APPENDIX B: TURBIDITY TUBE CONSTRUCTION
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The turbidity tube uses the correlation between visibility and turbidity to approximate a turbidity level. A marker is placed at the bottom of the turbidity tube until it can no longer be seen from above due to the "cloudiness" of the water. This height from which the marker can no longer be seen correlates to a known turbidity value. Although this correlation is less accurate than data obtained by a turbidimeter it is accurate enough for most applications.

Turbidity Tube Construction Overview

A turbidity tube consists of four key components (Fig. 1):

1. A Clear Tube
2. A Tube Cap
3. A Viewing Disc
4. A Measuring Device

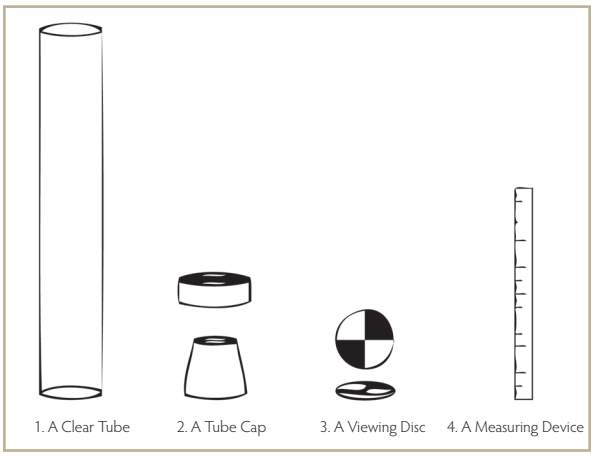

Fig. 1 Key Turbidity Tube Components

1. **Clear Tube:** The clear tube will hold the water sample being tested. The tube must be clear to allow for maximum light reflectance off of the marker being viewed. Even a light colored or white plastic tube will not let in enough light for the tube to work properly. A clear plastic tube will provide the most durability and reduce the chances of damage during transport, but a glass tube can be used if handled with caution. Possible Clear Tube Materials: Fluorescent light sleeve, graduated cylinder, etc.

2. **Tube Cap**: The tube cap prevents the water sample from leaving the clear tube. A seal to the end of the tube can be used, but a removable tube cap is preferred for cleaning of the tube and view disk. Make sure that whatever cap is used prevents leakage (a good seal is more important than removability). The size of your cap will depend on the size of your tube. Possible Tube Caps: Rubber stopper, PVC pipe cap, Gatorade lid with rubber washer, chair leg end cap, etc.

3. **Viewing Disc:** The viewing disk will be submerged in the water sample. A clear pattern must be visible on the disk as well. Generally, it is best to use a white background that is colored with a black checker pattern like the one shown in Figure 2 (this is the pattern typically found on a Secchi disk as well). The contrast makes the viewing disk very clear, which improves the accuracy of the reading. A white plastic disk patterned with black permanent marker works

extremely well. The disk should be sized to fit inside the plastic tube. If necessary, the disk can be made of a porous material such as wood or cardboard, but it must be sealed by lamination or with varnish. Possible Viewing Discs: Yogurt container lid cut into a circle, white poker chip, etc. Possible Marking Device: Black permanent marker, black paint, etc

4. **Measuring Device:** The level of the water at the point of non-visibility needs to be measured. This can be done in two ways. The water level can be directly measured from the viewing disc to the top of the water, and a chart can be used to find the turbidity level that corresponds to the measurement. A better way is to mark the turbidity tube with the corresponding turbidity levels before testing begins so that no conversion is necessary. Your choice will depend on the availability of materials and the construction of your tube (for example, if the removal and reinsertion of your tube cap changes the height of your viewing disk, the marking will no longer be correct.) Possible Measuring Device: Ruler, tape measure, etc.

General Construction

These instructions are very broad to encourage adaptations in the design. A set of specific instructions can be found on page 87 (Procedure for Turbidity Tube Construction). After obtaining the materials discussed above, do the following:

1. **Plan the Placement of Viewing Disk:** You will need to be able to see the viewing disk from the top of your clear tube (Fig. 2). The placement of the disk will depend on your tube cap. The disk can be dropped to the bottom of your tube if it is not made of a floating material. A dropped disk will need to be marked on both sides. You can also attach the disk to your tube cap with adhesive so that it will be visible when the cap is inserted. Another possibility is to mark the tube cap with a checkered pattern so that it can be treated as a viewing disk.

