DQM Information Paper 3.1.5
Measuring Suspended Solids and Water Column Turbidity

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1.0 About this Information Paper

(This section is essentially common to all DQM Information Papers. If you have seen it already, please skip to Section 2 below). This Information Paper is a new type of guidance. It has been created for our new integrated system of guidance and tools for water quality monitoring called "the Data Quality Management (DQM) System". DQM is implemented by the Clean Water Team (CWT) where needed to support collection of **reliable** data of **known quality** in a fully documented, **scientifically defensible** manner. Most DQM materials are delivered in Parameter-Specific Folders, which provide both the traditional "protocol" materials and new, expanded guidance in three types of inter-related documents: Fact Sheet, Information Paper, and Standard Operation Procedures. Background information on the ecological significance of each parameter and the regulatory benchmarks that have been developed for it is summarized in the FACT SHEET. The technical information on measurement methodology provided in this IP with its method-menu. Then there are several detailed standard operating procedures (SOPs) that provide step-by-step instructions for each instrument or kit, as well as instrument-specific Quality Assurance/Quality Control and CCRR directions and data validation checklists.

This Information Paper (IP), a part of the Parameter-Specific Folder for turbidity, provides "big picture" technical information on turbidity measurement methodology. If you are a Trainer or a Technical Leader of any monitoring project, this may help you select a good method to measure turbidity or transparency in your water body. It is also related to sediment sources and transport potential described in Fact Sheet FS-5.2.0 in another folder of this compendium.

Section 2 of this IP introduces a "method menu" table with a list of kits and instruments commonly used by citizen monitoring groups, agency staff, or laboratory technicians, with information on the limitations, approximate cost, measurement range and resolution, and associated labor of each device. Next (Section 3), a description of the different physical or chemical principles underlying the commonly used methods to measure turbidity is provided. Section 4 provides practical tips and advice on turbidity measurement based on our cumulative experience (The Clean Water Team and others). This section is meant to be updated as we learn more. Finally, the "Sources & Resources" section (Section 5) provides a list of available SOPs as well as contact and website leads into further information.

2.0 Ways to Measure transparency, turbidity, or suspended sediments

Table 3.1.5-1 lists some commonly used methods for evaluating the amount of suspended solids, either directly (i.e., by weight per volume) or through their effects on other

Table 3.1.5-1: Selected Methods and Devices for Measurement of Water Column Turbidity and Suspended Sediments

Code (Note a)	Principle	Method name (Parameter, unit)	Cost	Labor	Application	Limitation	Extent & Sources of Error
	Transparency	Murkiness *(Note b)*	None	30 sec	Turbidity watch, source ID		Not Applicable
SEC	Transparency	Secchi disk (Secchi depth, cm)	~$30	2 min	Status of Lakes and pools	Need to deploy from above Daylight only	± 30%; Individual operator's vision, Lighting, surface reflection, depth measurements
TRT	Transparency	Transparency tube (Transparency, cm)	$40	5 min	Turbidity in streams Source ID	Daylight only	± 30%; Individual operator's vision Length measurement, deposition
TUJ	Transparency match	Dual cylinder (Jackson turbidity, JTU)	$40	5 min	Turbidity in streams Source ID	Daylight only	± 40%; Individual operator's vision, quality of standard, volume measurements
TUN	Light-scattering	Nephelometer (Turbidity, NTU)	$300 and up	10 min cal 1 min measure	Turbidity in streams and lakes, Source ID		Error variable, depending on instrument
TUN	Light-scattering	Automated Nephelometer (Turbidity, NTU)	$1000 and up	Installation, calibration, download.	Use with data logger and/or trigger, storm events		Fouling of light absorbing surfaces, drift from the calibrated state
TSS	Gravimetric: Dry Weight per volume of sample aliquot *(Note c)*	Filtration for Total Suspended Solids (TSS, mg/l)	$2000 and up	20 min	Sediment loads assessments	Requires laboratory facility	Error variable, depending on operating procedures
SSC	Gravimetric: Dry Weight per volume (by water weight) of whole sample	Filtration for Suspended Sediment Concentration (SSC, mg/l)	$2000 and up	20-60 min	Sediment loads assessments	Requires laboratory facility	Error variable, depending on operating procedures
IC	Sinking	Imhoff Cone Method	~$30	5 min (setup and read)	Finer Separation by density	Requires cones	± 30%; Lighting, surface identification, volume measurements

Notes: (a) The Codes on the left are consistent with the Instrument codes used in all other DQM materials.
(b) Visual categories can include: "Clear Water", "Cloudy Water" (bottom visible under 4" of water), and "Murky" (bottom invisible).
(c) a sample aliquot is a portion of the sample, not the whole bottle.

properties of the water. Essentially, this Method Menu provides ways to measure transparency, turbidity and suspended sediments in water samples. The list is not inclusive of all available kits and instruments, and the user is encouraged to seek more information. You can look at it for selection of a device based on available resources and operators' skill, e.g., during the initial phases of your group's monitoring activities. Once you have formulated the monitoring question, decided which parameters you need to measure, developed your sampling design, and determined how much error you can tolerate in your measurements, you can refer to this menu again and find the device that will work for you. In some situations you might want to use more than one method to establish correlations between the outcomes of different methods so you can infer from one property of the water to another.

