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# Deploying and Field Testing Probeguard Anti-Fouling Device in an Estuarine Environment

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## Conversion Factors and Definitions

| Multiply | By | To obtain |
|---|---|---|
| meter (m) | 3.28 | foot (ft) |
| foot (ft) | 0.3048 | meter (m) |
| degrees Celsius (°C) | 33.8 | degrees Fahrenheit (°F) |

**Temperature** is given in degrees Celsius (°C)
**Specific conductance** is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C)
**Turbidity** is given in nephelometric turbidity unit (NTU)
**Dissolved oxygen** is given in percent saturation (% Sat) and milligrams per Liter (mg/L)
**Depth** is given in meters (m)

### Abbreviations and Acronyms

AC alternating current
ADCP acoustic Doppler current profiler
DC direct current
Kg kilogram
lbs pounds
mg milligram
MLLW mean lower low water
NIST National Institute of Standards and Technology
NWIS National Water Information System
ppm parts per million
USGS U.S. Geological Survey
YSI, Inc. Yellow Springs Incorporated
± plus or minus
> greater than
≥ greater than or equal to
< less than
≤ less than or equal to

Cover photo: Sunset, South San Francisco Bay (Photograph taken by Kurt Weidich)
Inset photo: Dumbarton Bridge (Photograph taken by Kurt Weidich)

# Field Testing and Deploying ProbeGuard Anti-fouling Device in an Estuarine Environment

By Kurt Weidich

## Abstract

This report presents the findings of a study by the United States Geological Survey, California Water Science Center's San Francisco Bay and Delta Sediment Transport/Salinity Monitoring Project to evaluate the ProbeGuard anti-fouling device and the components required to deploy the unit as part of a water-quality monitoring station. Biologic fouling of unattended water-quality instrumentation negatively impacts data and equipment. ProbeGuard uses biocide and a sampling chamber to reduce biologic fouling on multi-parameter water-quality instruments. ProbeGuard was integrated into an existing station in South San Francisco Bay at Dumbarton Bridge, California. The effectiveness of ProbeGuard was tested by co-locating two identical multi-parameter water-quality instruments, one with ProbeGuard and one without. The instruments were left unattended for 22 days. Data analysis characterized the influence and growth rates of biologic fouling on measured water-quality parameters. When recovered, the sonde equipped with ProbeGuard was primarily clean and the control sonde was heavily fouled.

## Introduction

Biologic fouling (biofouling) of water-quality instrumentation results in lost data and additional monitoring station maintenance. Frequent servicing visits due to rapid biofouling increase field costs and analyzing fouled data is time consuming and subjective. Anti-biofouling techniques and methods have been developed and many instruments come equipped with wipers and copper material. Dispensing of biocide to kill organisms is an effective methodology; however the challenge was to engineer a system that delivered biocide to the sensors and sampled native water. ProbeGuard, manufactured by Green Eyes LLC of Easton, MD.[1], has a cylindrical sampling chamber that opens and closes, a biocide dispensing unit and a magnetically driven stirrer (fig. 1). The timing of the biocide dispensing and opening of the chamber can be controlled externally by a datalogger or internally through pre-configured logging settings.

The United States Geological Survey (USGS) California Water Science Center's San Francisco Bay and Delta Sediment Transport/Salinity Monitoring group in Sacramento, California collects continuous water-quality data. Water-quality data collected include: depth, water temperature, specific conductance, turbidity (used as a surrogate for suspended-sediment concentration) and dissolved oxygen. The group currently operates nine water-quality stations in the San Francisco Bay (Bay) with seven of the stations operating two or more instruments (fig. 2). The instruments are deployed at depths ranging from 1 m to 20 m below mean lower low water (MLLW). Data are collected every fifteen minutes with many of the sites using cellular telemetry to transfer data to the National Water Information System (NWIS).

[1] All product and company names are trademarks ™ or registered ® trademarks of their respective holders. Use of them does not imply any affiliation with or endorsement by the U.S. Geological Survey.

The evaluation of ProbeGuard was achieved by deploying two identical YSI, Inc.[2] (YSI) water-quality instruments side-by-side; one outfitted with ProbeGuard and one with a standard YSI copper sonde guard. The instruments were deployed to a near-bottom location and left unattended for 22 days. Both instruments recorded data internally. Additionally, the data from the sonde with ProbeGuard was transmitted real-time to NWIS.

Photo courtesy of Green Eyes LLC.

**Figure 1.** ProbeGuard anti-fouling device.

## Site Description

South San Francisco Bay at Dumbarton Bridge (station number: 373015122071000) is located within a sub-embayment comprised of large shoals, marginal wetlands, salt evaporation ponds and tributary channels which drain the surrounding watersheds. The site has been operational since 1993 with a 15-month hiatus between December 2011 and March 2013 due to seismic retrofitting of the bridge. The site is currently equipped with two YSI 6920 multi-parameter water-quality instruments deployed at near-bottom and mid-depth locations, and an acoustic Doppler current profiler (ADCP). The tidal range of the site is 2-3 m and the tidal signal is mixed semi-diurnal with generally two high tides and two low tides daily. The maximum water velocities at the site are approximately 1 m per second. Table 1 is the range of data that was collected at the site in water year 2014.

[2] All product and company names are trademarks ™ or registered ® trademarks of their respective holders. Use of them does not imply any affiliation with or endorsement by the U.S. Geological Survey.

