Comparison of Three Turbidity Instruments

DTS-12, YSI, and Hydrolab

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Introduction

- Turbidity monitoring is an integral part of the Real-Time Water Quality Monitoring network. As an important aspect of environmental stewardship and sustainability, many industry partners of the Real-Time program require consistently accurate reporting of turbidity to manage the impact of their projects on water bodies in Newfoundland and Labrador.
- Recently, with increased reliance on reports from the Water Quality program, further investigation of alternate monitoring tools has become important. This report makes a brief investigation into some characteristics of various monitoring options, namely: the DTS-12 (FTS Systems), YSI 6600 (YSI Inc.), and the Hydrolab DS 4a (Hach Hydromet).
- Two questions asked of this report include:
    1. How do the turbidity values compare between the three instruments?
    2. Is there a difference between the turbidity measurements from each instrument?

Method

- Both YSI and Hydrolab turbidity probes share similar range of measurement and accuracy values and similar emission spectrum. Both instruments adhere to ISO 7027 specifying a light source between 830 – 890 nm and a 90^{o} angle between emitted light and detector.
    - It is known that the YSI multi-parameter probe allows for the configuration of data filters and smoothing software to reduce the impact of spurious peaks in data. It is not clear, however, if Hydrolab employs a similar technique. In either case, the settings are not readily available to the user.
- The DTS-12 appears to share similar qualities to other ISO 7027 sensors; however, the emitted near-infrared source is of a different wavelength from the YSI and Hydrolab sensors as a means to avoid interference from sunlight.
    - A unique methodology of the DTS-12 includes 20 Hz sampling over five seconds to generate a dataset of 100 samples. From this dataset, Min, Max, Median, Mean, Variance, and BES (a statistical measure) are provided. Using this dataset, the user has some ability to identify spurious turbidity peaks and reject, if necessary.
- A test station has been established at the end of Fowler's Road near the flow-controlled outlet of Paddy's Pond, near Conception Bay South. Equipped with a Satlink II datalogger and solar power, a single DTS-12, YSI, and Hydrolab multi-probe were connected to the datalogger and set to record on a 15 minute interval from September 8^{th}, 2011 to September 19^{th}, 2011 and then hourly from September 21^{st}, 2011 to October 4^{th}, 2011. Unfortunately, a mistake in logger programming meant that data was lost from the Hydrolab for most of this time – only a week and a half worth of data overlaps between the three instruments.

- From the YSI and Hydrolab multi-probes, only turbidity was recorded while min, max, median, and mean turbidity values were recorded from the DTS-12 sensor.
    - An error in programming resulted in the loss of most turbidity data from the Hydrolab. Only data from September 21 @ 16:00 onwards remained. This imposed using a smaller subset of the DTS-12 and YSI turbidity data in the comparisons of YSI and Hydrolab and DTS-12 and Hydrolab.

Results

How do the turbidity values compare between the three instruments?

- Figures 1 – 3, below depict the turbidity values recorded by each instrument deployed at Paddy's Pond in this trial period. Some differences in the figures are immediately visible, such as the frequency of very high peaks and the apparent baseline of the turbidity data.
    - An immediate difference between the three instruments is the amount of spikes and variation seen in the data. The Hydrolab and DTS-12 instruments tended to show a higher frequency of spikes and peaks compared to the YSI instrument. It is difficult to determine why the YSI instrument differs from the other two; however, the YSI provides documentation on the application of various filtering and data smoothing settings that could result in smoother appearing data.
    - The same turbidity event was observed on September 15th – 16th by both the DTS-12 and YSI turbidity probes. In the case of the DTS-12, the event peaked at 37.55 NTU at 0545. The peak during the same event as recorded by the YSI was 2.80 NTU at 0945.

DTS-12, Hydrolab, and YSI Turbidity Comparison

- Table 1, below, presents a simple comparison between each of the three instruments and a grab sample turbidity value. Only one sample was taken during the study limiting the power of such a comparison. YSI was closest in value to the Grab Sample, followed by Hydrolab and then DTS-12.

