

# Open-Source Turbidity Meter

## Operation Manual – Hardware Build T03

### 1 DESIGN OVERVIEW

The turbidity meter is composed of an 850 nm light source oriented at 90° to a light sensor which measures diffuse light scattered by turbidity in the sample. The infrared light source reduces the influence of sample color on turbidity measurements, and results are reported in formazin nephelometric units (FNU). The meter was developed using guidance from Water Quality Standard ISO 7027 (method c).

The light source is a vertical cavity surface-emitting laser (VCSEL, TT Electronics OPV332) with a total beam divergence angle (full-width at half intensity) of 4°. The VCSEL is operated in constant current mode to provide uniform light intensity for each measurement.

The sensor is a light-intensity-to-frequency converter (AMS TSL237), which produces a square wave pulse output proportional to the incident light intensity. Pulses are counted during the integration period by a microcontroller which also controls the system.

The inner wall of the sample holder is corrugated to enhance absorption of stray light. A spring-plunger pushes the sample vial against PTFE guide rods in the wall to ensure consistent centering of the vial on the VCSEL axis (Figure 1).

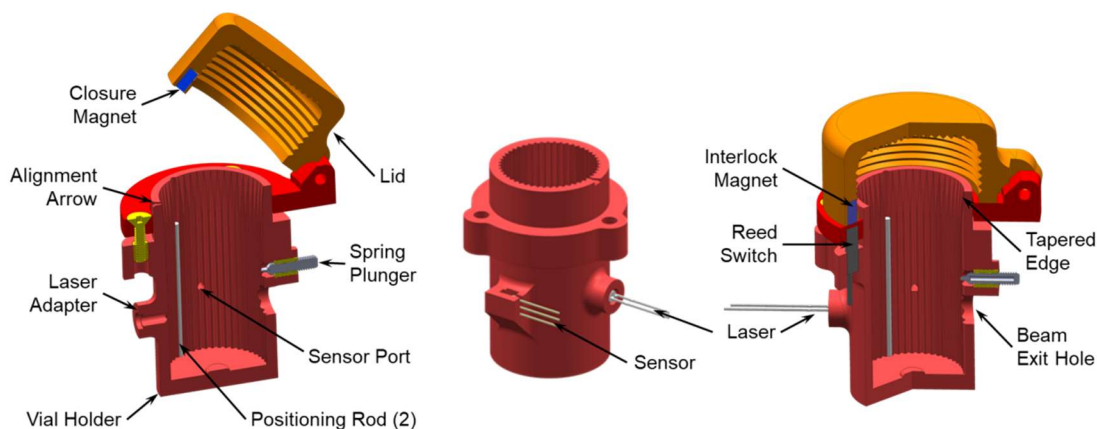


Figure 1. Turbidity Meter Optical System Design. The laser axis is arranged at 90° to the sensor view axis and both are normal to the vial axis. Left) The sensor is mounted at the end of a narrow bore to minimize stray light; Middle) The light source and sensor are mounted directly on the outside of the sample holder; Right) The spring-plunger aligns the sample vial and laser centerlines.

## 2 SAFETY

***Caution: Invisible laser radiation can cause eye damage. Avoid exposure to the beam.***

The turbidity meter contains a laser device that produces invisible radiation at 850 nm. If the laser is operated with a current in excess of the recommended maximum (i.e. in an overcurrent failure mode at 30 mA) it will produce class 3B laser radiation. Class 3B devices have beams that are normally hazardous when a direct exposure occurs within Nominal Ocular Hazard Distance (NOHD). The IEC 60825-1 laser safety standard specifies an NOHD of several meters for class 3B devices.

When used according to these instructions there is no danger of harm due to the radiation from the laser. The following turbidity meter design features are meant to protect the user from potentially harmful infrared radiation:

- An interlock switch connected in series with the laser prevents operation while the lid is open.
- A warning label is placed over the seam of the enclosure to remind users not to open the enclosure while the device is powered on.
- The laser is operated in constant-current mode, below the recommended maximum current (<12 mA).
- The axis of the laser beam is oriented parallel to the base of the measurement well so that laser light is not directed towards the user.