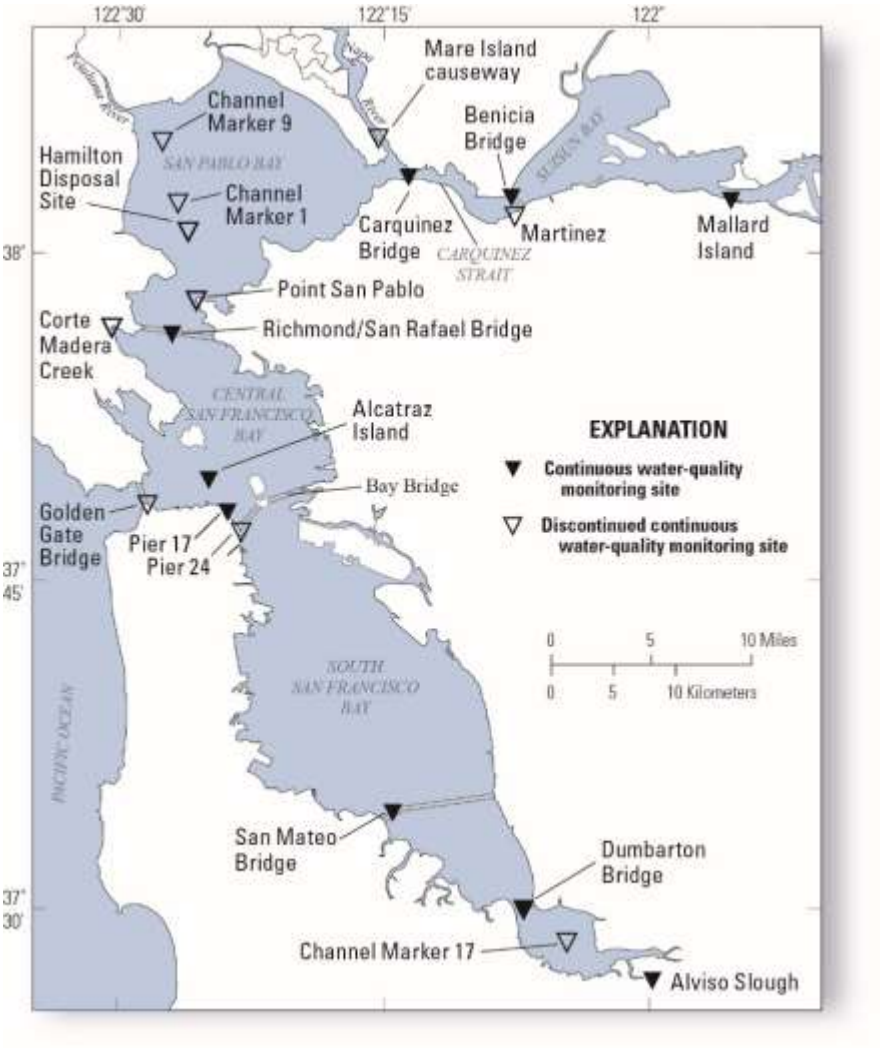


**Figure 2.** San Francisco Bay USGS sediment group station map.

**Table 1.** Maximum and minimum data for Dumbarton Bridge, lower sonde, water year 2014.

| Parameter | Maximum | Minimum |
|---|---|---|
| Temperature (°C) | 25.3 | 8.0 |
| Specific Conductance (µS/cm) | 52100 | 39200 |
| Turbidity (NTU) | 383 | 3.2 |
| Dissolved Oxygen (mg/L) | 9.4 | 4.6 |

## Description of Instrumentation

### Water-quality instrument

The YSI 6920 V2-2 multi-parameter water-quality sonde was designed for continuous monitoring in fresh or polluted marine environments. The sonde is 45.7 cm long, 7.24 cm in diameter and weighs 1.8 kg. The instrument logs data internally and can also output data to a datalogger via RS232 or SDI-12 communication protocols. Power requirements are met by 8-AA internally housed batteries or an external 12-volt direct current (DC) power source. The power options function simultaneously and provide backup if one fails. Optical sensors are equipped with self-cleaning wipers. Additional anti-fouling products available from YSI include: copper sonde guards, copper screening, copper tape, copper wiper bodies, copper port plugs and protective spray-on solution for conductance cells. Appendix A lists the technical specifications of the YSI 6920 sensors used in the study.

### ProbeGuard

ProbeGuard was designed to inhibit biological growth and the unit tested was designed to attach to a YSI 6920. The device is 45.7 cm long, 8.9 cm in diameter and weighs 1.8 kg. ProbeGuard uses a two-part sampling chamber that opens during sampling and closes afterward. When the unit is in the closed position, near-surface solar radiance is eliminated which helps slow the growth of many marine organisms. A magnetically coupled stirrer flushes the chamber after opening and periodically mixes biocide with the chamber closed. Additional "ambient flow" flushing can be achieved by leaving the chamber open for a programmed interval after flushing with the stirrer. Flushing the chamber prior to collecting data ensures only ambient native water is sampled. During the study the unit was programmed to open and flush the chamber every 15 minutes (for sampling) and dispense biocide every six hours. The biocide dispensing unit was filled with water soluble chlorine pellets. The manufacturer suggested using trichloroisocyanuric acid (tri-chlor), a common chlorine tablet that can be purchased at many swimming pool supply stores. The default solution release time is three seconds, achieving approximately a 3-5 ppm free chlorine concentration inside the closed chamber. A full biocide dispensing unit is anticipated to last 10-12 weeks, opening for three seconds, four times a day. The user can replace the entire dispensing unit or refill the cavity with tri-chlor. The stirring, biocide dispensing and sample chamber opening and closing durations are programmable. Appendix B lists the user-configurable settings.

ProbeGuard can run in self logging mode or be controlled by a datalogger (slave mode via RS232 or SDI-12 with an additional adapter). For this study ProbeGuard was set-up in slave mode and controlled by an external Campbell Scientific CR1000 datalogger. Bench testing and configuration of the settings can be completed using a terminal emulator such as PuTTy, HyperTerminal, GreenEyes' ComScript or through the Campbell Scientific CR1000 terminal emulator. Case sensitive commands are sent to the instrument in slave mode from a datalogger to initiate sampling and dosing operations. Appendix C lists commands used to run the instrument during a long-term unattended deployment. In self logging mode the internal datalogger runs through programmed routines; cleaning and collecting data at defined intervals. Data collected in self logging mode can be stored and plotted on the internet using GreenEyes' ComScript software. The unit requires a copper screen to limit debris or animals

from interfering with the opening and closing of the sampling chamber. The unit is powered and controlled through a wet mateable cable attached to a datalogger and 12-volt DC power source.

Datalogger program

A Campbell Scientific CR1000 datalogger was programmed to initiate sampling procedures and to collect and send data via telemetry to NWIS. During the study, the datalogger controlled two YSI 6920, ProbeGuard, and a YSI EXO. The datalogger triggers instruments to perform duties that are scripted into a program of scheduled commands. The program developed to control the instruments and manage data during the study was written in CRBasic Editor. CRBasic programs are divided into the Data Table section, Main Program, and Scan section. The Data Table categorizes the parameters measured by the instruments. The Main Program identifies what commands are sent to specific ports. The Scan section sets the timetable for scheduled events. Appendix D includes an abbreviated version of the program employed during the study, which was developed to bench test one YSI and ProbeGuard in the office prior to deployment.

ProbeGuard was connected to the datalogger using the RS232 transmit (Tx) and receive (Rx) ports. The YSI was connected to the datalogger SDI-12 port 1. Both instruments were powered through the 12 volt and ground ports. Every 15 minutes a “Y5” command was sent to ProbeGuard to open the chamber and an “m” command was sent to the YSI to initiate data collection. The YSI was set to run its two optical sensor wipers every hour. The user can program any wiping interval or can initiate wiping every time an “m” command is sent. ProbeGuard took one minute-twelve seconds to complete the operation initiated by the “Y5” command. The YSI recorded data one minute into the routine to ensure that ambient native water was sampled. A series of time delays were used to wake up ProbeGuard and allow the YSI to cycle through its optical wiping. The command to operate the biocide dispensing unit (Y6) was sent to ProbeGuard every six hours (five minutes past the hour to ensure no interference with recorded data). Upon receiving the “Y6” command ProbeGuard opened the biocide dispensing unit for three seconds while the sampling chamber was closed and the stirrer mixed the solution for 30 seconds. The sensors were left to bathe in the solution for 10 minutes. The next sampling routine (Y5) opened the chamber and flushed the chlorine solution.

Data collected by the datalogger was transmitted to NWIS through cellular telemetry. A scheduled data collection feature in Campbell Scientific’s Loggernet program autonomously connects to the datalogger and collects data every hour. The fifteen-minute data were uploaded to NWIS as provisional and are publicly accessible via NWISweb (http://waterdata.usgs.gov/nwis).

## Site Infrastructure

The YSI 6920 sondes were deployed in copper carriages at fixed locations along a stainless steel suspension cable with 125 lbs of weight attached to the bottom to keep it plumb. The cable was attached to a galvanized-steel davit bolted to the bridge railing. A deployment line attached to the carriages allowed the instruments to be easily retrieved for servicing and redeployed to their sampling position. Figure 3 is a schematic of a typical sensor deployment in

San Francisco Bay. ProbeGuard was installed on the lower sensor and the co-located control instrument was attached adjacently, 0.9 feet higher due to physical constraints that hindered locating the sondes at exactly the same depth. The ProbeGuard equipped YSI was connected to the datalogger with communication cables. A 12-volt DC battery connected to a charger ran off the 120-volt AC power at the site. A 20-watt solar panel would have been sufficient to power the system at sites without AC power. The datalogger, battery, and charger were housed in an environmental shelter on the bridge footing.