Figure 1: Mean turbidity values measured by the DTS-12 sensor at Paddy's Pond

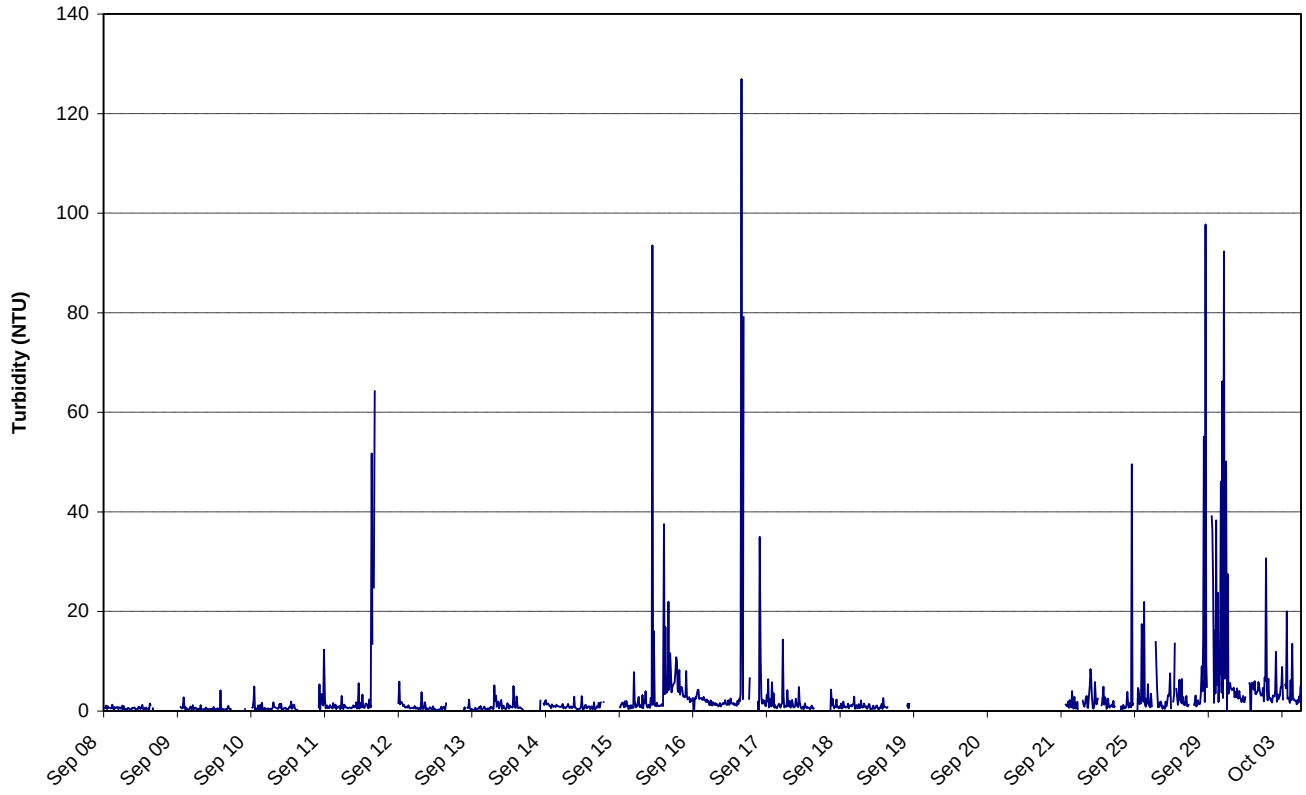


Figure 2: Turbidity values measured by the Hydrolab sensor at Paddy's Pond

