Appendix 14. Field Comparison between YSI EXO and YSI 6136 Turbidity Sensors at Neosho River at Neosho Rapids, Kansas (U.S. Geological Survey [USGS] Station Number 07182390), April 4 to May 9, 2017

Comparison Description

Station name: Neosho River at Neosho Rapids, Kansas (U.S. Geological Survey [USGS] station number 07182390).

Equipment: A Yellow Springs Instrument (YSI) EXO water-quality monitor equipped with a YSI EXO turbidity sensor and a YSI 6 series equipped with a YSI 6136 turbidity sensor were deployed at the site for comparison between the sensors. The monitors were set to log data every 15 minutes. The monitors were suspended in the stream in pipes that were attached to each other. No datum corrections were applied to either dataset. The YSI 6136 turbidity had a malfunction so all data was deleted from April 12 to April 30, 2017.

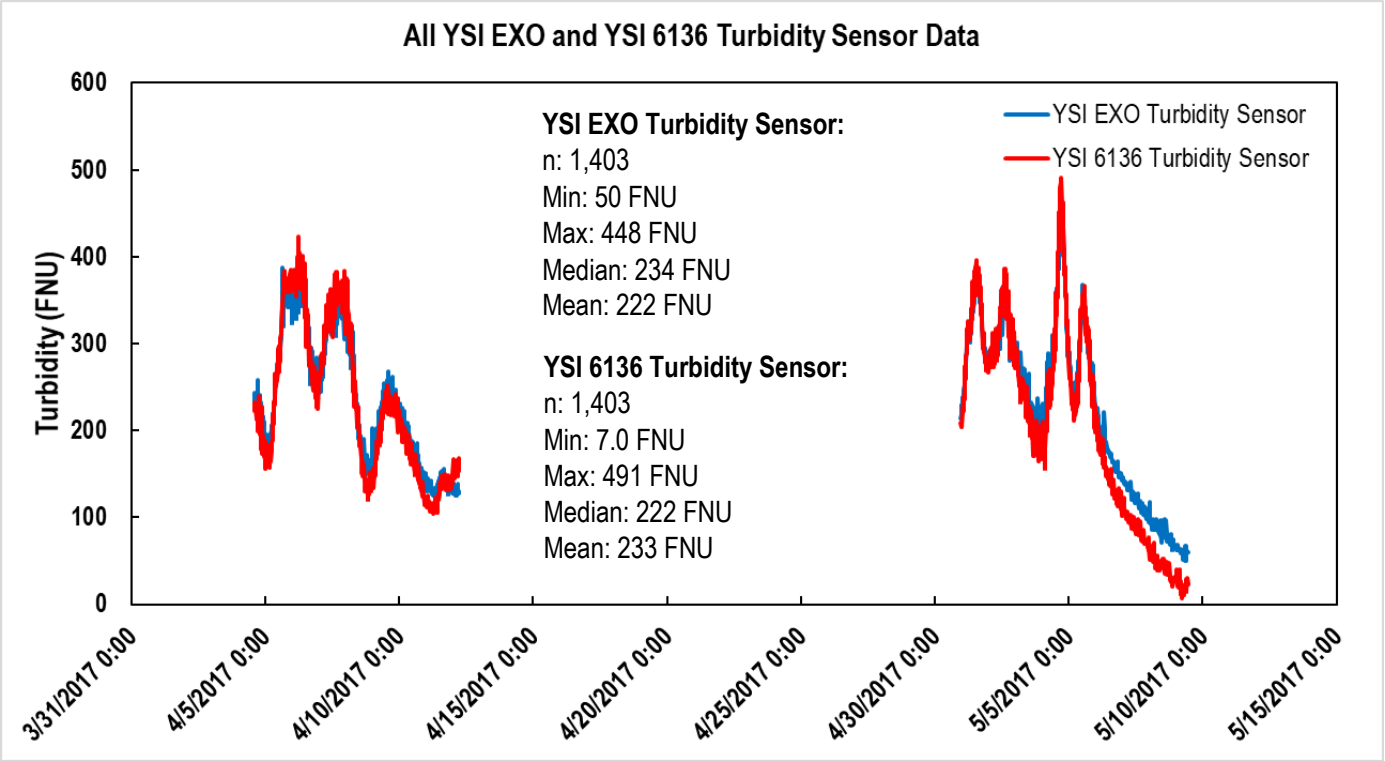
Calibration standard used: Hach StablCal standard

Side-by-side comparison data period: April 4 to May 9, 2017.

