Real-Time Water Quality Monitoring Network

Performance Testing and Evaluation (PTE) Process

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Table of Abbreviations

- **6600:** The larger 4" diameter member of the 6th series multi-parameter water quality instrument family from Yellow Springs International (YSI). Discontinuing production in 2017, the 6600 has seen some use in the RTWQ program.
- **DS5X/DS5/MS5:** *Datasonde/Minisonde, 5th series* – the fifth series of models from the Hydrolab brand by HACH. Datasondes are larger 4" diameter multi-parameter instruments while the Minisondes are smaller, 2" diameter multi-parameter sondes. The 'X' in DS5X refers to the "extended duration" set of features (battery pack, central sensor wiper).
- **EXO2:** The larger 4" diameter multi-parameter water quality instrument of the EXO family from YSI. The EXO family is Bluetooth-enabled and features advanced meta-data retention.
- **ICED**: *Inventory, Calibration, and Evaluation Database* – A tool designed to unify all the processes involved in the RTWQ program and simplify data management.
- **PTE:** *Performance Testing and Evaluation* – An annual refit of multi-parameter instrumentation completed by trained staff and intended to increase instrument longevity and assure factory-specified performance.
- **RTC**: *Real-Time Clock* – A battery powered time-keeping chip, independent of a computer's main power circuit. The RTC is intended to keep time when power isn't available.
- **RTWQ:** *Real-Time Water Quality (Network)* – A program under the purview of the Department of Environment and Conservation consisting of more than 30 stations across Newfoundland and Labrador.

Scope of Document

While the Real-Time Water Quality (RTWQ) monitoring program uses several varieties of multi-parameter water quality sondes, the majority in service are Hach Hydrolab DataSonde (DS5) or MiniSonde (MS) models. As a cost- and time-saving venture, the RTWQ program has undertaken relatively simple repair work and annual checkout and refit of these models. Previously, this work has been done out-of-province, incurring significant delays and expense.

Other than regular calibrations and standard procedures, no work is performed on models other than the Hydrolab series five instruments; as such, this manual will only discuss Hach Hydrolab DS5 and MS5 models. This manual is intended to illustrate the general principles in completing a performance test and evaluation (PTE); it is not intended to replace training received from the manufacturer.

Introduction

Maintaining an inventory of functional and accurate sondes for the RTWQ monitoring network is a challenging and time consuming process. Difficult deployment situations and persistent sensor issues demand that instruments are checked out regularly to ensure they are fully functional; the manufacturer suggests annual PTE. Maintaining sufficient numbers of sondes in regional offices to sustain program requirements while balancing the need for an efficient PTE schedule is important.

Troubleshooting problems with electronics is a skill that can be learned only through experience and thorough training. This is especially pertinent to the maintenance of multi-parameter sondes – they are expensive pieces of equipment requiring specialized equipment, parts, supplies, and techniques. Those involved in performing PTEs have undergone three days of hands-on training with the manufacturer that involved:

- **Removing and installing new sensors and related printed circuit boards**
- **Identifying, manipulating, and replacing components within the casing**
- **Removing, resetting, and deploying appropriate firmware**

At present two staff within the RTWQ program are qualified to perform PTEs according to the manufacturer's specifications.

Scheduling

As of March 2016, there are 67 government- and industry-owned Hydrolabs in the RTWQ inventory requiring annual servicing. Limited storage space in the St. John's Water Resources lab means that a staggered approach in receiving and returning sondes is needed. PTEs are performed on a regional basis and revolve around the Labrador RTWQ deployment season, since this region's substantial inventory is removed to avoid ice damage from approximately November to March.

Table 1: PTE Schedule

Date	Region
January February March	Labrador
April May June	Central/Western
July August September October November December	Avalon

Table 1 outlines an ideal schedule of PTEs for the RTWQ network. Experience has found that the Labrador inventory is best dealt with by sending the instruments in two loads beginning in December or January with the second load arriving in St. John's just as the first load is returned following the completion of PTE (late February). The Labrador inventory is usually completed by mid-March; in time for the spring deployment.

