





Standard Operating Procedure #003 Hach 2100Q Portable Turbidimeter

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Prepared by:
Water Resources Division
Natural Resources Department
Lummi Indian Business Council

Prepared for:
EPA Region 10

Approvals Signature (required prior to project start):

<u>Name and Title</u>	<u>Signature</u>	<u>Date</u>
Leroy Deardorff Lummi Indian Business Council (LIBC) Natural Resources Department Deputy Director		11/15/18
Kara Kuhlman, CFM WQM Program Project Manager and Quality Assurance Manager LIBC Water Resources Manager		11/7/18
Jamie L. Mattson WQM Program Quality Assurance Officer LIBC Water Resources Specialist II/Planner		11/8/2018
Hanna Winter WQM Program Coordinator LIBC Water Resources Specialist II		11/7/18

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DISTRIBUTION

Westley Foster, USEPA Project Manager, EPA Tribal Coordinator

Donald M. Brown, USEPA Region 10 Quality Assurance Officer

Leroy Deardorff, Lummi Nation Natural Resources (LNR) Deputy Director

Kara Kuhlman, CFM, LNR Water Resources Manager, Project Manager, and Quality Assurance Manager

Jamie L. Mattson, LNR Water Resources Specialist II/Planner, Quality Assurance Officer

Hanna Winter, LNR Water Resources Specialist II, Water Quality Program Coordinator

Shamania James, LNR Water Resources Technician II

Field copy, maintained by Hanna Winter

REVISION RECORD

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SIGNATURE PAGE

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The following technical staff has read this manual. A copy of this page will be distributed to the employee training record file.

Signature

Date

Name (printed)

Title

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TABLE OF CONTENTS

DISTRIBUTION	I
REVISION RECORD	II
SIGNATURE PAGE	III
1. INTRODUCTION	1
1.1 METHOD SUMMARY	1
1.2 HEALTH AND SAFETY WARNINGS	1
1.3 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)	1
2. INSTRUMENT OVERVIEW AND PREPARATION FOR USE	3
2.1 INSTRUMENT COMPONENTS	3
2.2 INSTRUMENT SPECIFICATIONS	3
2.3 INSTRUMENT PREPARATION.....	4
2.3.1 <i>Instrument Setup</i>	4
2.3.2 <i>Batteries</i>	5
2.4 SUPPLIES AND CONSUMABLES.....	5
3. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)	7
3.1 CALIBRATION	7
3.1.1 <i>Preparation of Standard Dilutions</i>	7
3.1.2 <i>Instrument Calibration</i>	8
3.1.3 <i>Secondary Standards</i>	9
3.2 ACCURACY CHECKS	10
3.2.1 <i>Calibration Verification using StablCal® Standard</i>	10
3.2.2 <i>Accuracy Checks using Gelex Secondary Standards</i>	10
3.2.3 <i>Accuracy Check Acceptance Criterion</i>	11
3.3 DUPLICATE.....	11
4. SAMPLE COLLECTION	13
4.1 REPRESENTATIVE LOCATION.....	13
4.2 SITE DISTURBANCE	13
4.3 SAMPLE COLLECTION WITH A SAMPLING WAND.....	14
4.4 SAMPLE COLLECTION BY HAND (WITHOUT A SAMPLING WAND)	15
4.5 GROUNDWATER SAMPLING	16
4.6 TURBIDITY READING	16
4.6.1 <i>Change from Background</i>	17
5. TROUBLESHOOTING	19
5.1 CALIBRATION	19
5.2 PRE-RUN	19
5.3 MID-RUN	20
5.4 DUPLICATE.....	21
5.5 POST-RUN	21
5.6 CONTINUED USE OF FAULTY EQUIPMENT.....	22

6. MAINTENANCE	23
6.1 CLEANING.....	23
6.2 STORAGE.....	23
6.2.1 <i>Sample Cells</i>	23
6.2.2 <i>Standards</i>	23
6.3 WASTE.....	23
7. ACRONYMS AND ABBREVIATIONS	25
8. REFERENCES	26

LIST OF FIGURES

Figure 2.1 Schematic of Hach 2100Q, Illustrating Instruments Components and Key Pad Description.	3
Figure 4.1 Sample Collection Using a Sampling Wand	15

LIST OF TABLES

Table 2.1 Range, Accuracy, Readability, and Resolution for Hach 2100Q.....	3
Table 2.2 Additional Equipment Details	4

1. INTRODUCTION

This document, the Standard Operating Procedures (SOP) for the Hach 2100Q, should be used any time the Hach 2100Q is used for water quality parameter measurement. This document describes the standard operating procedures and best practices for using the Hach 2100Q, including instrument preparation, calibration, quality assurance/quality control (QA/QC) activities, turbidity measurement, troubleshooting, instrument specifications, maintenance activities, and supplies and consumables. This document is to be used in conjunction with the relevant project Quality Assurance Project Plan (QAPP) and the Hach 2100Q User's Manual (Hach 2013).

Use of this SOP may require various data to be entered directly into Water Database or recorded on field datasheets and subsequently transcribed into Water Database. Details on data entry into the Water Database are provided in the Quality Management Plan (QMP) (LWRD 2018a) and Water Database User Guide (LWRD 2018b).

1.1 Method Summary

Prior to and during use of the Hach 2100Q in the field, calibration and QA/QC activities must be performed. Pre-run, mid-run, and post-run accuracy checks are required prior to, during, and following each use. The Hach 2100Q is calibrated once every three months (quarterly), or as needed, and accuracy checks are conducted after successful calibration. Periodic cleaning and other maintenance activities are recommended on an as-needed basis.