Datasets

All data were collected using USGS protocols (U.S. Geological Survey, variously dated) and are published in King (2021). Data were analyzed in three ways: (1) the entire dataset (0–1,000 formazin nephelometric units [FNU]) with only clearly erroneous data edited out, (2) 0–99 FNU with the rising limbs removed, and (3) 100–1,000 FNU with the rising limbs removed. Rising limbs were removed (on the basis of visual inspection, when the hydrograph became vertical to near vertical) to eliminate the effect of the highly variable turbidity readings commonly observed during this part of the hydrograph.

Time Series



Statistical Analyses – All Data

Slope comparison

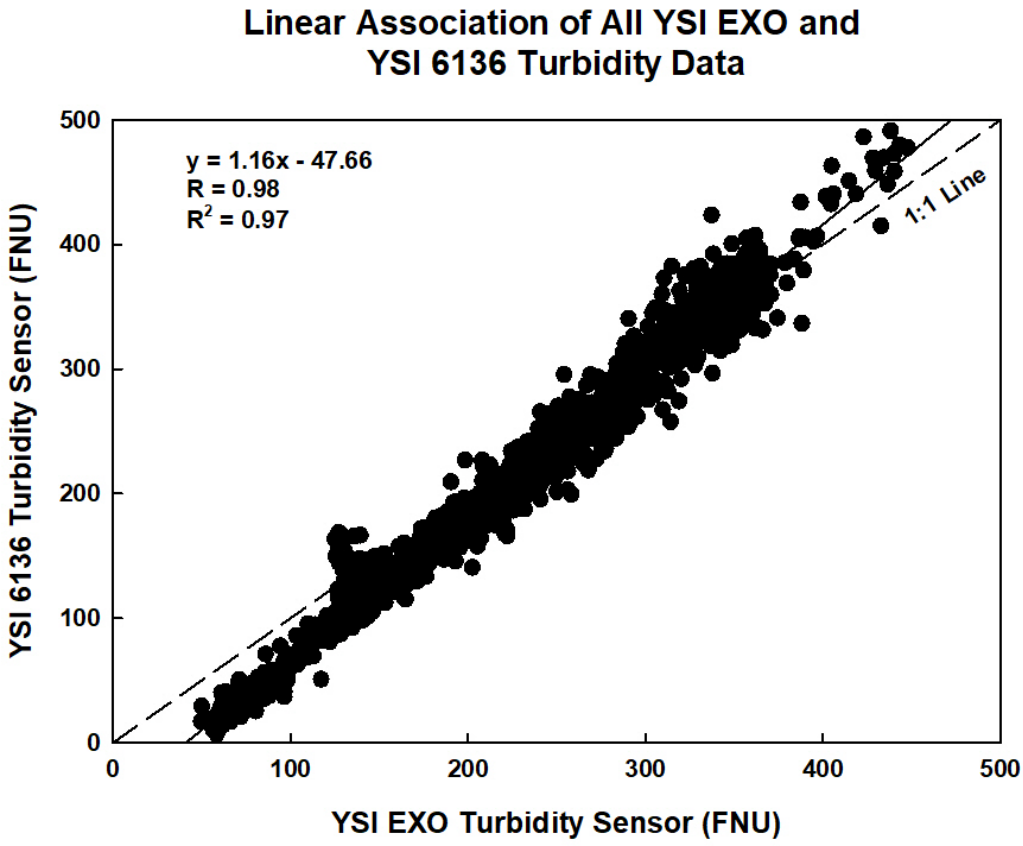
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor and a YSI 6136 turbidity sensor at Neosho River at Neosho Rapids, Kansas, April 4 to May 9, 2017.