Once Labrador PTEs are complete, Central, and Western Newfoundland region PTEs can be undertaken according to the workload of staff. Typically, these PTEs are completed over the summer months with the Avalon region falling into late summer and fall – before the cycle begins again with Labrador.

It is vital to coordinate PTEs with all staff involved in the RTWQ program as the shipping and receiving of equipment is time consuming and must avoid instruments being delayed in transit – especially during cold weather which can cause damage to sensors.

When sonde failures occur, efforts are made to ensure that a replacement sonde is available to continue monitoring at a station. Sondes can be inserted into the PTE process by generating a PTE Ticket through the Inventory, Calibration, and Evaluation (ICE) database. As time permits, the sonde is incorporated into the current region's PTE cycle and is returned.

The PTE Process

PTEs can be of two varieties: Standard, or Problem-Based. Standard PTEs are those which do not indicate any problems or issues with the sonde; a simple refurbishment is all that is needed. Conversely, Problem-Based PTEs present with an identified issue or infrequent/irregular problems hindering usage. Problem-based PTEs require specific knowledge and understanding of the Hydrolab to troubleshoot and remediate issues. Both processes are outlined below.

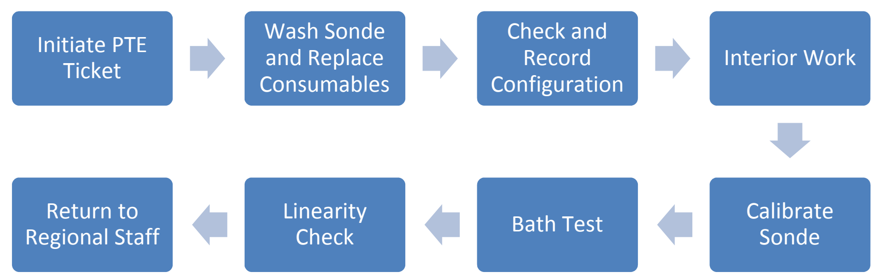


Figure 1: Generalized PTE Process

Standard PTE

The following is an idealized approach to performing PTEs on a Hydrolab Datasonde or Minisonde multi-parameter probe. In reality, the PTE process must be flexible to account for multiple modes of failure and even failure during the PTE process.

1) Initiate a PTE ticket in the ICE Database

This should be completed by the individual responsible for the Hydrolabs in a region prior to shipping to St. John's. A Ticket outlines the issues found (if any) with a Hydrolab and also allows staff in St. John's to expect the arrival of equipment and keep track of equipment.

2) Wash Sonde and Replace Consumables

Before beginning any work, the Hydrolab should be cleaned thoroughly according to Hydrolab documentation. This includes using a mild detergent (such as Simple Green) and lukewarm water[1]. Cleaning should be thorough

[1] Anecdotally, there may be a relationship between LDO sensor failure and immersing a cold instrument in warm or hot water. A good practice is to allow Hydrolabs to warm to room temperature and use lukewarm water for washing

and involve removing brushes and wipers from the self-cleaning mechanism and removing the battery cap to remove grit and re-grease O-Rings. Replace any damaged O-Rings, Teflon junction, LDO cap (if necessary), and wiper/brush assembly (if necessary).

3) Check Sonde Configuration

If a PTE Ticket has been issued, edit the relevant PTE (a PTE ticket creates a mostly-empty PTE with the Serial Number and complaint) If no PTE ticket was issued, create a new PTE.

Connect the Hydrolab to a calibration cable and fill in the details on the Basic Information and Sensor Setup tabs.

Confirm the Sensor Configuration is correct on the Sensor Configuration tab.

Update the main and sensor firmware as needed.

4) Check current draw

At rest, a connected and fully functional DS5X with turbidity and LDO sensors will yield a total current draw near 0.13 A. If the self-cleaning mechanism is in motion, the current draw can be expected to approach 0.17 A. A resting current greater than 0.25 A often indicates a problem with the turbidity and/or LDO sensors – the highest-drawing sensors on the Hydrolab. The best method to determine which sensor is at fault is to disconnect the respective daughter boards from the motherboard and disconnect sensor leads from the pinouts at the bottom of the motherboard. Individually check the current draw from the motherboard, followed by reconnecting the turbidity and checking the total current draw, and finally reconnecting LDO and checking the total current draw. Table 2 lists approximate values for current draw for each component of the Hydrolab.