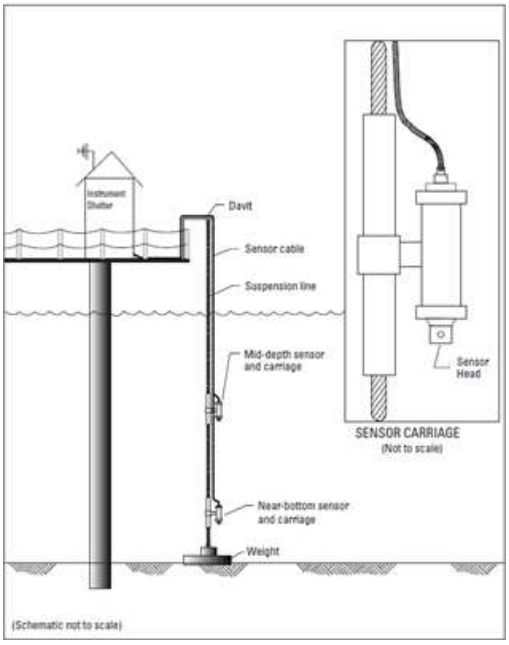


**Figure 3.** Water-quality monitoring installation, San Francisco Bay study.

## Sensor Calibration

The data was collected and evaluated based on USGS Techniques and Methods-1D3 (TM-1D3) Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting (Wagner and others 2006). A calibration check of the sensors was conducted before and after the 22-day deployment to verify sensor calibration drift and accuracy. The specific conductance sensors were checked against 10,000 µS/cm, 25,000 µS/cm and 50,000 µS/cm potassium chloride standards. These standards bracket the range of values measured at this site. The turbidity sensors were checked with 0 nephelometric turbidity unit (NTU), 50 NTU and 100 NTU formazin standards. The 0 NTU standard is deionized water which was used to dilute the stock 4000 NTU standard to the 50 NTU and 100 NTU dilutions. A National Institute of Standards and Technology (NIST) traceable thermistor was used to check temperature sensor accuracy. Additionally, the dissolved oxygen sensors were checked using water-saturated air, and the pressure transducers on both sondes were calibrated to zero depth prior to deployment.

Water-quality sensors are calibrated when the sensor performance is outside of an acceptable range. Table 2 lists the USGS standard calibration drift thresholds. Before and after deployment, calibration checks were within USGS criteria but corrections were applied to the datasets to isolate the influence of fouling. The conductance sensor output on the ProbeGuard equipped YSI in the three standards averaged 1.09% below expected values. Therefore, a +1.09% shift was applied to that dataset and the dissolved oxygen mg/L was recomputed. The dissolved oxygen data on the control sonde was shifted down 0.5% based on calibration checks. The temperature and turbidity sensors were accurate on both sondes and no calibration shifts were applied.

**Table 2.** Calibration criteria. Source: TM-1D3 (Wagner and others 2006)

| **Parameter** | **USGS Correction Criteria** (apply correction when the sum of the absolute values for fouling and calibration drift error exceeds the value listed) |
|---|---|
| Water Temperature | ± 0.2 ˚C |
| Specific Conductance | ± 5 µS/cm or ± 3% of the measured value, whichever is greater |
| Turbidity | ± 0.5 turbidity units or ± 5% of the measured value, whichever is greater |
| Dissolved Oxygen | ± 0.3 mg/L |

## Data Analysis

The instruments were downloaded after 22 days of unattended 15 minute sampling, totaling 2,009 data points. The bucket method outlined in TM-1D3 was used to quantify fouling shifts in the field. Two buckets of native water were collected at the same time and mixed. The retrieved instruments are placed in the first bucket and pre-cleaning values recorded. The instruments are cleaned and placed in the second bucket and post-cleaning values were recorded. The difference between the before and after cleaning values quantifies the fouling correction. Photos were taken after the instruments were recovered. Figures 4 and 5 illustrate the distribution of biofouling on both instruments. The sonde on the left was equipped with ProbeGuard; the control sonde is on the right. The organisms responsible for biofouling the sensors are primarily hydroids (*Obelia sp.*). Figure 5 shows how hydroids impact optical sensors even with self-cleaning wipers. Hydroids can extend beyond the end of the sensor body obscuring the optical window despite the presence of wipers.

Output from the two sondes was compared by calculating the difference between the co-located sensor values and by computing the Pearson correlation coefficient, r-value. The r-values for each of the parameters are shown in Table 7 and represent linearity of the data on a scale of 0 to 1. Low r-values indicate dissimilarity while values closer to one signify well-correlated datasets.

Photo taken by Kurt Weidich

**Figure 4.** Distribution of biofouling on ProbeGuard equipped YSI (left) and control sonde (right) after retrieval from unattended sampling from 03/26/14 to 06/16/14.

Photo taken by Kurt Weidich

**Figure 5.** Optical sensor fouling on ProbeGuard equipped YSI (left) and control YSI (right) after retrieval from unattended sampling from 03/26/14 to 06/16/14.

**Table 3.** Pearson correlation coefficients (r-value) from Probeguard equipped sonde and control sonde for each parameter.

| Parameter | Temperature (°C) | Specific Conductance (µS/cm) | Depth (meters) | Turbidity (NTU) | Dissolved Oxygen (mg/L) |
|---|---|---|---|---|---|
| r-value | 1.000 | 0.726 | 1.000 | 0.125 | 0.819 |

Temperature

Figure 6 is a plot of the two temperature datasets. The temperature data from the control sonde shows relatively no impact from biofouling despite heavy fouling. The Pearson correlation coefficient was 1.000, indicating the sensor outputs were nearly equivalent. Upon retrieval, both temperature sensors were compared to a NIST traceable thermistor and found to be accurate before and after cleaning. The YSI 6056 temperature sensor is stable, requiring little to no calibration corrections and is rarely impacted by biofouling. The stability of the temperature probe ensures that the calculation of specific conductance and dissolved oxygen milligrams per liter are precise.

