Geomorphic Processes
15-040-504

Laboratory #1: Gaging a Stream

Purpose:

1. To learn how to measure stream discharge using a current meter

2. To determine the accuracy of those discharge measurements

3 To practice making measurements with an alidade, plane table, and stadia rod

4. To use and test the accuracy of the Manning equation for determining stream discharge

5. To examine the morphology of the cross section of a stream channel

6. To estimate bankfull discharge

Readings:

Carter, R.W. and Davidian, Jacob. 1968. General procedure for gaging streams. in *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 3, Chapter A6. 13p.

Compton, R.R. 1962. The alidade and plane tabling, Chapter 6 in *Manual of Field Geology*. New York: John Wiley & Sons, Inc. p. 88-112.

Williams, G.P. 1978. Bank-full discharge of rivers: Water Resources Research. 14:1141-1154.

References:

1. Barnes, H.H., Jr. 1967. Roughness Characteristics of Natural Channels. *USGS Water-supply Paper* 1849. 213 p.

2. Buchanan, Thomas J. and Somers, William P. 1969. Discharge measurement at gaging stations. in *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 3, Chapter A8. 65p.

3. Davidian, Jacob. 1984. Computation of water-surface profiles in open channels. in *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 3, Chapter A15. 48p.

4. Leopold, L.B., Wolman, M.G., and Miller, J.P., 1964. *Fluvial Processes in Geomorphology*. San Francisco: W.H. Freeman & Co. 521 p.

5. Leopold, L.B. 1994. A View of the River. Cambridge: Harvard University Press. 298p.

6. Morisawa, M. 1968. *Streams*. New York: McGraw-Hill Book Co. 175 p.

7. Smoot, George F. and Novack, Charles E. 1968. Calibration and maintenance of vertical-axis type current meters. in *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 8, Chapter B2. 15p.

8. Wisler, C.O., and Brater, E.F. 1959. *Hydrology*, 2nd Ed. New York: John Wiley & Sons, Inc. 408 p.

Discussion

Stream Discharge Records:

You used stream discharge records published by the USGS for the first laboratory exercise on catastrophism. Similar discharge records are available from other sources (see Wisler and Brater, 1959, p. 354-398). The USGS compiles discharge records from data collected at gaging stations set up at numerous locations. These stations are established at places where a river's channel cross section will not change significantly with time (preferably where the channel is cut in bedrock). The discharge is measured with a current meter using the procedure we will use in this exercise. At the same time the discharge is measured, the depth or *stage* of the river at some fixed point in the channel is measured. After a sufficient range of discharges and stages have been measured, they are plotted to construct a stage-discharge curve or *rating curve* similar to the one shown below.

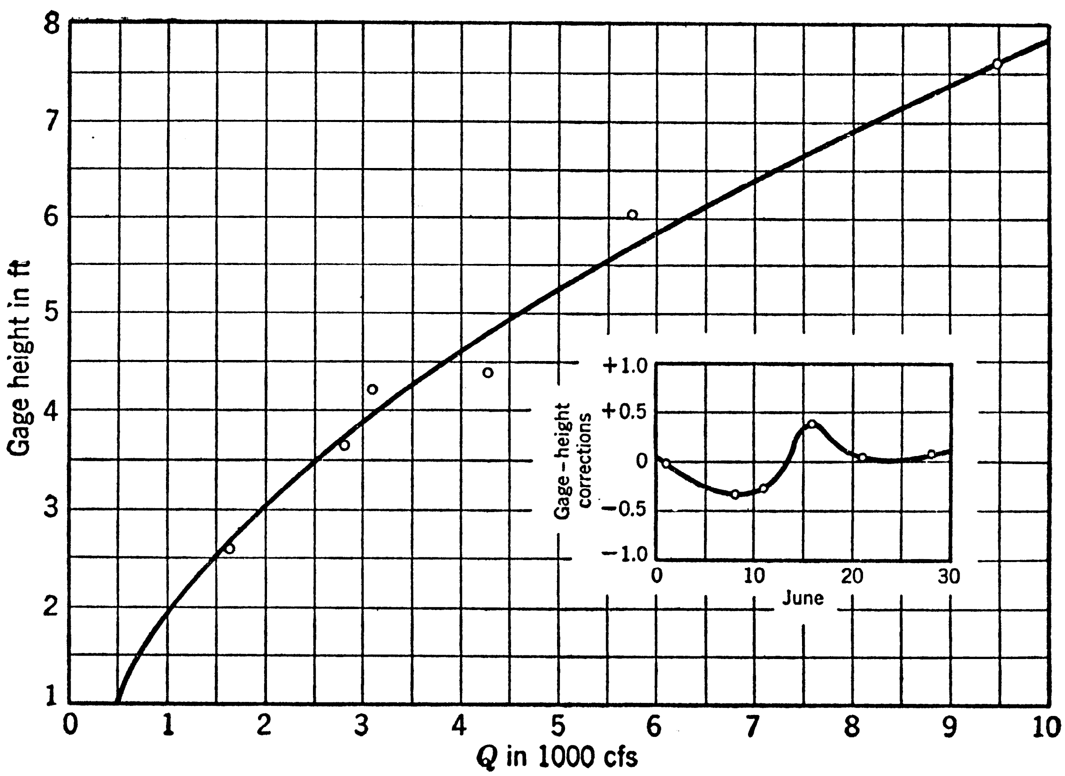

Figure 1. Copied from Wisler and Brater (1959), p. 390.

Once this curve has been established, it is then possible accurately to estimate the river's discharge by observing its stage without having to measure it directly with a current meter.

Cross Section of Stream Channels:

There is probably no such a thing as a *typical* river cross section. As we will discuss in class later, a river's cross section is a function of discharge, sediment load and caliber, erosional history, cohesiveness of the bank material, etc. Generally, if a cross section is made through a floodplain at a straight section of the channel it will look something like this:

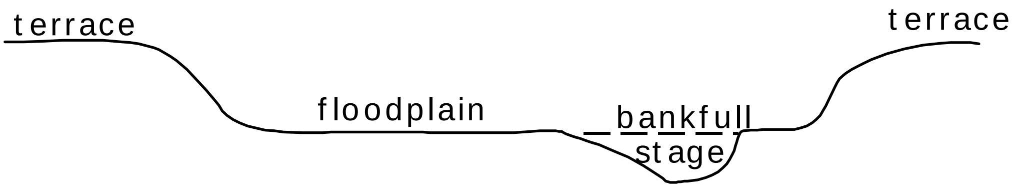

Figure 2.

