## STANDARD OPERATING PROCEDURE (SOP)

**Title:** Analysis of *In Situ* Turbidity in Ambient Surface Water at Pine Island Bayou for the Environmental Monitoring Response System Using Yellow Springs Instrument 6-Series Multi-probe

Team Leader:_____ Date: _____

Quality Control Review: _____ Date: _____

Section Manager: _____ Date: _____

Effective Date: 4/22/2015

## 1.0 PURPOSE

This document describes sampling, analytical, and quality control (QC) procedures for *in situ* continuous monitoring of turbidity for the Lower Neches Valley Authority (LNVA) Pine Island Bayou Environmental Monitoring and Response System (EMRS) using the Yellow Springs Instruments (YSI) 6-Series multi-probes.

## 2.0 SCOPE AND APPLICABILITY

2.1 This procedure is intended for use in the Texas Commission on Environmental Quality (TCEQ) Continuous Water Quality Monitoring Network (CWQMN).

2.2 The LNVA operates Continuous Ambient Monitoring Station (CAMS) 749 at Pine Island Bayou. This SOP is specific to turbidity. See TCEQ's SOP AMPM-011 for procedures for the station's other multi-probe measurement parameters.

2.3 The LNVA uses turbidity data on a near real-time basis for water management decisions. Turbidity measurements from the station provide LNVA general water quality information. No EMRS notification levels have been set for this station.

2.4 Leading Environmental Analysis and Display System (LEADS) data records for turbidity are not validated.

2.5 LEADS reports multi-probe YSI 6-Series turbidity measurements units in Nephelometric Turbidity Units (NTU). The International Organization for Standards (ISO) designates turbidity measurements collected using the ISO 7027 Method as Formazin Nephelometric Units (FNU).

2.6 Turbidity sensor QC check criteria are used to ensure measurement equipment is operating within limits.

2.7 The working ranges of the YSI 6136 turbidity sensor is listed in Table 1.

**Table 1**

| Parameter | Working Ranges |
|---|---|
| Turbidity | 0 to 100 or 1000 NTU/FNU |

FNU = Formazin Nephelometric Units

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## 3.0 METHOD SUMMARY

3.1 Multi-probes are deployed via deployment structures. Discrete *in situ* Turbidity measurements are collected every 15-minutes by a data logger and data are transmitted every 15-minutes to TCEQ's LEADS in Austin Texas.

3.2 Turbidity is the measurement of the content of suspended solids in water. The YSI turbidity sensor's light source is a light emitting diode (LED) which produces radiation in the near infrared region of the spectrum. The detector is a high sensitivity photodiode. The wavelength of the light emitted is between 830 and 890 nm and the angle between the emitted and detected radiation is 90 degrees (per ISO 7027).

3.3 Turbidity probes are equipped with a mechanical wiper which makes them ideal for unattended applications.

## 4.0 LIMITATIONS

4.1 Multi-probe deployment structures can be susceptible to damage due to high water events. Data loss can occur as a result of damage to deployment structures. Replacement can be expensive and require significant resources.

4.2 During deployment periods, the interface between measurement sensors and the environment can become fouled by a variety of organisms and sedimentation. Sensor fouling can compromise data quality. In some water bodies sensor fouling can occur seasonally or rapidly due to event driven changes in water quality. Multi-probe sensors and deployment tubes must be kept free of fouling for high quality data. Note: Multi-probe sensor and deployment tube fouling is not measured as part of this procedure.

4.3 Turbidity sensors' susceptibility to fouling is greatly increased should the mechanical wiper fail.

4.4 While the effect of temperature is small, the multiprobe software automatically calculates temperature-compensated readings. A 0.6%/degree C temperature coefficient is automatically activated when the sensor becomes active.

## 5.0 SAFETY

This procedure includes processes that can be hazardous. Therefore, before attempting this process, operators should review the *TCEQ Chemical Hygiene Plan* for proper equipment and procedures necessary for the safe completion of this procedure. Operators must also read and be familiar with the Material Safety Data Sheets for the various chemicals that can be used in this procedure. Lab coats, safety glasses with side shields and/or splash goggles and chemical resistant gloves should be worn when handling chemicals.

