

## 6.7.3 MEASUREMENT

Three methods for field measurement of turbidity are described in this section: the nephelometric method or “turbidimetric determination,” using a cuvette-based turbidimeter (6.7.3.A); “determination by submersible sensor” using a multiparameter water-quality instrument with a turbidity probe (6.7.3.B); and the absorptometric determination, using a spectrophotometer (6.7.3.C). Procedures are similar for use of turbidity instruments in surface water and ground water, although some applications may differ, as described below.

- ▶ **Turbidity is time sensitive**—Measure sample turbidity on site to avoid biased values that can result from (1) biodegradation, settling, or sorption of particulates in the sample; or (2) precipitation of humic acids and minerals (carbonates and hydroxides, for example) caused by changes in sample pH during transport and holding.
- ▶ **Biased or erroneous readings can result from unmatched cell orientation, colored sample solutions, gas bubbles, condensation, and scratched or dirty sample cells** (see TECHNICAL NOTE). Condensation on the sample cell commonly occurs on hot days when humidity is high.

TECHNICAL NOTE: Causes of low-biased readings include particulate settling or sorption on container surfaces, biodegradation, and sample solutions with true color (color from dissolved substances that absorb light—some instruments are designed with optics to eliminate bias from color). High-biased or false turbidity readings can be caused by the presence of condensation and finely-divided air or other gas bubbles in the sample or on the cell or probe surface, and scratches, fingerprints, or dirt on the surface of the sample cell or turbidity probe.

Be sure that sample cells are marked to indicate orientation—match orientation so that cells yield the same value when light passes through.

### ***Surface Water***

Collect samples for turbidity measurement or make in situ measurements using either discharge-weighted, pumped-sample, or grab-sample procedures, as appropriate for site characteristics and for study objectives (see NFM 6.0).

- ▶ If taking discrete samples from a churn splitter or other sample-compositing device, remove samples for turbidity measurement when the water volume in the compositor is near maximum.
- ▶ Verify the turbidity determination by measuring turbidity on two or more samples, if samples are removed from a compositing device or collected as grab samples from the surface-water body. Collect turbidity sample directly into the cuvette for immediate measurement or into a clean amber glass bottle for short-term storage.
- ▶ If turbidity is measured in situ, take three or more sequential turbidity readings, until readings stabilize to within  $\pm 10$  percent (see NFM 6.0).

### ***Ground Water***

Turbidity in ground water generally is less than 5 NTU. Natural ground-water turbidity of up to 19 NTU has been reported for some environmental settings (Nightingale and Bianchi, 1977; Strausberg, 1983; Puls and Powell, 1992). Contaminated ground-water systems, however, can have considerably higher turbidity (Wells and others, 1989; Gschwend and others, 1990; Puls and Powell, 1992; Backhus and others, 1993).

- ▶ **During well development**—Monitor turbidity caused by well installation, recording consecutive measurements to document decreases in turbidity as development proceeds.
- ▶ **During well purging**—Monitor changes in turbidity by taking sequential readings until purging criteria are met (NFM 6.0). The final stabilized turbidity value should be equal to or less than the value recorded at the end of well development. A decrease in turbidity values during purging indicates mitigation of subsurface disturbance caused by well installation and by deployment of data-collection equipment in the well.
- ▶ Report the median of the final five or more sequential measurements that meet the  $\pm 10$ -percent criterion for stability (NFM 6.0).