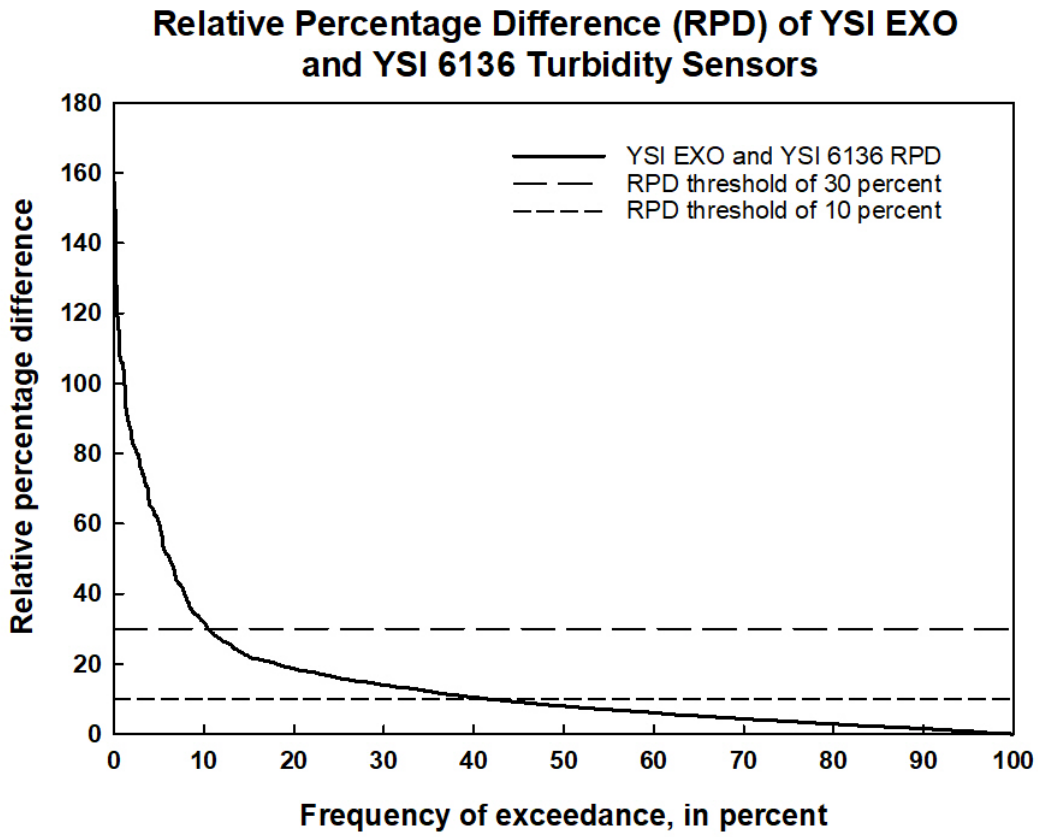
$$y = 1.16x - 47.66$$

where

y = turbidity measured with YSI 6136 turbidity sensor (FNU)

x = turbidity measured with YSI EXO turbidity sensor (FNU).


Linear Association of All YSI EXO and YSI 6136 Turbidity Data
y = 1.16x - 47.66
R = 0.98
R2 = 0.97
1:1 Line
YSI 6136 Turbidity Sensor (FNU)
YSI EXO Turbidity Sensor (FNU)
0
100
200
300
400
500



Wilcoxon Signed-Rank Test for All Data

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed (P < 0.050)

Group	N	Missing	Median	25%	75%
YSI EXO	1403	0	233.500	162.300	301.500
YSI 6136	1403	0	221.600	144.000	304.500

W= -510650.000 T+ = 235725.500 T-= -746375.500

Z-Statistic (based on positive ranks) = -16.858

(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  YSI 6136 and YSI EXO
V = 235725.5, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 -12.99998 -10.55009
sample estimates:
(pseudo)median
     -11.79998
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 0.98). Ten percent of the time, the relative percentage difference in turbidity values measured with the two sensors was greater than 30 percent. The data did not pass the Shapiro-Wilk test for normality (P<0.05); therefore, a Wilcoxon signed-rank test was performed. The difference between median values for the YSI EXO and YSI 6136 turbidity sensors was statistically significant (P<0.05).