About twice in three years, the river will flow at its *bankfull* stage, completely filling its channel. Usually the river's stage will be well below bankfull. On those rare occasions that the river overflows its channel, it is said to be in *flood*.

Current Meters:

There are a number of different types of meters for measuring current at a particular point in a stream (see Wisler and Brater, 1959, p. 371-373). The most commonly used and reliable is the Price Current Meter. We will use a scaled down version of this device, the Pygmy Price current meter. The meter consists of a shaft to which several conical cups are attached. When placed in a current, the cups spin the shaft at a rate proportional to the local water velocity. The Geology Department's meter is attached to headsets which can be set to register a "click" either every one or five revolutions of the shaft.

Observations are made by lowering the meter to the desired depth and, using a stop watch, determining the time required for a certain number of revolutions. As the velocity at any given point in a stream is not usually constant but subject to pulsations, a sufficient number of "clicks" should be measured for the true mean velocity at that point to be approximated. **The period of observation should generally be on the order of 50-60 seconds.** Once the time necessary for a particular number of revolutions is known, the water velocity may be determined using the table below (the table is **only** applicable to the particular make of meter we are using).

The meter may be used either suspended from a weighted cable or attached to a rigid rod (we will use a rod). The rod is marked in tenths of feet. The current meter is fixed at some desired distance above the base plate and is lowered into the water until the base rests on the bottom of the channel. It is important that the meter's fins point downstream and that the meter is held horizontally. **Stand well behind the meter**.

The Pygmy Price Meter is an extremely delicate and expensive instrument; if the shaft or any of the cups are bent, the meter becomes virtually useess. **Please be careful handling the meter**.

The Department also owns a more modern and easier to use current velocity meter, the Swoffer Instruments Model 2100. This meater has a digital read out and clever mechanism for placing the mechanism at a depth of 0.6 the total depth. **This instrument also needs extremely careful handling, make certain not to let the propeller come in contact with anything solid and never move the measuring staff up or down with the propeller housing**.

Measurement of Stream Discharge:

We will use the following standard procedure for measuring stream discharge:

1. A cord, marked at fixed intervals, is stretched across the stream.

2. The water depth at each marked interval is measured.

3. The *mean* water velocity is measured at each interval. Velocity is a function of depth and distance from the bank and therefore the mean velocity, $\overline{U}$, at any particular interval is difficult to determine. Note in the figure below that at a depth of y=0.6d (where *d* is total water depth) that $\frac{\overline{U}}{U_y}$ (where U_y is the water velocity at a depth of y) is equal to 1.0 in other words, the measured velocity at a depth of 0.6 of the total depth is equal to the mean velocity. Also note that if the average of the velocities measured at depths of y=0.2d and y=0.8d, $\frac{\overline{U}}{U_y}$ is again equal to 1.0. Thus the mean velocity at any interval may be approximated either by measuring the velocity at a depth of 0.6 of the total depth (called to *0.6* method) or by averaging the velocities measured at 0.2 and 0.8 of the total depth (called the *0.2 - 0.8* technique -- used by the USGS). Leopold (1994) suggests an easy way to estimate the mean interval velocity at a point in a stream is to measure the surface velocity with a floating orange peal. The mean interval velocity is about 0.8 of the surface velocity.

Figure 3. From Morisawa (1968), p. 34.

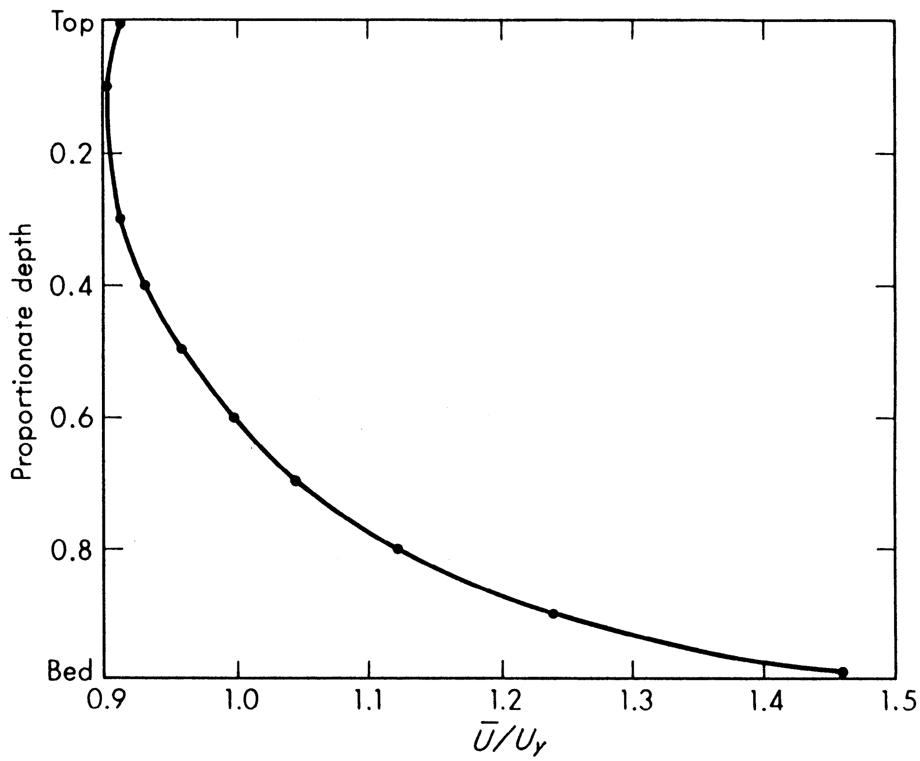

Fig. 3.4 Vertical velocity profile of the Mississippi River near Vicksburg, Miss. $\overline{U}/U_y$ is the ratio of average velocity to velocity at depth y. [Redrawn from Toffaleti (1963).]