## 6.0 EQUIPMENT AND REAGENTS

6.1 Equipment

- YSI 6-Series multi-probes (6600 EDS, 6600 V2, and 6920V1-2)
- YSI 6136 Turbidity Sensor
- YSI 6144 optical sensor wiper pads

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- C-spray anti-fouling nanopolymer
- YSI Multi-Parameter Display System (MDS)
- YSI field cable
- Calibration worksheets
- Instrument logbook
- Calibration cup
- Ring stand and clamp

6.2 Cleaning equipment/supplies for measuring sensor fouling

- Simple Green all-purpose cleaner in spray bottle
- Water and white vinegar solution (hard fouling)
- Spray bottle filled with DI water
- Five gallon bucket
- Kimwipes
- Large soft-bristle brush
- Small soft-bristle brush
- Cotton swabs
- Paper towels

6.3 Standards and Reagents (All reagents/chemicals must be analytical reagent grade).

- Hach Formazin Turbidity Standard 4000 NTU (see section 11.1 for disposal).
- De-ionized (DI) water
- Reagent Grade Water (E-pure)

7.0 PROCEDURE

Before the multi-probe is deployed, the sensor is cleaned and calibrated. The multi-probe is deployed, and every business day the station's turbidity measurements are monitored remotely by the station operator and the assigned data validator to evaluate operational status of the station. At the end of the deployment period, sensor drift is measured.

7.1 Service intervals, Station Monitoring, and Turbidity Sensor calibration.

7.1.1 The station is serviced and sensor is calibrated at a minimum of once every month. More frequent service visits may be needed depending on sensor fouling rates for a given water body, time of year, and employed anti-fouling measures. Station operators will need to determine appropriate deployment periods for their water bodies.

7.2 Turbidity Sensor Calibration

Sensor calibrations are performed immediately prior to each deployment period. A two-point calibration at 0 and approximately 100 NTU is used for most applications. A three-point calibration at values of approximately 0, 100 and 1000 NTU is optional to provide maximum accuracy. If the range of turbidity in the environment is well known, standards of other turbidity values can be utilized (three point or two point routines). In every calibration procedure, the beginning calibration point must always be 0 NTU. Calibration information is recorded on

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the YSI 6-Series Multi-probe Calibration Worksheet (see Appendix A).

- Sensor must be cleaned before calibration.
- Anti-fouling C-spray nanopolymer coating must be applied to sensors prior to calibration.
- Turbidity standards must be within expiration date.
- New optical sensor wiper pad must be installed prior to each sensor calibration and deployment period.
- Optical DO wiper pad must be removed before calibrating with formazin standard.
- Multi-probe and calibration standards must be allowed time to equilibrate to room temperature before calibration(s) or initial readings.
- Initial turbidity calibration value must be 0 NTU.
- Prepare 100 NTU standards by partially filling a 1000 mL volumetric flask with reagent grade water (e-pure). Measure and add 25 mL of the 4000 NTU Hach formazin standard using a class A volumetric pipette and fill to volume.
- For best results, use freshly prepared or purchased turbidity standards. Degradation of standards can occur on standing, particularly formazin prepared from dilution of concentrated suspensions such as Hach 4000 NTU standard.
- Care must be taken to minimize any air bubbles with all turbidity calibration standards.
- If air bubbles are noticed on the probe face or the initial readings do not look accurate, manually activate the turbidity wiper 1-2 times to clear any trapped air.
- A ring stand and clamp should be used to secure the multi-probe body.
- A small amount of calibration solution should be used to pre-rinse the sensors. Expired calibration solutions may be used for this.
- Operators should have several clean absorbent paper towels available. Shake the excess rinse water off the sensor. This will reduce carry-over contamination of calibration solutions.
- If calibrating the 6136 sensor with a short calibration cup, the cup must have a black bottom and you should engage only one thread to keep the probe face as far as possible from the bottom of the cup to avoid interference.
- Turbidity sensor MUST be calibrated in the upright position to eliminate interference from the meniscus of the standard.

7.2.1 C-Spray Anti- Fouling Sensor Application

Prior to sensor calibration, apply two coats of C-spray nanopolymer to sensor body and interface.

7.2.1.1 Ensure sensor body and sensor interface is clean and dry. Apply C-spray to sensor and allow to air dry. Apply a second coat of C-spray and allow to air dry. Proceed with calibration.

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7.2.2 Two-Point Turbidity Calibration

Calibration of the turbidity sensor consists of a two-point calibration with a Hach formazin standard. The initial calibration value must be 0 NTU (clear deionized or distilled water). The second value should be in the range of known turbidity for the water to be monitored, however, for general purpose measurements use 100 NTU.

7.2.2.1 Rinse sensor once with DI water.

7.2.2.2 Place the probe in the cal cup, with the sensors pointed down. Place enough clear, deionized or distilled water into a clean, dry, or pre-rinsed calibration cup to immerse the turbidity probe and thermistor (225-240 mL).