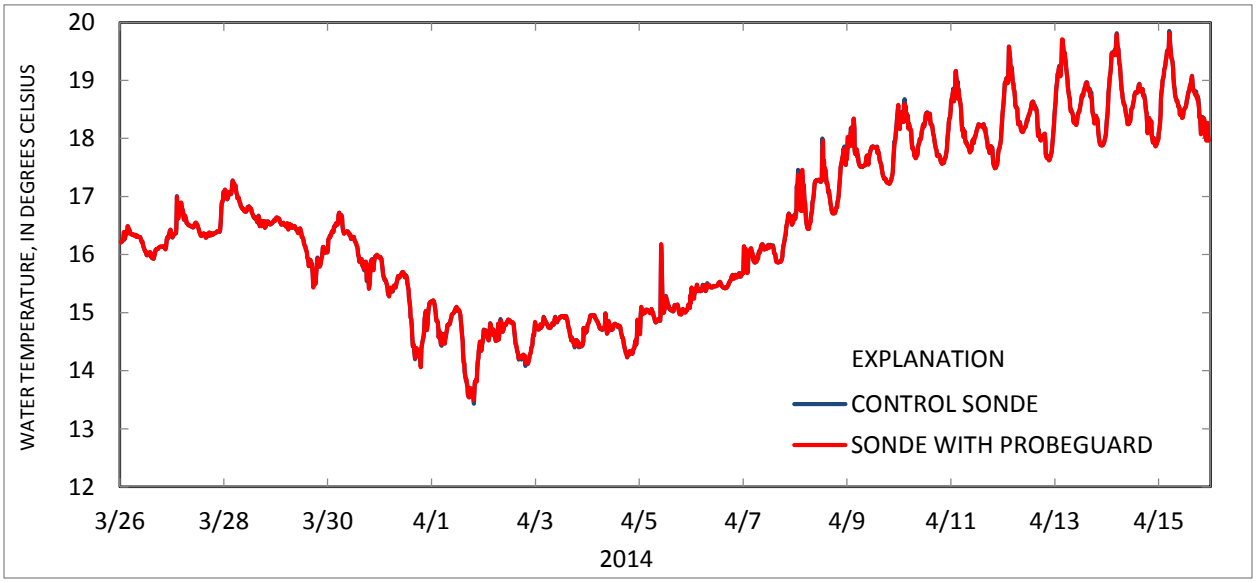


**Figure 6.** Water temperature datasets.

Specific Conductance

Figure 7 is a plot of the specific conductance datasets. The values begin diverging after fourteen days. For the remainder of the study the fouled control sonde data assumed a negative trend. The divergence of the datasets is supported by the 0.726 r-value. According to TM-1D3 a fouling shift may be applied to the specific conductance record unless the signal is compressed. Data compaction occurs during extreme cases of biofouling. From the bucket method checks for fouling, the sonde with ProbeGuard indicated a negligible shift and no correction was needed. The control sonde fouling checks indicated a 4400 µS/cm correction on 04/16/14. Figure 8 displays the datasets with a fouling shift applied to the control sonde data.

The shift start time, intensity and duration were achieved by reducing the sample size and removing the tidal influence. Ebb and flood data were isolated based on stage, and the median values for each tidal cycle were identified. Figures 9 and 10 are plots of the flood and ebb median percent difference data, respectively. The plots show the datasets start diverging 04/07/14 with early signs of minimal growth beginning 04/04/16. The ebb median data shows

fresh water entering the system via contributing watersheds on 04/07/14 and 04/09/14 from recent rainfall events.

Before fouling (03/26/14-04/07/14) the r-value was 0.989, indicating highly correlated datasets. Figure 11 shows the un-fouled median flood and ebb data together. After biofouling (04/07/14-04/16/14) the r-value was 0.555, indicating more poorly correlated datasets. Figure 12 compares the fouled median flood and ebb data. The dissimilar slopes of the data after biofouling, 112 and -308 µS/cm/day show that the rate at which biofouling reduced specific conductance values.