4. Once the water depth and average velocities have been measured at each interval across the stream, the total stream discharge may be calculated as follows:

$$Q = \sum_{i=1}^{N-1} \frac{W_i(\overline{U}_i+\overline{U}_{i+1})(d_i+d_{i+1})}{4} \qquad \text{(Eq. 1)}$$

where:

- d_i: total depth at the *ith* interval
- $\overline{U}_i$: mean velocity at the *ith* interval
- d_{i+1}: total depth at the *ith + 1* interval
- $\overline{U}_{i+1}$: mean velocity at the *ith + 1* interval
- N : total number of intervals (including the one actually on the far bank)
- W_i: width between the *ith* and *i+1th* interval on the cord
- Q: total stream discharge

<u>Bankfull stage:</u>

Bankfull stage is the stage at which the stream completely fills its channel. For some rivers, such as the Ohio at Cincinnati, it is relatively easy to define bankfull. For other streams, such as East Fork, it is extremely difficult... but we'll see what we can do. Read the definitions of bankfull in Williams (1978).

<u>Manning Equation</u>:

Manning found that it was possible to estimate stream discharge from various measured parameters:

$$R = \text{Hydraulic radius} = \frac{A}{P} \qquad \text{(Eq. 2)}$$

A = Channel cross section area

$$A = \sum_{i=1}^{N-1} \frac{W_i(d_i+d_{i+1})}{2} \qquad \text{(Eq. 3)}$$

P = length of wetted perimeter

$$P = \sum_{i=1}^{N-1} \sqrt{W_i^2+(d_i-d_{i+1})^2} \qquad \text{(Eq. 4)}$$

S = stream gradient or slope

n= measure of channel roughness termed the *Manning roughness coefficient*

If these parameters are known, total stream discharge, Q, may be calculated as follows (when measurements are in *English* units, for *SI* units, substitute 1.0 for 1.49):

$$Q = \frac{1.49}{n} R^{2/3} S^{1/2} A \qquad \text{(Eq. 5)}$$

Procedure

This exercise will be conducted at the confluence of two streams. We will follow the procedure below.

1. Before the laboratory, study the Compton reading *very carefully*. When we are out in the field, you will be expected to be able to plane table competently.

2. Stretch the marked cord across the main stream at some convenient point (make certain the cord is perpendicular to the stream).

3. Plane table in the end points of the marked cord stretched across the main stream.

4. Estimate channel roughness (*n*) of the main stream using Barnes (1967)

5. At each of the marked intervals measure the water depth, *d* and calculate the depths corresponding to 0.2, 0.4, 0.6 and 0.8 *d*. Remember that the depth must be measured up from the bottom using the meters staff.

6. Measure the water velocity 0.2, 0.4, 0.6, and 0.8 of the depth.

7. Measure the surface velocity at the interval by observing the time it takes a float (citrus peal) to go 20 feet downstream.

8. Repeat steps 1-6 on the two tributaries but only use the 0.6 method to calculate mean velocity at each interval.

9. Plane table in the stream valley morphology.

Analysis and Question: (to be done individually)

1. On graph paper, accurately plot the cross section of the main stream. Indicate the bankfull stage. You will probably want to use some vertical exaggeration; make sure you indicate how much.

2. On the cross section made in the previous step, plot the interval markers and write the current velocity at the point at which it was taken and draw *isovelocity* contour lines.

3. Calculate discharge for the main channel using Eq 1 (show all work and **BE NEAT**).

4. In tabular and graphical form, contrast the mean interval velocities measured by the 0.6 technique, the 0.2 - 0.8 technique and the surface velocity method.

5. Calculate *A*, *P*, and *R* for the main stream and calculate its discharge using the manning equation. Show all work and **BE NEAT**.

6. For the main stream, calculate the roughness coefficient (*n*) using the values of *A* and *R* calculated in question #5 and the measured discharge calculated in question #3. Show all work and **BE NEAT**.

7. Using the Manning equation, calculate the bankfull discharge of the main stream. Show all your work and **BE NEAT**.

8. List *all* the assumptions you made in calculating the bankfull discharge of the main stream and discuss the validity of each.

9. Calculate the ratio of the measured mean depth with the mean depth of bankfull flow. Plot this pair of ratios on the diagram below. Where does the point you plotted lie relative to the established curve?

