
TEMPERATURE 6.1

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TEMPERATURE 6.1

Measurements of air and water temperature at a field site are essential for water-quality data collection. Determination of dissolved-oxygen concentrations, conductivity, pH, rate and equilibria of chemical reactions, biological activity, and fluid properties relies on accurate temperature measurements.

Accurate air- and water-temperature data are essential to document thermal alterations to the environment caused by natural phenomena and by human activities. Water temperature can be subject to environmental regulation and monitoring by State and local agencies.

**TEMPERATURE:
a measure of
warmth or coldness
of a substance
with reference to
a standard value.**

This section describes methods for measuring temperature in air, surface water, and ground water. The methods are appropriate for fresh to saline waters.

- ▶ A thermometer is any device used to measure temperature, consisting of a temperature sensor and some type of calibrated scale or readout device. Liquid-in-glass thermometers and thermistor thermometers are commonly used to measure air and water temperature.¹
- ▶ The U.S. Geological Survey (USGS) uses the Centigrade or Celsius (C) scale for measuring temperature.

¹Some of the equipment and procedures recommended herein may not reflect the most recent technological advances; in this case, follow the manufacturer's instructions but comply with standard USGS quality-control practices.

6.1.1 EQUIPMENT AND SUPPLIES

Thermometers and other temperature-measurement equipment and supplies must be tested before each field trip and cleaned soon after use (table 6.1–1). Each temperature instrument must have a log book in which all calibrations and repairs are recorded, along with the manufacturer make and model and serial or property number.

Table 6.1–1. Equipment and supplies used for measuring temperature¹
[–, minus; +, plus; °C, degrees Celsius; L, liter; μS/cm, microsiemens per centimeter at 25°C]

- ✓ Calibration thermometer, liquid-in-glass or electronic-thermistor thermometer, either National Institute of Standards and Technology (NIST) certified or manufacturer-certified as NIST traceable. Must carry certificate of NIST traceability; its use not allowed after expiration of certification.
 - Temperature range, at least –5 to +45°C
 - 0.1°C graduations (liquid-in-glass) or less
- ✓ Thermometer, liquid-in-glass sensor, nonmercury-filled for field use
 - Temperature range, at least –5 to +45°C
 - Minimum 0.5°C graduated
 - Calibrated accuracy within 1 percent of full scale or 0.5°C, whichever is less
 - Calibrated and office-laboratory certified against a properly certified calibration thermometer (see above)
- ✓ Thermistor Thermometer
 - Calibrated accuracy within 0.1°C to 0.2°C
 - Digital readout to at least 0.1°C
 - Office-laboratory certified against a calibration thermometer (see above)
- ✓ Dewar flask and (or) plastic beakers (assorted sizes)
- ✓ Water bath, refrigerated (if available—see section 6.1.2)
- ✓ Soap solution (1 L), nonphosphate laboratory detergent
- ✓ Deionized water (1 L), maximum conductivity of 1 μS/cm
- ✓ Flowthrough chamber (for ground-water applications as an alternative to instruments with downhole capabilities)
- ✓ Paper tissues, disposable, soft, and lint free
- ✓ Log book, for recording all calibrations, maintenance, and repairs

¹Modify this list to meet specific needs of the field effort.

Temperature-measuring instruments for field and laboratory (calibration) use can be either a liquid-in-glass or thermistor thermometer. Field personnel should be familiar with the instructions for use of the thermometer that are provided by the manufacturer.

- ▶ **Liquid-in-glass field thermometer**—Total immersion thermometers that are filled with a stable liquid, such as alcohol, are recommended for water measurements in the field. (Partial immersion thermometers are not recommended: these have a ring or other mark to indicate the required immersion depth.) Thermometers for field use must not be mercury filled. Before making temperature measurements, check the type of liquid-filled thermometer being used.
- ▶ **Thermistor thermometer**—A thermistor thermometer is an electrical device made of a solid semiconductor with a large temperature coefficient of resistivity. An electrical signal processor (meter) converts changes in resistance to a readout calibrated in temperature units. Thermistors are incorporated into digital thermometers, individual-parameter instruments (such as conductivity and pH meters), and multiparameter instruments used for surface-water and ground-water measurements.