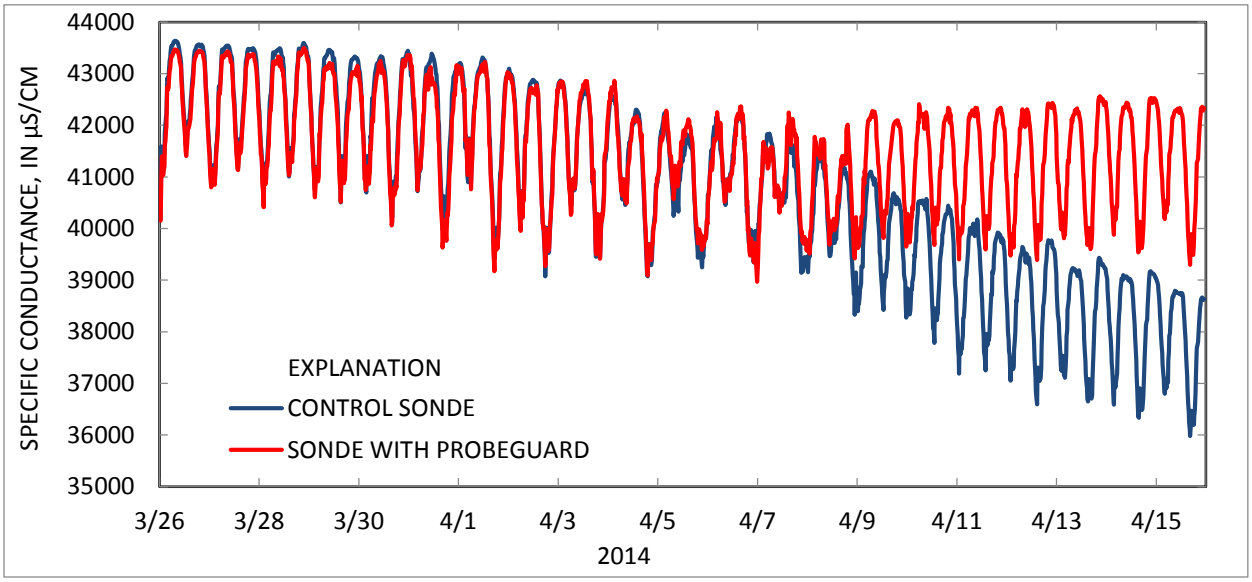


**Figure 7.** Specific conductance datasets.

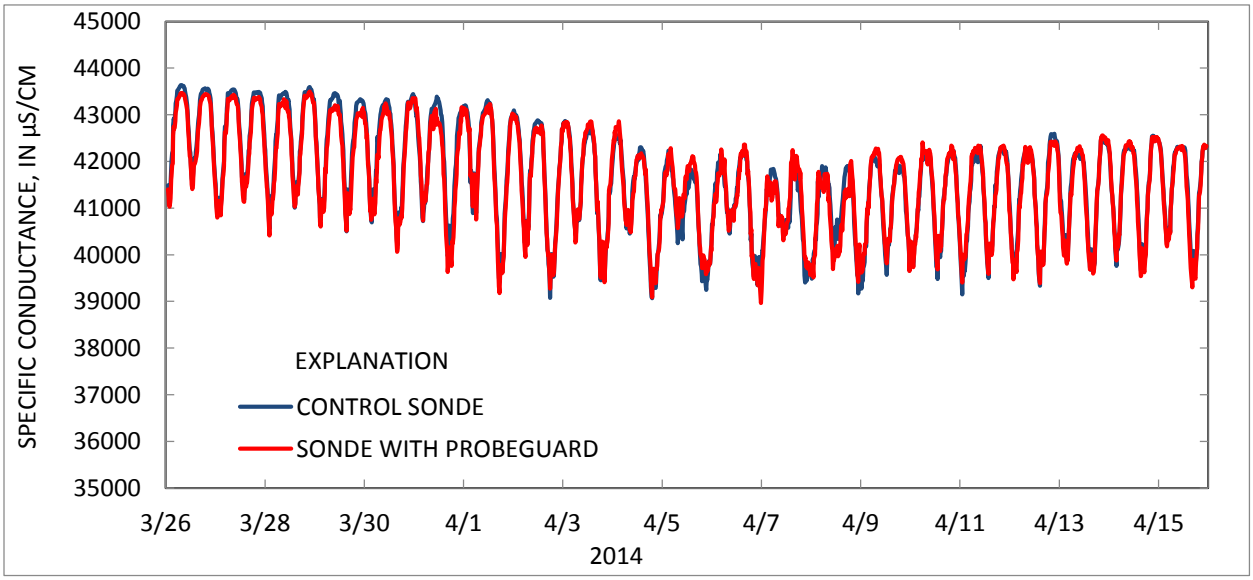


**Figure 8.** Shifted specific conductance datasets.

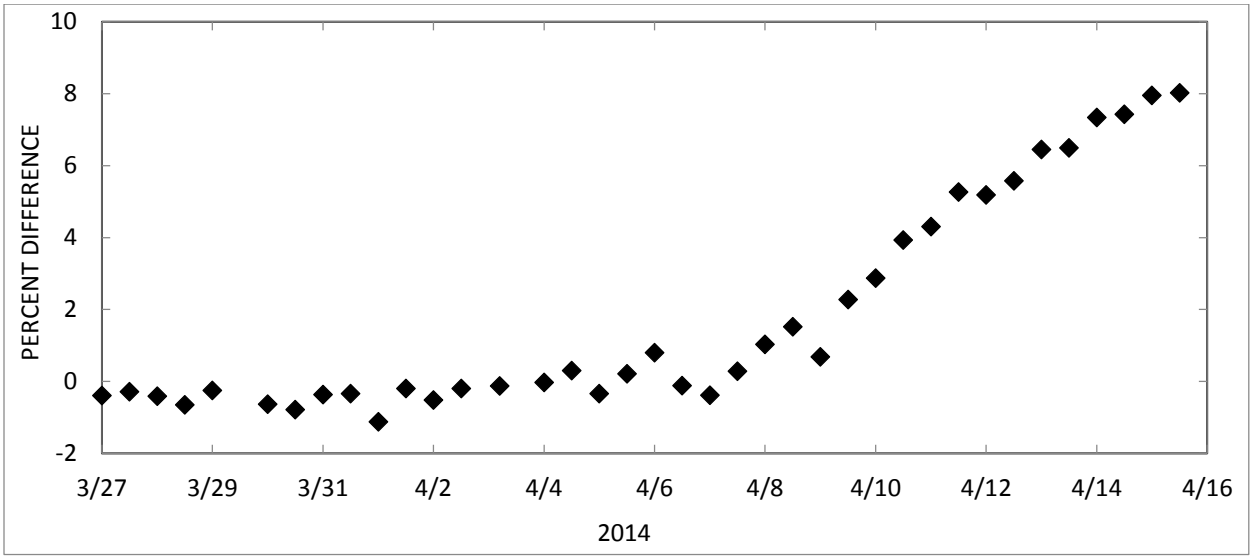


**Figure 9.** Percent difference between flood tide datasets.

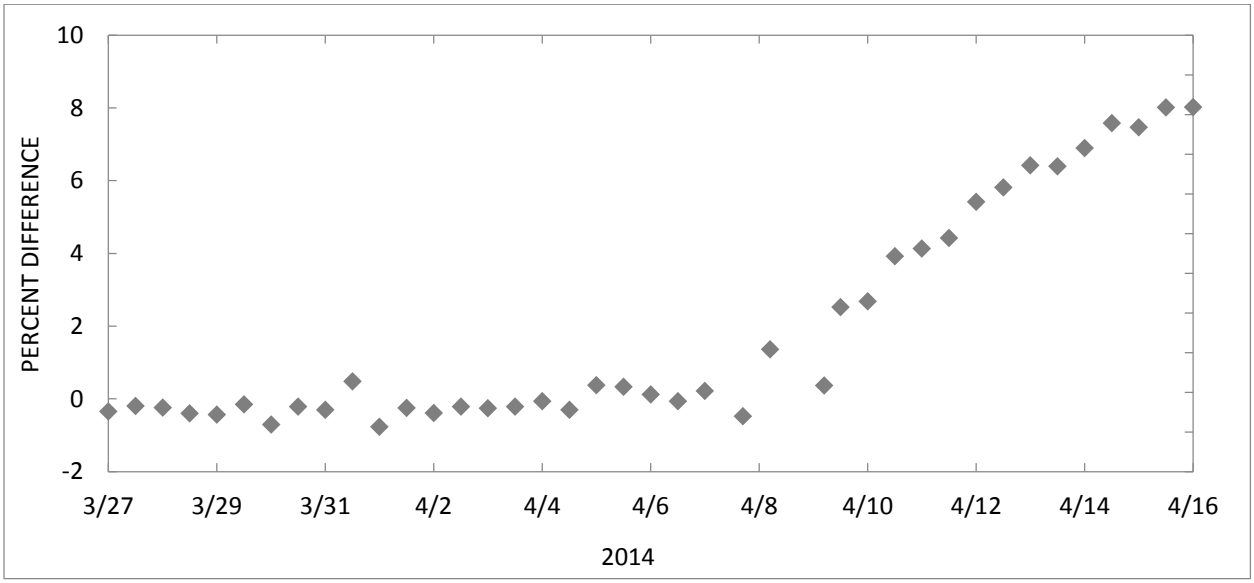


**Figure 10.** Percent difference between ebb tide datasets.

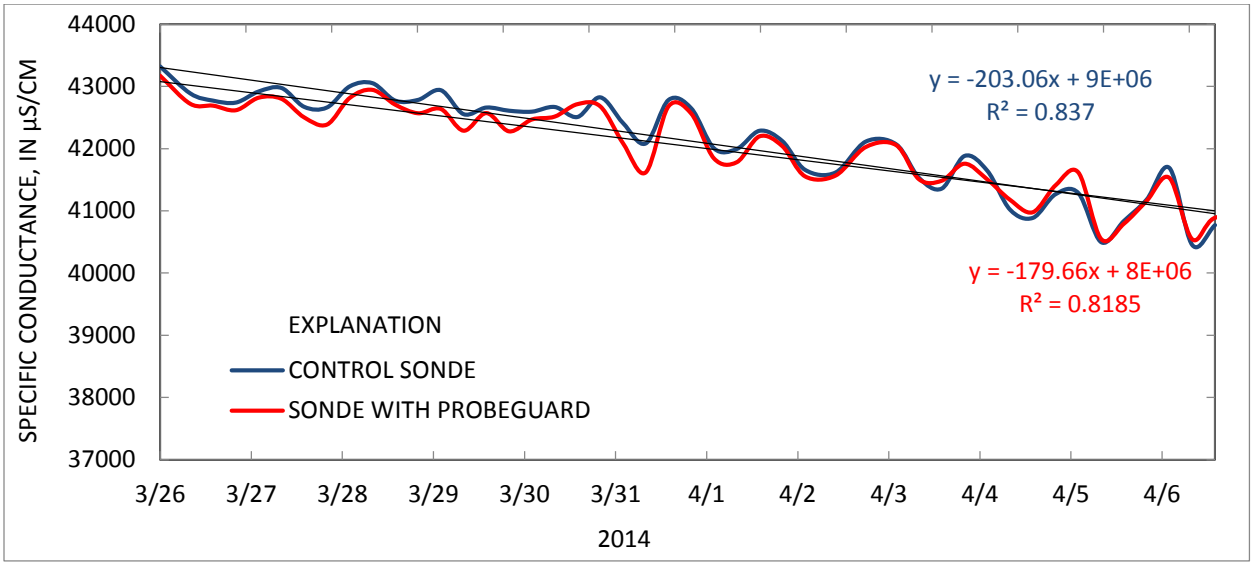


**Figure 11.** Correlation of specific conductance datasets before biofouling.

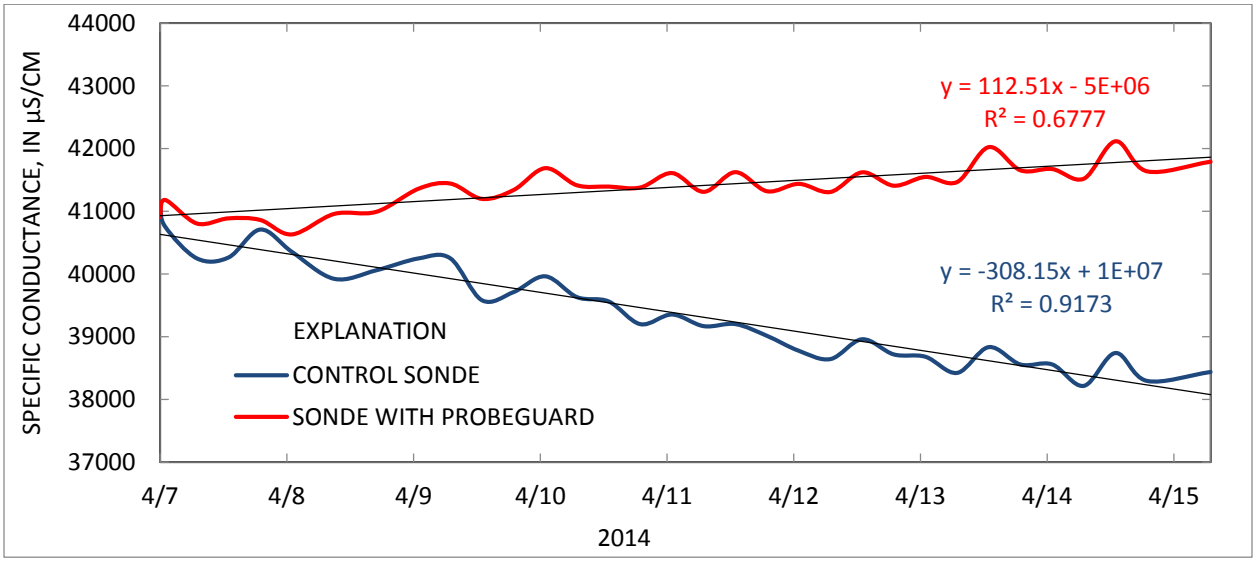


**Figure 12.** Correlation of specific conductance datasets after biofouling.

Turbidity

Figure 13 shows the turbidity data collected from both sondes. The bucket method fouling checks are not useful because a fouled turbidity signal is highly irregular. The turbidity sensor on the control sonde was heavily fouled and the data were unrecoverable after 04/11/14. The r-value was 0.125, indicating very little correlation between datasets. The spikes on 04/08/14 from the control sonde could be from aquatic organisms entering and leaving the sonde guard and likely do not represent actual turbidity. ProbeGuard is equipped with a copper screen to ensure no debris hinders the opening and closing of the sampling chamber, keeping out transient marine organisms. Figure 14 shows the comparison of data before fouling with

the 04/08/14 spikes removed. The datasets track together well and the r-value was 0.957. During the summer months when hydroid growth rates are high it is common to only collect one week of usable turbidity data at the Dumbarton Bridge site.

