ESTABLISHING A RELATIONSHIP BETWEEN TURBIDITY AND TOTAL SUSPENDED SOLIDS – A Student Project

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Real Time Water Quality Monitoring Workshop
June 7 - 8, 2011
St. John’s, NL
Overview

- Overview of Technical Project
- Purpose & Significance
- Types of Sampling
- CCME Aquatic Guidelines and Regulatory Limits for Turbidity and TSS
- Real Time Water Quality Monitoring
- Site and Basin Description
- Statistical analysis for Turbidity-TSS
- Turbidity-TSS Model (Parametric and Non Parametric)
- Real Time TSS Measurement
- Conclusion and Path Forward
Technical Project

- A three semester technical project for the Advanced Diploma Water Quality Program at the Marine Institute (MI) in partnership with the Water Resources Management Division

- Project Requirement
  - Literature Review - Cost Assessment
  - Field Work - Lab Work (MI)
  - Statistical Analysis - Presentation and Report

- Expert opinion and Lab facility was provided by the Marine Institute to analyze grab samples

- Expert opinion and instrumentation was provided by the Water Resources Management Division to measure turbidity in real time
Purpose

- Determine the relationship between Turbidity and Total Suspended Solids (TSS) for Leary Brook.
- Develop site specific regression model for TSS using Turbidity as a predictor.
- Apply the model to predict TSS in real time.
Significance

- Turbidity is one of the continuously measured parameters under the Real Time Water Quality Monitoring Program in NL.
- TSS is measured monthly through grab sampling.
- Prediction of TSS would be beneficial for the following reasons:
  - In Newfoundland and Labrador there is a regulatory limit for TSS thus aiding in compliance monitoring efforts.
  - Estimation of TSS in real time would save time, effort and cost required for lab analysis.
Types of Sampling

Grab Sampling:
- Provides a snapshot of water quality at the time the sample was taken.

Continuous/Real Time Sampling:
- Provides a clearer picture of water quality over time.
| Turbidity in clear flow for short and long periods | Maximum increase of 8 NTUs from background levels (BL’s) for a short-term exposure (e.g., 24-h period).  
Maximum average increase of 2 NTUs from BL’s for a longer term exposure (e.g., 30-d period). |
| Turbidity in high flow (turbid water) for short and long periods | Maximum increase of 8 NTUs from BL’s at any one time when BL’s are between 8 and 80 NTUs.  
Should not increase more than 10% of BL’s when background is >80 NTUs. |

➢ There is no regulatory limit for turbidity in NL regulations.  
(Environmental Control Water and Sewage Regulations, 2003)
<table>
<thead>
<tr>
<th>TSS in clear flow for short and long periods</th>
<th>Maximum increase of 25 mg/L from background levels (BL’s) for any short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from BL’s for longer term exposures (e.g., inputs lasting between 24 hand 30 d).</th>
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<tbody>
<tr>
<td>TSS in high flow for short and long periods</td>
<td>Maximum increase of 25 mg/L from BL’s at any time when BL’s are between 25 and 250 mg/L Should not increase more than 10% of BL’s when background is &gt;250 mg/L</td>
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</tbody>
</table>

➢ The regulatory limit for TSS is 30 mg/L in NL regulations. (Environmental Control Water and Sewage Regulations, 2003)
Project Site – Leary Brook

- Located in the vicinity of Avalon Mall and Memorial University.
- Runs in parallel with Prince Phillip Drive crossing Thorburn Road.
Leary Brook was the first real time water quality monitoring station established in 2001.
Leary Brook Basin Description

- Leary Brook basin is located next to Health Sciences Complex, Avalon Mall and most of The O'Leary Industrial Park.
Leary Brook Basin Description

- Business facilities including construction and engineering, electrical power, materials handling, manufacturing, wholesale and retail industry for food & beverage, recycling, transport and storage, oil and gas facilities are located in these areas.
Turbidity Measurement Using Field Sonde
TSS Measurement Using Grab Samples
Real Time Monitoring Network

Normal Transmission is generally every hour

Real-Time Monitoring Station

National Environmental Satellite Data Information System (NESDIS).
Operated by NOAA in Maryland, USA.

New Graphs every 3 hours

Users access using Web Browser to view graphs
Leary Brook Real Time Data

<table>
<thead>
<tr>
<th>STAT_NUM</th>
<th>WSC_NUM</th>
<th>YMD</th>
<th>NUM</th>
<th>WATER_TEMP</th>
<th>WAT (C)</th>
<th>Turbidity (NTU)</th>
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<tbody>
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<td>1.84</td>
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</table>
Leary Brook Timeline

- Timeline for the sampling period:
  January – May 2011
- Obtained from Leary Brook Webcam
1. Filter (pore size = 1µm) is soaked in distilled water and dried at 103 °C. Weights are read and recorded.

2. The filter is placed in a filtering flask.

3. The sample bottle is shaken and poured into the funnel.
4. The filter is dried at 103° - 105°C, cooled at room temperature and re-weighed.