CAUTION:

Do not use mercury-filled thermometers in the field.

MAINTENANCE, CLEANING, AND STORAGE

Liquid-in-glass and thermistor thermometers can become damaged or out of calibration, especially as a consequence of thermal shock or extended exposure to direct sunlight. It is important to be familiar with and to follow the manufacturer's instructions for use and care.

- ▶ Keep a log book for each thermometer in which the date, time, and location of every calibration are recorded.
 - Avoid direct exposure of the thermometer to sunlight.
 - Avoid submerging the thermometer sensor in corrosive solutions.
 - Follow the calibration guidelines and protocols described in section 6.1.2.

- Digital thermometer casings should not be submerged in water unless the manufacturer affirms that they are water-proof. Do not allow any liquid to enter open jacks that are part of some digital thermometers.
- ▶ Keep thermometers clean.
 - Clean thermometer sensors with a soft cloth dipped in a mild solution of lukewarm water and nonphosphate detergent.
 - If the digital thermometer case needs to be disinfected, use a weak (0.005 percent) bleach solution.
 - **Do not autoclave the thermometer** (unless autoclaving is sanctioned by the manufacturer).
 - If your digital thermometer has a detachable sensor with a plug termination, periodically wipe off or clean the sensor contacts. **Dirty contacts can affect temperature readings.**
 - Blot the thermometer sensor dry after use.
 - To clean an LCD lens, use only plastic-approved lens cleaners; do not use alcohol, acetone, or other harsh chemicals, as these will fog the lens.
- ▶ Store thermometers securely when not in use.
 - Keep thermometers in a clean protective case when not in use. Each thermometer sensor and the case must be free of sand and debris.
 - Keep thermometers dry and in a protective case during transit.
 - Store liquid-filled thermometers with the bulb down.
 - Store thermometers in a cool place and inside a building when not in use; do not leave a thermometer in a vehicle that could change in temperature to very hot or very cold, resulting in thermal shock to the thermometer.
 - Check the batteries of thermistor-type thermometers for proper voltage before using.
 - Record the calibration data in the log book for each thermometer—liquid-in-glass, thermistor thermometer, or thermistor-containing field-measurement instrument. Note if a thermometer has been serviced or replaced.

CALIBRATION 6.1.2

Thermometer calibration differs from the process by which a pH or conductivity sensor is adjusted until the accuracy of its performance conforms to that of an accepted calibration standard. For temperature measurements, calibration² refers to a comparison or accuracy check at specified temperatures against a thermometer that is certified by the National Institute of Standards and Technology (NIST), or is manufacturer-certified as NIST traceable. Calibration should be performed in a laboratory environment every 6 to 12 months, depending on the manufacturer's recommendation.

- ▶ **Field thermometers:** Only calibration thermometers having current NIST certification or traceability can be used for checking the accuracy of (calibrating) field thermometers.
 - **In the case of continuous monitors,** a nonmercury calibration thermometer can be used in the field to check or monitor temperature readings whenever other field-measurement sensors are calibrated. See Wagner and others (2006) for specific guidelines for continuous monitors.
- ▶ **Calibration thermometers** are calibrated during their manufacture and certified as NIST-certified or NIST-traceable at the manufacturing laboratory. The USGS requires that calibration thermometers be recertified by a professional calibration service at least every 2 years, or be replaced with a calibration thermometer having current certification.
 - Calibration thermometers should be reserved for calibration and should not be used routinely as field thermometers (see **TECHNICAL NOTE**). **Mercury-filled thermometers must never be used outside of the laboratory.**
 - The thermistors included in other field-measurement instruments must be calibrated (checked) routinely, as specified below for thermistor thermometers, since accurate determination of other field measurements depends on the accuracy of temperature measurements. Thermistors that are incorporated into instruments designed to measure, for example, specific electrical conductance, dissolved oxygen, and pH commonly provide automatic temperature compensation.