Table 2: Approximate Component Current Draw

Component	Current Draw (A)
MPL (Motherboard)	0.04
LDO Sensor and Daughterboard	0.07
Turbidity Sensor and Daughterboard	0.02 (add 0.06 when cleaning)
Other fluorometer	0.03

5) Interior work

Figure 2: Hydrolab DS5X Mother and Daughterboards

Interior work should only be performed after the exterior has been thoroughly cleaned and dried to prevent water or debris from entering the Hydrolab. The work space must also be dry, tidy, and protected from static discharge when opening the Hydrolab to prevent inadvertent shorting of electrical components.

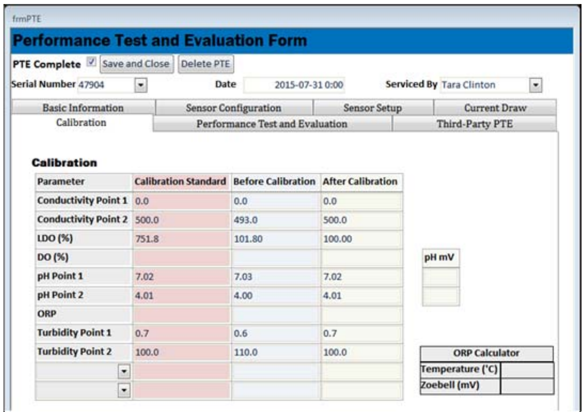
Remove the hex screws holding the body to the bulkhead and separate by pulling and rocking the two pieces gently. Do not twist the two pieces or damage will occur. Remove the two main O-rings. Clean and re-grease both the seating area and the O-rings. Replace the O-rings if there is any visible damage or deterioration.

Perform a general inspection of the circuit boards and observe for any corrosion spots, fragments of shattered ferrite beads (especially on the integrated speaker), or a scorched scent which indicates an electrical component failure.

Check and/or replace the real-time clock (RTC) BR 2032 coin cell and replace the desiccant packet. Ensure connectors are firmly in place before reassembling the Hydrolab.

6) Calibrate Sonde

Follow the manufacturer's instructions and record the calibration standard used and the "before" and "after" calibration values in the PTE form. Also record the pH sensor's mV output for slope calculation purposes. This greatly helps track the quality and condition of the pH sensors over time.


frmPTE

Performance Test and Evaluation Form

PTE Complete ☑ Save and Close Delete PTE

Serial Number 47904 Date 2015-07-31 0:00 Serviced By Tara Clinton

Basic Information | Sensor Configuration | Sensor Setup | Current Draw | Calibration | Performance Test and Evaluation | Third-Party PTE

Calibration

Parameter	Calibration Standard	Before Calibration	After Calibration
Conductivity Point 1	0.0	0.0	0.0
Conductivity Point 2	500.0	493.0	500.0
LDO (%)	751.8	101.80	100.00
DO (%)			
pH Point 1	7.02	7.03	7.02
pH Point 2	4.01	4.00	4.01
ORP			
Turbidity Point 1	0.7	0.6	0.7
Turbidity Point 2	100.0	110.0	100.0

pH mV

ORP Calculator	
Temperature ('C)	
Zoebell (mV)	

Figure 3: PTE Calibration

7) Bath Test

Most problems are identified during the current draw tests and sensor calibrations; however an extended testing in a controlled water bath can identify transient issues that only occur sporadically – such as occasional LDO sensor faults or turbidity failures. For additional rigor, test several Hydrolabs together and compare data from each instrument.

Bath testing should be for a minimum of 24 hours and ideally last a week. Ensure the internal batteries have sufficient charge for the duration of the test and set the log file accordingly.