7.2.2.3 From the *Calibrate menu*, select **Optic-T Turbidity-6136** to access the turbidity calibration choices; then select **2 point**. Press **Enter** and input 0 at the prompt. Press **Enter** and the current values of the enabled sensors will appear on the screen.

7.2.2.4 Observe the real-time turbidity reading to determine when the reading has stabilized (if the reading does not look accurate or if air bubbles are observed on the sensor face, activate the wiper 1-2 times by selecting **Clean Optics** and pressing **Enter**). After stabilization is complete, press **Enter** to "confirm" the first calibration. The display will indicate that the calibration is accepted.

7.2.2.5 After the 0 NTU calibration is complete, press **Enter** to continue. Rinse the multi-probe and calibration cup with the 100 NTU formazin standard waste before continuing.

7.2.2.6 Place enough of the 100 NTU formazin standard into a clean, dry, or pre-rinsed calibration cup to immerse the turbidity probe and thermistor (225-240 mL).

7.2.2.7 Input 100 as prompted on the display and press **Enter**. The current values of the enabled sensors will appear on the screen.

7.2.2.8 Observe the real-time turbidity reading to determine when the reading has stabilized. After stabilization is complete, press **Enter**. The display will indicate that the calibration is accepted. After the second calibration is completed, press **Enter** again. If you are performing a *2-point Calibration*, the display will return to the *Calibrate Menu.*

7. 2.2.9 After calibration is complete, rinse all sensors and calibration cup with tap water.

7.2.3 Turbidity Three-Point Calibration

The Turbidity sensor can be calibrated using a three-point procedure for maximum accuracy. The suggested values are 0, 100 and 1000 NTU,

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however, other turbidity values can be used if the range of the environmental sample is well known. The initial value MUST always be 0 NTU.

7.2.3.1 Rinse sensor once with DI water

7.2.3.2 Place the probe in the cal cup, with the sensors pointed down. Place enough clear, deionized or distilled water into a clean, dry, or pre-rinsed calibration cup to immerse the turbidity probe and thermistor (225-240 mL).

7.2.3.3 From the *Calibrate menu*, select **Optic-T Turbidity-6136** to access the turbidity calibration choices; then select **3 point**. Press **Enter** and input 0 at the prompt. Press **Enter** and the current values of the enabled sensors will appear on the screen.

7.2.3.4 Observe the real-time turbidity reading to determine when the reading has stabilized (if the reading does not look accurate or if air bubbles are observed on the sensor face, activate the wiper 1-2 times by selecting **Clean Optics** and pressing **Enter**). After stabilization is complete, press **Enter** to "confirm" the first calibration. The display will indicate that the calibration is accepted.

7.2.3.5 After the 0 NTU calibration is complete, press **Enter** to continue. Rinse the multi-probe and calibration cup with the second formazin standard before continuing.

7.2.3.6 Place enough of the second formazin standard into a clean, dry, or pre-rinsed calibration cup to immerse the turbidity probe and thermistor (225-240 mL).

7.2.3.7 Input the correct second turbidity value in NTU (100 NTU suggested) as prompted on the display and press **Enter**. The current values of the enabled sensors will appear on the screen.

7.2.3.8 Observe the real-time turbidity reading to determine when the reading has stabilized. After stabilization is complete, press **Enter**. The display will indicate that the calibration is accepted. After the second calibration is completed, press **Enter** again.

7.2.3.9 After the second NTU calibration is complete, press **Enter** to continue. Rinse the multi-probe and calibration cup with the third formazin standard before continuing.

7.2.3.10 Place enough of the third formazin standard into a clean, dry, or pre-rinsed calibration cup to immerse the turbidity probe and thermistor (225-240 mL).

7.2.3.11 Input the correct third turbidity value in NTU (1000 NTU suggested) as prompted on the display and press **Enter**. The current values of the enabled sensors will appear on the screen.

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7.2.3.12 Observe the real-time turbidity reading to determine when the reading has stabilized. After stabilization is complete, press **Enter**. The display will indicate that the calibration is accepted. After the third calibration is completed, press **Enter** again.The display will return to the *Calibrate Menu*.

7.2.3.13 After calibration is complete, rinse all sensors and calibration cup with tap water.

8.0 Turbidity Probe Cleaning and Storage

The 6136 probe requires only minimal maintenance.

**Note:** Section 8.1.1 details a nominal cleaning procedure. Station-specific sensor cleaning procedures may need to be developed when sensors are fouled by chemical coatings.