Statistical Analyses - Low-Turbidity Conditions (0 to 99 FNU)

The data from the side-by-side comparison were separated into low- and high-turbidity conditions. These statistical analyses are for low-turbidity conditions between 0 and 99 FNU.

Slope comparison

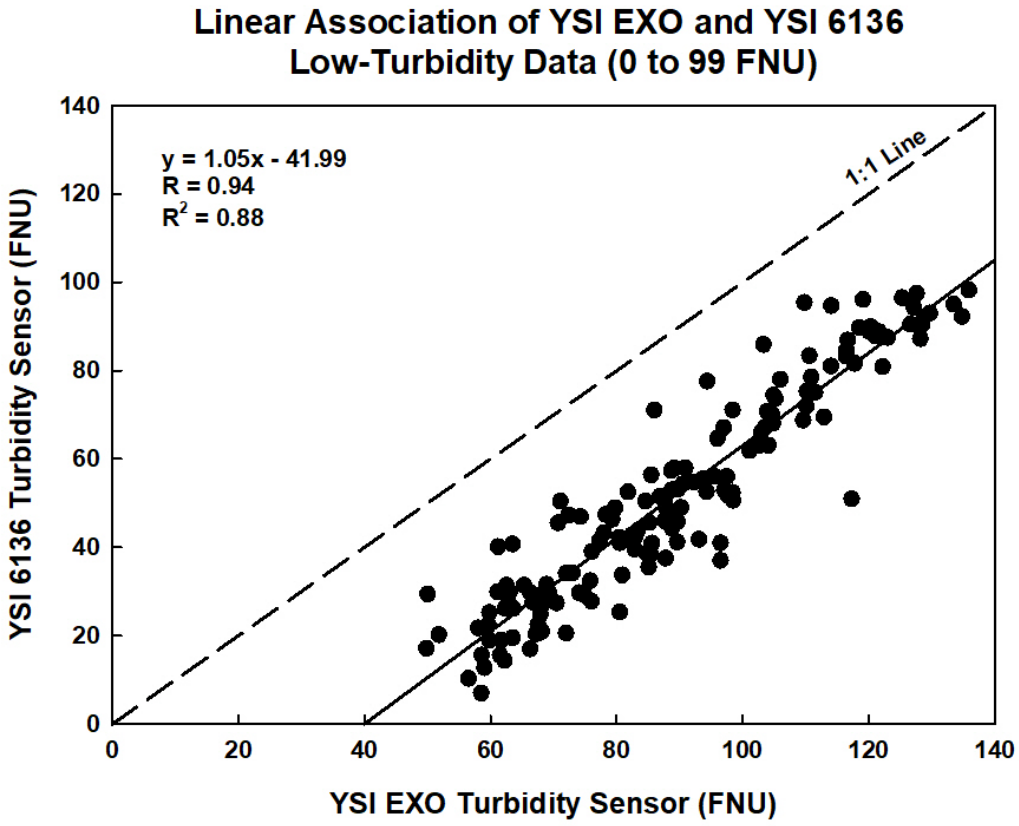
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor and a YSI 6136 turbidity sensor at low-turbidity conditions (0 to 99 FNU) at Neosho River at Neosho Rapids, Kansas, April 4 to May 9, 2017.