***For discrete-sample measurement using a turbidimeter or spectrophotometer:***

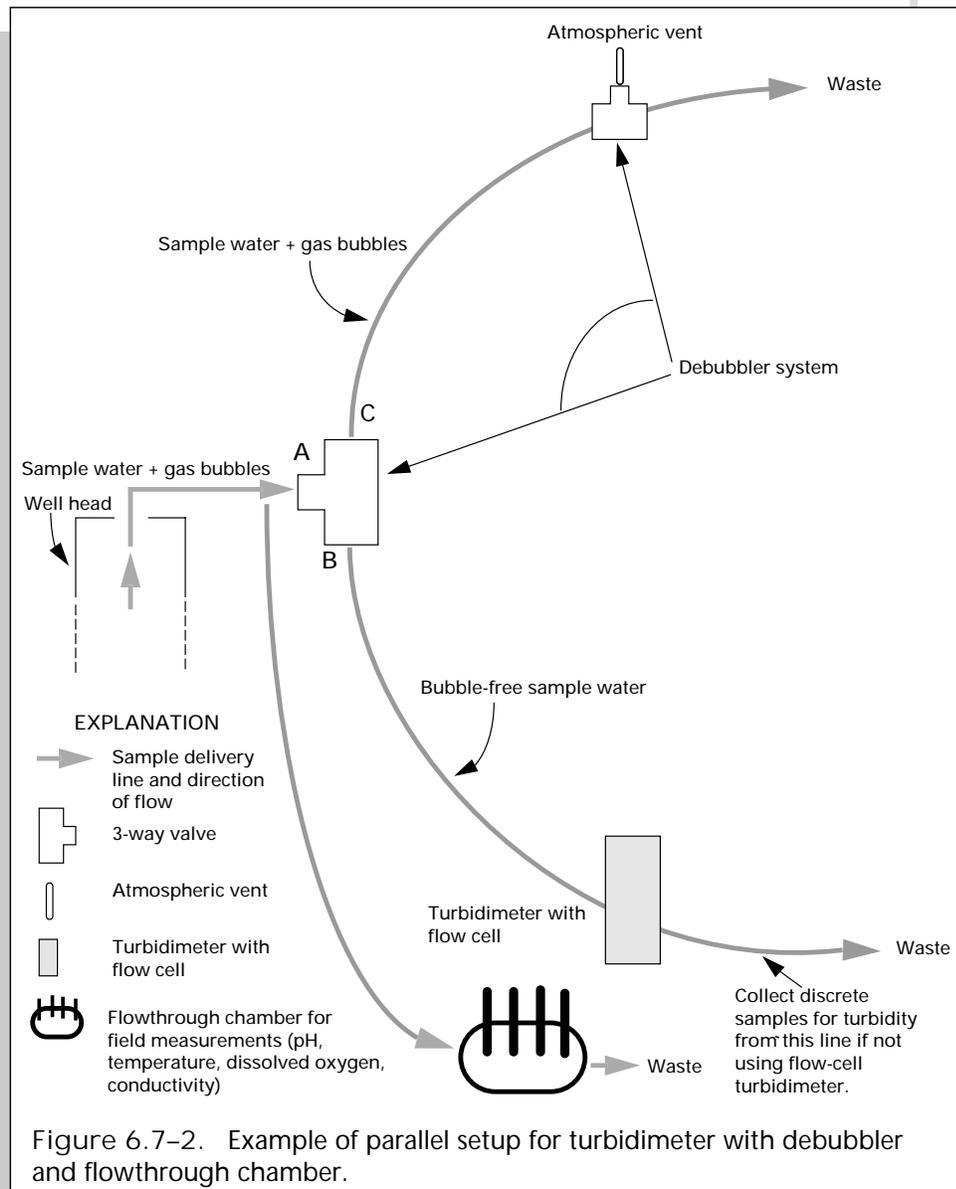
- Pump the ground-water sample directly from the sample discharge line into a precleaned glass or polyethylene sample-collection bottle.
- Bailers are not recommended for collecting turbidity samples, as bailer deployment can cause turbidity.
- Do not collect the discharge passing through the flowthrough chamber in which pH, conductivity, or other field-measurement sensors are installed.