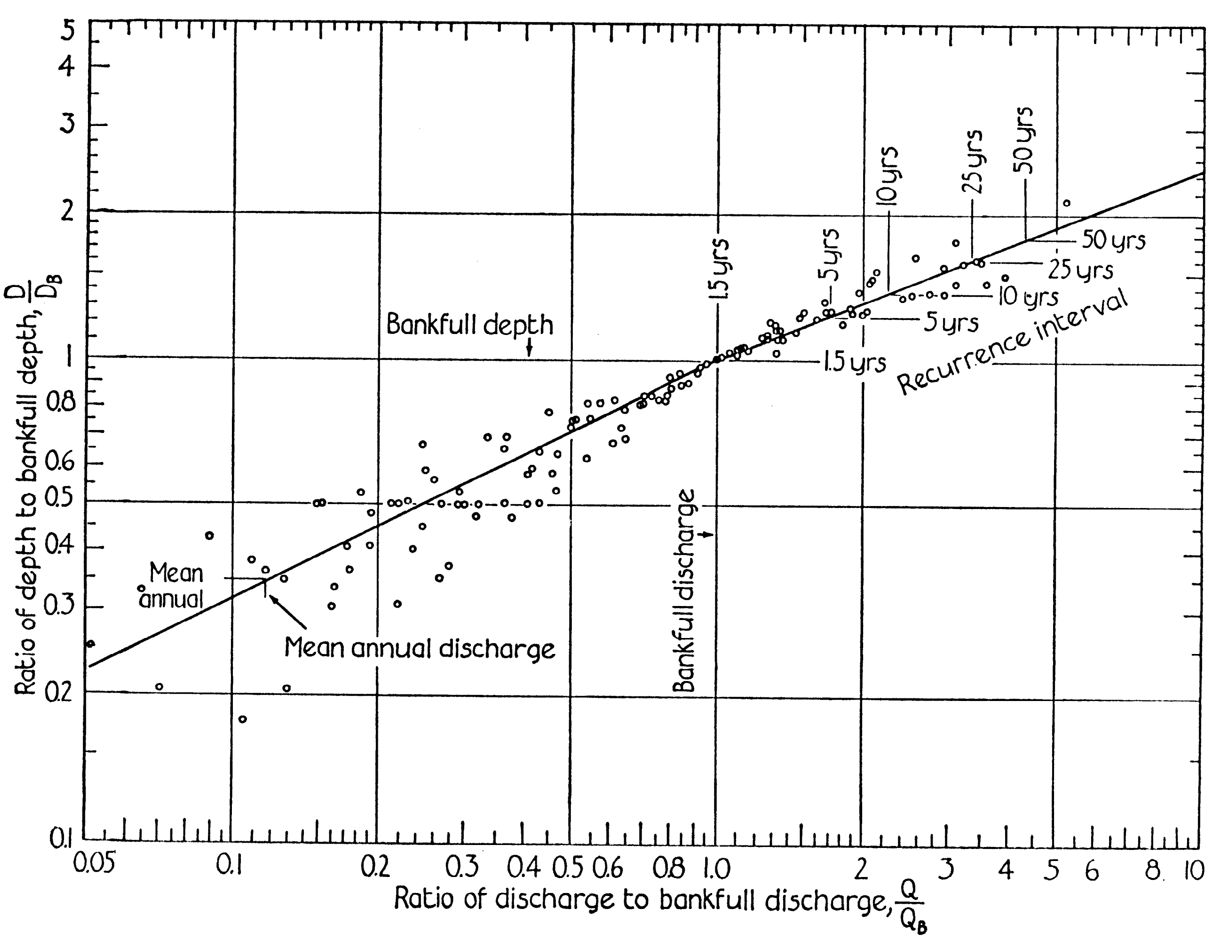

Figure 7-10. *A nondimensional rating curve for 13 gaging stations in the eastern half of the United States. Depth is expressed as ratio to mean height of streambanks, and discharge as ratio to bankfull discharge.*

Figure 4. Copied from Leopold, Wollman, and Miller (1967), p. 219.

Plane Tabling Instructions

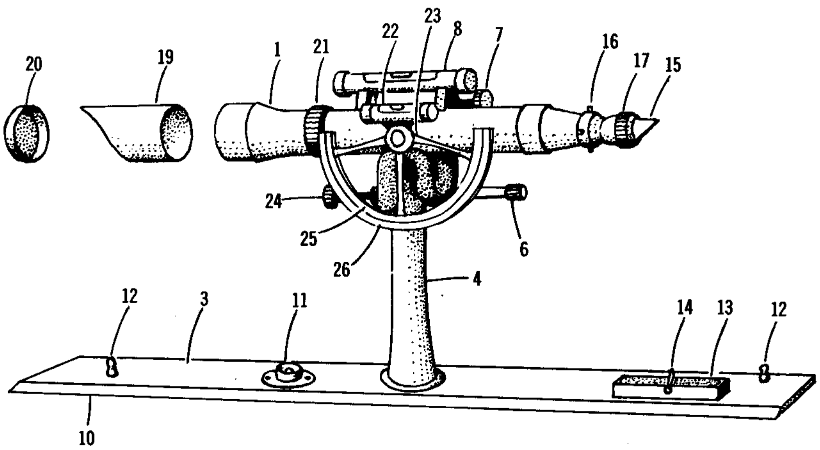

Figure 1. Alidade

Remember

- ***Never lift the alidade by anything other than the pedestal (4).***
- ***Never move the alidade on the plane table by anything other than the pedestal (4) or blade knobs (12).***
- ***Always focus (17) cross hairs and eliminate parallax.***
- ***Always use the same side of the blade (3) to draw sight lines.***

Plane Table Setup

1. Select a site affording a clear shot of as much of the map area as possible and which provides solid footing for the tripod.
2. Spread and adjust tripod legs until the top is about "belt-buckle level".
3. Securely drive the metal bottom of each of the tripod's legs into the soil.
4. Screw the plane table on to the top of the tripod.

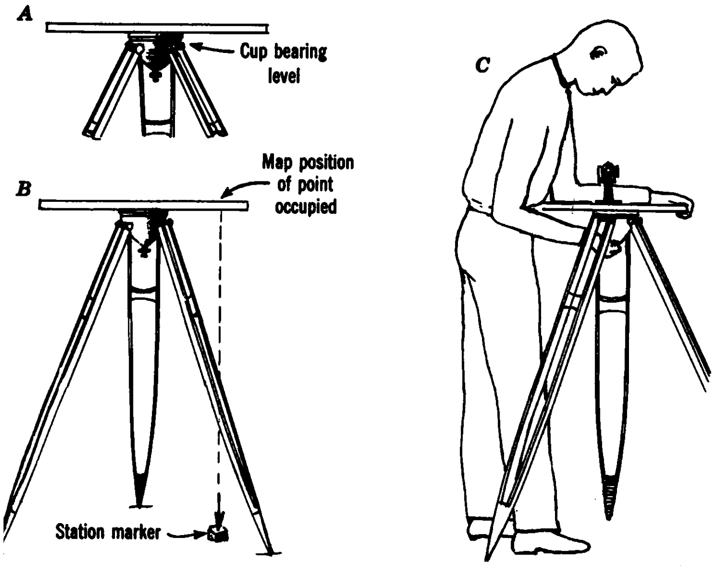

Figure 2

1. Loosen both wing nuts of the Johnson head (3 & 4 in figure 3).
2. Grasp the alidade by the pedestal and place at center of plane table (HOLD ON TO ALIDADE) and use bull's eye (11 in figure 1) to level board.
3. Tighten upper wing nut on Johnson head.
4. Pivot board to desired orientation and tighten lower wing nut. The board should now be secure.
5. Use the rod to determine the set-up height (distance from ground to the center of the alidade axis.
6. Determine the dimensions of the area to be mapped and select an appropriate scale.
7. Mark instrument location and ground elevation of the plane table sheet.
8. Calculate instrument elevation.