²Calibrate: “To check, adjust, or systematically standardize the graduations of a quantitative measuring instrument” (American Heritage Dictionary, 1976).

— **All thermometers must be tagged with their most recent date and source of certification** (NIST-certified or -traceable source for calibration thermometers and office-laboratory source for field thermometers).

- ▶ **A log book is required** in which the calibration and certification history of each calibration and field thermometer is recorded.

TECHNICAL NOTE: The accuracy of a thermometer may vary over time, depending on factors such as the quality of its manufacture, the frequency of its use, and the conditions to which it is exposed. Shock, contamination, rapid heating and cooling, and mechanical stress are some factors that can affect the stability of a liquid-in-glass or thermistor thermometer (ICL Calibration Laboratories, 2003, 2005; ASTM International, 2005).

6.1.2.A CALIBRATION THERMOMETERS

Calibration thermometers (table 6.1-1) can be either a liquid-in-glass (mercury or spirit) or thermistor (digital) type thermometer, but must carry a current NIST certification or NIST-traceable certification that is no more than 2 years old. The actual duration of the calibration depends on the date of thermometer certification (not the date of purchase), how frequently the thermometer is used, and the conditions (thermal, chemical, and physical) to which it has been subjected during field operations and storage (see “Maintenance, cleaning, and storage” in section 6.1.1).

- ▶ **Check that the calibration thermometer has an NIST certification or traceable certificate that is within a 2-year period of original certification or recertification.**
- ▶ **Liquid-in-glass calibration thermometer:**
 - Before each use, inspect the thermometer for cracks, internal condensation, and liquid separation; if any of these conditions are observed, the thermometer must be replaced.
 - If the thermometer has been stored or used improperly, exposed at some length to sunlight or heat, or if its accuracy is otherwise in question, **check its readings at temperatures of approximately 0°, 25°, and 40°C, against those of another calibration thermometer that has been certified within the past 2 years.** If the environmental air or water temperatures to be measured fall below or exceed this range, add calibration points to bracket the anticipated temperature range.

- ▶ **Thermistor calibration thermometer:**
 - Before each use, inspect the instrument (temperature sensor, digital display, wires or leads, and plugs) for signs of wear or damage; check that batteries are at full voltage.
 - If the thermometer has been improperly stored or used, exposed at some length to sunlight or heat or extreme cold, or if its accuracy is otherwise in question, check its readings at five temperatures within the range of 0° to 40°C, against those of another currently certified calibration thermometer. If the environmental air or water temperatures to be measured fall below or exceed this range, add calibration points to bracket the anticipated temperature range.
- ▶ **Once NIST certification has expired** (exceeded the 2-year USGS limit):
 - The thermometer either must be replaced with a currently certified thermometer or be recertified through a professional calibration service.³ An office-laboratory calibration check does not constitute recertification of NIST traceability of a calibration thermometer.
 - It is advisable to replace all mercury thermometers with a spirit or thermistor thermometer in order to avoid potential mercury contamination. The mercury thermometer must be disposed of in strict accordance with safety regulations.

Do not use calibration thermometers as routine field thermometers. Reserve their use for calibrating field thermometers.

FIELD THERMOMETERS 6.1.2.B

Field thermometers, whether of the liquid-in-glass or thermistor (digital) type, and whether or not they are themselves NIST-traceable,

³The cost of commercial calibration services can vary widely. Examples of laboratories that are accredited to perform thermometer calibrations and certification include: National Institute of Standards and Technology (<http://ts.nist.gov/ts/htdocs/230/233/calibrations/>); ICL Calibration Laboratories (www.icllabs.com); Lab Safety Supply, Inc. (<https://www.labsafety.com/calibration>). (URLs cited were accessed 11/28/2005).

require regular accuracy checks against a calibration thermometer. Carry an extra thermometer in the event that the accuracy of a field thermometer is in question. **Note, however, that field checking of a thermometer's accuracy does not substitute for the required annual laboratory calibration.**