***For turbidimeter measurement using a flowthrough cell:***

1. Split the sample flow from the well between the turbidimeter and the flowthrough chamber used for other field measurements, as illustrated in figure 6.7–2 (parallel lines are not needed if field measurements are made using a downhole or other in situ method, or when discrete samples are split from a composite). **The turbidimeter requires greater flow velocity than is appropriate for the flowthrough chamber.**
  - a. Position the sample-line split to the turbidimeter/debubbler system in front of (closer to the well) the flowthrough chamber to avoid sediment in the flowthrough chamber. (The higher velocity flow required through the turbidimeter can result in mobilizing sediment—see TECHNICAL NOTE.)
  - b. Set up the debubbler plumbing to maintain a constant head and constant velocity through the turbidimeter's flowthrough cell.
2. To construct a debubbler, use a short length of rigid plastic tubing with one perpendicular tee through which sample enters, another tee at the top end (the atmospheric vent), and hose clamps to secure the tubing. The diameter of the tubing and fittings needed for the debubbler is proportional to the rate at which sample flows through the turbidimeter. Referring to figure 6.7–2:
  - Water entering debubbler at "A" must exit at both "B" and "C."
  - Flow exiting at the top ("C") must be greater than the flow exiting at the bottom ("B").
  - The tubing extending from the debubbler bottom ("B") to the turbidimeter will probably need a smaller diameter than the top tubing to ensure a minimum velocity of 0.46 to 0.61 meters per second (1 1/2 to 2 feet per second).

- The atmospheric vent should be located at the highest point in the debubbler system to prevent siphoning.

TECHNICAL NOTE: Backpressure must not be allowed in a flowthrough chamber containing pH or dissolved-oxygen sensors, and the line to the flowthrough chamber must be disconnected or bypassed until any appreciable volume of sediment clears from the line. **Water should never discharge from the atmospheric vent.**



### 6.7.3.A TURBIDIMETRIC DETERMINATION

The nephelometric method for making turbidimetric determinations that is described in this section requires a photoelectric turbidimeter that meets USEPA specifications.<sup>5</sup> This method is applicable in the range of turbidity from 0 to 40 NTU without dilution, and from about 40 to 1,000 NTU with dilution. The method has been tested for drinking and process water and yields real values in NTU.

***Check the turbidimeter against a standard before measuring sample turbidity:***

1. Warm up the turbidimeter according to the manufacturer's instructions.
2. Rinse a clean, dry, scratch-free, index-marked cell with the turbidity standard selected at the NTU within the range of interest.
3. Shake and pour standard into the sample cell to the fill mark and dry the cell exterior with a lint-free cloth.
4. Follow manufacturer's instructions for readout of turbidity value and record the NTU of the standard used and the turbidity value measured in the turbidimeter calibration log.
5. Determine the required reading for the turbidity standard from the calibration curve for the instrument's range and adjust the calibration to the required NTU reading.
6. Measure sample turbidity as soon as sample is collected (see TECHNICAL NOTE).

TECHNICAL NOTE: Turbidity should be measured immediately. However, if temporary storage of samples becomes necessary, collect samples in clean amber glass bottles, keep out of sunlight, and keep chilled at or below 4°C to prevent biodegradation of solids. The holding time must not exceed 24 hours (American Society for Testing and Materials, 1990).

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<sup>5</sup>The nephelometric method using a calibrated slit turbidimeter is not described—refer to American Society for Testing and Materials (1990).

**Measurement of sample with turbidity less than 40 NTU:**

1. After instrument standardization check, empty the cell of turbidity standard and field rinse a freshly cleaned cell with the sample to be tested. Change gloves.
2. **Measurement of discrete sample** (skip to step 3 for flowthrough cell measurement):
  - a. Shake the sample vigorously to completely disperse the solids. Allow air bubbles to disappear before filling sample cell.
  - b. Pour the sample into a sample cell to the line marked (to the neck if there is no line). Do not touch cell walls with fingers.
  - c. Remove condensation from the cell with a clean, soft, lint-free cloth or tissue. If condensation continues, apply a thin coating of silicon oil on the outside of the cell about every third time the cell is wiped dry of moisture.
  - d. Orient the cell with standard in the turbidimeter. Go to step 4.
3. **If using an instrument with an internal flowthrough cell:**
  - a. Orient the cell in the cell chamber of the turbidity instrument.
  - b. Pump a steady stream of sample in-line from the sample source.
    - Use a constant flow rate through the turbidity instrument.
    - Flow to the turbidimeter must be sufficient to keep particulates suspended (1 1/2 to 2 feet per second).
  - c. Check periodically for condensation on flow cell—remove any moisture from cell using soft, lint-free wipe. If necessary, wipe cell walls with two drops of silicon oil and a lint-free wipe. If available, try a gas sweep of the flowthrough cell compartment using dry nitrogen gas.
    - **Make sure that the flow rate of the gas does not exceed the rate recommended by the manufacturer.**
    - Filter the gas to remove particulates and moisture—use a filter that includes desiccant (particulates or moisture in the gas stream can cause additional variability in the turbidity readings).
    - Eliminate air bubbles in sample before measurement using a debubbler device.