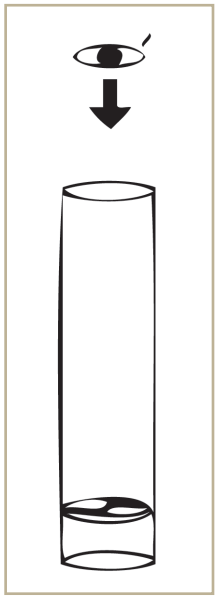

Fig. 2 Viewing the disk placement

2. **Combine Tube Cap and Viewing Disk:** Use adhesive or sealant to bind the viewing disk to the tube cap. Make sure the disk will fit properly when the tube cap is inserted into the tube (i.e. try it before you glue it.) You can also mark the checkered pattern directly on your tube cap, or a non-floating disk can be dropped from above, as in Fig. 3 (just make sure it is small enough as to not get stuck in the tube or the bottom).

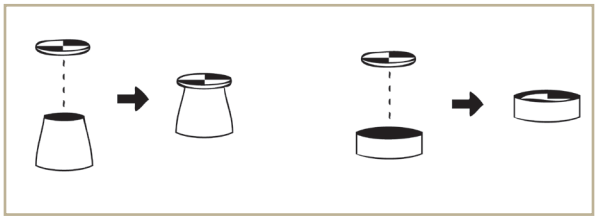

Fig 3. Combining the Tube Cap and Viewing Disk

3. **Affix Tube Cap to Bottom of Tube:** Ideally, the tube cap will be removable for cleaning, but the primary concern is that water does not escape the tube during testing. Some sort of sealant or putty can be used to seal the cap well. Make sure the disc is still clearly viewing from the top of the tube - See Fig. 4.

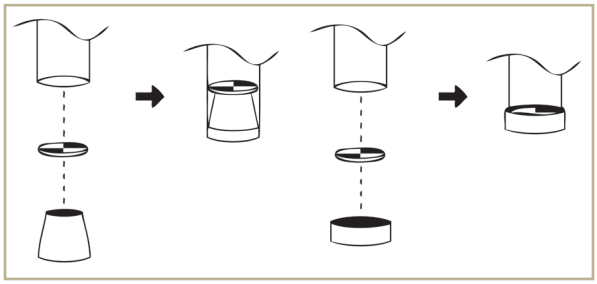

Fig. 4 Affixing the Tube Cap and Viewing Disk

4. **Mark Tube with Measurement Increments:** Ideally, the turbidity level will be marked directly onto the tube. Place the zero mark of a measuring tape or ruler even with the viewing disk and measure up the tube, marking the proper intervals found in Fig. 5.

Two rubber bands on each end of the tape will hold it in place well while you mark levels with a marker. These measurements will be used to find the corresponding turbidity found in Table 1 on page 89.

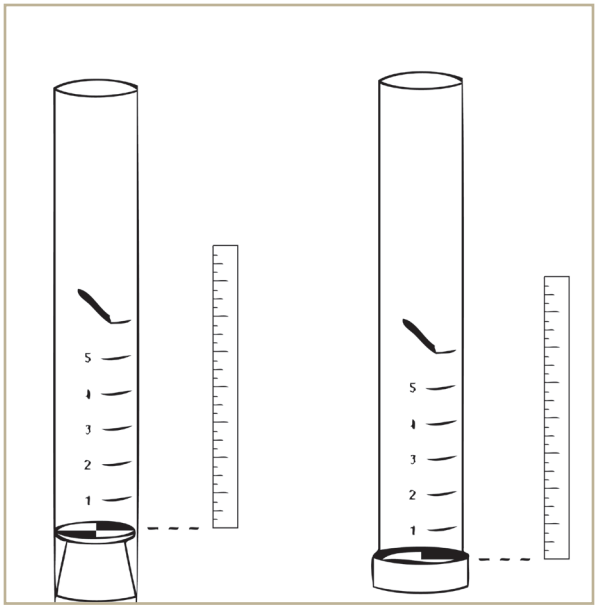

Fig. 5 Mark increments in centimeters on the turbidity based on Table 1 on page 89.

5. After all components have dried, test the tube for leakage and make adjustments accordingly. If you are not able to mark the tube directly and will be measuring the depth of the disk below the surface for each reading, try to attach the measuring device to the side of the tube, possibly using rubber bands or another device.