### **For your safety, please follow these directions:**

1. Make sure that the lid of the measurement well is closed when making measurements.
2. Do not operate the instrument with the bottom of the case removed.
3. Turn off the power to the instrument when changing the batteries.
4. Do not remove the laser from the housing, apply a different power source, or defeat the interlock switch.
5. Do not place a reflective object into the measurement well.
6. Do not look directly into the laser beam.

## 3 INSTRUMENT OPERATION

The features and controls of the instrument are shown in Figure 2. Sample vials are inserted into the measurement well and rotated to align the mark on the vial with the arrow on the edge of the well. The lid must be closed in order to operate the instrument correctly.

Measurements of sample turbidity are made using the following procedure:

1. Turn on the power and wait for “Open Water” to appear on the screen.
2. Press the yellow Enter button to access the menu.
3. Swirl the water sample thoroughly to ensure it is well mixed (without entraining air bubbles).
4. Use small aliquots of sample to rinse the sample vial, and then fill the vial to the shoulder with sample.
5. Wipe the outer surface of the sample vial with a clean, soft cloth.
6. Insert the vial into the measurement well with the white arrow on the vial aligned with the arrow marked on the rim of the well.
7. Close the lid. The laser will not operate with the lid open.
8. Press Enter to continue.
9. Measurement progress and the final result are displayed on the screen.
10. The measured turbidity value and the standard deviation of the readings are shown in FNU.

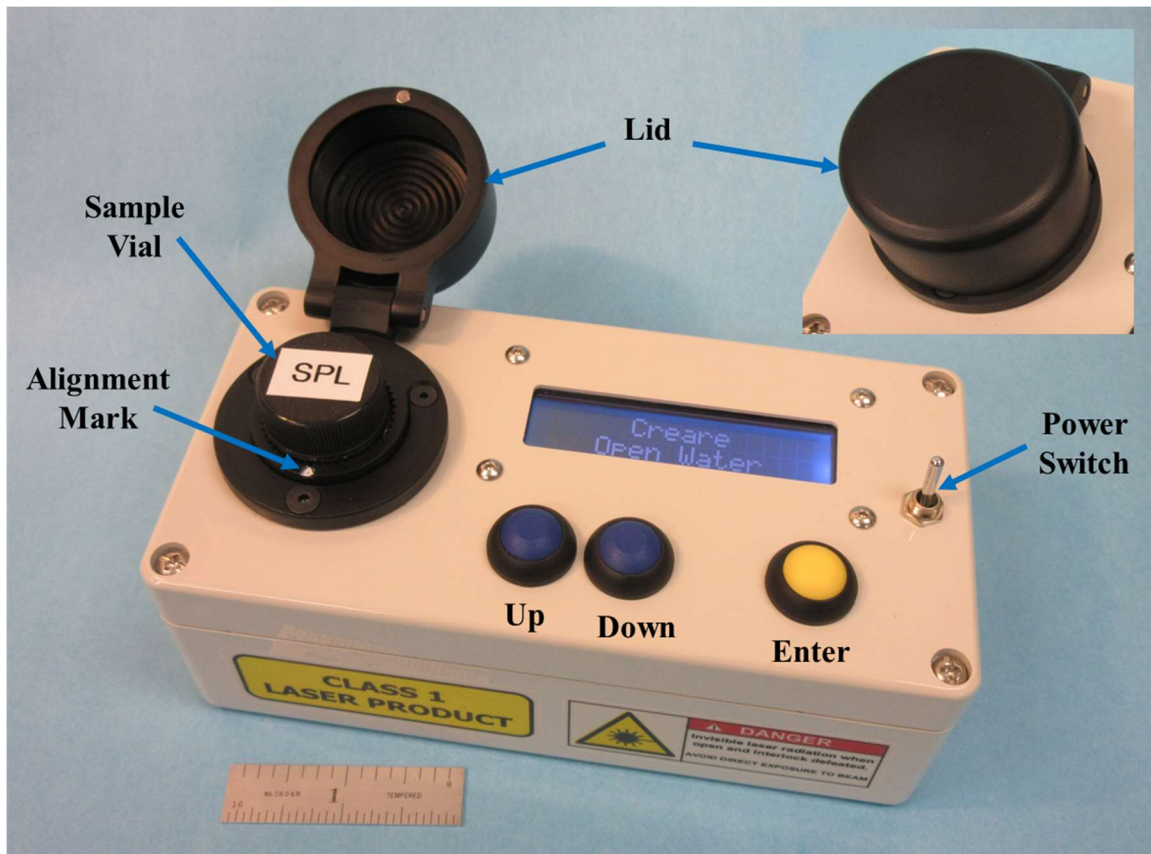


Figure 2. Prototype Turbidity Meter.