1.2 Health and Safety Warnings

No water quality measurement is worth risking injury or death. Field personnel must be aware of the environment, use common sense and training, and not exceed their abilities or limits. Field work is never conducted alone. All Lummi Natural Resources (LNR) Water Resources Division (LWRD) Health and Safety Plan (LWRD 2015) requirements and guidelines are followed at all times while conducting fieldwork.

Calibration and accuracy check solutions can be harmful to the health of the user. Safety Data Sheets (SDS) are stored in an accessible location in the LNR laboratory. Read SDS and container safety information before using laboratory equipment, including calibration and verification solutions.

1.3 Quality Assurance/Quality Control (QA/QC)

Quality assurance/quality control activities are integral to equipment maintenance and provide information to the sampler and analyst about equipment condition and data reliability. The QA/QC activities for assessment of equipment operation occur quarterly and before, during, and after sample runs. Equipment problems or failure to meet QA/QC activity acceptance criteria initiates troubleshooting and corrective actions (Section 5).

The sampler can take corrective actions based on the results of QA/QC activities to ensure that measurements have a known accuracy, precision, and traceability. All problems, corrective actions, outcomes, and resolution are documented in Water Database or on field datasheets.

Table 1.1 summarizes QA/QC activities required for use of the Hach 2100Q. Calibration and pre- and post-run accuracy checks are performed in the LNR laboratory, while mid-run accuracy checks are performed in the field. Post-calibration accuracy checks or secondary standard value assignment activities apply depending on type of accuracy check standard selected, and are performed in the LNR laboratory. Only manufacturer-recommended standards are used.

Table 1.1 Summary of QA/QC Activities: Calibration, Accuracy Checks, and Maintenance Requirements for the Hach 2100Q Turbidimeter

QA/QC Activity	Frequency	Details (e.g., standards used)
Calibration	Quarterly (every 3 months)	20, 100, 800 NTU calibration standards
Post-Calibration Accuracy Check	Quarterly (every 3 months) immediately following calibration	10 NTU verification standard
Secondary Standard Value Assignment	Quarterly (every 3 months) immediately following calibration	0-10, 10,100, 100-1000 NTU Gelex secondary standards
Accuracy Checks	Before (pre-run), during (mid-run), and after (post-run) field use of the Hach 2100Q	10 NTU verification standard
Maintenance	As needed	Periodic Cleaning

2. INSTRUMENT OVERVIEW AND PREPARATION FOR USE

This section provides an overview of the Hach 2100Q and describes instrument components, instrument specifications, setup options, battery replacement, and supplies and consumables required for use of the Hach 2100Q.

2.1 Instrument Components

The Hach 2100Q is a hand-held turbidimeter that can be used in the laboratory or in the field. The basic components of the instrument are provided in Figure 2.1.

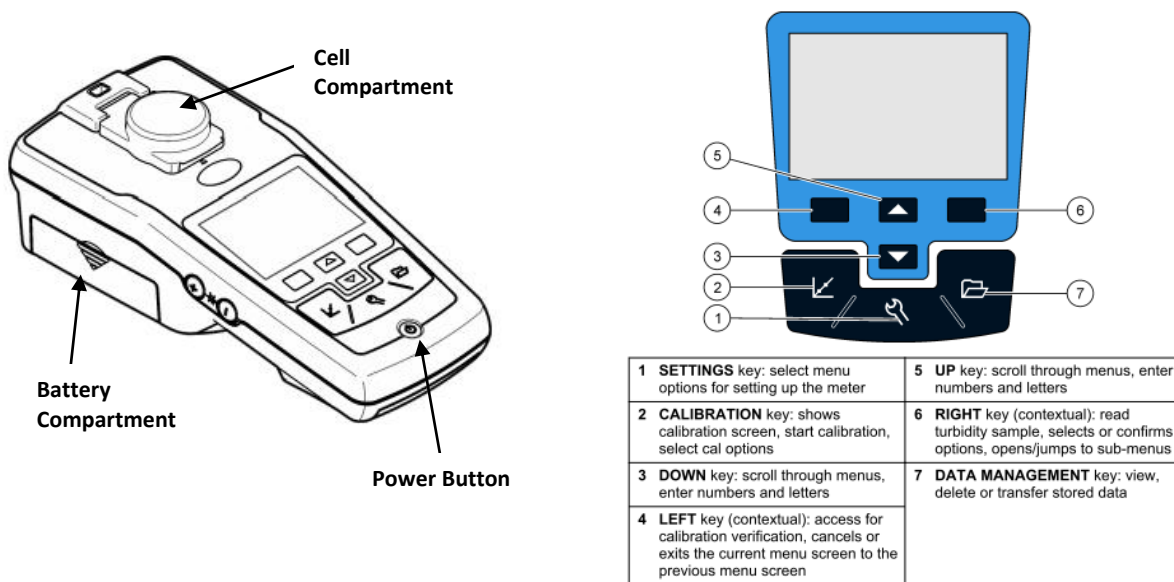


Figure 2.1 Schematic of Hach 2100Q, Illustrating Instruments Components and Key Pad Description.

2.2 Instrument Specifications

The Hach 2100Q meets EPA Method 180.1 requirements for turbidity. Table 2.1 lists the instrument specifications for the current configuration of the Hach 2100Q.