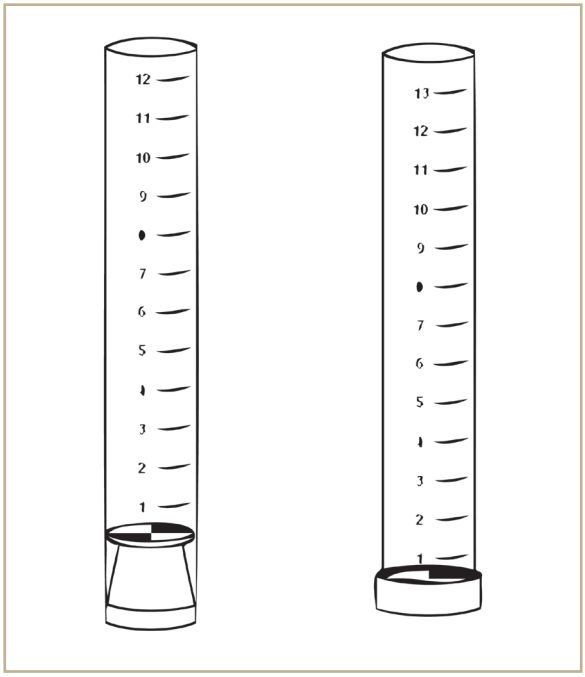

Fig. 6 Completed Turbidity Tubes

Procedure for Turbidity Tube Construction

Materials*

- Black Permanent Marker
- 4' or Longer Fluorescent Light Sleeve (available at most hardware stores)
- (2) Rubber Bands
- Rubber Stopper
- Scrap Paper or Newspaper
- Scissors
- Super-Glue
- Tape Measure
- White Plastic Milk Jug (Opaque)

* Many of the materials listed can be substituted with other materials depending on what is available to the user.

Construction

1. Cut a circle (a few centimeters larger than your tube diameter) out of a flat side of the milk jug. Place the circle on the ground and trace the tube mouth onto the plastic square.

2. Cut inside of the traced line such that the resulting plastic disk will fit easily into the fluorescent light sleeve. Use the black permanent marker to color the checkered pattern in Figure 6 onto the disk. This is your viewing disk.

3. Lay scrap paper down to prevent super glue from damaging any surfaces. Lay the viewing disk checked face down on the paper. Put a thin line of superglue on the rim of the rubber stopper, and quickly press the rubber stopper centered onto the back of the viewing disk until it properly adheres to the rubber stopper. CAUTION: Super-glue binds to the skin instantly.

4. Press the rubber stopper into the bottom of the fluorescent light sleeve and make sure it is inserted completely. The viewing disk may need to be scissor-trimmed to fit into the light sleeve properly.

5. Attach the tape measure to the tube using rubber bands at both ends. Align the zero-end of the tape measure with the viewing disk so that measurements increase as you move up the tube. Using Table 1 on page 89, place a short marking at each distance that corresponds to a specific turbidity level. Write the corresponding turbidity level next to each marking all the way up the tube. Example: Put a dash 6.7 centimeters from the viewing disk and write "240 NTU," then 7.3 centimeters from the disk and write "200 NTU," etc.

6. Trim the top of the tube to about 5 centimeters above the 5 NTU mark (the 5 NTU mark is located at about 85 centimeters from the viewing disk).

7. The tube is now complete. It can be cleaned by removing the stopper. If the permanent marker rubs off at some point, simply redraw the pattern.

Using a Turbidity Tube

Before You Begin:

- Be sure to use a clean bucket or other container to collect water samples
- Measurements should be taken in daylight, but not direct sunlight. Cast a shadow on the tube by placing yourself between the sun and the tube.
- Do not wear sunglasses when reading the tube.
- If possible, work with a partner to help verify measurements and disk visibility.

When Measuring, Remember:

- Highly colored water will register as having a higher turbidity than it actually does.
- The turbidity scale is logarithmic, so it cannot be linearly interpolated.

Measuring Procedure:

1. Dip the container into the water. Be careful not to include sediment from the bottom of the body of water.
2. Rinse the tube with the water that is going to be tested and pour it out.
3. Stir or swirl the water sample in the container vigorously until it is homogenous, introducing as little air as possible.
4. Place your head 10 to 20 centimeters directly over the tube so that you can see the viewing disk while the sample is being poured into the tube.
5. Slowly pour water into the tube. Try not to form bubbles as you pour. If bubbles do form: Stop pouring and allow any bubbles to rise and the surface of the water to become still.
6. Keep slowly adding water until the pattern on the disc becomes hard to see.
7. Watch the viewing disk closely and add water even more slowly. Stop pouring as soon as the pattern on the disk can no longer be seen. If you can still see the viewing disk pattern when the tube is full: Record the turbidity value as less than the final measuring mark. (Example: If your tube is full and your highest mark is 5 NTU, write down that the turbidity is "<5 NTU".)
8. Read the turbidity from the scale on the side of the tube. Remember: If your turbidity tube does not have turbidity values marked on the tube side, simply measure the water level with a ruler or tape measure and find the corresponding turbidity value in Table 1 (see page 89).

