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Evaluation of the Storm 3 Data Logger Manufactured by WaterLOG/Xylem Incorporated—Results of Bench, Temperature, and Field Deployment Testing

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U.S. Department of the Interior
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Cover Image. Photograph showing Waterlog/Xylem Incorporated Storm 3-00 data logger (see figure 1, p. 2).

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By Gerald A. Kunkle

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Contents

Figures

Tables

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Abstract

The Storm 3 is a browser-based data logger manufactured by WaterLOG/Xylem Incorporated that operates over a temperature range of −40 to 60 degrees Celsius (°C). A Storm logger with no built-in telemetry (Storm3-00) and a logger with built-in cellular modem (Storm3-03) were evaluated by the U.S. Geological Survey (USGS) Hydrologic Instrumentation Facility (HIF) for conformance to the manufacturer's specifications with bench tests, for recording data over the device's operating temperature range with temperature chamber tests, and for field performance with an outdoor deployment test.

The procedures followed and the results obtained from the testing are described in this publication. The device met most of the manufacturer's stated specifications. An exception was power consumption, which was about 10 percent above the manufacturer's specifications. It was also observed that enabling WiFi doubles the Storm 3's power consumption. In addition, several logging errors were made by two units during deployment testing, but it could not be determined whether these errors were the fault of the Storm or of an attached sensor.

Introduction

The U.S. Geological Survey (USGS) Hydrologic Instrumentation Facility (HIF) evaluates the performance of instruments and equipment that are used to directly measure hydrologic data. These devices may measure parameters needed to quantify streamflow (such as river stage, water velocity, or water discharge) to monitor groundwater levels or to measure water-quality parameters in a variety of field settings. These devices include data loggers and recorders, radios for data telemetry, power supplies, solar panels, batteries, cableway and bridge-measuring equipment, and water-quality sampling devices. The primary factors evaluated are:

- the manufacturer's stated specifications for accuracy and resolution;
- any relevant USGS accuracy requirements;
- the ability of the device to operate under a wide range of environmental conditions at remote, unmanned field stations;
- power source and power consumption; and
- compatibility with existing USGS field hydrologic data-collection infrastructure and equipment.

The evaluations may involve extended operation in one or more field locations and (or) may employ testing chambers designed to reproduce a range of environmental conditions. Instrument and equipment evaluations are done primarily to determine if particular devices would be suitable for use by USGS personnel for hydrologic data collection.

This report describes the procedures followed and the results obtained from the evaluation testing of a commercially available data logging device, the Storm 3, operating with firmware version 1.4.0. The results are applicable only to the versions of the devices tested and may or may not be representative of the results obtained with different versions of the devices.

Description of the Storm 3 Data Logger

The Storm 3[1] (fig. 1) is a browser-based data logger produced by WaterLOG/Xylem Incorporated (Inc.) (WaterLOG). Selected manufacturer specifications for this device are listed in table 1 and are available in the Storm product brochure (WaterLOG/Xylem Incorporated, 2014a). At the time of this report, WaterLOG has not released an operating manual for the Storm 3. Existing documentation includes a brief getting-started guide and a BASIC programming guide. There are also built-in help buttons within the browser-based software interface. Although experienced users may find the Storm 3 easy to configure, the lack of complete documentation may present a challenge if any obstacles are encountered. Throughout the remainder of the paper, the Storm 3 is referred to as the Storm.

The Storm can be programmed using a Web browser with either a personal computer (PC) or a WiFi-compatible mobile device, such as a smartphone or tablet. No custom software is required to be installed on the device used to program the Storm. The Storm's graphical user interface (GUI) (fig. 2), which is used to program the Storm, is accessed using a Web browser. WaterLOG states that the Storm is compatible with all standard Web browsers. No Internet connection is required.

Communication options for the Storm include Universal Serial Bus (USB), serial, and WiFi. Connecting to the Storm using WiFi requires use of the included WiFi adapter. The WiFi adapter can be installed in either of the USB ports on the front panel of the logger. When the adapter is active, the Storm will appear on compatible WiFi devices as an available WiFi network. When a device is connected to the logger using a USB or WiFi connection, the Storm will temporarily override the device's browser settings to automatically redirect the browser to the Storm's GUI. Once disconnected from the Storm's WiFi network, the device's browser settings will return to their original configuration.

The Storm is sold without telemetry (Storm3-00) and with multiple built-in cellular telemetry options as shown in table 2. This report describes the evaluation of the Storm3-00 and Storm3-03. The Storm3-00 is only the data logger with no internal telemetry included. Telemetry using the Storm3-00 requires the use of an external modem. The Storm3-03 is the data logger with an internal cellular code division multiple access (CDMA) modem. The data logging hardware included in each version is identical.

WaterLOG/Xylem Inc. also provides a cloud-based data service named StormCentral (http://stormcentral.waterlog.com). StormCentral is a cloud-based data-collection service designed to be used with WaterLOG's data loggers. The functionality of the service was included in this evaluation, but it should be noted that reliance on third-party data-collection services is generally not recommended at USGS sites.

To use StormCentral, the user must create an account and input telemetry information for a Geostationary Operational Environmental Satellite system (GOES)- or cellular-based site. At this time, only sites using GOES satellite or cellular telemetry are supported. The user must log into their account and request a registration code to link their logger to their StormCentral account. StormCentral will then collect real-time telemetered data, which can be viewed on the StormCentral Web site (fig. 3). StormCentral also allows the user to set up text or email-based alarms if the data meet user-defined conditions. There is currently no cost to the user to use StormCentral. All collected data are also saved internally to a log file, which can be viewed or downloaded using the Storm's browser-based GUI.