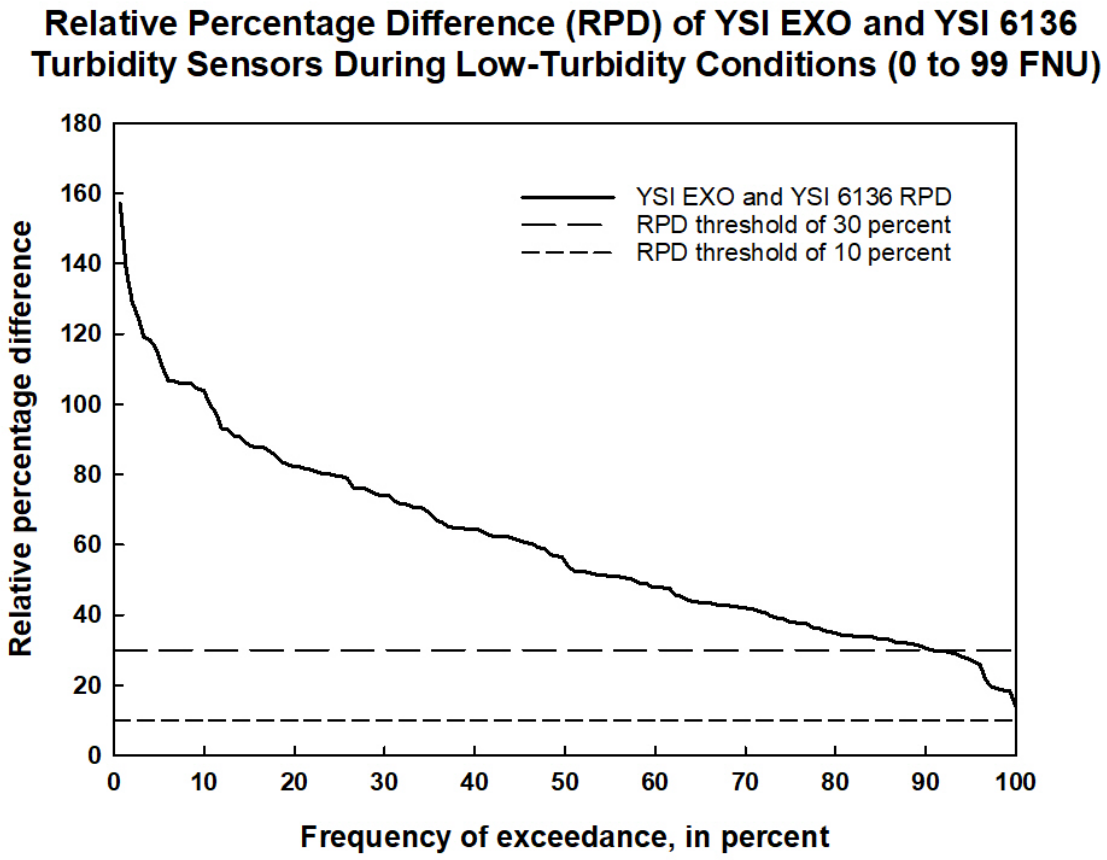
$$y = 1.05x - 41.99$$

where

y = turbidity measured with YSI 6136 turbidity sensor (FNU)

x = turbidity measured with YSI EXO turbidity sensor (FNU).


Linear Association of YSI EXO and YSI 6136
Low-Turbidity Data (0 to 99 FNU)
y = 1.05x - 41.99
R = 0.94
R2 = 0.88
1:1 Line
YSI 6136 Turbidity Sensor (FNU)
YSI EXO Turbidity Sensor (FNU)
0
20
40
60
80
100
120
140



Paired t-test for Low-Turbidity Data

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Passed (P = 0.134)

Paired t-test:

Treatment Name	N	Missing	Mean	Std Dev	SEM
YSI EXO	151	0	89.554	21.868	1.780
YSI 6136	151	0	52.063	24.454	1.990
Difference	151	0	37.491	8.467	0.689

t = 54.410 with 150 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: 36.129 to 38.852

Two-tailed P-value = 1.172E-100

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change (P = <0.001)

One-tailed P-value = 5.859E-101

The sample mean of treatment YSI EXO exceeds the sample mean of treatment YSI 6136 by an amount that is greater than would be expected by chance, rejecting the hypothesis that the population mean of treatment YSI 6136 is greater than or equal to the population mean of treatment YSI EXO. (P = <0.001)

Power of performed two-tailed test with alpha = 0.050: 1.000

Power of performed one-tailed test with alpha = 0.050: 1.000

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 0.94). Ninety percent of the time, the relative percentage difference in turbidity values measured with the two sensors was greater than 30 percent. The data passed the Shapiro-Wilk test for normality (P=0.134); therefore, a paired t-test was performed instead of the Wilcoxon Signed-Rank Test; the difference between mean values for the YSI EXO and YSI 6136 turbidity sensors was statistically significant (P<0.05).

Statistical Analyses - High-Turbidity Conditions (100 to 1,000 FNU)

The data from the side-by-side comparison were separated into low- and high-turbidity conditions. These statistical analyses are for high-turbidity conditions between 100 and 1,000 FNU.