Table 2.1 Range, Accuracy, Readability, and Resolution for Hach 2100Q

Parameter	Range	Accuracy	Repeatability	Resolution
Turbidity	0 to 1000 NTU	± 2% of reading plus stray light (stray light is <0.02 NTU)	± 1% of reading or 0.01 NTU, whichever is greater	0.01 NTU on lowest range

Additional instrument specifications, including measurement method, memory, size, and power source, are listed in Table 2.2.

Table 2.2 Additional Equipment Details

Category	Specifications
Detector	Silicon Photodiode
Dimensions	22.9 x 10.7 x 7.7 cm (9.0 x 4.2 x 3.0 in.)
Weight with batteries	630 g (1.37 lbs)
Power	4 AA alkaline batteries
Measurement method	Ratio turbidimetric determination using a primary nephelometric light scatter signal (90°) to the transmitted light scatter signal.
Lamp source	Tungsten filament lamp
Data logger	500 records
Calibration logger	Records the last 25 successful calibrations
Verification logger	Records the last 250 successful verifications
Operating conditions – temperature	0-50°C (32-122°F)
Operating conditions – relative humidity	0-90% at 30°C, 0-80% at 40°C, 0-70% at 50°C, noncondensing

2.3 Instrument Preparation

The Hach 2100Q is inspected for basic proper function (*e.g.*, battery, calibration, and accuracy checks) before every use of the equipment. Instrument setup activities can be set or corrected as needed.

2.3.1 Instrument Setup

Date and time are set or corrected under the Date & Time option under Settings. On the Hach 2100Q, click the Settings button (wrench icon; button 1 in Figure 2.1), navigate to the Date & Time option using the arrow keys and click Select (right of the arrow keys). Select the appropriate format, click Select, and set or change the date or time as needed. Other features including power management (backlight and auto-shutoff options), display contrast, sounds, and meter information are also available under Settings.

As defined by this SOP, the acceptance criterion for accuracy checks using the Hach 2100Q is $\pm 5\%$ (Section 3.2.3). The accuracy check acceptance criterion (called calibration verification in the Hach 2100Q User Manual and on the instrument) can be changed in the calibration verification menu using the following steps.

1. Click Verify Cal, the left contextual key when on the main measurement view.

2. Click Options, the up arrow key.
3. Click the down arrow key to highlight Set Acceptance Criteria. Click Select, the right contextual key.
4. Use the arrow keys to change the acceptance criterion to 5%. See Section 3.2.3 for details.

2.3.2 Batteries

The battery charge level should be checked before every sample run and batteries changed prior to use, if charge is below one-quarter. The Hach 2100Q uses four AA alkaline batteries or AA nickel metal hydride batteries. Make sure that the batteries are installed in the correct orientation. Never mix battery types.

2.4 Supplies and Consumables

The following equipment items are needed for measurement of turbidity in the field:

- Calibrated Hach 2100Q portable turbidimeter
- Calibration standards:
 - Fresh (not expired) EPA-approved StablCal® formazin primary calibration standards (20, 100, 800 NTU) or
 - 4000 NTU formazin turbidity standard (diluted to 20, 100, and 800 NTU immediately prior to calibration)
- Accuracy check standards:
 - Fresh (not expired) EPA-approved StablCal® formazin verification standard (10 NTU) or
 - Gelex secondary standards (0-10 NTU, 10-100 NTU, 100-1000 NTU) with values assigned immediately following successful calibration
- Distilled and deionized water
- 3 matched and indexed turbidity cells
- Lint-free towels stored in ziplock bag
- Silicone oil
- Clean bacteria or similar sample bottle provided by contract laboratory
- Mild detergent (*e.g.*, Alconox)
- Sample wand
- Complete set of replacement batteries (four AA alkaline or nickel metal hydride batteries)

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3. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Quality assurance/quality control procedures include quarterly calibration, assignment of values for secondary standards (if used) immediately following quarterly calibration; pre-run, mid-run, and post-run accuracy checks; and completing duplicate turbidity measurements (as required by project QAPP). All QA/QC information is documented in Water Database or on field datasheets.

3.1 Calibration

Once quarterly (every three months), the Hach 2100Q is calibrated for turbidity using a three-point calibration with unexpired StablCal® formazin standards or a series of dilutions prepared immediately prior to the calibration from a 4000 NTU formazin standard solution.

3.1.1 Preparation of Standard Dilutions

The following steps are used to prepare 20, 100, and 800 NTU calibration standards from 4000 NTU formazin stock standard solution (adapted from Sadar 2003). Gloves and goggles are worn throughout preparation of dilutions. Dilutions will begin to degrade immediately after preparation, especially the 20 NTU calibration solution, and should be prepared just before instrument calibration.

❖ **NOTE:** When mixing solutions, do not shake; swirl or gently invert to mix. Vigorous shaking can introduce bubbles, causing erroneous readings, and/or oxygen that can result in oxidation or fracturing of the formazin polymer chains (Sadar 2003).

❖ **NOTE:** All dilutions are prepared using standard laboratory practices, including rinsing glassware prior to use and avoiding contamination. Never pipet directly from stock standard solution. Use the following steps to properly rinse and pipet from stock solution to working stock solution or calibration solution.

1. Pour small amount of stock solution into a container (*e.g.*, beaker), rinse by swirling solution to cover all inside surfaces of the container.
2. Discard into waste container and note approximate volume and concentration (in NTU) of waste log.
 - Waste log is stored in the LNR wet lab.
3. Pour small amount of stock solution into rinsed container.
4. Pipet stock solution from container and rinse by moving solution through pipet to cover all inside surfaces.
5. Discard solution from rinsed pipet and container into waste container and note approximate volume and concentration (in NTU) of waste log.
6. Pour slightly more than the required amount of stock solution into rinsed container and measure desired amount in rinsed pipet.

