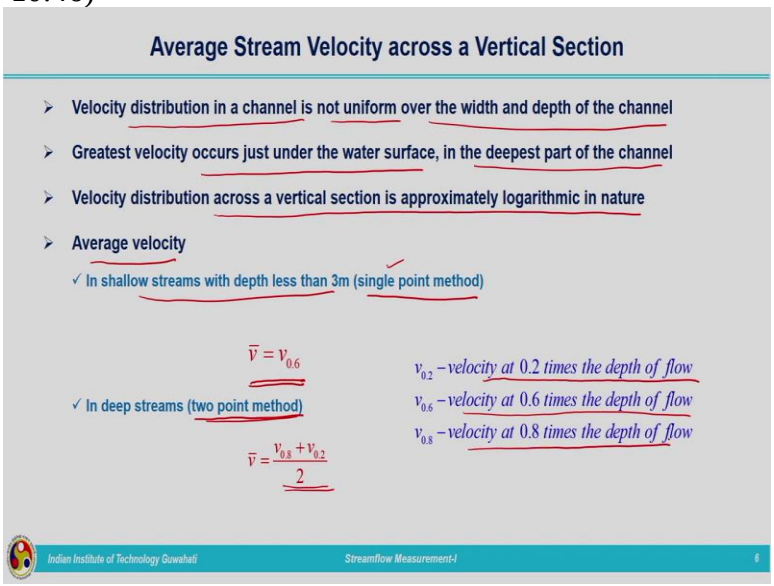

Now, let us move on to the topic of determining average stream velocity, that is average stream velocity across a vertical section. We all know velocity distribution in a channel is not uniform over the width and depth of the channel. When we talk about the velocity distribution in a channel or in a river, it is not uniform. For simplification purpose, we used to consider the flow to be uniform and uniform velocity will be calculated by using the corresponding formula. But, always it is not like that in actual condition, it is not uniform across the width and also the depth. The greatest velocity occurs just under the water surface in the deepest part of the channel, it is not on the water surface, certain depth below the water surface, the maximum velocity will be occurring. Velocity distribution across a vertical section is approximately logarithmic in nature. When we plot the velocity distribution curve, it is logarithmic in nature. I am not going deep into those details, how the velocity distribution will be in an open channel that you might have covered already in open channel hydraulics. So, here what we want, we want the average velocity for that what we are doing? We will be measuring the velocity at different depths and based on the velocity measurement, we will be calculating the average velocity.

There are different ways to get the average velocity. Commonly we will be using one-point method and two-point methods. So, in shallow streams with depth less than 3 meters, we will be using single point method. What is meant by this single point method? In this what we are doing, we are measuring the velocity at a depth of 0.6 times the depth of the stream, i.e.,

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

We know the water depth, water depth will be measured, based on that, we will be determining the position where the depth is 0.6 times the depth of the channel. At that location, we will be measuring the velocity. We will be measuring velocity at two different depths and we will be taking the average of those two values to get the average velocity. This is an approximate method to calculate the average velocity. Both these methods are approximations only. In deep streams, what we are doing average velocity is equal to

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

Where, $v_{0.2}$ is the velocity at 0.2 times the depth of flow, $v_{0.6}$ that we have seen in the single point method is the velocity it is 0.6 times the depth of flow and $v_{0.8}$ is the velocity at 0.8 times the depth of flow. So, that way in shallow streams, we will be measuring the velocity at a single point that is velocity at 0.6 times the depth of the stream and in the case of deeper streams, we will be measuring the velocity at two points, that is at 0.2 times the depth of the stream and also 0.8 times the depth of the stream the velocities will be measured. The average of these two velocities is considered as the average velocity of the stream.