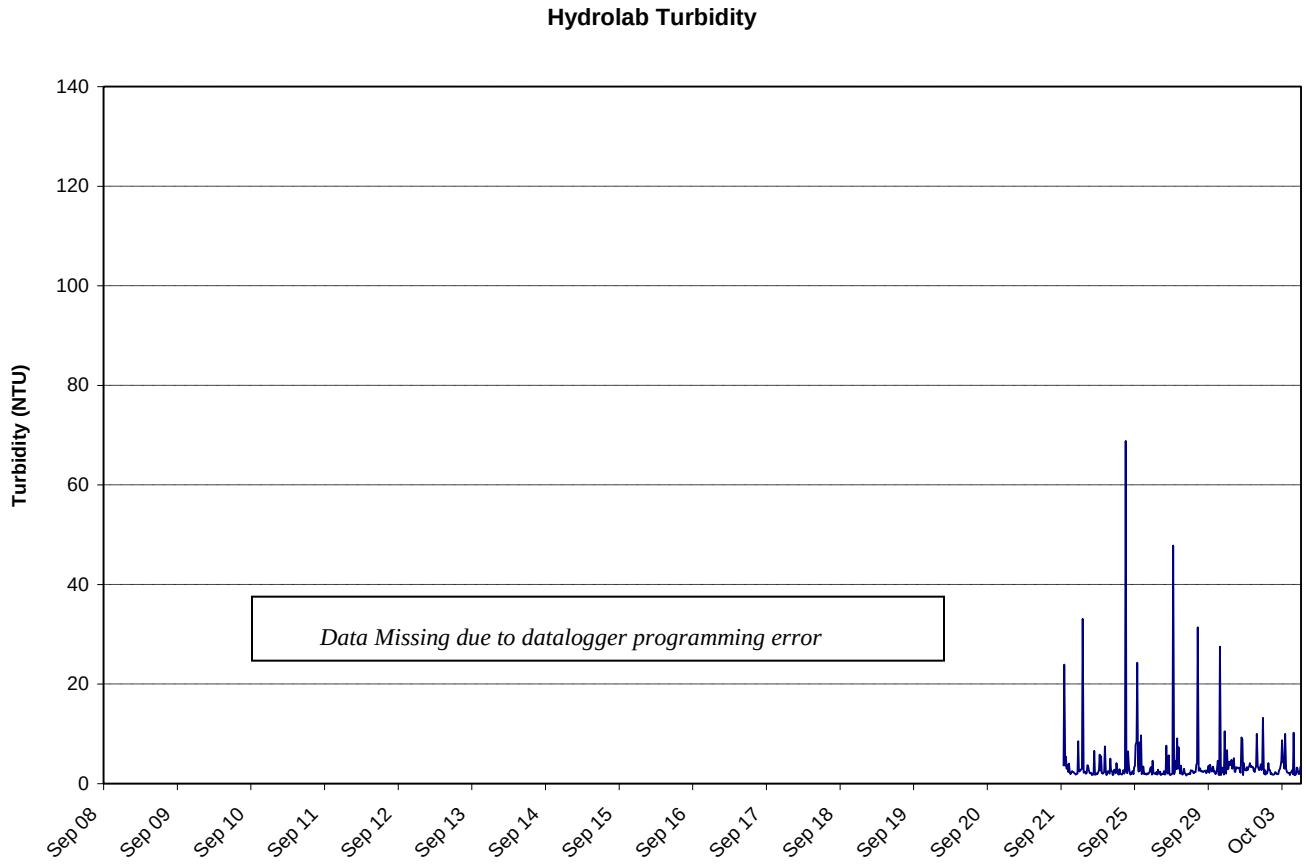


Figure 3: Turbidity values measured by the YSI sensor at Paddy's Pond

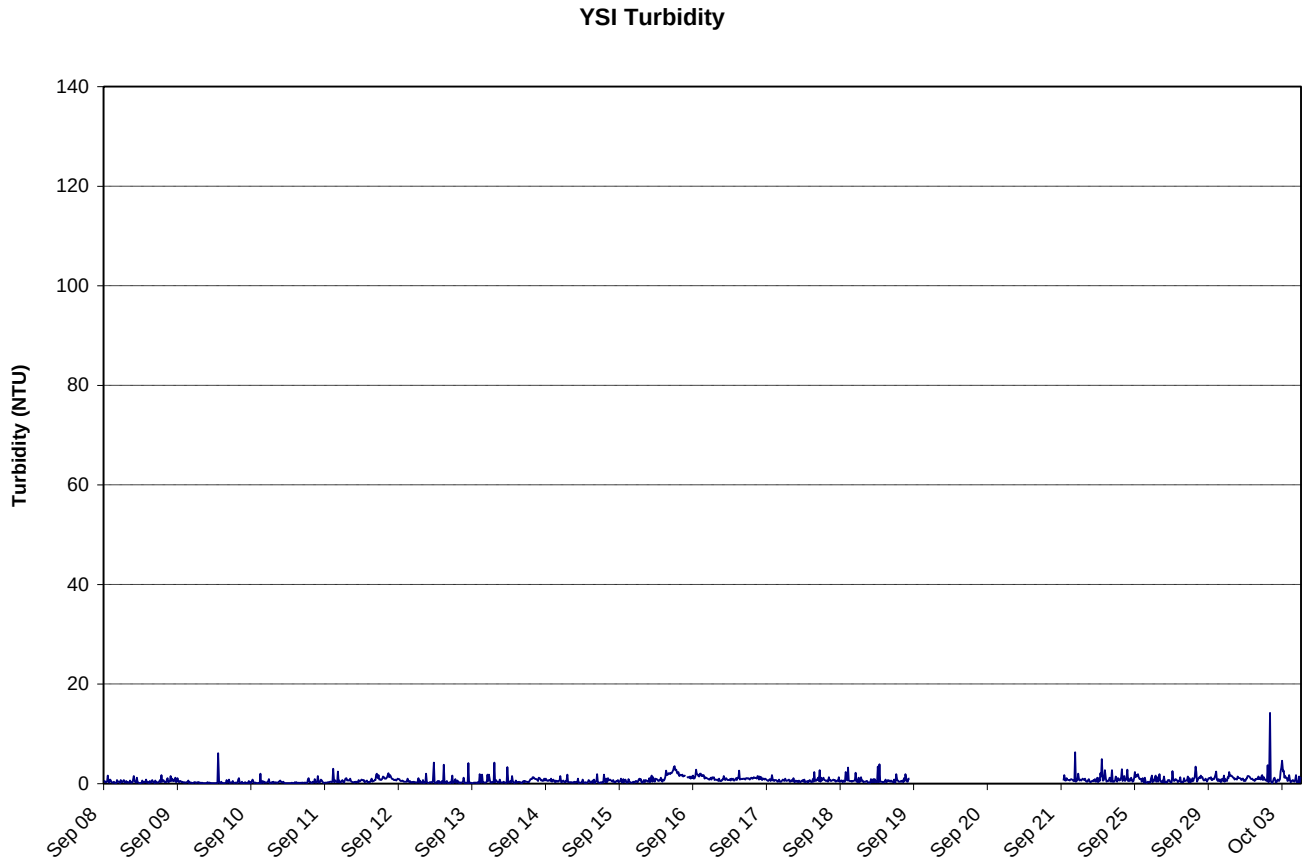


Table 1: Comparison of Grab Sample and Instrument Reading

	Turbidity Value	Instrument-Grab Sample Error
DTS-12	5.13	1.13
YSI	3.5	-0.5
Hydrolab	1.3	-2.7
Grab Sample	4.0	--