Using standard laboratory practices as outlined above, prepare 20, 100, and 800 NTU calibration standards as follows.

1. Prepare a 1000 NTU working stock solution by transferring 50 ml of 4000 NTU formazin solution into a clean and dry 200 ml volumetric flask using 20 and 10 ml volumetric pipets. Use proper rinsing techniques listed above. Dilute to the mark with distilled, deionized water. Swirl or gently invert flask several times to mix.
2. Prepare 800 NTU calibration solution using either method below:
 - Transfer 160 ml of 1000 NTU working stock solution into a 200 ml volumetric flask using a 20 ml volumetric pipet. Use proper rinsing techniques listed above. Dilute to the mark with distilled, deionized water. Swirl or gently invert flask several times to mix.
 - Transfer 40 ml of 4000 NTU formazin solution into a 200 ml volumetric flask using a 20 ml volumetric pipet. Use proper rinsing techniques listed above. Dilute to the mark with distilled, deionized water. Swirl or gently invert flask several times to mix.
3. Prepare 100 NTU calibration solution by transferring 20 ml of 1000 NTU working stock solution into a clean and dry 200 ml volumetric flask using a 20 ml volumetric pipet. Use proper rinsing techniques listed above. Dilute to the mark with distilled, deionized water. Swirl or gently invert flask several times to mix.
4. Prepare 20 NTU calibration solution by transferring 4 ml of 4000 NTU working stock solution into a clean and dry 200 ml volumetric flask using a 1 ml volumetric pipet. Use proper rinsing techniques listed above. Dilute to the mark with distilled, deionized water. Swirl or gently invert flask several times to mix.
5. One at a time, beginning with 20 NTU calibration solution, rinse a sample cell with calibration solution and discard into waste container, noting volume and NTU in waste log. Fill sample cell with calibration solution to the mark.
 - Follow instructions in Section 3.1.2 for calibration of instrument.
 - Repeat step 5 for 100 NTU and 800 NTU calibration solutions, in turn, using the same sample cell. The same sample cell is used to avoid introducing additional error to the calibration due to slight differences in sample cells.

3.1.2 Instrument Calibration

Calibration begins with a 20 NTU standard, followed by the 100 NTU standard, and ending with the 800 NTU standard. Note that the standards can be either StabCal® calibration standards purchased from the manufacturer (Hach Company) appropriate for the 2100Q turbidimeter, or calibration standards prepared by diluting 4000 NTU formazin stock solution (Section 3.1.1). Step-by-step instructions for calibration of the Hach 2100Q are provided below:

1. Turn on the Hach 2100Q by pressing the blue power button.
2. Push the calibration key (graph icon on the left side of the instrument) to enter calibration mode. Instructions are listed on the display, and are repeated here in more detail.

3. Find the 20 NTU calibration standard and gently invert 10 times. Do not shake the standards; bubbles in the standard solution can cause the instrument to improperly calibrate.
4. Place a bead of silicone oil on the standard cell below the black arrow/orientation mark and wipe gently with the oiling cloth to spread the oil thinly and uniformly. Take care not to touch the glass portion of the standard bottle or sample cell.
5. Wait for 2-3 minutes.
6. Insert the 20 NTU standard cell into the cell compartment at the top of the instrument, aligning the standard cell so that the black arrow/orientation mark lines up with the arrow at the front of the cell compartment. Close the lid.
7. Push **Read**. The display shows “Stabilizing” and then shows the result.
8. Repeat Step 3-7 with the 100 NTU and 800 NTU calibration standard.
9. Push **Done** to review calibration details.
10. Press **Store** to save the results.

The Hach 2100Q will prompt verification of the calibration immediately after calibration is complete. If using Gelex secondary standards for accuracy checks, perform value assignment immediately following calibration (Section 3.1.3). If using StablCal verification standard for accuracy checks, follow the instructions under Section 3.2.1 for conducting an accuracy check to verify the calibration.

If an error message appears on the Hach 2100Q screen during or after calibration, attempt the calibration again using the procedures listed in this SOP. If calibration remains unsuccessful, attempt troubleshooting and corrective actions listed in Section 5.1.

Following successful calibration of the Hach 2100Q, enter the calibration and accuracy check details in the Water Database Equipment module following instructions provided in the Water Database User Guide.

3.1.3 Secondary Standards

If using Gelex secondary standards for accuracy checks, the standards must have values assigned to them immediately after each successful calibration of the Hach 2100Q. Gelex secondary standards are within the ranges of 0-10 NTU, 10-100 NTU, and 100-1000 NTU. After successful calibration, follow the instructions in Section 4.6 to obtain a reading for each of the three standards. Check the reading by removing the vial from the instrument, re-wiping the vial with the lint-free cloth, and obtaining a second reading. If the reading has not changed (*i.e.*, difference of less than 1% or 0.01 NTU, whichever is greater), the value can be assigned. If the reading has changed (*i.e.*, difference of more than 1% or 0.01 NTU, whichever is greater), repeat until a stable reading is obtained or attempt corrective actions. Write the assigned value, date, and initials on a piece of masking tape and place on the lid of the Gelex secondary standard vial. The assigned value is the reference value for the standard for subsequent accuracy checks.