## 4 CALIBRATION PROCEDURE

The instrument must be calibrated prior to measurement of samples. The calibration can be checked before sample measurement using the 8 NTU standard. In case the check standard does not fall within the acceptable range (7.5-8.5 NTU), the calibration can be repeated in the field with the following steps:

1. Turn on the power and wait for “OpenWater” to appear on the screen.
2. Press the yellow Enter button to access the menu.
3. Press the blue Down (right-hand) button to select “Calibrate”.
4. Press the Enter button.
5. The “Print Counts” setting is displayed.
6. Press the blue Up (left-hand) button to choose No, or the Down button to select Yes.
7. Press Enter to continue.
8. The “Number of Averages” setting is displayed.
9. Use the Up and Down buttons to select the desired number.
10. Press Enter to continue.
11. The “Integration Time” setting is displayed.
12. Use the Up and Down buttons to select the desired time.
13. Press Enter to continue.
14. The “First Solution Concentration” setting is displayed.
15. Use the Up and Down buttons to select the desired concentration.
16. Wipe the outer surface of the 0 NTU vial with a clean, soft cloth.
17. Insert the vial into the measurement well with the white arrow on the vial aligned with the arrow marked on the rim of the well.
18. Close the lid. The laser will not operate with the lid open.
19. Press Enter to continue.
20. The “Second Solution Concentration” setting is displayed.
21. Use the Up and Down buttons to select the desired concentration.
22. Wipe the outer surface of the 20 NTU vial with a clean, soft cloth.
23. Insert the vial into the measurement well with the white arrow on the vial aligned with the arrow marked on the rim of the well.
24. Close the lid. The laser will not operate with the lid open.
25. Press Enter to continue.
26. The display will return to the menu.

Note: The Print Counts setting can be changed without changing the calibration. After selecting the desired value (Yes or No), press Enter and power off the device. The new display setting will be saved for subsequent measurements.

## 5 SMARTPHONE APPLICATION

The turbidity meter leverages the power of an open-source framework called WeatherCitizen (<https://weathercitizen.org/>). It consists of a mobile application and a cloud database that enables collection and sharing of geolocated environmental measurement data. Measurements can be displayed on an interactive map in near real-time or downloaded by any user (Figure 3). Photographs and additional observations can be added to the data record to assist with interpretation by other users.

