Evaluation of “Paired” Turbidity Measurements from Selected North Shore Streams Using Different Turbidimeters

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Background

Turbidity is a parameter that has a significant amount of variability associated with the measurement values reported. Unlike many water quality parameters which are a measurement of mass of constituents in a volume of water, turbidity is a measure of the optical properties of a water sample which causes light to be scattered and absorbed (Federal Water Pollution Control Administration, 1968). The optical properties are affected by the biological, physical and chemical components in the water. Differences in the constituents' response to light contribute to this variability. Adding to this variability, differences between turbidity meter types can result in different turbidity values being measured for the same water samples. The USGS and others have published papers documenting the variation in turbidity measurements that can occur due to different sensor configurations, detector angle, and light wavelength used (Pavelich 2002, Ankcorn 2003, Anderson 2005). While the manufactured meters comply with standard method requirements of the EPA, different results may occur when using different types of turbidity meters and sensors. The variation occurs across different manufacturing company sensors and even within different generations of the same model sensor within a company. To address this issue, the United States Geological Survey (USGS) developed a reporting unit/category system to distinguish between the different sensor groups (Miller 2004, Anderson 2005).

Differences in turbidity values between meters have been observed in Minnesota through various monitoring efforts. Descriptions of these differences are present in the Minnesota Pollution Control Agency (MPCA) Turbidity TMDL Protocol (MPCA 2007) and in an appendix to the Pipestone Creek Turbidity TMDL (MPCA 2008, submitted to EPA for approval). The appendix, titled "Evaluation of "Paired" Turbidity Measurements from Two Turbidimeters for Use in Two TMDL Projects", documents the difference in turbidity values in paired samples from two lab turbidimeters and provides a "conversion factor" for use in estimating NTU values from measured NTRU values.

Methods

A small sampling effort was initiated in October 2007 with the onset of significant precipitation and resulting runoff and increases in stream flows to compare turbidity values measured using different meters and/or meter configurations. The comparison was made to determine if there is a statistically significant difference between turbidity values from the meters/meter configurations based on the USGS turbidity reporting categories. Most of the recent turbidity data has been measured as NTRUs and NTUs, with field measurements being made as FNUs.

Much of the Poplar River turbidity data is in the form of NTRUs as measured by a Hach 2100 AN with the ratio mode "On" by the MDH Lab. This meter is set to measure turbidity utilizing a single white light source and two (multiple) light detectors. One detector is located at 90 degrees to the light source and the second light detector is located at a wider angle with a “ratio” compensation being made between the two (J. Klang, personal communication, 2006). The USGS unit reporting category for this meter is NTRU. Most of the Knife River data is in the form of NTUs as measured by a Hach 2100 AN with the ratio mode "Off" by Era Labs (B. Magnuson, personal communication, 2007). This meter is set to measure turbidity utilizing a single white light source and a single light detector located at 90 degrees to the light source. The USGS unit reporting category for this meter is NTU. Field measurements have been made with YSI sondes and a Hydrolab sonde providing turbidity measurements as FNUs (Miller 2004, Anderson 2005).

A HF Scientific Micro 100 turbidimeter was also used by the MDH Lab in measuring turbidity for this comparison of turbidity reporting units. The configuration of the Micro 100 includes a single light source and single light detector at 90 degrees to the light source providing turbidity measurements as NTU values (HF Scientific 2004).