- ▶ At a minimum, calibrate each field thermometer every 12 months—the time interval depends on the amount of use and abuse to which the thermometer has been subjected and on its manufacture. According to thermometer manufacturers, some models of thermistor thermometers require calibration every 6 months (YSI, 2005). Quarterly or possibly monthly calibration can be required if the thermometer is in heavy use; was exposed to thermal shock, an extended period of direct sunlight, or extreme shifts in temperature; or was exposed to aggressive chemical solutions. The calibration history from the log book can indicate the expected life of the thermometer.
- ▶ **Each thermometer that passes the accuracy check must be tagged with the date of calibration.** Thermometers that do not pass the accuracy check must be repaired, if possible, or else discarded or otherwise retired from use.
- ▶ The annual calibration of field thermometers can be performed in the office laboratory or by an NIST-accredited commercial laboratory. To calibrate a thermometer, check its readings across a range of temperatures as described below in the instructions for water-bath calibration procedures. Temperature checks must bracket and include points that represent the temperature range expected to be encountered in the field. **EXCEPTION:** Thermistors in continuous water-quality monitors can be field-checked annually (or more frequently, if necessary) with a nonmercury NIST-certified or NIST-traceable thermometer.
 - Fully submerge the bulb and liquid column if using a total-immersion liquid-in-glass thermometer.
 - Keep calibration and field temperature sensors (thermistor or liquid-in-glass type) submerged throughout the calibration process.
 - Record thermometer readings throughout the bath warming and cooling periods and while keeping the water stirred or otherwise circulated (thermistor readings will be recorded with greater frequency).
 - Check meter batteries periodically for proper voltage when using a thermistor-type thermometer.

- Record the calibration data in the instrument log book for each thermistor thermometer (including thermistor-containing field meters), noting if a temperature sensor has been replaced.

Calibrate field thermometers every 12 months.

To calibrate field thermometers when a commercial refrigerated water bath is available:

1. Precool the sensor of the thermometer(s) being tested (field thermometer) to 0°C by immersing it in a separate ice/water bath.
2. Immerse the field and calibration temperature sensors in the refrigerated bath with a water temperature of approximately 0°C.
3. Position the temperature sensor(s) so that they are properly immersed and so that the scales can be read. Stir the water bath and allow at least 2 minutes for the thermometer readings to stabilize.
4. Without removing the temperature sensor(s) from the refrigerated water bath, read the field thermometer(s) to the nearest graduation (0.1 or 0.5°C) and the calibration thermometer to the nearest 0.1°C.
 - a. Take three readings within a 5-minute span for each field thermometer.
 - b. Calculate the mean of the three temperature readings for each field thermometer and compare its mean value with the calibration thermometer.
 - c. If a liquid-filled field thermometer is found to be within ± 1 percent of full scale or $\pm 0.5^\circ\text{C}$ of the calibration thermometer, whichever is less, set it aside for calibration checks at higher temperatures.
 - d. If a field thermistor is found to be within $\pm 0.2^\circ\text{C}$ of the calibration thermometer, set it aside for calibration checks at higher temperatures.
5. Repeat steps 1–4 in 25°C and 40°C water. Keep the bath temperature constant. Check the thermistors at two or more additional intermediate temperatures (for example, 15°C and 30°C).
6. Tag acceptable thermometers as “office-laboratory certified” with calibration date and certifier’s initials.

To calibrate field thermometers when a commercial refrigerated water bath is not available:

A. For the 0°C calibration

1. Freeze several ice cube trays filled with deionized water.
2. Fill a 1,000-milliliter (mL) plastic beaker or Dewar flask three-fourths full of crushed, deionized ice. Add chilled, deionized water to the beaker. Place the beaker of ice/water mixture in a larger, insulated container or Dewar flask. Place the calibration thermometer into the ice/water mixture and make sure that the temperature is uniform at 0°C by stirring and checking at several locations within the bath.
3. Precool the sensor of the field thermometer(s) to 0°C by immersing in a separate ice/water bath.
4. Insert the field thermometer(s) into the ice/water mixture. Position the calibration and field thermometers so that they are properly immersed and so that the scales can be read. Periodically stir the ice/water mixture and allow at least 2 minutes for the thermometer readings to stabilize.
5. After the readings stabilize, compare the temperature of one field thermometer at a time with that of the calibration thermometer. Without removing the temperature sensor(s) from the test bath, read the field thermometer(s) to the nearest graduation (0.1 or 0.5°C) and the calibration thermometer to the nearest 0.1°C.
 - a. Take three readings for each thermometer within a 5-minute span.
 - b. Calculate the mean of the three temperature readings for each thermometer and compare its mean value with the calibration thermometer.
 - c. If the field liquid-filled thermometer is found to be within ± 1 percent of full scale or $\pm 0.5^\circ\text{C}$ of the calibration thermometer, whichever is less, set it aside for calibration checks at higher temperatures.
 - d. If the field thermistor is found to be within $\pm 0.2^\circ\text{C}$ of the calibration thermometer, set it aside for calibration checks at higher temperatures.

B. For the “room temperature” calibration (25°C)

1. Place a Dewar flask or container filled with about 1 gallon of water in a box filled with packing insulation. (A partially filled insulated ice chest can be used for multiparameter instruments.) Place the calibration container in an area of the room where the temperature is fairly constant (away from drafts, vents, windows, and harsh lights).
2. Properly immerse the calibration and field thermometer(s) in the water. Cover the container and allow the water bath and thermometers to equilibrate.
3. Stir the water and, using the calibration thermometer, check the bath for temperature uniformity. Repeat this every 2 hours. It may be necessary to let the bath equilibrate overnight.
4. Compare one field thermometer at a time against the calibration thermometer, following the procedures described above in step A5 for the 0°C calibration.

C. For each temperature that is greater than 25°C

1. Warm a beaker of 1,000 mL or more of water to the desired temperature (for example, 40°C) and place it on a magnetic stirrer plate.
2. Follow the procedures described above in step A5 for the 0°C calibration.

Tag acceptable field thermometers as “office-laboratory certified” with the calibration date and certifier’s initials.

Corrections can be applied to measurements made with a thermometer that is within ± 1 percent of full scale or $\pm 0.5^\circ\text{C}$ of the calibration thermometer. Corrections should be applied by using a calibration curve or table, which is plotted in the log book for the instrument. **Thermistors found to be out of calibration by more than 0.2°C must be returned to the manufacturer for repair or replacement.**

Remember to tag and date acceptable field thermometers after calibration.

6.1.3 MEASUREMENT

Air temperature, in addition to water temperature, should be measured and recorded whenever water-quality samples are collected. Water temperature must always be measured in situ and in a manner that ensures that the measurement accurately represents the intended sample conditions. Before measuring air or water temperature:

- ▶ Inspect the liquid-in-glass thermometer to be certain that the liquid column has not separated.
 - Inspect the glass bulb to be sure it is clean.
 - Inspect the protective case to be sure it is free of sand and debris.
 - ▶ Check that batteries are fully charged for thermister thermometers or temperature sensors incorporated into other field meters.
-

6.1.3.A AIR

Measure air temperature using a dry, calibrated thermometer.

- ▶ Place or hang the thermometer about 5 feet above the ground in a shaded area that is protected from strong winds but open to air circulation. Avoid areas of possible radiant heat effects, such as metal walls, rock exposures, or sides of vehicles.
- ▶ Allow 3 to 5 minutes for the thermometer to equilibrate, then record the temperature and time of day.
- ▶ Measure the air temperature as close as possible to the time when the temperature of the water sample is measured.
- ▶ Report routine air temperature measurements to the nearest 0.5°C. If greater accuracy is required, use a thermistor thermometer that has been calibrated to the accuracy needed.

6.1.3.B SURFACE WATER

The reported surface-water temperature must be measured in situ—**do not measure temperature on subsamples** from a sample compositing device. Measure temperature in such a manner that the mean or median temperature at the time of observation is represented (consult NFM 6.0 and fig. 6.0–1). Record any deviation from this convention in the data base and report it with the published data.