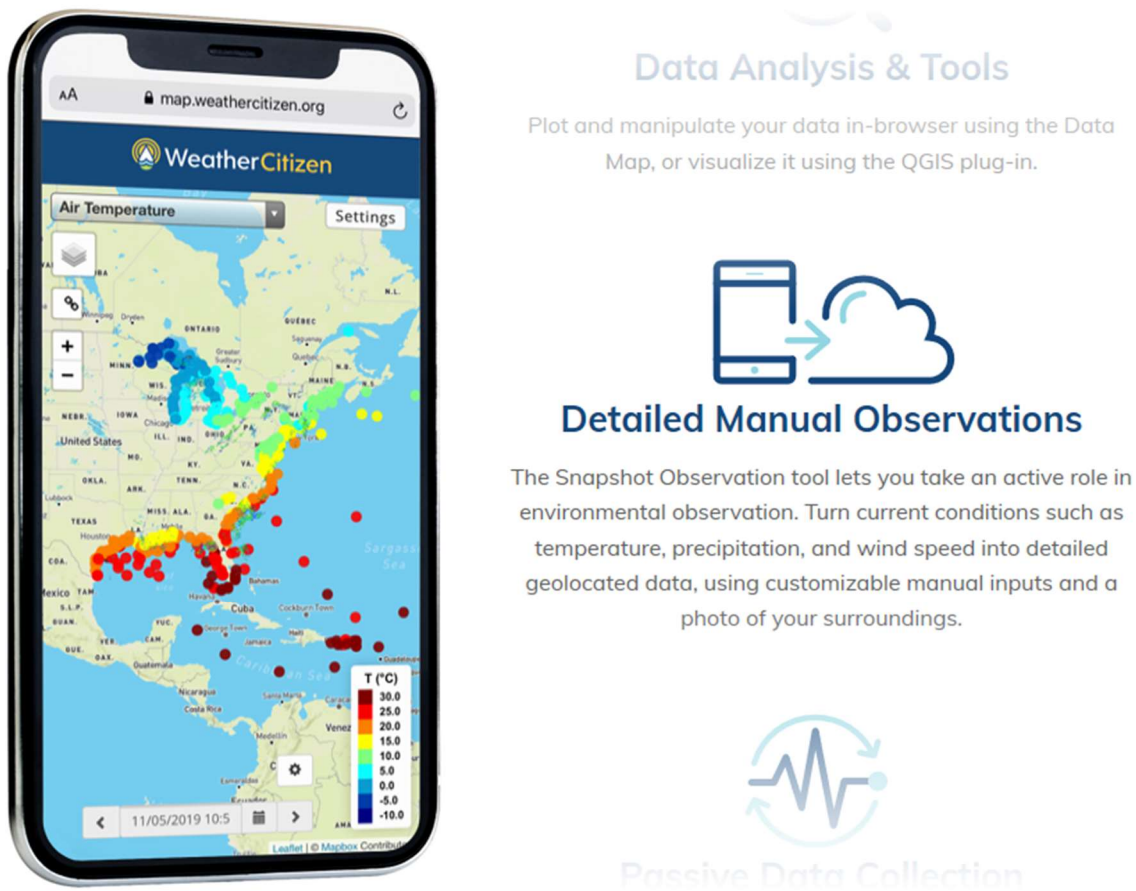


Figure 3. WeatherCitizen Mobile Application.

The turbidity meter can be used with the WeatherCitizen application with the following steps:

1. Download and install the latest version of WeatherCitizen from the Google Play Store (Android OS) or the Apple App Store (iOS).

2. Turn on BlueTooth in your phone Settings.
3. Open the WeatherCitizen application and connect to the turbidity meter:
  - a. Turn on the turbidity meter.
  - b. Tap Menu (≡) > Connect External Sensors > Start Scan.
  - c. Tap the Connect button next to the turbidity meter (the device name will be the serial number of the meter). A WaterMonitor device should now be listed under Connected Devices, with Creare as the manufacturer.
  - d. Tap the back arrow (◀) to return to the application.
4. Place a water sample into the measurement well and close the lid.
5. Tap on Make an Observation > Snapshot. The meter will automatically make a turbidity measurement.
6. Choose to take a photo, select an existing photo, or not add a photo to the observation.
7. Add information to the observation, such as weather conditions and notes.
8. Tap the Submit button. Review the observation data for accuracy.

The turbidity meter can be calibrated from WeatherCitizen with the following steps:

1. Place the low standard (usually 0 FNU) into the measurement well and close the lid.
2. Connect to the turbidity meter by following step 3 above.
3. Calibrate the turbidity meter:
  - a. Tap Menu (≡) > Calibrate Sensors.
  - b. Scroll down to the WaterMonitor heading, tap the Calibrate button, and confirm.
  - c. Follow the prompts on the turbidity meter to complete the calibration.
  - d. Tap OK and check that the Last Calibrated field was updated correctly.
  - e. Tap the back arrow (◀) to return to the application.

## **6 DEFAULT SETTINGS**

The following default values were set before instrument delivery:

- Low calibration standard: 0 NTU
- High calibration standard: 20 NTU
- Number of readings per measurement: 3
- Integration time: 3 seconds
- Show individual results: No

## 7 BATTERY REPLACEMENT

***Caution: Take care to avoid exposure to laser radiation while the device is disassembled.***

Batteries will need replacement after approximately 30 hours of operation. Please read the safety information provided in Section 2.

1. Make sure that the power switch is OFF.
2. Carefully cut through the label connecting the two halves of the enclosure. Doing so indicates that you accept responsibility for laser radiation safety.
3. Unscrew the fasteners at each corner of the top panel (they are captive screws and will not fall out).
4. Move the top panel to one side, being careful not to damage the electrical wires connected to the battery.
5. Remove and replace the batteries.
6. Replace the top panel and retighten the four screws.