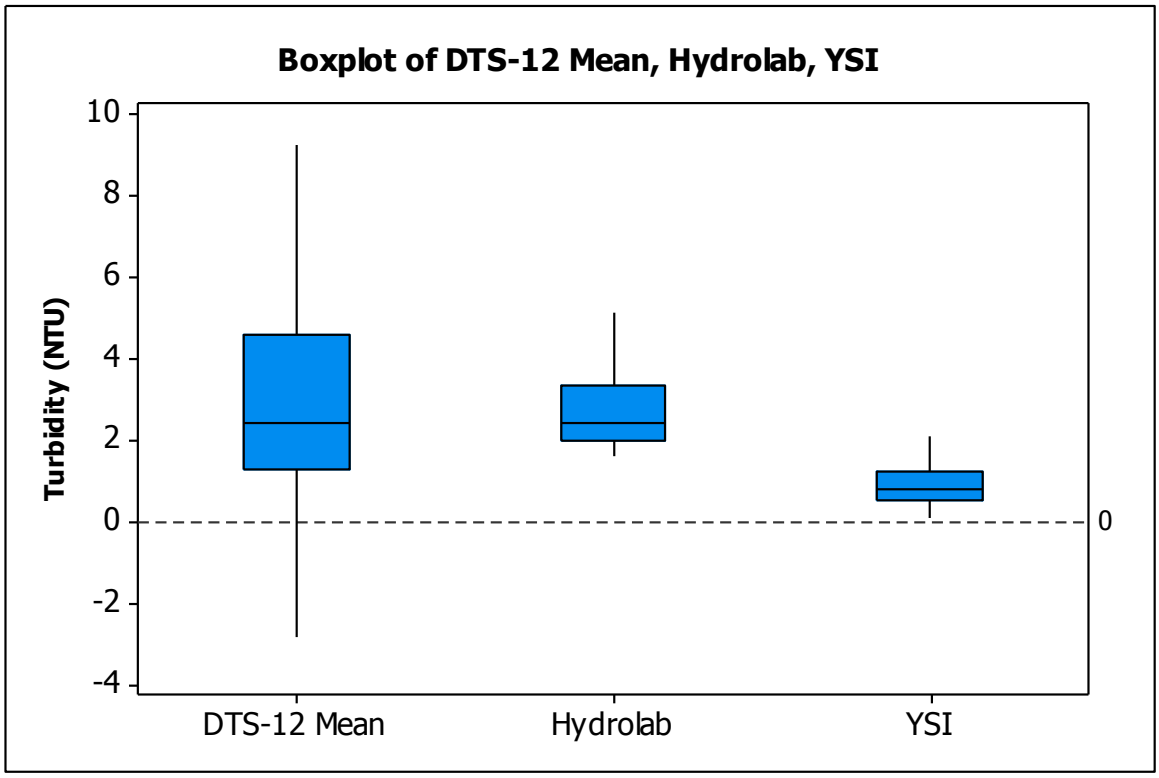
Is there a difference between the turbidity measurements from each instrument?

- It is understood that multiple consecutive measurements of turbidity using the same device will yield a series of values that are close, but differ slightly. Since each individual record is only a point estimator of the actual conditions in a water body at a particular place and time, statistical analysis of some sort is useful in determining a value most representative of actual conditions.
- This point is exacerbated through the use of dissimilar equipment utilizing different analytical techniques. Indeed, even devices that use similar measuring methods may use smoothing software to modify results.

- In this section of the paper, simultaneously recorded turbidity data between the DTS-12, Hydrolab, and YSI instruments are compared to determine if there is a systematic difference between the turbidity readings of each.
    - As Figure 4 implies, there appears to be a difference between the turbidity recordings of each instrument. Immediately, it is seen that the DTS-12 will occasionally produce counterintuitive negative turbidity values while the YSI and Hydrolab distributions are entirely positive values.
    - To determine if there is a significant difference between each of the groups, Mann-Whitney tests were computed for all three pair-wise groups:

1. DTS-12 – Hydrolab
2. DTS-12 – YSI
3. Hydrolab - YSI

Figure 4: Distributions of turbidity recorded by three instruments from September 21st to October 4th