5. TSS is calculated using the following:

\[
\frac{(A - B) \times 1000}{C}
\]

Where
A = End weight of the filter
B = Beginning weight of the filter
C = Volume of water
Regression Model

Turbidity Data - Turbidity Sensor

Measured at the same time

Regression Analysis

TSS Data - Lab Sampling

Turbidity - TSS Regression Model
Statistical Analysis

- 23 TSS samples (in triplets).
- Average TSS using triplicate samples.
- Average turbidity for corresponding TSS samples.
- Anderson Darling (Normality test), Box Plot (Outlier test) and Scatter Plot for all data.
- Log Transformation of sample values.
- Model TSS using Ordinary Least Square regression and Kendall Theil Robust Line.
### Normality and Outlier check for Turbidity and TSS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AD Normality Test</th>
<th>Box-Plot (Outlier Detection)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal/Non Normal</td>
<td>P-value</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Non Normal</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>TSS</td>
<td>Non Normal</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Log (10 *Turb)</td>
<td>Normal</td>
<td>0.295</td>
</tr>
<tr>
<td>Log (10 * TSS)</td>
<td>Normal</td>
<td>0.884</td>
</tr>
</tbody>
</table>
Scatter plot for original and log transformed Turbidity-TSS

Scatterplot of AvgTSS vs AvgTurb

Scatterplot of logAvgTSS10 vs logAvgTurb10
**Ordinary Least Square Regression Model (Original Data)**

<table>
<thead>
<tr>
<th>Computed Variable</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.23 – 75.17</td>
</tr>
<tr>
<td>Regression Model</td>
<td>AvgTSS = 0.943 + 0.385 *AvgTurb</td>
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<tr>
<td>R-Sq(adj)</td>
<td>93.7%</td>
</tr>
<tr>
<td>P-value</td>
<td>0.000</td>
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<tr>
<td>Standard Deviation</td>
<td>4.15799</td>
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<tr>
<td>No. of Samples</td>
<td>23</td>
</tr>
</tbody>
</table>
Residual for original values were non normal and hence violates the assumption for regression model.
### Ordinary Least Square Regression Model (Log Transform)

<table>
<thead>
<tr>
<th>Computed Variable</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.37–3.24</td>
</tr>
<tr>
<td>Regression Model</td>
<td>$\text{AvgTSS} = \left[10^{0.16 + 0.775 \times \log (10 \times \text{AvgTurb})}\right]/10$</td>
</tr>
<tr>
<td>R-Sq(adj)</td>
<td>74.1%</td>
</tr>
<tr>
<td>P-value</td>
<td>0.000</td>
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<tr>
<td>Standard Deviation</td>
<td>0.325</td>
</tr>
<tr>
<td>No. of Samples</td>
<td>23</td>
</tr>
</tbody>
</table>
Residual for log transformed values were normal and hence fits assumption for regression model.
Real Time Graph for TSS and comparison to grab samples (OLS)

Real Time TSS (Parametric)

TSS (mg/L)

- TSS Predicted
- TSS Grab
- Discharge Limit

Time:
- January 15th
- February 7th
- February 13th
- February 20th
- March 3rd
- March 15th
- April 6th
- April 14th
- April 20th
- April 26th
- May 4th
- May 15th
# Kendall Theil Robust Line (Non Parametric)

<table>
<thead>
<tr>
<th>Computed Variable</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.23 – 75.17</td>
</tr>
<tr>
<td><strong>Kendall Theil Line</strong></td>
<td>*<em>AvgTSS = 2.412 + 0.3564 <em>AvgTurb</em></em></td>
</tr>
<tr>
<td>Median Deviation</td>
<td>-1.7123</td>
</tr>
<tr>
<td>Median Absolute Deviation</td>
<td>2.3014</td>
</tr>
<tr>
<td>Root Mean Square Error</td>
<td>4.424</td>
</tr>
<tr>
<td>Confidence Interval (95%)</td>
<td>0.2636 – 0.4396</td>
</tr>
</tbody>
</table>
Real Time Graph for TSS and comparison to grab samples (KTRL)

Real Time TSS (Non Parametric)

- **TSS Predicted**
- **TSS Grab**
- **Discharge Limit**

TSS (mg/L)
Conclusion

- Increased variation in sample measurement provides a clearer picture of sample matrix and leads to a better model.
- Enable industry partners to meet regulatory limits using real-time TSS estimates.
- TSS can be predicted in real time using turbidity as an indicator parameter.
Path Forward

- Estimation of Turbidity-TSS models at select industry stations (using TSS grab sample data from accredited laboratory).
- Estimation of ionic concentration using specific conductance as a predictor.
- Model for less than detection limit values.
- Site specific Real Time Water Quality Index Calculator using surrogate parameter measurement.
QUESTIONS

Don’t forget the Web Camera is back there...

...make it look like we are working hard!
• Marine Institute:
  – Rob Trenholm, Mary Pippy, Geoff Whiteway

• Water Resources Management Division:
  – Renee Paterson, Keith Abbott, Tara Clinton, Ryan Pugh, Kyla Brake, Leona Hyde