3.0 Principles and Applications of Methods

The principles and applications of measuring turbidity and suspended materials in various water bodies are discussed in three sections, below. The first section discusses methods of measuring water column turbidity through *transparency and light scattering evaluations.* The second section discusses evaluating the amount of material suspended in the water column by measuring the concentration of *suspended sediment.* Evaluating the potential for sedimentation of suspended material by assessing *settlable solids* is discussed in the third section.

3.1 Water Column Turbidity

Water appears less clear, or less transparent, if there are particles of solids (soil, algae, etc) suspended in it. The more particulates, the more turbid water can become. This attribute of water can be quantified in one of two ways:

- Transparency evaluations (Visual observation, Secchi disk, Transparency Tube, or Dual cylinder for transparency match)
- Light-scattering measurement (Nephelometric turbidity meters)

Transparency evaluation is done by looking at the visibility of objects through a layer of water. The simplest assessment can be by visual categories, e.g., "Clear water", "Cloudy water" (bottom visible under 4" of water), and "Murky" (bottom invisible). One can also look at objects with clear patterns (e.g., Secchi disk) deployed in the water column, or in a long Transparency Tube. Either way, the column of water above the pattern is altered gradually and the depth of disappearance is recorded as "Secchi depth" or as "transparency", in centimeters (or meters in Lake Tahoe!). Another way is comparing the visibility of a given pattern (black dot on white background) with a "turbidity" standard in a dual-cylinder test kit; the results are recorded in Jackson Turbidity Units (JTU) which reflect the amount of Standard solution added to match the sample's transparency. All the evaluations mentioned in this section can be performed in the field; the Transparency Tube and Dual Cylinder tests can also be performed in the lab, using a sample in a jar.

Nephlometric measurements utilize an instrument that shines light on the particles and measures the reflection or backscatter of the light by the particles. This value is expressed in

Nephelometric Turbidity Units, or NTU (recently transformed to FTU). Light backscatter produces a measurement value (NTU) that is totally different from the light absorbance of the particles, which is measured by a photometer. Turbidity meters can be used both in the field and in the lab. Turbidity probes can also be installed in a stream or lake for continuous measurements, using automatic data loggers.

3.2 Suspended matter concentration

Evaluating the amount of material suspended in water by a gravimetric method is done in a lab, because it requires time and bulky/heavy/non-mobile equipment. Collection of a representative sample (in terms of suspended solids) is a challenge, and the reader is urged to seek adequate guidance. Once the water sample is in a jar/bottle, suspended matter can be quantified by a method that involves collection of the suspended solids on a filter, drying, and weighing the loaded filter (and then subtracting the weight of the empty filter). This is called a "gravimetric" method because it deals with weight, and the results are normally reported as milligram (mg) suspended solids per one liter of sample (mg/l). Laboratories may use one of two variants:

- **Total Suspended Solids (TSS)** – only a portion of the sample (i.e., a sample aliquot), rather then the whole bottle, is transferred to the filter for filtration; it is sometimes difficult to take a representative aliquot. Moreover, the amount of sample liquid used for filtration (i.e., the size of that aliquot) is measured directly as volume, rather than by the weight and specific gravity of the water in it.
- **Suspended Sediment Concentration (SSC)** - the entire sample is filtered, on multiple filters if needed, rather than aliquots of it. The amount of sample used is measured by weighing the sample bottle (full and empty) and computing the volume from the water weight. This method is much more accurate because it circumvents error generated by sub-sampling (aliquoting) and error associated with volume measurements (ASTM 1997, RSL 2000).

It must be noted that there is no direct relationship between the optical methods (transparency and Nephelometric turbidity) and the gravimetric methods, because each of the measured values is affected by different properties of the particles. However, the correlation between two parameters (e.g., TSS and NTU, or SSC and NTU) can be established for a particular drainage of uniform geological features and then NTU can be used as surrogate values to estimate TSS and possibly sediment loads.

3.3 Potential for Sedimentation

The potential for sedimentation of materials transported in water can be assessed either mechanically (by evaluating the amount of particles larger than a given size, as separated by sieving) or functionally (by evaluating the amount of particles that sink rapidly).