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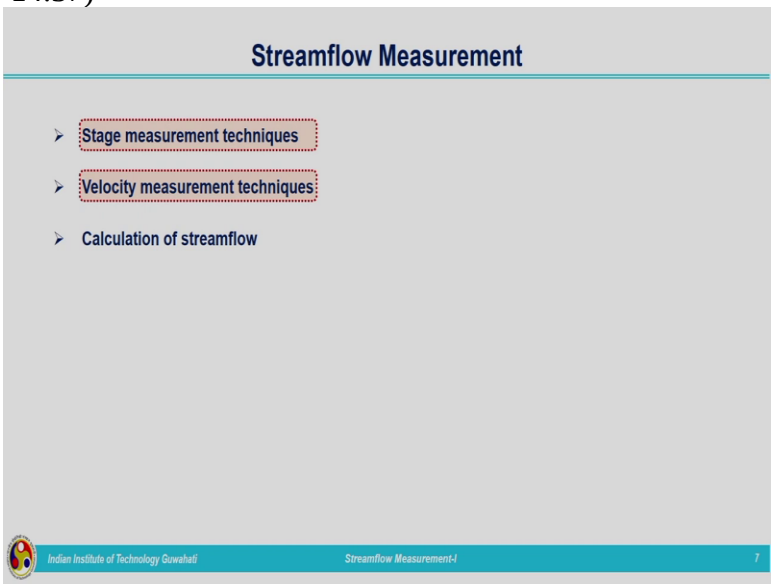

Now, let us move on to stream flow measurement, that is, we need to have stage measurement techniques. We need to have velocity measurement techniques and after that we need to calculate the stream flow. First, we need to measure stage and velocity. Once the stage and velocity are measured, after that we can go for the calculation of streamflow. So, in this lecture, we are going to look into stage measurement techniques and velocity measurement techniques. In the next lecture, we will move on to calculation of streamflow that we have already seen that is by making use of the continuity equation $Q = AV$.

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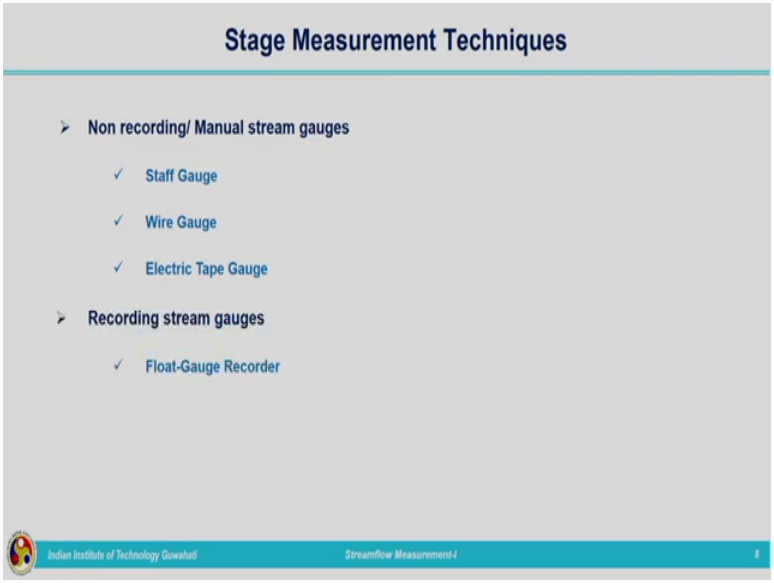

So, let us start with the stage measurement techniques. Different measurement techniques are there which are very commonly used or conventional techniques we will be looking into in this lecture. When we were discussing about rainfall, we have seen two different techniques are there recording type and non- recording types, that is manual and automatic. In the similar way in the case of stream flow also, we are having two different types of measuring methodologies: one is recording and the other one is the non- recording. So, let us see different stage measurement techniques: non- recording or manual stream gauges, that is in that I am going to include: staff gauge, wire gauges, electric tape gauge and recording stream gauges, we will be looking into float gauge recorder.

So, regarding stage measurement techniques, two types of methods are there: one is recording type and the other one is non recording. Under non-recordings staff gauge, wire gauge and electric tape gauge will be seen and in the case of recording stream gauges, we will be looking into float gauge recorder.