Slope comparison

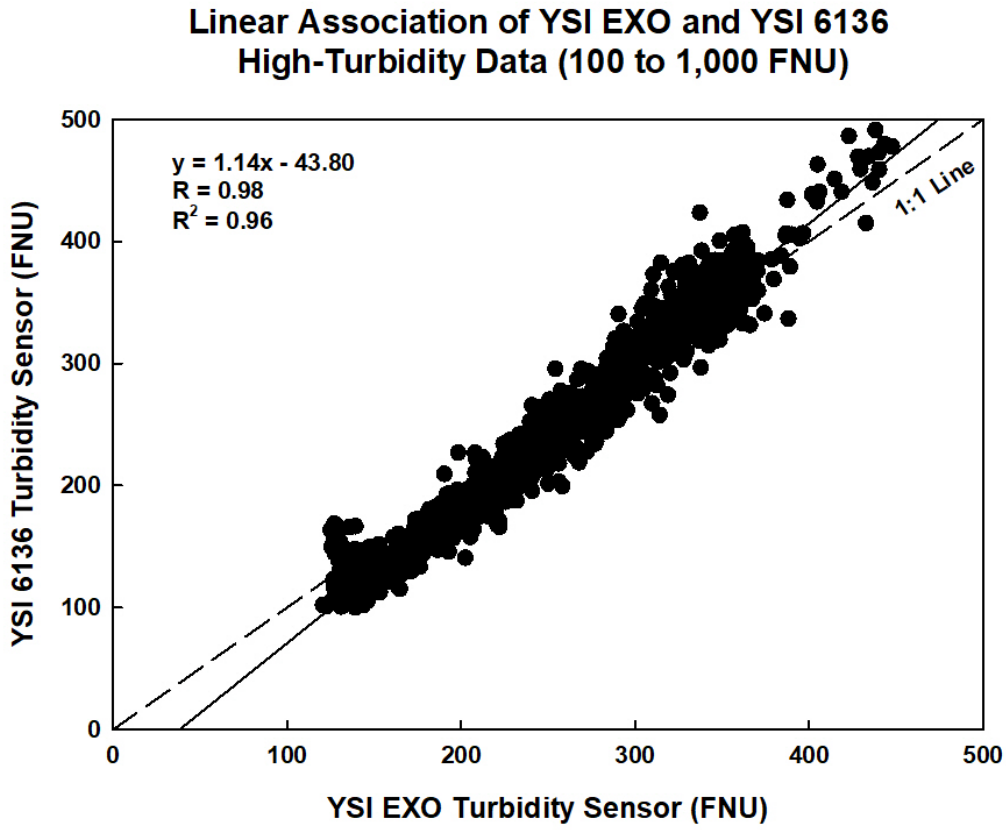
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor and a YSI 6136 turbidity sensor at high-turbidity conditions (100 to 1,000 FNU) at Neosho River at Neosho Rapids, Kansas, April 4 to May 9, 2017.