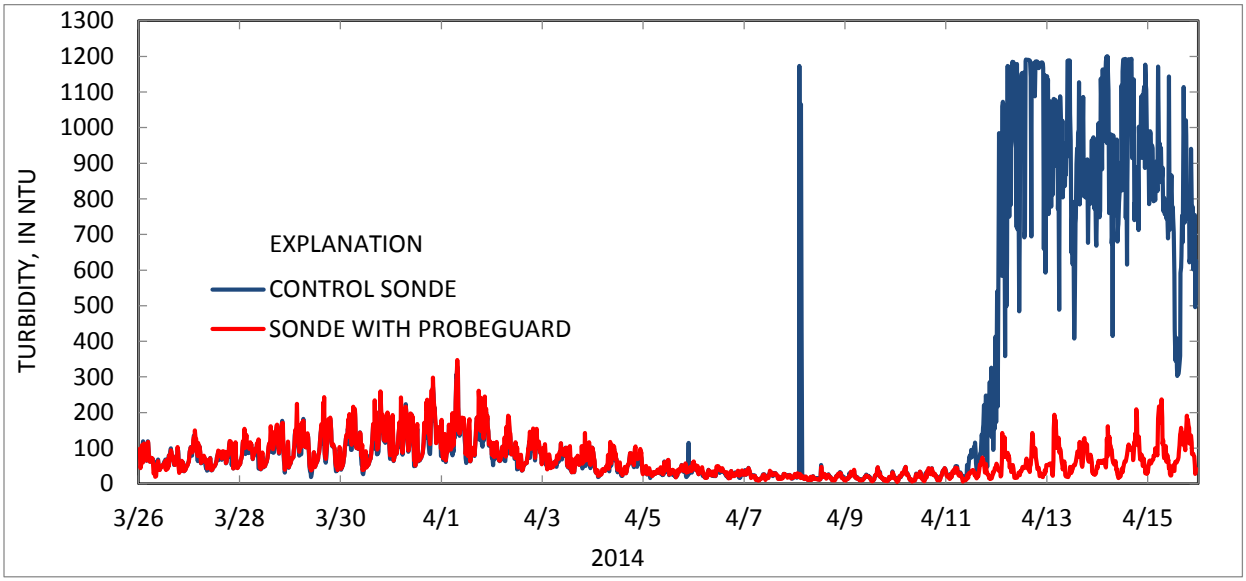


**Figure 13.** Turbidity datasets.

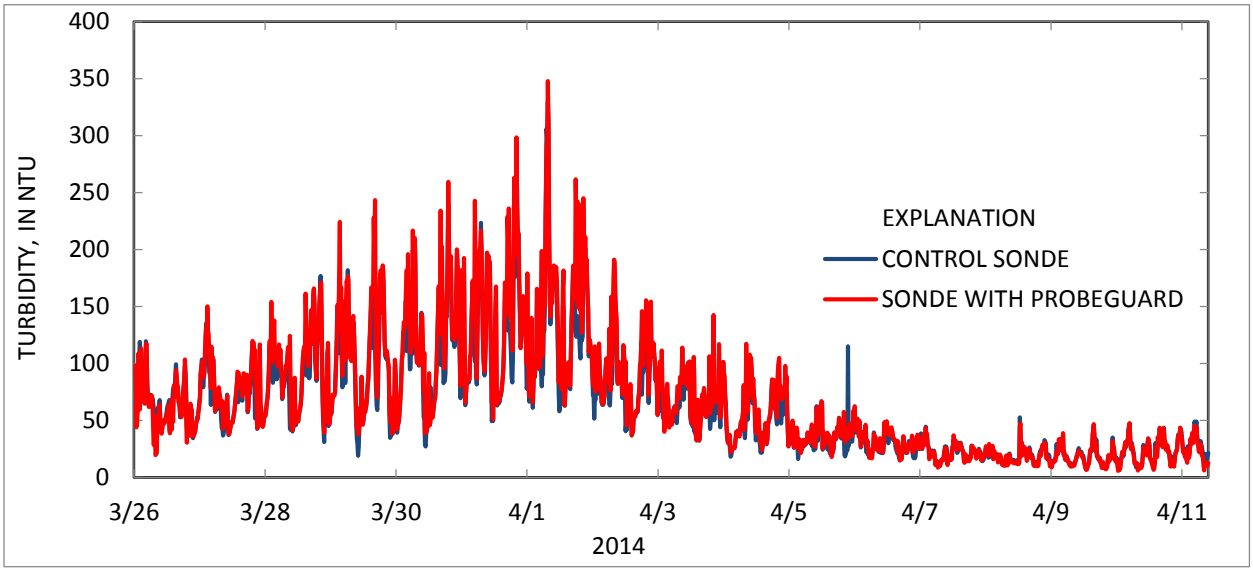


**Figure 14.** Un-fouled turbidity datasets.

Dissolved Oxygen

Figure 15 shows the dissolved oxygen datasets. The datasets are well correlated, the r-value was 0.819. The control sonde data exhibited fouling on 04/11/14, the same day that the turbidity data showed fouling effects. Fouled dissolved oxygen data often manifest as downward spikes at certain tidal phases. Figure 16 shows the dissolved oxygen and depth data. The largest downward spikes occur at high slack tide. Shifting fouled dissolved oxygen data is difficult because there is no simple metric to assess fouling effects, and fouled data would likely be deleted.

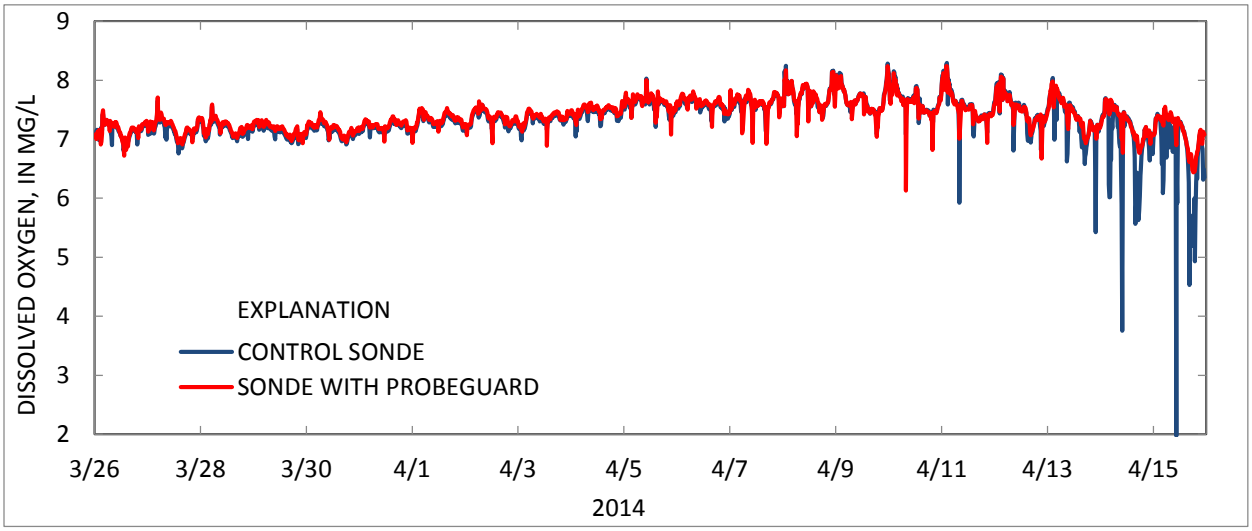


**Figure 15.** Dissolved oxygen datasets.

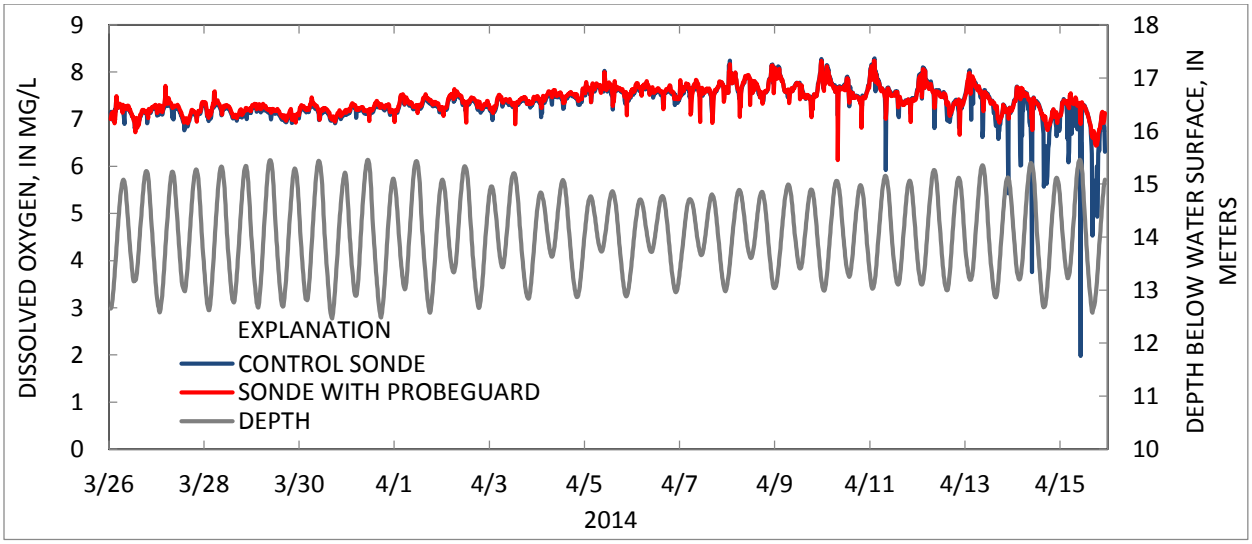


**Figure 16.** Dissolved oxygen and depth data.

## Summary

ProbeGuard kept the water quality sensors clean and reduced biofouling. The sonde with ProbeGuard yielded high quality data and no shifts due to biofouling were required. The control sonde experienced heavy biofouling and all parameters were affected except water temperature and depth. The short-term deployment did not allow adequate time to fully evaluate ProbeGuard under the harshest conditions in South San Francisco Bay. An additional three-week study was conducted in June 2014, but the control sonde turbidity and specific conductivity sensors failed shortly after deployment.

ProbeGuard had a low energy footprint and was easy to install by modifying an existing instrument carriage. The configurations were easily customized using a terminal emulator. The CR1000 program was straightforward due to the simple Y5 and Y6 commands, but coordinating the sample timing and delays took a few iterations. ProbeGuard costs approximately $5000 and comes with a wet mateable cable. Data managers rely on high-quality data and biofouling is a constant challenge. ProbeGuard may save time and funds by eliminating site visits and providing higher quality data.

## Acknowledgments

The site is supported through funding provided by the U.S. Army Corps of Engineers. Special thanks to Paul Buchanan, for his guidance and mentorship with site installation, sensor maintenance and data analysis. Also thanks to Travis VonDessonneck for providing the CR1000 program used at the site to control and collect data. Thanks to Robert Castagna, Maureen Downing-Kunz, Stephen Huddleston, Emily Novick, Amber Powell, Dave Schoellhamer, Chris Silva, Greg Shellenbarger, and Paul Work.

## References

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at *http://pubs.water.usgs.gov/tm1d3*.