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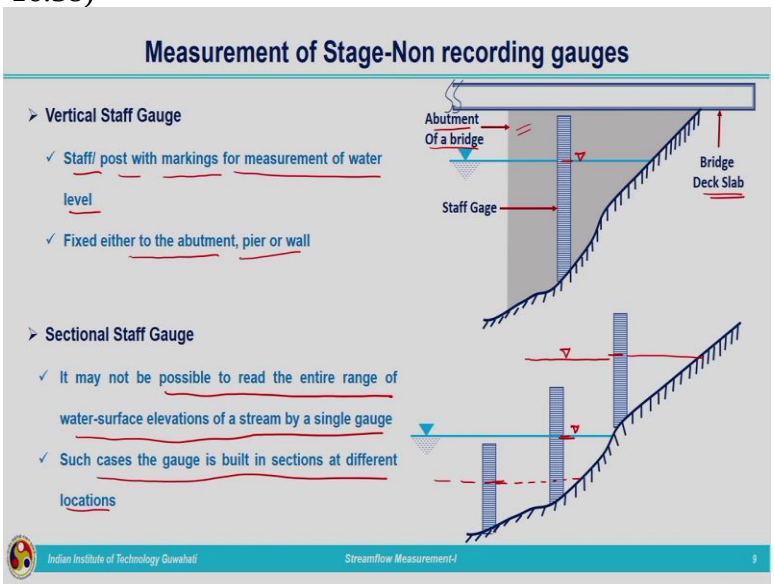

Let us see one by one. First one is the vertical staff gauge. Vertical staff gauge why specifically mentioning? There is certain type of gauges in which inclined one also placed. So, here let us see what is vertical staff gauge? This is nothing but a simple staff or post with some markings of the length for measurement of water level. So, one staff is there or a post is there on that the markings length marking are made. Based on the water level corresponding to that staff level we can get the water level or stage at that particular location. How it is done, let us see. This is fixed

either to the abutment or pier or some wall. Some hydraulic structure will be present in the stream to the wall of that particular structure or pier it will be attached the staff will be attached. We can see it by means of a schematic diagram, this is the riverbed and water surface elevation are up to this, that marked by this blue line and we are having the hydraulic structure bridge and this is representing the bridge deck slab and this is our abutment of the bridge. This is our staff gauge that is fixed to the abutment of the bridge, sometimes to the abutment of the bridge or sometimes to the bridge pier or any other hydraulic structure, the staff gauge will be fixed on to that and we can measure the water surface elevation. Here in this case, this is the water surface elevation that can be read from the staff gauge. So, how much is the depth of water level or how much is the stage, value of stage that can be observed from this staff gauge.

Second one is the sectional staff gauge. This is also staff gauge, sometimes it may not be possible to read the entire range of water surface elevations of a stream by single gauge. You can imagine a large river in that during the lean period that is summer season water level will be very low. But on contrary to that, during the monsoon season, water level will be very high. So, measuring these much of water level that is high water level and low water level by means of single staff may not be possible always. In such cases the gauge is built in sections at different locations. It can be visualized by means of a schematic diagram. This is the river bed and we are having the water level at particular season up to this and different staff gauges are placed in the river like this. So, during the high flood time, we may be having water level up to this level. So, at the time, this particular staff will be giving us the readings corresponding to water level and some other season water level will be up to this level and we can make use of this gauge which is present in between and during lean period, water level in rivers will be very low and we can make use of the one which is corresponding to that particular level.

So, that is sometimes single staff would not be serving the purpose. So, we will be providing intermittent staffs in order to measure the water level in all the seasons. In addition to these types of vertical staff gauge, sometimes we will be placing in any inclined way also with a bed it will be attached and by knowing the angle of inclination which the staff is making, we can find out the depth of water within the stream.

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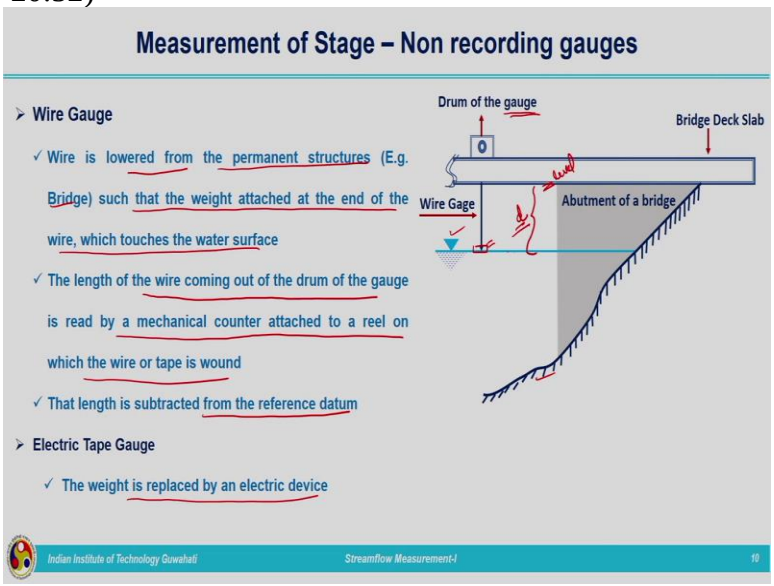