Separation by size (using sieves): An offshoot of the SSC method described above (ASTM 1997, RSL 2000) utilizes mechanical separation of sand and other particles by passing a sample through a sieve of certain pore size. The “size fraction” that remains on the sieve is then dried and weighed separately from the fraction of smaller particles (which had passed through the sieve). The results are usually reported as "percent sand" or as concentration, in mg/l, of each fraction. This method is somewhat indirect as it does not differentiate between slow-settling materials and fast-settling materials.

Separation by gravity: "Functional" separation, by gravity, is used to separate fast-settling materials from slow-settling materials. A water sample is placed in a container, such as an Imhoff cone (see Table 3.5.1, bottom line) that allows measurement of the amount of material, in terms of volume, that settles out of a water sample within a given period of time. The results of the evaluation are normally reported as milliliters (ml) of settleable solids per 1 liter of sample. Stormwater runoff "settleable solids" data, obtained by Imhoff cones, have been successfully used in the design of sedimentation basins and similar best management practices (BMPs) built to remove sediments from stormwater runoff.

4.0 General Measurement Tips

4.1 Quality Control, Check, Record, and Report (CCRR) guidance for transparency and turbidity measurements

(This paragraph is essentially common to all DQM-IPs. If you have seen it already, please skip to Section 4.2 below) The DQM guidance and tools provide ways to Control, Check, Record, and Report (CCRR) the quality of numerous water quality measurements. Essentially, **"Control"** is about things we can do to affect and improve data quality. **"Check"** is about testing how good a measurement actually is. **"Record"** is about the language we use to express the results of our quality checks and about entering our findings into the "placeholders" on DQM forms or spreadsheets. **"Report"** is about the way we calculate the measures of quality, i.e., the data quality indicators, so they can be shared with others. Specific CCRR procedures are added on top of the generic quality assurance procedures such as keeping everything clean, waiting for stabilization of the reading, and keeping good records. Because each type of instrument or kit requires its unique CCRR actions (that cannot be generalized for all measurement devices), the step-by-step instructions for these actions are provided in the instrument-specific standard operating procedures (SOP).

4.2 NTU and FTU

Recent instrument kits provide Standards made of Formazin and attach directions to express the measurement results in Formazin Turbidity Units, or FTU. Because in the case of nephelometric turbidity measurement your results represent what your Calibrator Standard represents, it makes sense to be more specific and attach to the results Units that contain information about the Standard (Formazin) rather than use generic units (NTU) that do not specify to what material the instrument has been calibrated. In essence, numeric values of NTU and FTU are the same, are interchangeable, and can be combined for the same parameter (turbidity). Formazin is unpleasant to work with and has not been a very "popular" Standard for years, however the technology of packaging Formazin to yield stable and safe Standards is developing fast.

4.3 Sampling suspended solids

Particulate matter remains suspended in water for a limited period of time. Tiny and light particles may be found uniformly suspended in the water column of a pond or a river, but heavier particles that tend to sink fast are usually distributed in an uneven way in the water column. Thus, collection of a representative sample (in terms of suspended solids) is a challenge, particularly in conditions when sediment transport occurs or when pond/lake sediment is re-suspended by wind action. The reader is strongly urged to refer to further guidance on representative sampling, including IP-2.1.1(Samp) for reference to sampling devices with isokinetic nozzles and the DQM Representativeness Check List (available with your CWT coordinator).

5.0 Sources and Resources

This IP is an integral part of the Data Quality Management (DQM) System implemented by the Clean Water Team, the Citizen Monitoring Program of the California State Water Resources Control Board. This Information Paper has been created by a CWT member in conjunction with a Technical Advisory Committee (TAC) work group efforts, and has been published as part of the TAC products in 2001.

For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit our website at www.swrcb.ca.gov/nps/volunteer.html

If you wish to cite this IP in other texts you can use "CWT 2004" and reference it as follows: "Clean Water Team (CWT) 2004. Measuring Suspended & Settlable Solids and Water Column Turbidity, DQM IP-3.1.5. in: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA."

Available SOPs (2004 Compendium)

- SOP-3.1.5.1(SEC) Determination of transparency with a Secchi disk
- SOP-3.1.5.2(TRT): Measurement of Water Transparency Using a Transparency Tube
- SOP-3.1.5.3(TUJ): Measuring turbidity with the dual cylinder kit
- SOP-3.1.5.4(TUN): Measuring turbidity with a Nehplometer

References used in the IP

American Society For Testing and Materials (ASTM) 1997. Standard Test Method for Determining Sediment Concentrations in Water Samples. Designation: D 3977 - 97. American Society For Testing and Materials, 100 Barr harbor Dr., West Conshohocken, PA 19428

Redwood Science Laboratory (RSL) 2000. Laboratory procedures for "total suspended solids" USDA Forest Service, Arcata, CA. (Note: the method is referred to as suspended sediment concentrations (SSC) by USGS and in the method menu table above).