3.2 Accuracy Checks

An accuracy check is required following calibration (if using StablCal verification standard), prior to every sample run (pre-run), once during the mid-point of the sample run (mid-run), and after every sample run has been completed (post-run). Note that the Hach User's Manual and instrument refer to accuracy checks as calibration verification.

Accuracy checks can be conducted using either:

- Unexpired 10 NTU StablCal® verification standard or
- Gelex secondary standard with values assigned immediately after the most recent quarterly calibration (Section 3.1.3)

3.2.1 Calibration Verification using StablCal® Standard

Detailed step-by-step instructions for conducting accuracy checks, called calibration verification in the Hach 2100Q User Manual, using a StablCal® verification standard follow.

1. If not already on, turn on the Hach 2100Q by pressing the blue power button.
2. Press the **Verify Cal** button on the left contextual key when on the reading display.
3. Find the 10 NTU StablCal® verification standard and gently invert 10 times. Do not shake the standard. Shaking can introduce bubbles, causing erroneous readings.
4. Place a bead of silicone oil on the standard cell below the black arrow/orientation mark and wipe gently with the oiling cloth to spread the oil thinly and uniformly. Take care not to touch the glass portion of the standard cell.
5. Wait for 2-3 minutes.
6. Insert the 10 NTU verification standard into the cell compartment at the top of the instrument, aligning the standard cell so that the black arrow/orientation mark lines up with the arrow at the front of the cell compartment. Close the lid.
7. Push **Read**. The display shows "Stabilizing" and then shows the turbidity reading in NTU and indicates whether the calibration verification passed or not.
8. Push **Done** to accept the calibration verification and return to the reading display.

If the accuracy check failed to read within limits ($\pm 5\%$, 9.5-10.5 for 10 NTU standard), repeat the accuracy check carefully following the instructions above. If the accuracy check continues to fail to meet the acceptance criteria, attempt troubleshooting and corrective actions listed in Section **Error! Reference source not found.**

3.2.2 Accuracy Checks using Gelex Secondary Standards

Detailed step-by-step instructions for conducting accuracy checks using Gelex secondary standards during pre-run, mid-run, and post-run follow.

1. If not already on, turn on the Hach 2100Q by pressing the blue power button.
2. Find the 0-10 NTU Gelex secondary standard. Place a bead of silicone oil on the standard cell below the black arrow/orientation mark and wipe gently with the oiling cloth to

spread the oil thinly and uniformly. Take care not to touch the glass portion of the standard bottle.

3. Insert the 0-10 NTU Gelex secondary standard into the cell compartment at the top of the instrument, aligning the standard bottle so that the black arrow/orientation mark lines up with the arrow at the front of the cell compartment. Close the lid.
4. Push **Read**. The display shows “Stabilizing” and then shows the reading in NTU.
5. Record the assigned value for the Gelex secondary standard and the instrument reading in Water Database or on field datasheet.
6. Repeat steps 2-5 using the 10-100 NTU and 100-1000 NTU Gelex secondary standards.

If the accuracy check failed to read within limits, repeat the accuracy check carefully following the instructions above. If the accuracy check continues to fail to meet acceptance criterion ($\pm 5\%$), attempt troubleshooting and corrective actions listed in Section 5.

3.2.3 Accuracy Check Acceptance Criterion

The acceptance criterion for accuracy check results in $\pm 5\%$. The same acceptance criterion applies to accuracy checks conducted immediately following calibration, prior to the sample run (pre-run), during the midpoint of the sample run (mid-run), and at the end of the sample run (post-run).

If an accuracy check fails to meet the acceptance criterion, repeat the accuracy check carefully following the instructions in this SOP. If the accuracy check continues to fail to meet the acceptance criterion, attempt troubleshooting and corrective actions listed in Section 5.

3.3 Duplicate

Duplicate turbidity readings are conducted at 10% of sample sites analyzed for turbidity, or more frequently, as required by the relevant project QAPP. Duplicate samples document both instrument precision and field variability of turbidity measurements. If duplicate turbidity measurement difference exceeds 5%, collect additional measurements to determine whether variability is caused by instrument malfunction (low precision), operator error, or field variability. See troubleshooting and corrective actions for details (Section 5).

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4. SAMPLE COLLECTION

Turbidity samples are collected from a representative location that has not been disturbed by the sampler. The sample collection bottle and turbidity sample cell are properly rinsed prior to sample collection and turbidity measurement.

4.1 Representative Location

Turbidity samples are collected at a representative location. The following are considered when selecting a representative location at the sampling site:

1. Avoid areas along margins, where debris accumulates, and other areas that are not characteristic of the waterbody.
2. Select an area that minimizes disturbance to the waterbody (Section 4.2).
3. For wading sites, unless safety precludes wading into the water, avoid collecting samples along the shoreline where waves are breaking and washing across the beach.
 - Sample seaward of debris and seaweed generally found in the water close to the shoreline.
 - If samples are collected from within the wave or debris zone, assign data qualifier to result and the reason in Water Database or on field datasheet. See QMP and Water Database User Guide for details.
 - Avoid areas of entrained air in the wave-wash zone.
4. If a representative location cannot be found, use professional judgment to determine whether the site should be sampled.
 - If the site is not sampled due to inability to find a representative location, note this in Water Database or on field datasheet.
 - If the site is sampled, assign data qualifier to result due to non-representative sampling location in Water Database or on field datasheet.