Next one is the wire gauge, this is again the same figure, we are having the river bed, stream is present, water level is up to this level and we are having the bridge abutment and this is the bridge deck slab. In this we are having a gauge, drum of the gauges present over the deck slab and from there the wire is lowered from the permanent structures such as bridge such that the weight attached at the end of the wire will be touching the water surface that is the wire is lowered from the bridge like this and here at the bottom we will be having a weight attached to it, that way it will be touching on the water surface. This wire gauge is lowered from the permanent structures such as bridge and the length of the wire coming out of the drum of the gauges is read by a mechanical counter attached to the reel on which the wire or tape is wound. There is a reel on which the wire is wound and this winding of the reel is done, from there how much is the length of the wire which is lowered so that the weight is touching the water surface that much length will be measured and that will be giving us the depth of the water level from the arbitrary datum and if we subtract that length from the reference datum we will get the water depth in the river. So, from this particular point to water level, how much is the depth we will be getting and from the reference datum, from this datum level, how much is the level, from that we will be subtracting this *d* so that we will get the water level at this particular point. Depending upon the position of the weight, we can get different, different water levels.

Next one is the electric tape gauge. In this case the weight is replaced by an electric device. Here this particular weight is replaced by an electric device, the rest of the mechanism is same as that

of the wire gauge. Wire is lowered from the top from the drum of the gauge and this weight is replaced by means of an electric device.

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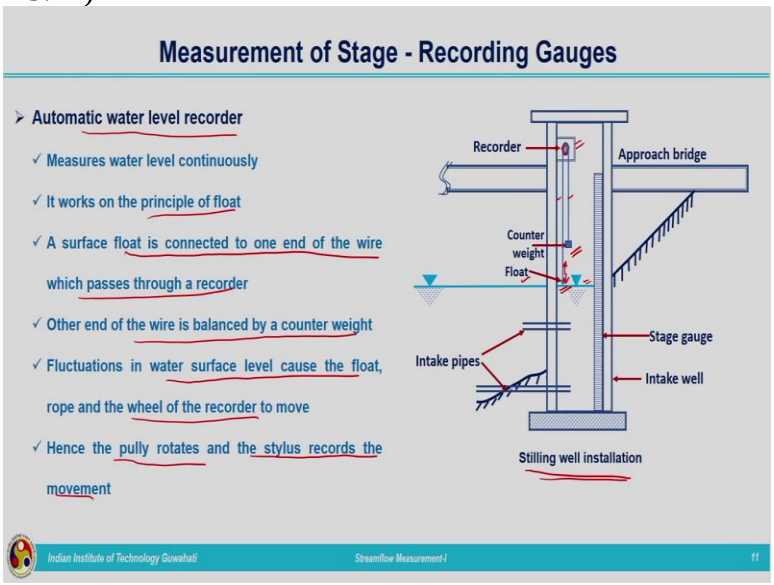

Now, next one is the recording gauge: automatic water level recorder. So, in this case manually we do not have to measure, automatically it will be measuring the water depth that is there will be some data logger and that will be providing the data in the computer. So, how the mechanism is let us see that. It measures water level continuously, in the case of manual measurement whenever required we will be doing it manually. But in this case since it is automatic, it is recording the water level continuously. It works on the principle of float and again schematically we are having the stream, we are having the approach bridge like this and here in this case since it is a continuous measurement technique, continuous measurement of water level is taking place we are having a stilling well installation to protect the instruments. So, this is the stilling well installation and we are having an intake well within that we will be having one gauge for the manual measurement and also one automatic water level measurement mechanism.