4. Determine the measured NTU value of the sample either by reading turbidity directly from the instrument scale or by using the instrument value and calibration curve, as is appropriate for the instrument being used (see TECHNICAL NOTE).
  - a. Record three to five separate readings at regularly spaced intervals.
  - b. Report the median of the last three or more sequential values that fall within  $\pm 10$  percent.

TECHNICAL NOTE: When using the 0.2-NTU scale only, you may need to subtract a correction factor from the reading to correct for stray light. The Hach Company reports the correction for the 0.2-NTU scale to be on the order of 0.04 NTU for the Hach 2100P™. The stray-light correction is determined by reading turbidity from an empty instrument (without cuvette).

**5. Quality control.**

- a. Repeat discrete sample measurement on two additional samples and check that they fall within the  $\pm 10$ -percent criterion. Report the value of the first if two samples are measured, or report the median if three or more samples are measured.
- b. Using a clean sample cell, repeat the procedure, substituting turbidity-free water to run a blank. Run the blank either before or after the sample, following manufacturer's instructions.

***For measurement of sample with turbidity exceeding 40 NTU:***

1. Obtain discrete sample.
2. Dilute the sample with one or more equal volumes of turbidity-free water until turbidity is less than 40 NTU after mixing and degassing.
3. For 100- and 1,000-NTU ranges only—place the cell riser into the cell holder before the sample cell. This decreases the length of the light path in order to improve the linearity of measurements. **Do not use the cell riser for the lower NTU ranges.**
4. Follow procedures for samples with turbidity less than 40 NTU.
5. Based on the dilution factor and original sample volume, compute the turbidity of the original sample (see 6.7.2, "Calibration for Turbidimeter," steps 11 and 12):
  - a. Add volume of dilution water (in mL) to sample volume (in mL).

- b. Multiply by NTU of diluted sample.
- c. Divide by the volume of sample (in mL) that was diluted.

EXAMPLE: If 5 volumes of turbidity-free water were added to 1 volume of sample, and the diluted sample showed a turbidity of 30 units, then the turbidity of the original sample is computed as 180 units.

Don't forget to adjust the turbidity value of diluted samples using the dilution factor.

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### DETERMINATION BY SUBMERSIBLE SENSOR 6.7.3.B

Determination of turbidity using a multiparameter instrument with submersible sensor-containing sonde is useful for water-quality studies in which the turbidity data will be used qualitatively and not for regulatory or compliance purposes. Turbidity sensors for these instruments utilize an LED with near infrared radiation as the light source and turbidity values normally are reported as NTU. Current instrumentation of this type is not approved by the USEPA.

Multiparameter instruments can be used with a flowthrough chamber, instead of being deployed in situ, for monitoring ground-water field measurements. If measurements will be made in a flowthrough chamber, the turbidity probe is part of the sonde bundle that includes other field-measurement sensors (for example, pH, conductivity, temperature, and dissolved oxygen) and a separate or parallel setup for turbidity measurement (fig. 6.7-2) is not needed.

Multiparameter instruments with internal batteries and memory can be used in surface-water studies that require long-term deployment. Guidelines for long-term instrument deployment falls under the topic of continuous monitors, and is beyond the scope of this chapter—refer to manufacturer's instructions and recommendations and to guidance documents for continuous monitors.