4.2 Site Disturbance

Ensure that the sample site is not disturbed by the sampler prior to turbidity sample collection. A site is disturbed if sediments or other materials (*e.g.*, plants, benthic algae) settled at the bed of the waterbody are suspended into the water column, or debris falls into the water at the sample site. Re-suspended sediments can result in temporary uncharacteristically high turbidity readings. Strategies for avoiding site disturbance include:

- Avoiding walking in or near the edge of the waterbody
- If wading into the waterbody is required, approach the sample site from the downstream/down-gradient side
- Using a wand to collect samples

Occasionally, it will be necessary to collect a second turbidity sample. If the area appears disrupted by the first sample collection attempt, consider the following when attempting to re-sample:

1. Subsequent samples should be at a different, but representative location at the sample site.
2. If overall conditions at the sample site are stable, the disturbance will dissipate within a few minutes, and if water quality is not likely to change from when sampling started, the disturbed location may be re-sampled after the disturbance has passed. If this approach is taken, record in Water Database or on field datasheet.
3. If subsequent samples cannot be relocated or sampled at a slightly later time, consider a complete re-sampling of the site at a later time in the sample run. If this approach is taken, record in Water Database or on field datasheet.

4.3 Sample Collection with a Sampling Wand

Use sample wand for surface water turbidity sample collection unless impractical or unsafe (Figure 4.1).

1. Label clean and undamaged laboratory-supplied sample bottle "turbidity." Use the same bottle for all turbidity samples collected during the sample run to conserve sample bottles.
2. Attach capped sample bottle to wand. The top of the sample bottle should be several inches upstream/up-gradient of every part of the sample wand (*i.e.*, no sample water will touch any part of the wand before flowing into the sample bottle).
3. Open sample container. Do not place bottle or cap on ground and do not allow dilution from rain water or contamination from dust and debris to enter bottle.
4. Vertically dip the sample bottle, opening first, into the water column and in one motion, rotate the bottle in the direction of the current (upstream), so that trapped air can escape as the bottle fills in an upstream/up-gradient arc.
 - The bottle should be no deeper than approximately 6 inches below the water surface.
 - The water from the surface should not enter the bottle, unless low flows prevent sampling of water below the surface.
5. Ensure that bottle opening is always upstream of wand.
6. Continue the motion until bottle is nearly full, then rotate the bottle to remove it vertically from the waterbody.
7. Carefully rinse the bottle in sample water by pouring out the water collected in the bottle downstream of the sample site, on land downstream of the sample site, or in a bucket. Repeat steps 4-6 two more times, discarding the rinse water carefully without disturbing the sampling location each time.
8. Repeat steps 4-6 to collect the actual turbidity sample to be analyzed.
9. Conduct turbidity measurement using steps in Section 4.6.



Figure 4.1 Sample Collection Using a Sampling Wand

4.4 Sample Collection by Hand (Without a Sampling Wand)

Turbidity samples can be collected by hand if use of the sampling wand is unsafe, unpractical, or would cause site disturbance. Extremely high flows, such as those out of a culvert during high-flow seasons, can cause the sample bottle to detach from the sample wand. Very low flows can result in the sample wand disturbing the bottom of the waterbody during sample collection. In these cases, and when use of the sampling wand is unsafe, a turbidity sample can be collected by hand as follows:

1. Label clean and undamaged laboratory-supplied sample bottle “turbidity.” Use the same bottle for all turbidity samples collected during the trip to conserve sample bottles.
2. Hold capped sample bottle near base with hand. The top of the sample bottle should be several inches upstream/up-gradient of the sampler’s hand (*i.e.*, no sample water will touch the sampler’s hand before flowing into the sample bottle).
3. Open sample container. Do not place bottle or cap on ground and do not allow dilution from rain water or contamination from dust and debris to enter bottle.
4. Vertically dip the sample bottle, opening first, into the water column and in one motion, rotate the bottle in the direction of the current (upstream), so that trapped air can escape as the bottle fills in an upstream/up-gradient arc.
 - The bottle should be no deeper than approximately 6 inches below the water surface.
 - The water from the surface should not enter the bottle, unless low flows prevent sampling of water below the surface.
5. Ensure that bottle opening is always upstream of hand.
6. Continue the motion until bottle is nearly full, then rotate the bottle to remove it vertically from the waterbody.

7. Carefully rinse the bottle in sample water by pouring out the water collected in the bottle downstream of the sample site, on land downstream of the sample site, or in a bucket. Repeat steps 4-7 two more times, discarding the rinse water carefully without disturbing the sampling location each time.
8. Repeat steps 4-6 to collect the actual turbidity sample to be analyzed.
9. Conduct turbidity measurement using steps in Section 4.6.

4.5 Groundwater Sampling

Occasionally, collection of a groundwater turbidity sample from a domestic or tribal supply well may be required.

1. Flush source from designated tap:
 - For active wells, adequate flushing is determined by stabilization of the temperature or by flushing the well for three minutes, whichever is longer.
 - For wells not pumped regularly, it is recommended that at least three casing volumes be pumped prior to sample collection.
 - Where well production is inadequate to flush the source as described above, flush source as much as possible and note sampling conditions in Water Database or on field datasheet. Assign data qualifier due to potentially incomplete flushing (see QMP and Water Database User Guide for details).
2. Collect turbidity sample:
 - Label clean and undamaged laboratory-supplied sample bottle “turbidity.” Use the same bottle for all turbidity samples collected during the trip to conserve sample bottles.
 - Open sample container. Do not place bottle or cap on ground and do not allow dilution from rain water or contamination from dust and debris to enter bottle.
 - Fill sample bottle, and pour out sample to rinse bottle.
 - Rinse sample bottle two more times following the instructions in the step above.
 - Fill bottle to nearly full. Ensure that water flow is low enough to not cause entrained air to enter the sample bottle. Air bubbles can cause uncharacteristically high turbidity results.
3. Conduct turbidity measurement using steps in Section 4.6.