So, this is our stage gauge that is water level measurement, manually can be done and we will be having intake pipes, two intake pipes are provided so that water will be entering into the intake well through those intake pipes and the water level which is present on the stream will be maintained within the intake well also. Now, how this water level measurement is done automatically? We are having a recorder like this; pulley weight arrangement is there and a surface float is connected to one end of the wire passing through this recorder. You can see this

is a wire through this pulley it is moving, at one end of the wire, there is a float which is present and depending on the water level, this float will be moving up or getting lowered. If the water level is increasing the float will be moving up, based on that this weight will be moving down. So, this movement of this float and the weight will be noted down by the recorder. So, one end of the wire is balanced by the counter weight that is marked over there and the fluctuations in water surface level make the float and rope along with the wheel of the recorder to move. So, as the pulley rotates, the stylus or the pen, which is present over there will be recording the movement. So, based on that we can understand how much is the variation taking place in the water surface or water level. So, whenever the water level is rising, float will be rising and the weight will be lowering. So, pulley action will be taking place there and the stylus or the pen which is attached to this pulley will be noting down the water level readings.

So, that much about the measurement of stage and different techniques are there other than this like ultrasound depth measurement meter. So, those type of measuring techniques the sound waves will be sent to the bottom of the river and one transducer will be sending the signal and the same will be collecting that, the time taken for these waves to travel to the bottom and coming back to the transducer will be noted down and based on that we can get how much is the depth of water and also velocity of water all these things can be understood. Here I have explained only the conventional ways of measuring stage or the water level.

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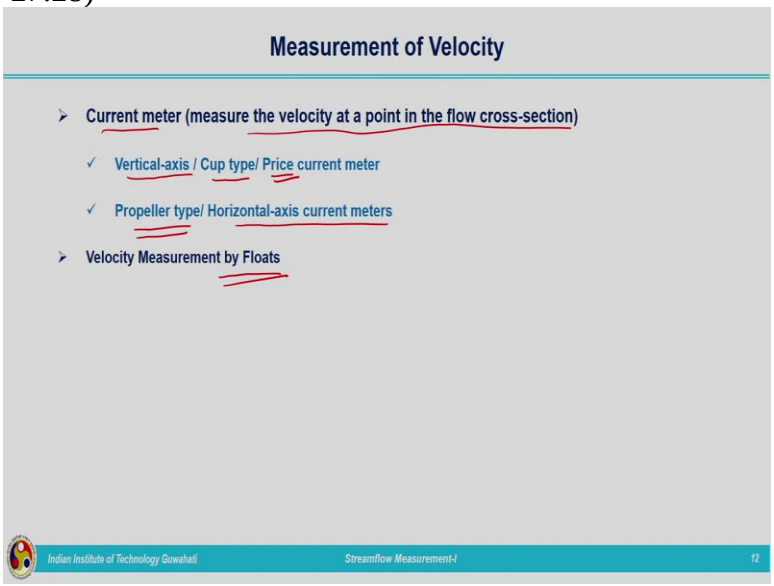

Now, let us move on to the velocity measurement techniques. Very commonly used velocity measuring technique is by means of current meter. It measures the velocity at a point in the flow cross section. So, current meter is the one which is measuring the velocity at a particular point where we are positioning this current meter based on that velocity at that particular point will be obtained by making use of current meter. So, when I was discussing about average velocity, I told you in the case of shallow rivers, we need to measure the velocity at a depth of 0.6 times the depth of flow. So, at the locations if the depth is *y*, *0.65y* we will be positioning the current meter so that we can get the velocity at that particular depth. In the similar way whichever be the depth at which the velocity is required we will be positioning the current meter.

So, different types of current meters are there: vertical axis current meter, and also horizontal axis current meter. Vertical axis current meter is also known as cup type current meter commonly termed as price current meter and the horizontal axis current meter is the propeller type current meter. So, these are the two types of current meters which are commonly used in the field. Now, other way of measuring velocity is by means of floats. We can make use of floats for the measurement of velocity also. So, two ways are there: by means of current meter and also by means of floats.