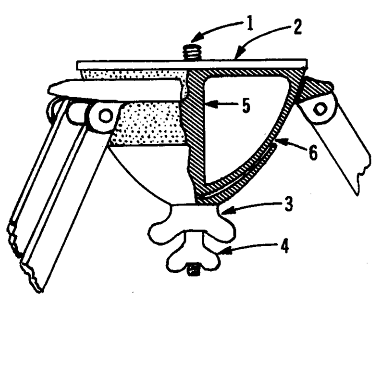

Figure 3. Johnson tripod head

Making a level shot

1. Rod person sets up on location and takes notes on his/her location in field book.
2. Instrument person lines alidade blade on rod using striding-level gun sight (8) and moves blade so it passes through mapped instrument location.
3. Draw very thin, light sight ray but don't bring it to point representing instrument location.
4. Level striding level using tangent screw 24 then adjust lower cross hair on nearest hole interval on rod.

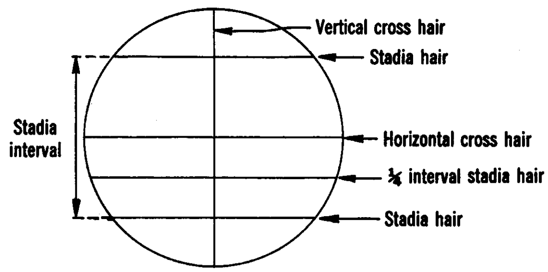

Figure 4. Stadia cross hairs

5. Read upper cross hair
6. Record upper and lower stadia
7. Level striding level, read and record middle cross hair.Reverse striding level and re-level telescope, reread middle cross hair and average two readings.
8. Determine distance by multiplying stadia interval by 100.
9. Determine ground elevation by subtracting middle cross hair intercept from instrument elevation.
10. Using appropriate scale, mark and label shot location on map.

Making a Beaman shot

1. Repeat steps 1-3 of level shot.
2. Level Beaman level.
3. Elevate or depress telescope until it's sighting at mid-rod.
4. Use Beaman screw to move V scale to nearest whole interval then adjust slightly up or down so lower cross-hair is at nearest whole division on rod.
5. Read and record upper and lower stadia.
6. Move scope back to whole V mark and record V and H and read middle cross hair.
7. Determine stadia interval.
8. Horizontal distance to rod is (100-H) times stadia interval.

9. Ground elevation is (V-50) times stadia interval plus instrument elevation minus middle cross hair.
10. Using appropriate scale, mark and label shot location on map.

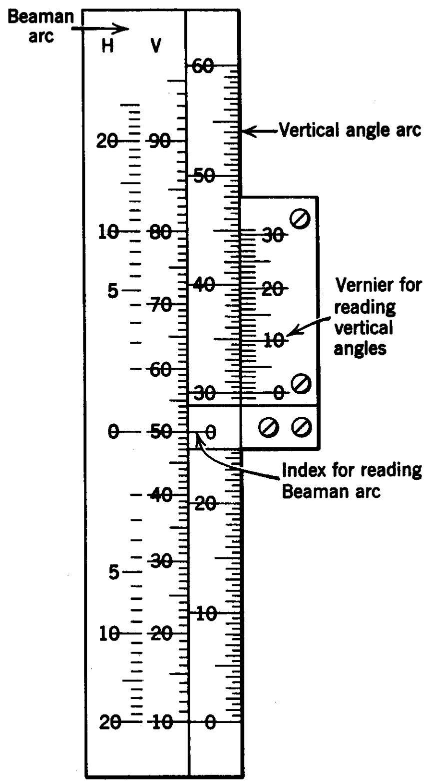

Figure 5. Beaman scale

SWOFFER INSTRUMENTS, INC.

MODEL 2100 SERIES CURRENT VELOCITY METERS

INDICATOR FEATURES and OVERVIEW

The *Model 2100* Current Velocity Meter provides stream current measurements from 0.1 to 25 feet per second by reading directly in feet or meters per second. Velocity is displayed on a liquid crystal readout and units of measure are selected by a toggle switch located in the battery compartment at the back of the indicator.

The display has three averaging periods selected by the rotary switch. These averaging periods range from a minimum time of about 5 seconds to a maximum time of about 90 seconds. The display holds the average velocity for the most recent update period until the end of the next period when the new average velocity will appear in the display and hold.

The *Model 2100* Indicator is powered by a single 9 volt battery which also supplies power to the photo-diode and the photo-transistor in the sensor. A 2-inch propeller drives a rotor containing two fiber-optics bundles. The rotation of these fiber-optics bundles gates infrared light from the photo-diode to the photo-transistor creating a pulse rate that is proportional to the propeller RPM. The pulses are counted and stored then compared to a quartz crystal oscillator and processed to display velocity.

The *Model 2100* Indicator can be calibrated in the field and corrections can be made for optimum accuracy at the velocities most often encountered. Velocities below about 1 foot per second may require some minor calibration adjustments which will be discussed later in the CALIBRATION section.

The battery compartment at the back of the indicator can be opened by use of the four thumb screws at the corners of the caseback. Space in the compartment is provided for both the operating battery and a spare plus there are cutouts in the foam lining for those accessories required for the particular Model being used.

The *Model 2100* Indicator is water sealed at the case front and at the bottom of the battery compartment. The battery compartment itself is not water tight however, and can fill with water if the indicator is immersed. The indicator will float even with the battery compartment filled because the foam lining is closed-cell and will not absorb moisture except on its surface.

The electrical connector between the sensor and the indicator is water-resistant only when mated. The connector is keyed and locks with a twist of its collar.

A shoulder strap is furnished with the Model 2100 and it clips to the loops located at the top and bottom ends of the indicator.

QUICK OPERATING INSTRUCTIONS FOR THE MODEL 2100

All *Model 2100* instruments regardless of the Model Number operate in the following manner:

1. Remove the sensor protection cap and install the propeller rotor using the Rotor Installation Wrench (1/16" Allen wrench).

2. Connect the Sensor Wand to the Model 2100 Indicator by using the twist lock connector.

3. Rotate the selector switch to the CALIBRATE position. The display should read about 186 (feet per second mode) or 610 (meters per second mode). Change to whichever unit of measure is wanted by use of the FEET/METERS switch located inside the battery compartment.