4.6 Turbidity Reading

Turbidity readings are conducted only after the instrument has passed pre-run accuracy checks, the sample has been collected from a representative location, and the sample bottle has been rinsed three times before collection of the turbidity sample to be measured.

In the field, the following steps should be followed for measuring turbidity using the Hach 2100Q turbidimeter.

1. Place the Hach 2100Q turbidimeter on a stationary, level surface. Do not hold the instrument while making measurements.
2. Turn on the Hach 2100Q by pressing the blue power button.
3. Rinse a sample cell three times with the sample water and discard.
4. Fill the rinsed sample cell with approximately 15 ml of sample water to the white line at the top of the cell. Take care to handle the sample cell by the top and cap the cell.
5. Wipe the cell with a soft, lint-free cloth to remove water spots and fingerprints.
6. Place a bead of silicone oil on the sample cell below the white arrow/orientation mark and wipe gently with the oiling cloth to spread the oil thinly and uniformly. Take care not to touch the glass portion of the sample cell.
7. Insert the sample cell in the instrument cell compartment so the white arrow/orientation mark on the sample cell aligns with the black arrow/orientation mark in front of the cell compartment. Close the cell compartment lid.
8. Push **Read**. The display shows “Stabilizing” and then shows the turbidity reading in NTU.
9. Record turbidity reading in Water Database or on field datasheet. The reading is stored automatically by the instrument.
10. Rinse sample cell with distilled water, dry outside with soft cloth, and store in the turbidimeter carrying case out of direct sunlight.

4.6.1 Change from Background

Occasionally, turbidity measurements are taken during construction projects to monitor temporal changes in turbidity during ground-disturbing activities. Typically, background turbidity is determined by collecting several turbidity samples and averaging the results. Surface water is then repeatedly sampled on a regular interval to monitor changes in turbidity from the established background level. Readings must be within a specified range from the background turbidity level; for example, Class AA (Excellent) surface waters shall not exceed 5 NTU over background turbidity when background turbidity is 50 NTU or less or 10% increase in turbidity when the background turbidity is more than 50 NTU.

If readings are not within an acceptable variance from background levels due to a reason other than variation of the sample water, determine whether it is caused by operator error or instrument malfunction. The error must be identified, corrected, and documented prior to proceeding with readings. See Section 5 for details on identifying causes of error, steps to take to correct the problem, and instructions on steps to take if the problem cannot be corrected.

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5. TROUBLESHOOTING

For all troubleshooting activities, document observations, corrective actions, and outcomes in Water Database or on field datasheet, as specified by the relevant project QAPP and Water Database User Guide. The sections below provide steps to be taken to identify and remedy equipment problems as they arise during performance of QA/QC activities and use of the Hach 2100Q in the field. See Hach 2100Q User's Manual pages 22-23 for troubleshooting assistance on common problem messages or symptoms.

5.1 Calibration

If calibration details indicate a failed calibration, repeat the calibration carefully using the procedures contained in Section 3.1 of this SOP. If calibration remains unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

1. Contaminated standard: Use new, unexpired standard and attempt calibration again.
 - Ensure that calibration standards prepared from stock solution are properly prepared.
2. Operator error: Correct operator error and attempt calibration again.
 - Ensure that calibration standards have been properly mixed before calibration. Standards should be gently inverted, not vigorously shaken, to mix the solution.
 - Ensure that calibration standards have rested for 2-3 minutes after being mixed before attempting calibration.
 - Ensure that calibration standard cells are cleaned of fingerprints and debris, and properly oiled.
 - Ensure that calibration standard cells are placed into the cell compartment oriented correctly.
3. Equipment malfunction: Have instrument serviced and replaced as soon as possible.

Do not use Hach 2100Q for measuring turbidity in the field if calibration is unsuccessful. Contact manufacturer for replacement calibration standards or instrument servicing as recommended.

5.2 Pre-run

If a pre-run accuracy check is unsuccessful, attempt accuracy check again using the procedures listed in Section 3.2 of this SOP. If accuracy check remains unsuccessful, re-calibrate the Hach 2100Q using best practices. If pre-run accuracy checks continue to remain unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

1. Contaminated standard: Use new, unexpired standard, if available, and attempt accuracy check again.
 - Ensure that Gelex secondary standards were properly assigned values immediately following most recent calibration.

2. Operator error: Correct operator error and attempt accuracy check again.
 - Ensure that StablCal® verification standard has been properly mixed. Standard should be gently inverted, not vigorously shaken, to mix the solution.
 - Ensure that StablCal® verification standard has rested for 2-3 minutes after being mixed.
 - Ensure that accuracy check standard cells are cleaned of fingerprints and debris, and properly oiled.
 - Ensure that accuracy check standard cells are placed into the cell compartment oriented correctly.
3. Equipment malfunction: Have instrument serviced as soon as possible.

Do not proceed to field run if pre-run accuracy checks are unsuccessful. Contact manufacturer for verification standard replacement or instrument servicing as recommended.