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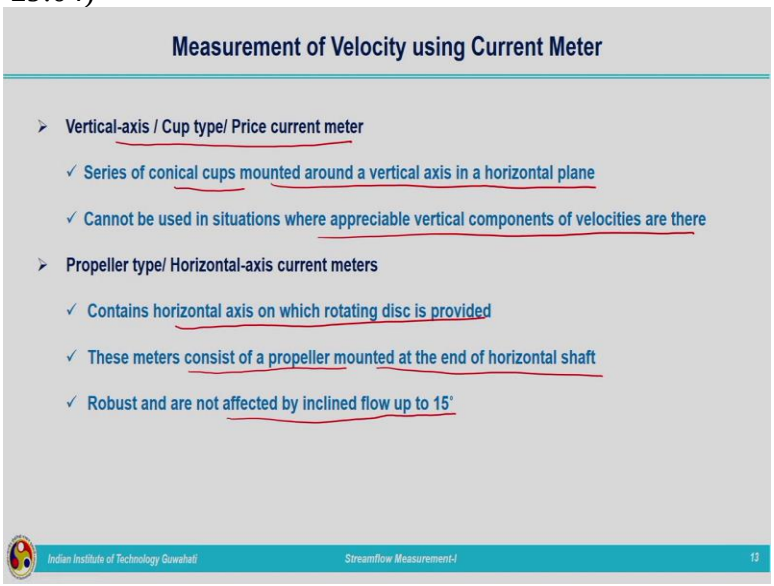

Let us look into the case of current meter. First is the vertical axis cup type price current meter. Series of conical cup mounted around a vertical axis in a horizontal plane. So, this is the vertical axis current meter. So, in this series of cups are mounted around a vertical axis in a horizontal plane and the disadvantage in this case is that it cannot be used in situations where appreciable vertical components of velocities are there. If vertical components of velocities are there it would not be giving us the accurate measurement of velocity.

Second one is the propeller type or horizontal axis current meter. It contains horizontal axis on which the rotating disc is provided. Only difference is that in this case it is the horizontal axis on the other hand in the case of vertical axis current meter, the conical cups are mounted on a vertical axis in a horizontal plane. In the case of propeller type these meters consists of a propeller mounted at the end of horizontal shaft and these are robust and not affected by inclined flow up to 15 degree. These are horizontal axis current meters, even for some inclination it will give accurate measurements. So, two different types of current meters: one is the vertical axis current meter and the other one is the horizontal axis current meter. So, conical cups are attached to it, the movement of the cups due to the velocity of flow will be noted down that rotations per minute or rotations per second will be noted down and those rotations will be converted into the velocity. So, for that, the current meter will be having certain formula to calculate the velocity.

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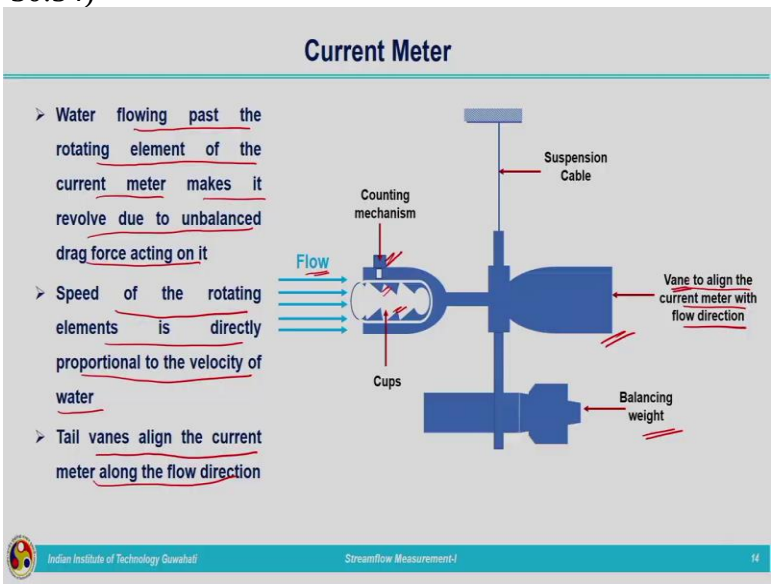

This is the schematic representation of a current meter, we are having suspension cable, from there the current meter is suspended. Our flow is taking place in this direction and because of this flow, the cups which are attached to the current meter will be rotating. So, the cups are present over here, different number of cups are there and these cups due to the movement of flow due to the velocity of flow these cups will be rotating. On the other side, other side of the current meter, there is a vane present to align the current meter with the flow direction. This is the vane which is there in the current meter. The main purpose of this vane is to make the current meter or to align the current meter in accordance with the flow. That is why this vane is always made off some streamlined body, some shape similar to that of a fish. So, those types of streamlined structure will be provided for this vane and this will be aligning the current meter in proper position with the streamflow. Here we are having a balancing weight provided. What is the role of this balancing weight is that when we are suspending the current meter, it has to be in position for that we need to provide certain weight at the bottom that is the balancing weight.