8.1 The deployed multi-probe is gently removed from the deployment tube. After removal, the multi-probe is cleaned. Field cleaning includes the thorough cleaning of the sensor interface, sensor body, and multi-probe body using cleaning supplies listed in Section 6.2.

8.1.1 Remove optical turbidity wiper.

8.1.2 Spray entire multi-probe and turbidity sensor body with Simple Green cleaning solution.

8.1.3 Clean sensor body with a soft cloth or brush. Clean the optical surface with moist lens cleaning paper

8.1.4 Using a spray bottle filled with tap water, thoroughly rinse multi-probe, sensor body, and sensor interface. Inspect multi-probe (especially sensory interface) and repeat steps 8.1.1.2, 8.1.1.3, and 8.1.1.4 if necessary.

8.1.5 Reinstall optical turbidity wiper pad assembly (containing a new turbidity wiper pad).

8.3 No special precautions are necessary for either the short or long-term storage of YSI turbidity probes. For long-term storage, the user may wish to remove the probe from the multi-probe, install a port plug, and store the probe in dry air to minimize any cosmetic degradation and to maximize the life of the wiper.

8.4 QC Calculations

Measurement Accuracy

8.4.1 Measurement accuracy is expressed in terms of the Absolute Error (AE) or Relative Percent Error (RPE) and is defined as:

$$AE = Measured\,Value - Actual\,Value$$

$$RPE = \frac{Measured\ value - Actual\,Value}{Actual\,Value} * 100$$

Sensor Calibration Drift Calculations

8.4.2 Multi-probe turbidity sensor calibration drift ($C_d$) over the deployment period is evaluated using RPE:

$$C_d = \frac{(S_r - S_v)}{S_v}(100)$$

Where:

$S_r$= sensor response; and
$S_v$ = formazin theoretical standard value.

8.4.3 Turbidity $C_d$ over the deployment period can be evaluated using AE:

$$C_d = (S_r - S_v)$$

Where:

$S_r$ = turbidity sensor response; and
$S_v$ = formazin theoretical standard value

## 9.0 QUALITY CONTROL

### 9.1 QC Samples

QC samples are used to ensure that acceptable data quality is maintained throughout the measurement process.

### 9.2 Turbidity Sensor Drift Measurement Procedures

Calibration Verification Samples (CVS) are analyzed every service interval. Allow the multi-probe to equilibrate to room temperature for a minimum of two hours before analyzing CVSs. CVS results should be entered into the CVS worksheet (see Appendix B).

Turbidity Sensor CVS

9.3.1 Formazin CVSs are analyzed at a minimum of once monthly to assess analytical drift from the previous calibration.

9.3.2 The multi-probe and turbidity sensor must be cleaned prior to analysing CVSs.

9.3.3 Formazin CVS solutions are introduced using the calibration vessel. **Note:** Rinse calibration vessel and sensor twice with DI water and calibration standard before measuring standard.

### 9.3 Temperature Sensor Check

The multi-probe's temperature sensor is checked after each deployment period using procedures found in AMPM-011.

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**Table 9-1: QC Checks**

| QC Check | Purpose | Frequency | Acceptance Criteria | Response Action |
|---|---|---|---|---|
| Two or three-Point Formazin Calibration | To establish slope used for quantitation | Prior to deployments | Instrument accepts calibration | 1) Analyze standard again and re-calibrate<br>2) Check for contaminated standard<br>3) Clean sensor<br>4) Replace sensor |
| Formazin Calibration Verification Samples (CVSs) | To Assess Sensor Drift | At the conclusion of every deployment period. A minimum of once monthly | ± 3 NTU AE/FNU or ± 5% RPE | 1) Perform corrective action as necessary<br>2) Replace sensor |
| Turbidity Sensor Cleaning | Improve Sensor Responses | As needed and at the conclusion of deployment periods | None | Clean sensors more frequently |

## 9.0 DEFINITIONS

See Appendix A of the *Continuous Water Quality Monitoring Network Quality Assurance Project Plan.*

## 10.0 REFERENCES

*Continuous Water Quality Monitoring Network Quality Assurance Project Plan*
*U.S. Geological Survey Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting TM1D3*
*Yellow Springs Instrument 6-Series Operator's Manual*
*Yellow Springs Instrument 6-Series Calibration, Maintenance & Troubleshooting Tips*
*Surface Water Quality Monitoring Procedures Manual, Volume I*
*TCEQ Operating Policies and Procedures, Chapter 6.13*

## 11.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Supervisors, sampling personnel, and laboratory analysts should identify and implement innovative and cost-saving waste reduction procedures as part of the method development, review, and revision of standard operating procedures. Wastes that do result from these procedures are managed and disposed of in accordance with appropriate state and federal regulations.