5.3 Mid-run

If a mid-run accuracy check is unsuccessful, attempt accuracy check again using the procedures contained in this SOP. If accuracy check remains unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

1. Contaminated standard: Use new, unexpired standard, if available, and attempt accuracy check again. If new standard not available, proceed with field visits.
2. Operator error: Correct operator error and attempt accuracy check again. Proceed with field visits.
3. Equipment malfunction:
 - Re-calibrate instrument, redo accuracy checks. **Data qualifier must be assigned to all previous field measurements in Water Database.** Detailed procedures on assigning data qualifiers are provided in the QMP and Water Database User Guide.
 - Redo accuracy checks at each site. Repeating accuracy check at each site allows for calculation of error of the instrument. If consistent throughout the remainder of the sample run, the error of the measurements can be adjusted using a correction factor.
 - Proceed with field visits.

Use best professional judgment when determining the best course of action for remedying suspected equipment malfunction during a field visit. **Recalibrating the Hach 2100Q at mid-run requires assigning a data qualifier to all previously collected turbidity data** (see QMP and Water Database User Guide for details on data qualifiers). If Hach 2100Q is not re-calibrated at mid-run despite a failing mid-run accuracy check, a successful post-run accuracy check can still result in fulfillment of the minimum QA/QC requirements, assuming that pre-run accuracy checks met acceptance criteria. Alternatively, if the parameter is not re-calibrated at mid-run

after a failing mid-run accuracy check, an unsuccessful post-run accuracy check will result in an automatic rejection of all turbidity data collected for that day.

5.4 Duplicate

If duplicate measurements vary by more than 5%, collect a third measurement using the procedures contained in this SOP. If third measurement varies by more than 5% from either the first or second measurement, determine if error is due to natural variability, operator error, or equipment malfunction. If:

1. Natural field variability: Continue with field visit. Natural variability is accounted for by the averaging of the duplicate (or triplicate) measurements for data analysis.
2. Operator error: Correct operator error and collect another measurement. Reject measurements affected by operator error in Water Database. Proceed with field visits.
3. Equipment malfunction: Conduct accuracy check. If accuracy check fails to meet acceptance criteria, see corrective actions for mid-run accuracy checks (Section 5.3).

Note that duplicate samples document both instrument precision and field variability of turbidity measurements. Variation of more than 5% is not necessarily an indicator of poor instrument precision; field variability can frequently account for turbidity differences of duplicate measurements, especially during soil disrupting activities and rainfall events.

5.5 Post-run

If a post-run accuracy check is unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If accuracy check remains unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

1. Contaminated standard: Use new, unexpired standard, if available, and attempt accuracy check again.
 - Ensure that Gelex secondary standards were properly assigned values immediately following most recent calibration.
2. Operator error: Correct operator error and attempt accuracy check again.
 - Ensure that StablCal® verification standard has been properly mixed. Standard should be gently inverted, not vigorously shaken, to mix the solution.
 - Ensure that StablCal® verification standard has rested for 2-3 minutes after being mixed.
 - Ensure that accuracy check standard cells are cleaned of fingerprints and debris, and properly oiled.
 - Ensure that accuracy check standard cells are placed into the cell compartment oriented correctly.
3. Equipment malfunction: Have instrument serviced prior to next field visit to prevent equipment malfunction in the future.

5.6 Continued Use of Faulty Equipment

If Hach 2100Q error cannot be remedied, it is recommended that the instrument not be used to collect further measurements. Accuracy checks and duplicate sample readings will allow for calculation of precision and accuracy. The problem, reason for use of the sub-optimally functioning instrument, and all QA/QC activity information are documented in Water Database or field datasheet. **All data collected are assigned a data qualifier due to poor QA/QC performance** (details on data qualifiers are provided in the QMP and Water Database User Guide). Upon return to the lab, corrective actions are taken and/or the instrument is serviced or replaced so that the use of faulty equipment is not repeated.

6. MAINTENANCE

Maintenance activities for the Hach 2100Q, including cleaning the meter and storing and discarding standards are described below. The instructions in this section should be supplemented by detailed information in the Hach 2100Q User Manual (Hach 2013).

6.1 Cleaning

The Hach 2100Q is designed to be maintenance-free and does not require regular cleaning for normal operation. Exterior surfaces may be cleaned as necessary. Do not clean the instrument with solvents to avoid damage to the instrument. As needed, clean the meter with a dust- and lint-free dry or slightly damp cloth. A mild soap solution can also be used for liposoluble contamination.

6.2 Storage

6.2.1 Sample Cells

Store the sample cells capped and filled with distilled and deionized water to prevent the cells from drying. Do not air dry. Wipe the outside of the sample cells dry with a soft cloth before storing.

6.2.2 Standards

All standards should be kept in a cool, dark location. Gelex secondary standards or StablCal® turbidity standards can be kept in the Hach 2100Q turbidimeter carrying case or in their own carrying case. Bulk formazin stock solution is kept in the laboratory in a locked cabinet. Standards, especially Gelex secondary standards, should not be exposed to temperatures below freezing or greater than 50°C (122°F).

6.3 Waste

Bulk and sealed vials of turbidity calibration and accuracy check standard contain formazin, which is composed of hazardous ingredients. All formazin-containing waste is decanted into a designated waste container. An associated waste log tracks the volume and concentration (in NTU) of waste discarded in the waste container. Once annually, or as needed, the final concentration of the waste is estimated from the waste log and the formazin waste is delivered to Disposal of Toxics, or an equivalent hazardous waste disposal facility for disposal.

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7. ACRONYMS AND ABBREVIATIONS

LNR	Lummi Natural Resources
LWRD	Lummi Water Resources Division
NTU	Nephelometric Turbidity Unit
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
SDS	Safety Data Sheet
SOP	Standard Operating Procedure

8. REFERENCES

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