So, here we are having a counting mechanism. This counting mechanism will be making the measurement or the number of rotations which the cups are moving due to the velocity of flow that will be recorded by means of this counting mechanism. So, water flowing past the rotating element of the current meter makes it revolved due to unbalanced drag force acting on it. Water flow is there and based on that there will be a drag force acting on that, because of that these conical cups will be rotating those rotations are of interest, that is recorded by means of the counting mechanism.

So, speed of these rotating elements is directly proportional to the velocity of water that is the way in which it is related. How much is the speed with which the cups are rotating that determines the velocity of flow. If it is a very turbulent condition, then the rotation of the current meter cups or the conical cups will be at a higher RPM, higher rotations per minute will be there. So, depending on the RPM or the depending on the number of rotations, we will be getting the velocity of flow because that velocity of flow is creating the rotations of these cups. This tail vanes align the current meter along the floor direction I have already told you this tail vanes will be having the shape of a streamline body, so that their alignment will be proper along with the flow.

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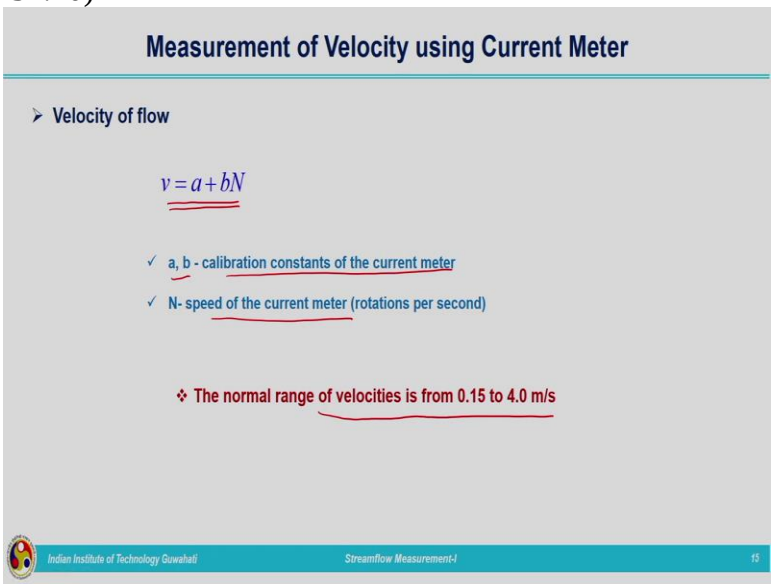

Now, by using the current meter how to measure the velocity of flow? Velocity of flow can be calculated by using this formula

$$V = a + bN$$

where a and b are the calibration constants of the current meter. This depends on the current meter, it will be provided in the manual itself. Sometimes we may have to go for calibration of the current meter. So, N is giving us the speed of the current meter that is rotations per second, in one second how many rotations have been taken place for these conical cups that will be noted by the counting mechanism. If that RPM or rotations per minute or rotation per second is available to us, that can be utilized along with the calibration constants to get the velocity of the flow by making use of the current meter. The normal range of velocity is measured by current

meter is between 0.15 to 4 meters per second, up to 4 meters per second we can make stream velocity measurement by using current meter. Any of these, vertical axes current meter or horizontal axis current meter, we can measure velocity within this range 0.15 to 4 meter per second. Formula also similar to this, calibration constants will be different for different current meters.