8) Linearity Check

After the bath test, lightly clean the Hydrolab and perform a linearity check on the pH and conductivity sensors. Linearity checks should be done by immersing the sensor in a standard that was not used during the calibration stage. For example, if a pH sensor was calibrated using pH 7 and pH 4 buffers, pH 10 buffer could be used as a linearity check. Calibration is not done in this step, only a check to ensure that the value is read within an acceptable range (see Table 3).

Table 3: Average pH and Conductivity deviations from linearity following bath testing

Parameter	Average Linearity Check % Error (n = 129)
Conductivity	-0.38
pH	0.033

Problem-Based PTE

Problems with a Hydrolab are usually identified by regional staff during routine maintenance and calibration. Often a problem with connectivity can be resolved by regional staff by troubleshooting cable, power, or computer issues. If the problem is not resolved, it is often useful to contact those trained in performing PTEs to assist with identifying the problem. If that isn't successful, or time doesn't permit, a PTE Ticket must be submitted by regional staff through the ICE database prior to sending the Hydrolab to St. John's for repair (see Appendix: Related Documents).

For PTE staff, taking on a sonde with a known problem can be complicated and requires flexibility in approach. For this reason, deviation from the previously discussed standard PTE process is needed.

Description of Problem and PTE Procedure

Often the problem submitted with the PTE ticket gives a clue as to the required fix for the Hydrolab. In some cases where the issue is unclear, it is wise to proceed with the standard PTE process while keeping the problem in mind. This allows for a step-by-step elimination of problems that could occur (see Table 4 for possible modes of failure).

Table 4: Common Modes of Failure

Procedure	Possible mode of failure
Failure to connect	CPU board
Current overdraw	LDO, Turbidity, or fluorometer failure
Calibration failure	Relevant sensor failure
Poor/unstable bath test results	Relevant sensor failure

Because of this troubleshooting process, backtracking through the PTE process is common. In some cases, multiple problems may be identified during the PTE, requiring several backtracks.

Case Study of a PTE

The following is a case study for a PTE performed on an instrument scheduled for annual PTE with an unexpected failure.

A Hydrolab DS5X was removed from service for an annual PTE and refit to replace worn parts. A PTE was initiated and basic information was recorded (serial number, parameter order). Next, the instrument was thoroughly cleaned in lukewarm soapy water and the pH Teflon reference junction was replaced, and the KCl reservoir was refilled – including a KCl salt tablet.

Next, the instrument was brought to the static-discharge protected workstation and disassembled. The main O-rings and seating area were wiped clean and the O-rings very lightly re-greased. The circuit boards were visually inspected for damage or corrosion and the RTC battery voltage was checked. Main and sensor firmware versions were checked to ensure they were up-to-date. According to manufacturer recommendations, the turbidity sensor was relocated from underneath the LDO sensor to an open slot (this recommendation seeks to avoid turbidity stability problems related to the daughterboard overheating). To accommodate this change, the firmware and leads for the sensor were adjusted to reflect the location change. Date format, date, and time were re-set to the NST time zone and the instrument was reassembled. Calibration was completed next and a log file was setup for a one-week checkout in the waterbath.

One week later, the instrument was removed from the bath and quickly cleaned of accumulated growth and slime. The instrument was connected to Hydras 3LT and the log file was downloaded and examined. It was quickly noticed that the LDO sensor had failed as both concentration and saturation values were recorded as 0 mg/l and 0 % sat, respectively.

Because this instrument was industry-owned, the industry partner was provided with the part number required and the supplier's contact information with the request that the part be forwarded to St. John's once the purchasing process was completed.

Once received, the instrument was disassembled once more and the new sensor was replaced, the firmware adjusted, and the serial numbers adjusted in the ICE database. The new sensor was recalibrated and the instrument was tested for another two days. At this point, the new log file was downloaded and examined before completing the linearity check on the conductivity and pH sensors. With all final checks passing, the PTE was complete and the instrument was returned to service.

PTE Reports

PTE reports can be generated by users from the ICE database and distributed as needed in pdf format. As such, they are not distributed as a matter of routine. Major works and findings are communicated via email to Regional staff – especially in the case of sensor replacements, as outlined in the next section.