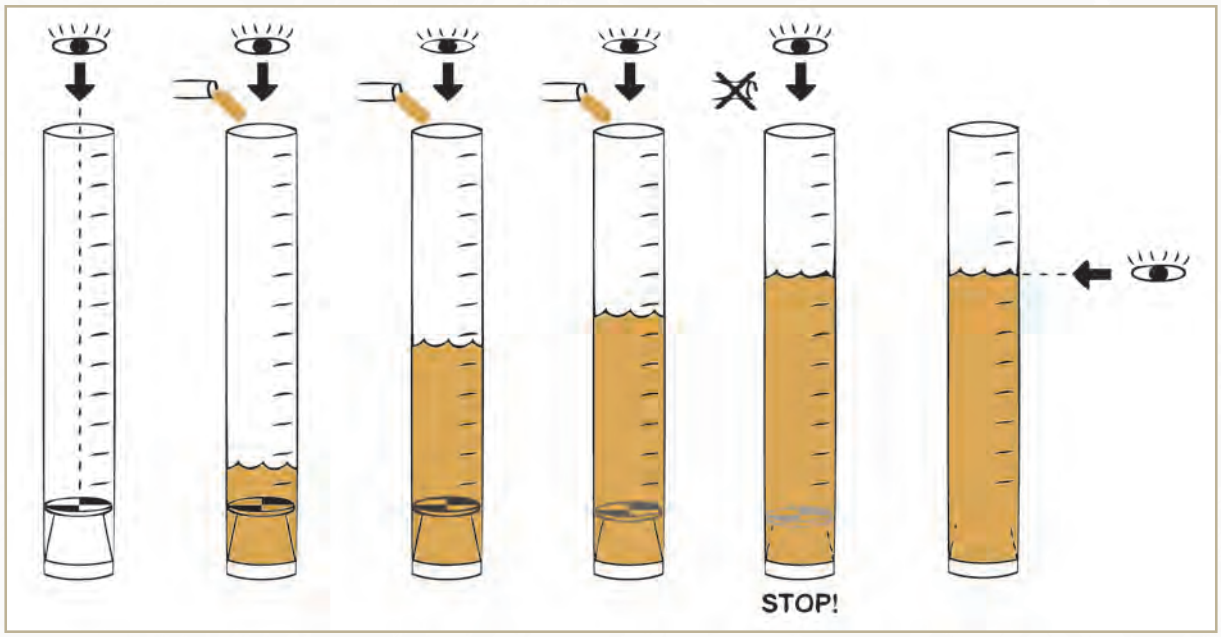

Fig. 7 One student should pour water into the turbidity tube, while another student observes the disk carefully and says, "stop!" when it becomes hard to see the viewing disk.

Length-to-Turbidity Conversion Chart

Table 1 provides the turbidity values (in NTU) that correspond to different lengths measured above the viewing disk. These values can be used to mark the turbidity tube directly or to convert measured values to turbidity units.

Table 1: Length-to-Turbidity Conversion[1]

Centimeters	NTU
6.7	240
7.3*	200*
8.9	150
11.5	100
17.9	50
20.4	40
25.5	30
33.1	21
35.6	19
38.2	17
40.7	15
43.3	14
45.8	13
48.3	12
50.9	11
53.4	10
85.4*	5*

*Interpolated/Extrapolated Values (See explanation below)

The relationship between the depth of the viewing disc and the turbidity is exponential. Plotting the non-highlighted values in Table 1 and using a computer to give the best fit line yields the following equation:

$$\text{Depth in Centimeters} = 244.13 * (\text{Turbidity in NTU})^{-0.662}$$

An R^2 Value of 0.996 was calculated for the above equation. We then used the equation to calculate the depths for our desired values of 5 NTU and 200 NTU. These values were mentioned in this paper, so we felt they should be included. If another turbidity value is important to the user, the corresponding depth can be found using the above equation.

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[1](UW Extension, 2003). Several tables of slightly different conversions are currently in use. This table was chosen from among the alternatives because of the reliability of the source and because the values were more conservative than in other tables.