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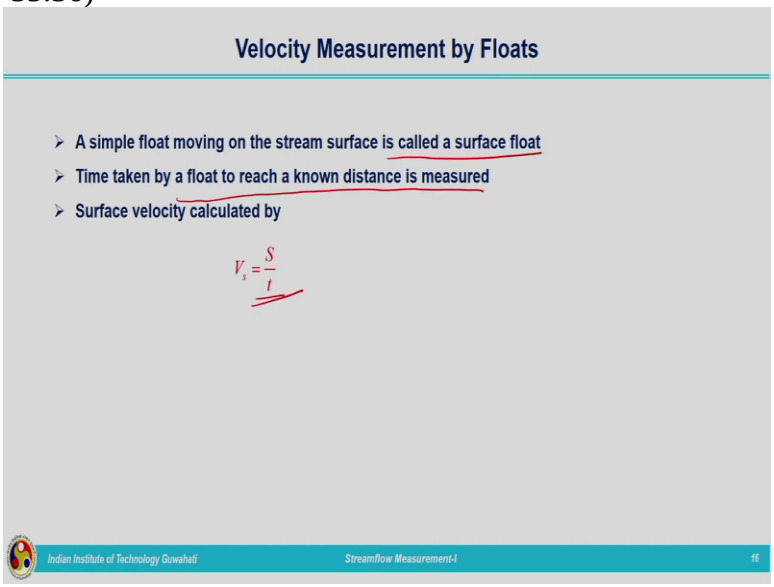

Next, just the velocity measurement by means of floats. So, a simple float moving on the stream surfaces is called as surface float, that is a float is allowed to move on the surface of the water that is called surface float. The time taken by the float to reach a known distance is measured. Actually, we will be fixing two points within the range within the stable reach and from one point to other point, how much is the time taken by the float to travel, that time and we already know that distance, both will be noted and if we know the distance travelled within that particular interval of time we can get the velocity with which the float is moving that is nothing but the velocity of flow. So, it can be calculated as velocity of flow V_s is given by

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

Where S is the distance travelled and t is the time interval taken for traveling this much of distance by the float.

So, now, it is time to wind up this lecture. So, just let me summarize this topic. In this lecture we have seen what are the different components of streamflow, we have seen runoff, baseflow interflow and the precipitation which is directly falling on the channel or streams. The stream flow values are very important whenever we are talking about the water resources project implementation and also planning and management.

So, how to measure streamflow regarding that we were discussing in this lecture. Streamflow measurements directly we would not be doing, we will be measuring the water depth and the corresponding velocities at different points will be measured and based on that we can calculate the stream flow by making use of the continuity equation $Q = AV$ and after that we have seen what are the different ways of measuring stages or the water level in the stream and also, how can we measure the velocity. Mainly current meters which are commonly used for measuring the velocity of flow in a stream and we can get the average velocity at a particular point. So, once we know that depth of flow, and also the velocity of flow and the corresponding width of the river also will be measured and then by making use of the continuity equation we can calculate the streamflow.

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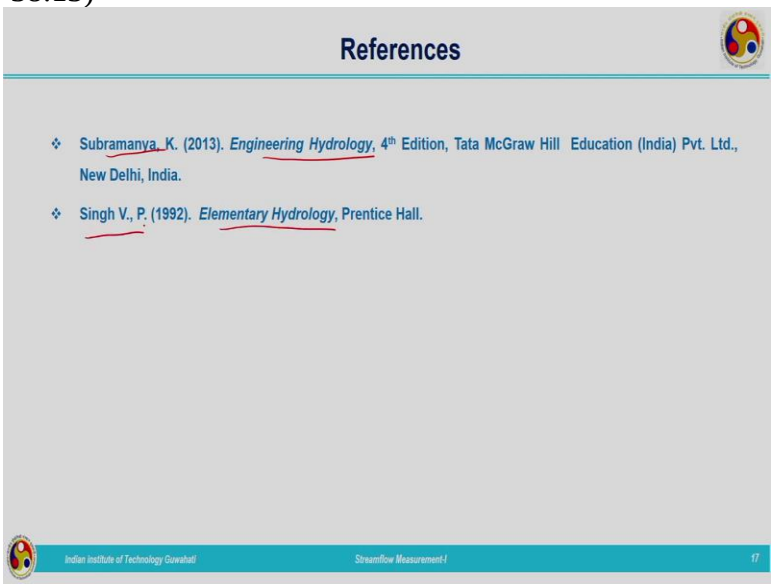

So, related to this topic, the reference material is engineering hydrology by Professor Subramanya and elementary hydrology by Professor V.P. Singh. So, here I am winding up this lecture. Thank you.