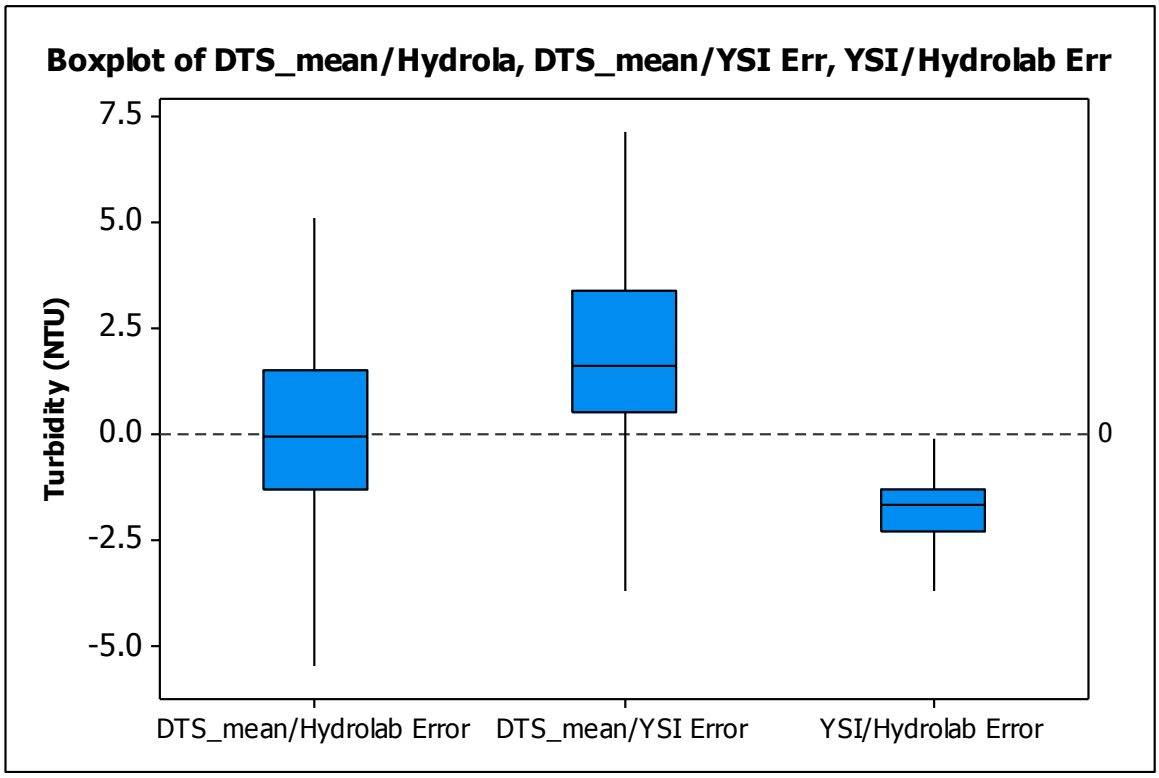
- The result of the three pair-wise Mann-Whitney tests indicates that statistically significant differences were observed between each of the three instruments (See Table 2).

Table 2: Mann-Whitney comparison of instruments

Pair- Wise Comparison	p-Value
DTS-12 – Hydrolab	0.0237
DTS-12 – YSI	0.0000
Hydrolab – YSI	0.0000

- While all three tests are significant at an α of 5%, a slightly larger p-value calculated in the DTS-12 – Hydrolab comparison indicates that the difference is slightly less than between the other instruments. This is observed in Figure 4 where a substantial amount of overlap in the turbidity distributions is seen between DTS-12 and Hydrolab, but less so between the others.
- To further support this distinction, Figure 5 shows boxplots of the error calculated between each of the pair-wise groups. Error is calculated by simply subtracting concurrent values in one group from the other. In this case, the groups are DTS minus Hydrolab, DTS minus YSI, and YSI minus Hydrolab. Boxplots found closer to the 0.0 NTU line indicate that the difference between the group is less substantial than those plots further from the 0.0 NTU line.
    - The DTS-12 – Hydrolab plot neatly straddles the 0.0 NTU line indicating that the two groups are quite similar (through still statistically different).
    - Because the DTS-12 – YSI plot is above the 0.0 NTU line, it is inferred that turbidity recorded by the YSI instrument is less than the DTS-12.
    - Opposite to the plot mentioned above, because Hydrolab turbidity values are generally greater than concurrent YSI values, the error terms are mostly negative resulting in a plot below the 0.0 NTU line.

Figure 5: Pair-wise error between three turbidity sensors from September 21st to October 4th



Conclusions

- In each instrument comparison a difference was found between turbidity readings; notably between the YSI and Hydrolab and YSI and DTS-12. A lesser difference was found between Hydrolab and the DTS-12. As a result, should the DTS-12 be brought into the Real-Time Water Quality Monitoring Prgoram, it should be expected that that the data are close in scope, but not entirely comparable.
- In conversation with HACH Hydromet service personnel in Loveland, CO, a recommendation was made to use 0.7 NTU as the first point of calibration for the Hydrolab turbidity sensor. Anecdotally, this was found to enhance the turbidity probe response in low-turbidity climates reducing the number of 0.0 NTU encountered.