The Data

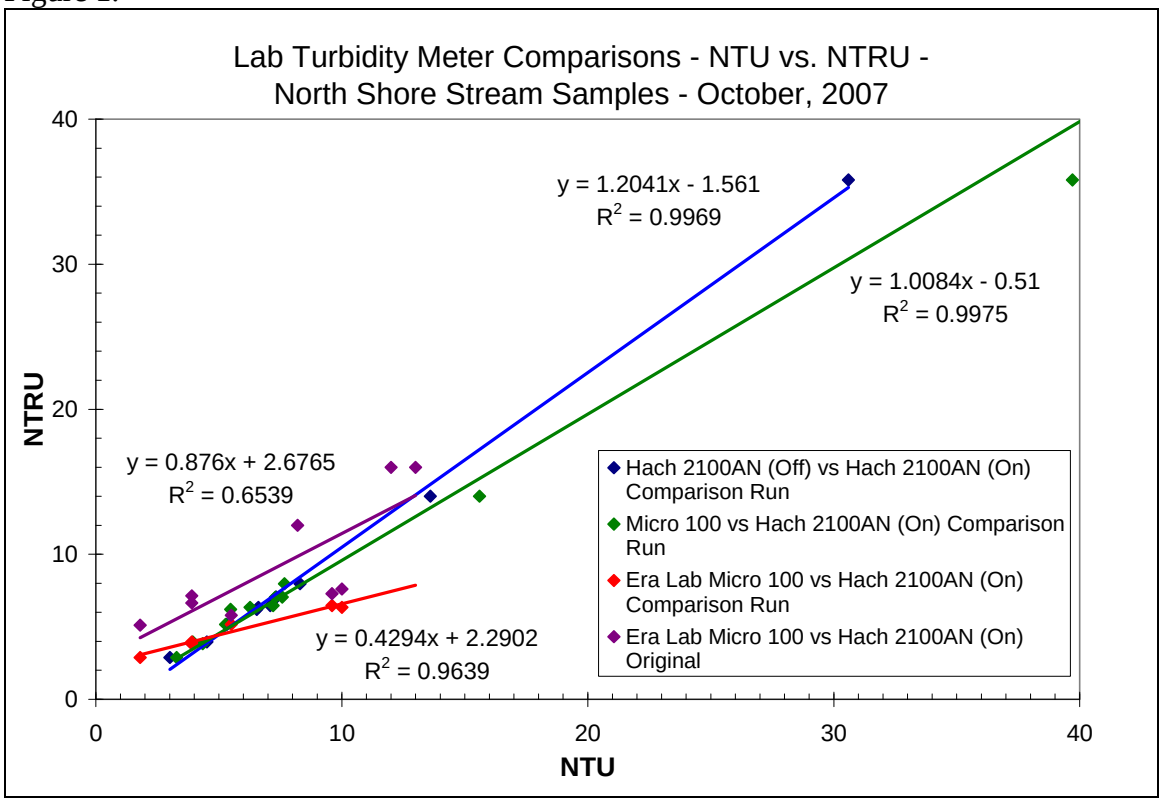
"Paired" sets of turbidity measurements were completed from 21 water samples from monitoring sites on the Poplar River, Knife River, Brule River, Talmadge River, Sucker River, French River, and Amity Creek. Turbidity measurements were made at the MDH and Era Labs. The MDH Lab measures turbidity using a Hach 2100AN turbidimeter with the ratio mode "On" which results in turbidity values of NTRU. The Era Lab uses a Hach 2100AN turbidimeter with the ratio mode "Off" which in turbidity values of NTU. The MDH Lab then re-ran the water samples they received with the Hach 2100AN turbidimeter with the ratio mode "On", the Hach 2100AN turbidimeter with the ratio mode "Off", and a HF Scientific Micro 100 which provides turbidity measurements as NTU. Field measurements of turbidity were also made providing measurements of FNU. The data is included at the end of this document.

Data Analysis

Plots of the various "pairs" of data were made to check for visual relationships and linear "trendlines" were plotted on the charts using Excel (Figure 1). Some "pairs" showed

relatively strong linear relationships that appeared close to a one-to-one ratio. Others showed greater variability and "poorer" fits. Statistical analysis of the data was then completed with Minitab and checked with an on-line statistical analysis package (http://faculty.vassar.edu/lowry/VassarStats.html) provided by Vassar College (R. Lowry, accessed 1/11/08).

Figure 1.



With a null hypothesis that the "paired" measurements are not significantly different, a paired t-test was initially run in Minitab for the two NTRU measurements (original lab run and run when other methods were used) indicating that the two were not significantly different at p=0.05. However, the data had not been checked for normality. In lieu of doing so and likely having to log-transform the data, the nonparametric Mann-Whitney test in Minitab was used to check for a significant difference in the median of each set of measurements. No significant difference was found between any pairing of the data sets. The Wilcoxon signed rank test in VassarStats was then used to parallel the use of the parametric paired t-test. Again, no significant difference was found between any pairing of the data sets.

Conclusions

The various data analysis methods used indicate that there is no significant difference between the individual pairings of the various lab turbidity measurements made in this sampling and turbidity measurement effort. The "strongest" test of this (without checking the raw data for a normal distribution and using a paired t-test) is the Wilcoxon

signed rank test. The specific "pairings" of lab measurements tested with the test results are:

	W	**$n_{s/r}$**	**Z**	**P(2-tail)**
1) NTRU-original, NTRU-comparison	50	16	1.28	0.2005
2) NTRU-comparison, NTU-MDH	-36	12	-1.39	0.1645
3) NTRU-comparison, NTU-Micro	-30	16	-0.76	0.4473
4) NTRU-original, NTU-Era	35	9	n/a	>=0.05
5) NTRU-original, FNU-Field	88	21	1.52	0.1285
6) NTU-Era, FNU-Field	-9	9		<0.05

The Wilcoxon signed rank test for the MDH Lab NTRU and the field turbidities as FNU also showed no significant difference between the values, but it indicated a significant difference between the Era NTUs and the Field FNUs; however, there were 3 field measurements that were much different than any of the coincident lab measurements suggesting that there may have been a problem with the field meter that day.