Parts and Supplies Inventory

Responding to urgently needed repairs requires maintaining a stock of frequently-needed parts and supplies, since purchasing delays can be substantial. Repairs to Hydrolabs owned by the Department of Environment and Conservation are straightforward in that sensors can be drawn from stock and replenished once the purchasing process is completed and purchases are delivered from the supplier (Campbell Scientific).

Stock levels should be kept as low as possible to avoid warranty periods from expiring in stock. Additionally, first-in-first-out stock rotation is important. Paying attention to the date of manufacture embedded in serial numbers and marking supplies with receipt date should be sufficient. Recommendations on stocking levels are in Table 5. These levels should be assessed periodically to be sufficiently reactive and balance costs.

Table 5: Suggested Parts and Supplies Inventory

Part	Number in Stock
Small Parts	
Teflon Reference Junction	1 per instrument in Region
LDO Cap	1 for every 4 instruments in Region
O-Rings	1 for every 4 instruments in Region
RTC Battery	1 per instrument in Region, every second year
Desiccant Pack	1 per instrument in Region
Sensors	
pH	2
Turbidity	1 – 2
LDO	1 – 2

Repairs to industry-owned Hydrolabs are more complex than repairs to instruments owned by Environment and Conservation. The following is the process for industry-owned Hydrolabs requiring sensor replacement:

1. **Submit PTE Ticket outlining problem and send instrument to St. John's Staff for repair.**
2. **St. John's staff performs PTE, confirming problem.**
3. **St John's staff notify Regional staff of needed materials**
4. **Regional staff member notifies industry contact of needed materials**
5. **Industry contact places order for needed materials**
6. **Industry forwards received materials to St. John's staff or advises supplier to ship directly to St. John's**
7. **PTE is completed and shipped back.**

This process can be time consuming and may require shipping a substitute Hydrolab to the regional staff to cover the time needed for repairs.

As a courtesy, and to simplify the purchase of replacement parts, all instruments belonging to a particular industry partner should be undertaken simultaneously, or as close as reasonably possible. This allows the industry partner to purchase multiple sensors on a single requisition, if needed.

Cost Benefit Analysis

Annual servicing of a large sonde inventory is challenging considering the supplier cost, shipping distance, and time. The time needed for scheduled PTEs has been reduced substantially by completing them within the province. Since Fiscal Year 2011/2012 most PTEs have been performed in-house by RTWQ staff (Table 6).

Table 6: PTEs performed by Supplier and RTWQ Staff

Fiscal Year	Number of PTEs performed by: RTWQ Staff	Supplier
2011 – 2012	13	0
2012 – 2013	28	15
2013 – 2014	41	6
2014 – 2015	41	8
2015 – 2016	64	4
Total	187	33

The cost savings of performing PTEs in-house are also considerable. At current (2016) prices, each PTE performed by RTWQ staff costs approximately $282 in calibration solutions and consumables for a total of $52734, since 2011/2012. If these PTEs were carried out by the supplier, the total cost would be $98175, for a savings of $45441, since in-house PTEs were implemented.

Conclusions

Due to the number of Hydrolabs in the RTWQ program inventory, careful consideration must be given to the logistics of sending equipment around the province – timing of repairs and lab space are major limitations that impact when various regions should undergo PTE. Because many of the instruments reside in Labrador and are removed from service during the winter to prevent ice damage, the Labrador region is considered the starting point of a PTE season. A limited stock of sensors and a prolonged purchasing process for industry partners means that multiple variables must be considered during the PTE process. This can become very confusing and detailed notes should be kept for each active PTE.

PTEs are a complex process requiring specialized training from the manufacturer. As such, only qualified individuals should endeavor to disassemble a Hydrolab.

Appendix: Related Documents

The following documents should be referenced in relation to usage and operation of materials used in PTEs:

Inventory, Calibration, and Evaluation database (ICED) – M:\STJH\Shared\Env\RTWQ\Performance Testing and Evaluation\Database\ICED-Readme.docx

Hydrolab Datasonde Manual – https://s.campbellsci.com/documents/ca/manuals/series_5_man.pdf