## Appendices

**Appendix A.** - Technical specifications for YSI 6920 sensors. *Source: YSI.com*

| **Sensor** | **Range of Detection** | **Resolution** | **Accuracy** |
|---|---|---|---|
| Depth | 61 m | 0.001 m | ±0.12 m |
| Temperature 6560 | -5 to +50°C | 0.01°C | ±0.15°C |
| Conductance 6560 | 0 to 100,000 µS/cm | 1 to 100 µS/cm (range dependent) | ±0.5% of reading + 1.0 µS/cm |
| Optical Turbidity 6136 | 0 to 1,000 NTU | 0.1 NTU | ±2% of reading or 0.3 NTU, whichever is greater |
| Optical Dissolved Oxygen 6562 | 0 to 50 mg/L | 0.01 mg/L | 0 to 20 mg/L: ± 0.2 mg/L or 2% of reading, whichever is greater; 20 to 50 mg/L: ±6% of reading |

**Appendix B.** - ProbeGuard configurations. *Source: gescience.com*

| Setting | Description | Range |
|---|---|---|
| Stir Flush | Seconds stirrer is run to flush Sampling Chamber after opening. | 10 to 60 |
| Open Flush | Seconds Sampling Chamber is left open after Stir Flush to allow for continued ambient flow flushing. | 0 to 120 |
| Biocide Open | Seconds BDU is opened to release biocide. | 0-10 default = 3 |
| Instrument Warmup | Seconds ProbeGuard will pause after powering instrument or instructing instrument to sample before collecting data. | 5 to 180 |
| Instrument Baud | Instrument Baud Rate for RS232 communications. | 1200, 2400, 4800, 9600, 19200, 38400, 57600 |
| Logging Interval | Minutes between sampling while in Logging Mode. | 5 to 120 |

**Appendix C.** ProbeGuard commands. *Source: gescience.com*

| Command | ProbeGuard Action |
|---|---|
| c999 | Displays current configuration table. |
| D | SD card functions and data retrieval. |
| H | Displays header info. |
| J | Automated logging cycle. |
| M | Moves inner sampling chamber cup in forward direction. |
| R | Moves inner sampling chamber cup in reverse direction. |
| T1 | Sets real time clock date and time. |
| X1 | Resets CPU. |
| Y1 | Move inner cup to index position. |
| Y2 | Move inner cup to index position and then to home position (windows fully closed). |
| Y3 | Move inner cup to index position and then to fully open position. |
| Y4 | Move inner cup forward 1/8 of a revolution (fully open to closed). |
| Y5 | Open chamber, run stirrer for Stir Flush, pause for Open Flush and close chamber. |
| Y6 | Introduce biocide into the sampling chamber. Biocide Open is used to control the size of the dose. |
| Y7 | Sample test: A complete test of Inner Cup motion, stirring and instrument communication. |
| Y10 | Turn instrument power off. |
| Y11 | Turn instrument power on. |
| Y12 | Test instrument communication only; no Inner cup motion or stirring. |
| Y13 | Prime BDU: Opens BDU vent and valve for 10 seconds to fill chamber with ambient water. |
| Z1 | Puts CPU into low power sleep, send any character to wake CPU. |

**Appendix D.** CR1000 program.

Note: Lines that begin with an apostrophe (‘) are user-friendly programming notes and are not carried out by the program.

```
'CR1000 Series Datalogger
'YSI 6920 and ProbeGuard
'One YSI collecting Date, Time, Temp, SpCond, Salinity, Turbidity, DOmg/L, DO%sat, Depth and Battery Volts
'YSI flying lead wires, white-data port C1, clear shielded-ground port G, black-ground port G, red-12Volt port
'YSI SDI address 1, YSI fifteen minute data collection, optics wipe every hour
'ProbeGuard-RS232 in COM4 Tx and Rx ports, black wire ground port and red wire 12V port
'ProbeGuard opens every 15 minutes, flushes chamber, pauses while the YSI samples and closes - command Y5
'Every 6 hours, 5 minutes past the hour ProbeGuard runs through a  biocide cleaning cycle - command Y6

Public PTemp, PBatt ‘Declare public variables, CR100 panel temp, panel voltage and site number
Units PTemp = degC ‘Panel temp units
Units PBatt = volts ‘Panel voltage units
Public SiteNum As String * 20 ‘Site identifier = USGS site number

Public YSI(10) 'YSI public variables and units
Public Date, Time, Temp, SpCond, Sal, Depth, Turb, DOSat, DOmgL, YBatt
Units Temp = degC
Units SpCond = uS/cm
Units Depth = ft
Units Turb = ntu
Units DOSat = %
Units DOmgL = mg/L
Units YBatt = volts

DataTable (Dumbarton,1,-1) 'YSI data table (Dumbarton)
DataInterval (0,15,Min,10) ‘Collect mininimum panel voltage, panel temp and 10 YSI parameters every 15 min
Minimum (1,PBatt,FP2,0,False)
Sample (1,PTemp,FP2)
Sample (1,Date,IEEE4)
Sample (1,Time,IEEE4)
Sample (1,Temp,IEEE4)
Sample (1,SpCond,IEEE4)
Sample (1,Sal,IEEE4)
Sample (1,Depth,IEEE4)
Sample (1,Turb,IEEE4)
Sample (1,DOSat,IEEE4)
Sample (1,DOmgL,IEEE4)
Sample (1,YBatt,IEEE4)
EndTable

Sub PGopenYSIsample ‘Sub routine ProbeGuard opens, stirs, pauses and YSI samples, ProbeGuard closes
SerialOpen (Com4,19200,0,0,50) ‘Open the serial port to begin sending commands
SerialOut(Com4," " + CHR(13),"",0,100) 'Wake the instrument up by sending carriage return (CHR(13))
Delay(0,5,Sec) ‘5 second delay
SerialOut(Com4,"Y5" + CHR(13),"",0,100) 'Open, flush the chamber, pause and close
Delay (0,45,Sec) 'Delay to finish mixing and optical wiping, YSI samples while the chamber is open
```

```
SDI12Recorder (YSI(),1,1,"M!",1.0,0) ‘M command-YSI samples all parameters
Delay(0,10,Sec) ’10 second delay
SerialClose(Com4) ‘End communication and close the serial port
EndSub ‘End the subroutine

BeginProg 'Main program
SiteNum = "3730151222071000" ‘USGS site number
Scan (30,Sec,0,0) ‘Scan rate of 30 seconds
PanelTemp (PTemp,250)
Battery (PBatt)

If TimeIntoInterval (0,15,Min) ‘Every 15 minutes the YSI and ProbeGuard sampling routine is run and the
Dumbarton data table is populated
Call PGopenYSIsample
CallTable Dumbarton
EndIf

If TimeIntoInterval (5,360,Min) 'Every 6 hours, 5 minutes past the hour ProbeGuard dispenses biocide
SerialOpen (Com4,19200,0,0,50) ‘Open the serial port at a 19200 baud rate
Delay(0,5,Sec) ‘5 second delay
SerialOut(Com4," " + CHR(13),"",0,100) 'Wake the instrument up by sending carriage return (CHR(13))
Delay(0,10,Sec) 10 second delay
SerialOut(Com4,"Y6" + CHR(13),"",0,100) 'Dispense biocide, mix sampling chamber
Delay(0,5,Sec) ‘5second delay
SerialClose(Com4) ‘End communication and close the serial port
EndIf

NextScan
EndProg
```