4. Rotate the selector switch to the COUNT position. Spin the propeller and confirm that the indicator reads increasing counts (sensor output pulses) as the propeller spins. There should be four counts per revolution. (Spin test is described later in instructions)

5. Rotate the selector switch to the minimum update time. (First position from the left side OFF position).

6. Place the sensor in the stream with the propeller facing into the flow.

7. Press and release the RESET button to zero the display.

8. The next figure which appears on the display will be the stream velocity.That velocity will remain on the display until the next update period ends. The figure in the display will always be the velocity of the last averaging period. (The indicator does not provide a "moving average").

For specific instructions for your Model 2100 see the documentation for the wand assembly which came with your current meter.

CARE AND MAINTENANCE OF THE MODEL 2100 INDICATOR

Should the indicator fall into the stream, open the battery compartment as soon as possible and dry the battery terminals and the cable connections. Since the foam lining is closed-cell, water will not absorb into more than just its surface. Allow the compartment to air dry or use a hair dryer if available before replacing cover.

Always make sure that the **CAL ADJUST** cover screws located at the bottom end of the indicator are tightly fitted. These provide DIRECT ACCESS TO THE CIRCUIT BOARD an if loose, will allow water to enter the indicator.

Clean the indicator only with a solution designed for plastics. The indicator lens is made of acrylic and can be easily scratched if an abrasive cloth is used. The indicator case is ABS and there are many chemicals which act as solvents for ABS, severely effecting its appearance if they make contact.

Periodically check the condition of the pins and sockets in the connector. Keep the contacting surfaces clean and bright and make sure the pins are not bent and that the sockets still fit the pins snugly. Although the connection cable is rugged, avoid sharp bending and re-bending and **DO NOT SUSPEND THE WAND OR INDICATOR BY THE CABLE**.

Extreme temperatures will effect the *Model 2100* Instrument. At below freezing temperatures the liquid crystal display becomes sluggish making response time slow. Some "ghosting" of unused digit segments may also be noticed. This condition is only temporary and the instrument will operate normally after temperatures rise to normal operating levels.

The battery is also affected by low temperatures and may not have enough power to bring the calibration numbers up to the correct level for accurate measurement. Check calibration number frequently when working in low temperatures. For best results keep the indicator close to the body inside your coat during operation in the cold. Keep extra batteries in your coat and exchange them often.

High temperatures and direct sunlight will also effect the operation of the *Model 2100*. DO NOT LEAVE THE INDICATOR IN A CLOSED VEHICLE IN THE SUN. Cover the indicator and avoid prolonged exposure of the liquid crystal display to ultra-violet rays. Ultra-violet will eventually degrade the display requiring its replacement.

High temperatures may also cause the indicator electronics to give erroneous readings due to pulse-count-timing errors.

In short, keep the Model 2100 within the recommended operating temperatures for optimum results.

NORMAL OPERATING TEMPERATURE 77°F (25°C)
MIN. TEMP (FOR RELIABLE OPERATION) -14°F (-10°C)
MAX. TEMP. 180°F (82°C) @ LESS THAN 15% RELATIVE HUMIDITY
120°F (49°C) @ LESS THAN 95% RELATIVE HUMIDITY

BATTERY CONDITION AND ITS EFFECTS ON THE MODEL 2100

The battery which powers the *Model 2100* is a single alkaline type 9 volt transistor cell. This battery powers both the indicator electronics and the sensor photo-diode/transistor circuitry. **The indicator alone draws very little current, however the sensor circuit (if allowed to remain on constantly) can drain a fully charged battery in a very short time.** Depending on your use of the *Model 2100*, a fresh battery can last as long as several months or a short as a few days. Be sure to return the selector switch to one of the "OFF" positions after each measurement has been taken and to always have a fresh spare battery on hand.

One way to determine battery strength is to check the Calibration Number held by the indicator. Rotate the selector switch to the calibrate position. If the displayed calibration number is much less than it should be then the battery should be replaced. **NOTE:** This test must be performed with the sensor connected to the indicator so that maximum battery draw-down is achieved.

In no case should you use a battery with less than 6 volts remaining. Below the threshold of about 6 volts the battery will operate the indicator electronics *but not the sensor circuit*. The sensor will not be able to transmit a signal to the indicator or will transmit only an occasional signal which will give erroneous readings.

This situation can usually be avoided by first checking the sensor output. Spin the propeller while the indicator is in the COUNT mode. If the display counts up the sensor pulses as the propeller rotor spins then the battery can be considered acceptable. There are four counts per revolution. (One revolution of the propeller should produce 4 counts on the LCD).

Errors in measurements due to battery voltage drop {and subsequent CALIBRA TION NUMBER drop) will be in direct percentage proportion to the difference between the "ideal" calibration number and the displayed calibration number.

CALIBRATION OF THE MODEL-2100 CURRENT METER

The *Model 2100* Current Meter is designed to be easily calibrated by the user. This calibration should be done with each Indicator-Rotor combination you use. The calibration numbers recommended by *SWOFFER INSTRUMENTS, INC. are not necessarily correct for all measuring situations, therefore for optimum accuracy the user should calibrate the instrument before use*.

If very accurate velocity measurements are required then you must calibrate your Model 2100 and check the calibration often. The instructions below should be followed very carefully for accurate measurements with the *Model 2100*.

> **NOTE:** "Calibrating a sensor" is actually calibrating a particular propeller rotor for use with the *Model 2100* Indicator. If you use more than one rotor assembly you must check the calibration for each rotor assembly and adjust the Indicator Calibration Numbers accordingly as you switch from one propeller assembly to another.

Calibration numbers correctly matching a sensor-rotor assembly to an indicator are especially important at the lower velocities (1.5 FPS and lower) and can vary greatly depending on many factors; bearing surface condition in the rotor, type and amount of lubrication (if used), condition of the water being measured (amount of suspended particulates), damage to the propeller, rotor, shaft, etc.

CHECKING AND CHANGING CALIBRATION OF THE MODEL 2100

Before applying corrections to the *Model 2100* rotate the selector switch to the **CALIBRATE** position. A figure will appear in the display and will be either the FEET CAL. NUMBER or the METERS CAL. NUMBER depending on the position of the FEETIMETERS switch (located in the battery compartment). For most measuring applications the CAL NOS. will be as follows:

FEET	=	186
METERS	=	610

If the displayed figures are much lower than these figures the first thing to check is the battery. A weak battery will allow the indicator CAL. NO.s to "drift" downward and will cause errors in measurements. Connect the sensor to the indicator when confirming battery strength. Always keep a full charge 9 volt battery in the compartment as a spare.