Refer to Chapter 6.13 of the *TCEQ Operating Policies and Procedures* for guidelines on general recycling, waste reduction, and water and energy conservation. Review these procedures for specific employee responsibilities and mechanisms for office-related waste prevention and management. Consult the *Monitoring Operations Hazardous Waste Disposal Plan* for laboratory-specific waste minimization recommendations and requirements for proper handling of hazardous waste that result from laboratory procedures.

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### 11.1 Formazin Disposal Considerations

Dilute the material with excess water making a weaker than 5% solution. Open cold water tap completely, slowly pour the material to the drain. Flush system with plenty of water. For container disposal, rinse three times with appropriate solvent and dispose in normal trash.

Note – These disposal guidelines are based on federal regulations and may be superseded by more stringent state or local requirements. Please consult your local environmental regulators for more information.

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Appendix A

| YSI 6-SERIES MULTI-PROBE CALIBRATION WORKSHEET | | | |
|---|---|---|---|
| Analyst: | Date: | Time: | Date Deployed: |
| CAMS: | MDS Serial Number: | | Multi-probe Serial Number: |
| Optical DO Sensor type (6150 or 6150+): | Optical DO membrane date of manufacture | | Date membrane installed to DO sensor: |
| Optical DO membrane Temp. Coefficient: | | | |
| Barometric Pressure (Actual) Used For DO Calibration (mm/Hg): | | | |

| Standard | Manufacturer | Lot No. | Expiration Date |
|---|---|---|---|
| Conductivity | | | |
| pH 7.00 | | | |
| pH 4.00/10.00 | | | |
| Turbidity | | | |
| Conductivity Sensor Zero Ambient Air Check: | Result | Criterion ≤ 3 µS/cm | |

| Parameter | Temp. of Standard | Concentration SC or pH of Calibration Standard | Initial Reading | Calibrated to | Comments/Results |
|---|---|---|---|---|---|
| Specific Conductance (µS/cm) | | | | | |
| Conductivity Cell Constant | | | | | Criteria 5.0 ± 0.45 |
| pH Calibrated (~7.00) | | | | | |
| pH mV for pH 7 solution | | | | | Range 0 ± 50 mV |
| pH Slope (~ 4.00/10.00) | | | | | |
| pH mV for pH 10.00<br>pH mV for pH 4.00 | | | | | Range: -160 ± 50 mV<br>Range: +160 ± 50 mV |
| Dissolved Oxygen (%sat) | | | | | |
| Turbidity (NTU/FNU) | | 0 NTU | | | |
| | | 100 NTU | | | |
| Dissolved Oxygen Gain | | | | | Criteria: 0.85 – 1.15 |

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Appendix B

## YSI SERIES-6 MULTI-PROBE CALIBRATION VERIFICATION WORKSHEET

| | | |
|---|---|---|
| Date: | Time: | Analyst: Thermometer Serial No. |
| Date Retrieved: | | Multi-probe Type and Serial No. |

| Standard | Manufacturer | Lot No. | Expiration Date |
|---|---|---|---|
| SC | | | |
| pH 7.00 | | | |
| pH 4.00/10.00 | | | |
| Turbidity | | | |

| Parameter | Temp. of Standard | CVS Standard | CVS or temp results | Result | Criteria |
|---|---|---|---|---|---|
| Specific Conductance (µS/cm) | | | | | ≤ 5.0 RPE |
| pH calibrated (~7) | | | | | ± 0.50 pH unit |
| pH slope (~ 4/10) | | | | | ± 0.50 pH unit |
| Dissolved Oxygen (mg/l) | | | | | ± 0.50 mg/l |
| Dissolved Oxygen (% Saturation) | | | | | ± 6 % saturation |
| Turbidity (NTU/FNU) | | 0 NTU | | | ± 3.0 NTU/FNU Or ± 5.0 % |
| | | 100 NTU | | | |
| Temperature (ºC) | NA | NIST Reading | | | ± 0.50 ° C |

**DO mg/L CVS VALUE DETERMINATION**

CF = (ABP) _____ mmHg
760 mmHg

DO Calibration Value (mg/l) = CF x DO Saturation Value

CF_____ x DO Saturation Value

_____ mg/l

= DO CVS Value _____ mg/l

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