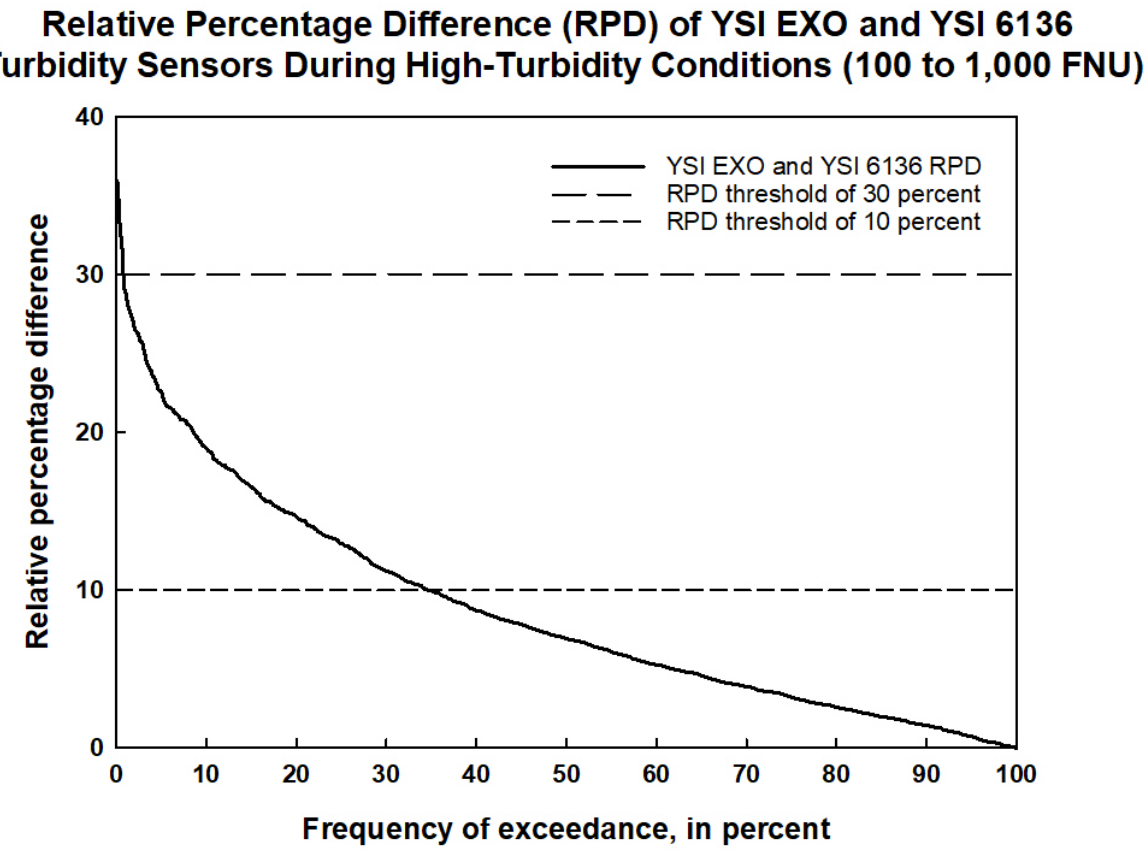
$$y = 1.14x - 43.80$$

where

y = turbidity measured with YSI 6136 turbidity sensor (FNU)

x = turbidity measured with YSI EXO turbidity sensor (FNU).


Linear Association of YSI EXO and YSI 6136
High-Turbidity Data (100 to 1,000 FNU)
y = 1.14x - 43.80
R = 0.98
R2 = 0.96
1:1 Line
YSI 6136 Turbidity Sensor (FNU)
YSI EXO Turbidity Sensor (FNU)
0
100
200
300
400
500



Wilcoxon Signed-Rank Test for High-Turbidity Data

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed (P < 0.050)

Group	N	Missing	Median	25%	75%
YSI EXO	1252	0	246.950	191.625	309.875
YSI 6136	1252	0	232.850	169.525	313.425

W= -323836.000 T+ = 229019.500 T-= -552855.500

Z-Statistic (based on positive ranks) = -12.684

(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  YSI 6136 and YSI EXO
V = 229019.5, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 -9.750037 -7.349964
sample estimates:
(pseudo)median
     -8.550077
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 0.98). Less than one percent of the time, the relative percentage difference in turbidity values measured with the two sensors was greater than 30 percent. The data did not pass the Shapiro-Wilk test for normality (P<0.05); therefore, a Wilcoxon signed-rank test was performed. The difference between median values for the YSI EXO and YSI 6136 turbidity sensors was statistically significant (P<0.05).

Selected References

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots: Journal of the American Statistical Association, v. 74, no. 368, p. 829–836.

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources—Hydrologic analysis and interpretation: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 522 p. [Also available at https://doi.org/10.3133/twri04A3.]

King, L.R., 2021, Laboratory and field data for selected turbidity standard and sensor comparisons, October 2014 to September 2017: U.S. Geological Survey Data Release, https://doi.org/10.5066/P9EVSDHH.

U.S. Geological Survey, variously dated, The national field manual for the collection of water-quality data: U.S. Geological Survey Techniques and Methods, book 9, chaps A1–A10. [Also available at https://water.usgs.gov/owq/FieldManual/.]