It is important to note that errors in measurements due to Calibration Number variation will be in direct percentage proportion to the difference between the ideal (correct) Calibration Number and the number that the indicator displays. Example: If the ideal number is 186 and the displayed number is 184 then the velocity error due to calibration error will be about 1%.

To determine a reliable calibration number for your *Model 2100* [something you should definitely do if you are working with slow flows (below about 1.5 FPS) and for measurements taken in very shallow streams] perform the following:

Mark a straight course of 10 to 20 feet in length in a body of calm, current-free water along which the sensor can be towed by walking the course. A swimming pool or dock into a quiet lake serves well. Rotate the selector switch to the **COUNT** position and press and release **START/STOP**. If the display does not show all zeros press and release **RESET**. The decimal point does not show in the **COUNT** mode.

Place the sensor in the water a few feet before the beginning of the course, 6 to 12 inches below the surface. Begin walking the sensor through the course at a rate close to that which you will be measuring. If shallow flows are to be encountered try to duplicate those conditions when making calibration checks. Using the wand rather than the sensor as a guide, press and release **START/STOP** at the instant the wand enters the course. The indicator will begin counting the number of sensor pulses generated as you walk. At the instant the wand leaves the course press and release **START/STOP** again. The display now shows (and will hold) the number of pulses generated through the course length. Several passes through the course in both directions are recommended to develop a reliable average figure. Press and release **RESET** each time a run is completed to re-zero the display.

When you have determined the average number of pulses generated through the course, compute the number of pulses that the sensor would generate if the course were exactly 10 feet. This will be the CALIBRATION NUMBER that the *Model 2100* Indicator should hold for accurate measurements with that rotor assembly in feet per second:

$$\textbf{FEET CAL. No.} = \frac{\textbf{10 x AVERAGE No. OF PULSES}}{\textbf{COURSE LENGTH (IN FEET)}}$$

This number can then be multiplied by 3.281 (the number of feet in one meter) to determine the CAL NO. for meters.

Next, rotate the selector switch to the **CALIBRATE** position. Put the **FEET/METERS** switch (in battery compartment) in the "F" position and the indicator will display the Calibration Number it presently holds for measuring in Feet Per Second. With a good battery it should be around 186. If your derived Calibration Number is different from the number displayed you can change the CAL NO. by using the CAL ADJUST screws at the bottom end of the indicator. Remove the **CAL ADJUST** cover screws (black plastic fillister-head screws). USING ONLY A JEWELER'S SCREWDRIVER (to prevent damage to the adjustment screw) rotate the screw clockwise to increase the displayed number and counterclockwise to decrease the number. Do the same for the Meters Cal. No.

The **CAL ADJUST** screw is a 1 5-turn potentiometer with very fine resolution and plenty of latitude for normal adjustment given a full charge 9 volt battery.

REPLACE THE ADJUSTMENT SCREW COVER SCREWS AFTER MAKING CALIBRATION CORRECTIONS. INDICATOR IS NOT-WATER RESISTANT WITHOUT THESE COVER SCREWS IN PLACE !

Note and store with the *Model 2100* Indicator your new Calibration Number(s). Every time the instrument is used the CAL NOs. and rotor assembly should be confirmed (rotate switch to **CALIBRATE**) before relying on readings. Be sure to check the CAL NO. with the sensor connected to the indicator to achieve maximum battery current draw.

IMPORTANT: Errors in measurements due to Calibration Number variation will be in direct percentage proportion to the difference between the ideal (correct) Calibration Number and the number that the indicator displays.

MODEL 2100 SERIES CURRENT METER-INDICATOR FUNCION SWITCH

OFF & OFF Redundant positions. Cuts all power from battery to the indicator and the sensor.

VELOCITY Display Averaging Three positions; from the minimum display update time to the maximum. Indicator displays and holds the stream velocity for the previous update time until the next averaging period is completed. Update times vary with the selection of FEET or METERS and also vary with the value of the calibration numbers held by the indicator. Approximate update times are as follows:

	FEET	METERS
MIN	10 SEC	1.5 SEC
---	20 SEC	6.0 SEC
MAX	90 SEC	30.0 SEC

START/STOP Used mainly when calibrating. Begins and ends **COUNT** function. Display will hold data until **RESET**. NOTE: In some instances it may be necessary to hit the **START/STOP** button after switching the indicator from the right hand OFF position to the **COUNT** position before indicator will record sensor pulses.

RESET Resets the display to zero. Will operate in any rotary switch position (except OFF). Used to begin timing functions at "time zero" (i.e the first reading after the rotary switch has been shifted to a new position may not be accurate. Use of the RESET switch will eliminate "first averaging period" timing errors.

CALIBRATE Display will show the figure that the indicator holds as the Calibration Number". The **FEET METERS** switch in the battery compartment is used to change the CAL NO from feet to meters. See CALIBRATION INSTRUCTIONS.

COUNT Indicator counts and displays the number of sensor output pulses generated. Used when calibrating the Model 2100. See CALIBRATION.

FEET/METERS A toggle switch located inside the battery compartment. Changes the indicator readout from meters per second co feet per second.

CAL ADJUST Removing the plastic, fillister-head screws at the bottom end of the indicator provides access to the Calibration Adjustment Screws. With the rotary switch in the CALIBRATE position the displayed figure can be altered by turning the adjustment screws. Clockwise rotation increases the CAL NO. Use only a jeweler's screwdriver when making adjustments to prevent damage to the CAL ADJUST Screws. The plastic screws must be replaced after adjustments to preserve the water-resistance of the Indicator.

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WAND OPERATION INSTRUCTIONS

Model 2100-12, -13, -14, -C80 & -C140

STREAM VELOCITY MEASUREMENTS

1. Extend the Guide Rod slightly and swivel the Sensor to the 90° reading position.

2. Remove the Sensor Optics Protection Cap and install the Rotor Assembly (2100-A21) on the Sensor (21 00-A22). Make sure that the Set Screw is snug against the rotor shaft (2100-A26) but do not tighten it too much to avoid stripping the threads or cracking the sensor. Check that the Rotor Assembly spins very freely.