***The following procedures apply to in situ determination and to determination of turbidity in a flowthrough chamber:***

1. Calibrate the instrument in the laboratory or office before leaving for the field site (see 6.7.2).
2. At the field site, follow procedures for selection of surface-water and ground-water sampling locations and for in situ (Procedure A) or flowthrough-chamber (Procedure B) field measurements, as described in NFM 6.0.

**Procedure A: In situ measurement**—Immerse the sonde with turbidity and other field-measurement sensors in the water body.

**Procedure B: Flowthrough chamber**—Secure chamber cover over sonde/probe to form an air-tight and water-tight seal. Discharge first sample aliquot to waste, then open connection to flowthrough chamber and pump sample from water source to flowthrough chamber according to instructions in NFM 6.0.3.

3. Activate instrument to display turbidity values in real time.
4. Agitate the turbidity-containing sonde to remove bubbles from the optical surface: move sonde up and down or in a circular pattern and (or) activate wiper mechanism if available.
5. Monitor turbidity readings as described for other field measurements in NFM 6.0.
  - Allow at least 2 minutes before recording the required number of sequential readings.
  - Stability is reached if values for three (for in situ procedure) to five (for flowthrough-chamber procedure) or more sequential readings, spaced at regular time increments, are within 10 percent.
6. Record turbidity readings on field form and in field notes. Log the reading into instrument memory, if applicable.
7. **Surface-water sites**—Repeat steps 2–5 for in situ measurements (Procedure A) at each vertical to be measured.
8. Before leaving the field site, clean the sonde with a thorough rinse of deionized water and replace sonde in the storage vessel.
9. **Quality control.** Check instrument performance periodically by placing a check standard in the instrument storage vessel and comparing standard value with the reading displayed.

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### ABSORPTOMETRIC DETERMINATION 6.7.3.C

The absorptometric method described below uses a field spectrophotometer to provide a relative measure of the sample turbidity. The spectrophotometer shoots a beam of light through the sample at a specific wavelength and measures the amount of transmitted light absorbed by solids present in the sample compared to how much of the transmitted light is absorbed by a Formazin standard.

- ▶ **This method is not approved by the USEPA.** It is a useful method, for example, if the purpose for the turbidity determination is as an indicator of ambient or “stabilized” conditions during well development or purging.
- ▶ Spectrophotometric measurement of turbidity yields readings in FTU. **Do not enter absorptometrically derived turbidity values into the data base.**
- ▶ **Turbidity values below 50 FTU—the range of most surface water and ground water—are inaccurate using this method** and the procedure is recommended only as a relative measure of sequential turbidity values.

The absorptometric method for a Hach DR/2000™ portable spectrophotometer is described below, because this is the instrument that currently is in use for most USGS field work. **Check operating instructions if using an instrument of different make, model, or manufacturer—the position on the dial for wavelength of turbidity may vary for different instruments.**

1. Enter the stored program number for turbidity and rotate the wavelength dial until the display indicates the wavelength value in nanometers (nm) for the instrument in use—450 nm for a Hach DR/2000™, for example.
2. Put on gloves. Measure standards on the instrument that bracket the range anticipated in the sample solution. This step checks the accuracy of the calibration scales. **Change gloves with each change in standard and sample.**
3. Pour 25 mL of deionized water into a clean sample cell for the blank. Hold the cell by the rim—do not touch the cell wall.
4. Place blank sample into cell holder, close the light shield, and press zero. The display should show “wait” and then “0. FTU turbidity.”

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5. Shake environmental sample vigorously to suspend all solids and allow air bubbles to dissipate.
6. Pour 25 mL of sample into another clean sample cell, holding cell by the rim (top lip).
7. Carefully place sample into cell holder.
  - a. Close the light shield. Press read/enter.
  - b. The display first will show "wait" and then show the turbidity value in FTU.
  - c. Record the FTU reading.