To measure the temperature of surface water:

- ▶ Making a cross-sectional temperature profile first, to determine the temperature variability of the stream section, is recommended—a hand-held digital thermometer works best for this purpose.
 - ▶ To determine which sampling method to use (NFM 6.0), examine the cross-sectional profile and consider study objectives.
 - ▶ Measure temperature in those sections of the stream that represent most of the water flowing in a reach. Do not make temperature measurements in or directly below stream sections with turbulent flow or from the stream bank (unless this specifically represents the intended condition to be monitored).
1. Use either a liquid-in-glass thermometer or a thermistor thermometer tagged as “office-laboratory certified” and dated within the past 12 months.
 2. Record on field forms the temperature variation from the cross-sectional profile, and the sampling method selected.
 - **Flowing, shallow stream**—wade to the location(s) where temperature is to be measured. To prevent erroneous readings caused by direct solar radiation, stand so that a shadow is cast on the site for temperature measurement.
 - **Stream too deep or swift to wade**—measure temperature by lowering from a bridge, cableway, or boat a thermistor thermometer attached to a weighted cable. Do not attach a weight directly onto the sensor or sensor cable.
 - **Still-water conditions**—measure temperature at multiple depths at several points in the cross section.

3. Immerse the sensor in the water to the correct depth and hold it there for no less than 60 seconds or according to the manufacturer's guidelines until the sensor equilibrates thermally. The sensor must be immersed properly while reading the temperature; this might require attaching the thermistor to a weighted cable.

TECHNICAL NOTE: For in-situ measurement with liquid-filled, full-immersion thermometers—the water depth to which the thermometer is immersed must be no greater than twice the length of the liquid column of the thermometer in order to make an accurate measurement.

4. Read the temperature to the nearest 0.5°C for liquid-in-glass and 0.2°C for thermistor readings—**do not remove the sensor from the water.**
 - When using a liquid-in-glass thermometer, check the reading three times and record on field forms the median of these values.
 - When using a thermistor thermometer, wait until the readings stabilize to within 0.2°C, then record the median of approximately the last five values.
5. Remove the temperature sensor from the water, rinse it thoroughly with deionized water, blot it dry, and store it.
6. Record the stream temperature on field forms. Determine the values as follows:
 - **In still water—median** of three or more sequential values.
 - **For equal discharge increments (EDI)—mean** value of subsections measured (use median value if measuring one vertical at the centroid of flow).
 - **For equal width increments (EWI)—mean or median** value of subsections measured.

6.1.3.C GROUND WATER

Measurements of ground-water temperature must be made downhole or with a flowthrough system at the end of purging to ensure that the temperature measured accurately represents ambient aquifer water conditions (consult NFM 6.0 for guidance). **Do not report a temperature value measured from a bailed ground-water sample.**

To measure the temperature of ground water:

- ▶ Select either the downhole or flowthrough-chamber sampling system (see NFM 6.0, fig. 6.0–4) and record the method used.
 - ▶ Measure temperature with a thermometer that has been office-laboratory certified within the past 12 months and within the temperature range to be encountered.
1. Prepare the instruments for either the downhole or the flowthrough-chamber system.
 - **Downhole system**—lower the sensor in the well to just below the pump intake (the intake location depends on the sampling objectives).
 - **Flowthrough-chamber system**—properly immerse the thermistor or liquid-in-glass thermometer in the chamber. Keep the pump tubing from the well to the chamber as short as possible, out of direct sunlight, and off the ground. Keep the chamber out of direct sunlight and wind.
 2. Begin water withdrawal from the well. Allow the thermometer to equilibrate with ground-water temperature for no less than 60 seconds or in accordance with the manufacturer’s guidelines; record the readings and time intervals throughout the period of purging.
 3. Toward the end of purging, record five or more sequential measurements, spaced at increments of 3 to 5 minutes or more.
 - If the thermistor temperature is stable within the 0.2°C criterion, report the median of the final five measurements (table 6.0–1). (For a liquid-in-glass thermometer, there should be only slight fluctuation around 0.5°C.)
 - If the stability criterion has not been met, extend the purge time and consult the well-purging objectives of the study. Report the median of the last five (or more) sequential measurements and record any instability on field forms.
 4. Remove the thermometer from the water, rinse it thoroughly with deionized water, blot it dry, and store it as described in 6.1.1.