Based on this data set and statistical analyses, the turbidity values reported as NTRUs by the MDH Lab can be considered equivalent to NTU values for the Poplar River TMDL study. Additional paired measurements should be made to check this in subsequent monitoring of North Shore streams if turbidity has been or is measured as NTRU.

References

Anderson, C.W., September 2005, Turbidity (version 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.7, accessed Dec. 13, 2007 from http://pubs.water.usgs.gov/twri9A6/.

Ankcorn, P.D. 2003. Clarifying Turbidity – The Potential and Limitations of Turbidity as a Surrogate for Water-Quality Monitoring. Proceedings of the 2003 Georgia Water Resources Conference, held April 23–24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

HF Scientific, Inc. 2004. Owner's Manual – HF Micro 100 Laboratory Turbidimeter. Catalog No. 22155 (12/04). Rev. 2.8. Accessed January 14, 2008 at http://www.hfscientific.com/PDF%20-%20Manuals/Micro%20100/MICRO%20100%20Manual.pdf.

Lowry, R. Undated. VassarStats: Web Site for Statistical Computation. http://faculty.vassar.edu/lowry/VassarStats.html. Accessed January 14, 2008.

Miller, T.L. 2004. Revision of National Field Manual Chapter 6, Section 6.7--USGS Water-Quality Technical Memorandum 2004.03
http://water.usgs.gov/admin/memo/QW/qw04.03.html

MPCA. 2007. Turbidity TMDL Protocols and Submittal Requirements. Accessed December 13, 2007 at http://www.pca.state.mn.us/publications/wq-iw1-07.pdf.

MPCA. 2008. Pipestone Creek Fecal Coliform Bacteria and Turbidity Total Maximum Daily Load Report. Submitted to EPA for approval.

Pavelich, P. 2002. Turbidity Studies at the National Water Quality Laboratory. Proceedings of the Federal Interagency Workshop on Turbidity and other Sediment Surrogates, April 30-May 2, 2002, Reno, Nevada. J.R. Gray and G.D. Glysson, editors. U.S. Geological Survey Circular 1250. [http://pubs.water.usgs.gov/circ1250]

"Paired" Turbidity Measurements from Selected North Shore Streams

MDH and Era Laboratories Analytical Data and MPCA and Cook SWCD Field Measurements

All samples were collected during October, 2007

Site Name	Date Collected	Field Turbidity (FNU)	Hach 2100 AN (On) (Original)	Hach 2100 AN (On) (Comp)	Hach 2100 AN (Off)	MDH Micro 100	Era Hach 2100 AN (Off)
Sucker	10/8/2007	60	67.6	71.3		72.3	
Talmadge	10/8/2007	35	37.9	35.8	30.6	39.7	
Amity	10/8/2007	62	74.4	82.5		79.5	
French	10/8/2007	56	55.7	67.9		67.8	
Brule	10/3/2007	12	13.9	14.0	13.6	15.6	
Poplar-Up	10/3/2007	4.9	5.79	5.17	5.32	5.27	5.5
French	10/3/2007	8	8.19	7.04	7.34	7.3	
Amity	10/3/2007	9.4	8.33	7.97	8.3	7.67	
Poplar-Dn	10/3/2007	6.6	7.61	6.34	6.61	6.27	10.0
Poplar-GC	10/3/2007	7.5	7.28	6.46	7.09	7.21	9.6
Sucker	10/3/2007	7.9	8.97	7.05	7.32	7.58	
Talmadge	10/3/2007	6.4	6.58	6.2	6.54	5.48	
Poplar-Up	10/17/2007	30.7	5.12	2.88	3.01	3.28	1.8
Poplar-Dn	10/17/2007	41	7.13	3.96	4.52	3.94	3.9
Poplar-GC	10/17/2007	54.5	6.64	3.83	3.92	4.34	3.9
Knife	10/18/2007	38.5	366	346	NA	280	
Brule	10/9/2007	3.2	7.1				
Poplar-Up	10/9/2007	9.3	12				8.2
Knife	10/9/2007	38	43				
Poplar-Dn	10/9/2007	10.5	16				13.0

Poplar-GC	10/9/2007	11.1	16				12.0
STD 1.46			1.42	1.26	1.80	1.82	