3. Connect the sensor to the indicator via the twist-lock connector. The connector is "keyed" and only mates one way.

4. Place the Sensor Wand vertically in the stream and point the propeller rotor into the stream flow.

5. With the Foot of the Guide Rod at the stream bed, adjust the Depth Rod up or down until the tip of the propeller is intersected by the stream surface

6. Read the stream depth on the Depth F.,d Scale. Depth is measured at the top of the Slide Index fitting (see diagram back page).

7. Next lower the sensor until the top of the Slide Index fitting is opposite the corresponding numerical depth reading on the 6/10 Depth Scale. The sensor propeller is now at 6/10 of the stream depth from the surface of the stream.

8. Rotate the indicator selector switch to one of the Velocity reading positions (see the Model 2100 Indicator Operation Instructions). The Model 2100 should now be reading the stream velocity directly in feet or meters per second.

SENSOR WAND-CARE AND MAINTENANCE

1. Treat the Propeller Assembly very gently. The calibration could be changed by propeller or sensor damage. Never put the wand assembly back into the carrying case with the Rotor Assembly still attached. Replace the Rotor with the Protection Cap (1/2" Cap Plug) and store the Rotor Assembly elsewhere, preferably with the Model 2100 Indicator.

2. When swiveling the sensor from the "stowed" position to the "read" position grip the Sensor Boom, not the Rotor or the Sensor Body. The Rotor Shaft could be damaged and the Sensor Body harmed if the swivel joint is too tight.

3. The connector is weatherproof only when mated. Keep both ends of the connector dry when not coupled

4. Dry the Sensor Wand completely before returning it to storage to reduce the possibility of corrosion. Although the wand is made of aluminum alloy, some amount of corrosion will occur making sliding of the Guide Rod difficult. A light film of oil or grease will help maintain proper sliding characteristics.

5. The sliding resistance of the Scale Rod on the Guide Rod can be adjusted by loosening the plastic set screw protruding from the Slide Index Fitting. Tightening of this screw will increase friction between the Guide Rod and the Depth Rod.

6. Keep the Sensor/Propeller above the sueam bed when taking readings to prevent sand and silt from entering the bearing surfaces of the Rotor. The Photo-Fiber-Optic sensor should be frequently checked for freedom of rotation especially if the water has suspended particulates. In some cases it may be necessary to clean the sensor after each immersion.

CARE OF THE MODEL 2100 SENSOR

The Sensor of the *Model 2100* Current Meter is the single most important part of the instrument and great care must be observed for its continued accurate output.

Keep the Sensor/Propeller assembly above the stream bed when taking readings and avoid rocks and other hazards when moving from one measuring site to another. This will prevent damage to the Rotor, Rotor Shaft, Propeller and the Sensor Body.

Never transport or store the sensor wand with the propeller rotor installed*. Use the 1/16" hex screwdriver to loosen the setscrew and remove the entire rotor assembly when not using the Model 2100.*

Always replace the battery in the *Model 2100* Indicator with a fresh one.

1. During rough use check the propeller frequently for frayed leading edges and for cracks. Chipped or cracked props should be replaced. Frayed leading edges can be brought back to acceptable levels of operation by reshaping them with 150 grit (or finer) sandpaper. Propellers which show signs of being bent or misshapen should be discarded.

2. Rotational friction is by far the biggest cause of erroneous data especially at velocities below 2 feet per second. Check the freedom of rotation frequently especially in turbid water or after rough handling. In some measuring situations it may be necessary to completely disassemble the rotor and clean the parts with clear water after each immersion. Use spare rotor assemblies and interchange them often. ***Never leave the rotor assembly attached to the sensor after taking readings.***

3. Water is the lubricant for the *Model 2100* rotor. "Canned air" and spray type degreasers should be used to regularly clean the "bore" of the Rotor (**2100-A27**) and the polished surface of the Rotor Shaft (**2100-A26**). Avoid oil & grease if possible.

4. The Rotor Assembly (**2100-A21**) should spin very freely when held in the vertical position (propeller pointing up) and simply blow lightly on the propeller. If it does not, clean the bore of the Rotor and the surface of the Rotor Shaft thoroughly. One method to determine an acceptable level of low-velocity performance by a particular Rotor Assembly is to perform a "Spin Test": Install the Rotor on the sensor, connect the sensor to the Indicator, and place the Indicator in the **COUNT** mode. With the propeller pointing up blow very hard straight down on the propeller. *At the instant you stop blowing* hit the **RESET** button on the indicator and allow the rotor to coast to a stop. A rotor which will perform to the low velocity limits of its design produces counts on the indicator of at least 300.

5. If the Rotor begins to "buzz" when spun by hand it means that the bore diameter of the Rotor (**2100-A27**) and the outside diameter of the Shaft (**2100-A26**) are too far apart. In this case it is advised to replace the Rotor with a new one. If the shaft shows visible signs of wear replace it also. Severe buzzing indicates that the rotor is bouncing off the shaft as it rotates around it. This slows the rotor significantly especially at velocities above 3 FPS and will cause readings to be slower than actual. **Note:** Some slight buzzing may be heard in the later versions of the rotor when it is spun "dry". This buzzing should cause no significant loss of efficiency.

6. Periodically examine the Thrust-Bearing Nut (**2100-A23**) and check inside on the bottom (the bearing surface). If a pronounced "cup" begins to form (wear from the ball-shaped end of the Rotor Shaft) the **2100-A23** should be replaced. This is especially necessary when using the *Model 2100* in low flow situations, 2 FPS or lower.

7. The Photo-Optics in the sensor body must be kept clean. Use soap and water and a soft tooth brush to keep the "eyes" clean if necessary. *Be careful and do not scratch the Photo-optics as this could cause unwanted light scattering and therefore erroneous readings*. Likewise the Fiber optics "eyes" in the base of the Rotor (2100-A27) should also be kept clean.

Treat the *Model 2100* Rotor Assembly and Sensor with care and it will continue to produce accurate data with minimum maintenance.

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