6.1.4 TROUBLESHOOTING

Contact the instrument manufacturer if the suggestions on table 6.1-2 fail to resolve the problem, or if additional information is needed.

When using thermistor thermometers:

- ▶ Check the voltage of the batteries.
- ▶ Start with good batteries in instruments and carry spares.

Table 6.1–2. Troubleshooting guide for temperature measurement

Symptom	Possible cause and corrective action
Liquid-in-glass thermometer does not read accurately	<ul style="list-style-type: none"> • Check thermometer to see that the liquid is not separated—if separated, take back to the office laboratory to reunite column or for disposal.
Thermistor thermometer does not read accurately	<ul style="list-style-type: none"> • Dirty sensor—remove dirt and oil film. • Weak batteries—replace with new batteries.
Erratic thermistor thermometer readings	<ul style="list-style-type: none"> • Bad or dirty connection at meter or sensor—tighten or clean connections. • Break in the cables—replace cables. • Weak batteries—replace with new batteries.
Thermistor thermometer slow to stabilize	<ul style="list-style-type: none"> • Dirty sensor—clean sensor to remove dirt and oily film.

6.1.5 REPORTING

USGS temperature measurements should be stored in the National Water Information System (NWIS) data base. These data may be published electronically and (or) on paper as the verified negative or positive value measured, as described below.

- ▶ **Thermistor thermometer measurements:** Store manually recorded temperature measurements in the data base to the user-verified precision of the instrument (generally, 0.1 or 0.2°C, provided that the thermometer calibration verifies this accuracy). Electronically recorded temperature data may be stored unrounded. Unrounded temperature data in the database must be rounded when retrieved for publication.
- ▶ **Liquid-in-glass thermometer measurements:** Record temperature measurements in the data base to the nearest 0.5°C.
- ▶ Any values less than 0.1°C are highly questionable and should be published only after a complete calibration check of the equipment used.
- ▶ USGS field measurements of air and water temperature must be entered on the paper or electronic field form and stored in the NWIS data base.
 - Be sure to store all data under the correct parameter and method (if available) codes.
 - Store air and water temperature measurement data with replicate samples **only if replicate measurements were made**. Enter replicate measurements under the correct medium code for quality-control (QC) samples; alternatively, distinguish the replicate from the regular sample by using the unique time-of-sampling that was assigned to QC samples for that site and date.
 - Do not store the regular-sample measurement data with the replicate-sample data. **Enter regular-sample data only once in the NWIS data base.**
- ▶ Record the accuracy range of the instrument in the data base, if possible. Report the accuracy range with the published values.

Report only those water temperature values that were measured in situ.

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ACKNOWLEDGMENTS

This National Field Manual responds to advances in technology and science and to the developing needs for water-quality monitoring. Its aim is to provide scientifically sound guidance to USGS personnel and to document USGS requirements for collecting water-quality data. As a result, the expertise of numerous scientists has been tapped in developing this manual and keeping it current. A great debt of gratitude is owed to the following original authors, editors, and reviewers of Chapter A6, Section 6.1 of this field manual: M.E. Brigham, E.A. Ciganovich, I.M. Collies, J.V. Davis, C.M. Eberle, R.J. Hoffman, R.T. Iwatsubo, J.K. Kurklin, R.J. LaCamera, V.W. Norman, C.E. Oberst, B.B. Palcsak, K.A. Pearsall, D.B. Radtke, F.C. Wells, Chester Zenone, and the analysts of the USGS National Water Quality Laboratory. Special appreciation is extended to our colleagues and collaborators from the Hach, In-Situ Inc., and YSI Inc. companies.

Improvements to the technical quality of this revision of Section 6.1, Temperature, can be attributed to the expertise and conscientious efforts of technical reviewers D.A. Evans, K.K. Fitzgerald, and S.C. Skrobialowski. The editorial and production quality of this report is a credit to I.M. Collies and L.J. Ulibarri.