The Storm supports multiple-sensor input types, including analog, digital, and serial digital interface (SDI)-12 (SDI-12 Support Group, January 2013). Data processing is also supported, including built-in slope/offset correction. More complex or customized algorithms can be created using BASIC programming. Data are logged internally and log files can be saved to a USB device using either of the USB ports on the front of the logger. The Storm's software lacks the ability to set up alarm conditions. Alarms are only available to users of the StormCentral cloud-based data-collection service.

Figure 1. Photograph showing Waterlog/Xylem Incorporated Storm 3-00 data logger.

[1]Manufactured by WaterLOG/Xylem Incorporated, Yellow Springs, Ohio.

Table 1. Manufacturer's specifications for the WaterLOG/Xylem Inc. Storm data-collection platform.

[°C, degrees Celsius; V, volts; %, percent; mA, milliAmperes]

Feature	Specification
Housing dimensions	4.37 inches in length x 2.45 inches in width x 7.375 inches in height
Housing material	Extruded aluminum
Weight	2 pounds
Operating temperature range	−40 to +60 °C
Analog inputs	4
Analog input range	0.0 to 5.0 V
Analog input accuracy	±0.025% of full scale
Digital inputs/outputs	4 bidirectional
Digital input range	0.0 to 5.0 V
Digital output range	0.4 V to 3.5 V (at maximum 5 mA current)
Switched voltages	1, 12 V
Telemetry options	GSM/GPRS, CDMA (optional), compatible with external GOES/METEOSAT/INSAT modem
Communication interfaces	2 USB A, 1 USB Mini B, 1 RS-232, 1 RS-485
SDI-12 Support	Version 1.3 compliant
Power consumption	Without internal modem: Typically 3.5 mA standby, 50 mA active With internal modem: Typically 4.5 mA standby, 100 mA active

Figure 2. Screen capture of WaterLOG/Xylem Incorporated Storm 3 data logger user interface, opened in Internet Explorer Web browser, version 8.0.

Table 2. Versions of the WaterLOG/Xylem Inc. Storm 3 data logger.

[GSM-3G, Global System for Mobile communication, third generation; CDMA, code division multiple access; GPRS, general packet radio service]

Model number	Description
Storm3-00	Storm3 data logger (no integrated telemetry)
Storm3-02	Storm3 data logger with integrated GSM-3G cellular modem
Storm3-03	Storm3 data logger with integrated CDMA-1X cellular modem
Storm3-04	Storm3 data logger with integrated GSM-GPRS international cellular modem
Storm3-05	Storm3 data logger with integrated GSM-3G international cellular modem

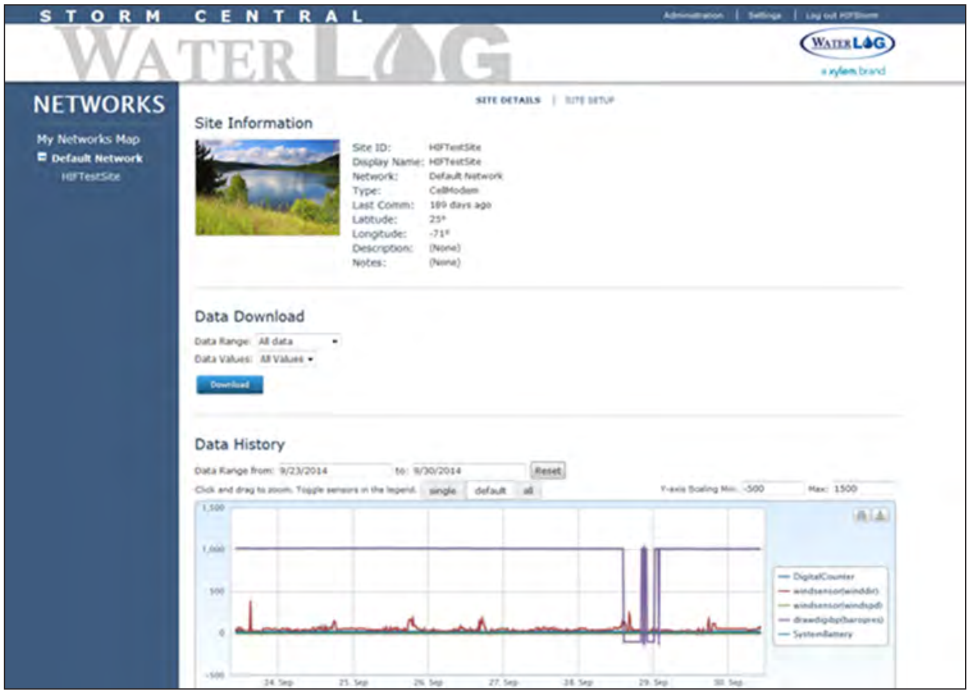

Figure 3. Screen capture of StormCentral Web site (http://stormcentral.waterlog.com).

Methods

Three Storm data loggers were evaluated with multiple sensors under varying temperatures and environmental conditions. Testing consisted of three phases. First, basic functionality and accuracy were evaluated on a test bench. In the next phase, one of the Storm3-00 units was evaluated in an environmental test chamber (ESPEC[2] ESZ-3CA, serial no. 017947). Finally, two Storms were deployed outdoors at the HIF for an extended period of time to evaluate their performance in a realistic environment. All testing was performed with Storm firmware version 1.4.0.

Bench testing of the Storm was performed on one Storm3-00 data logger, serial number 1056. Testing was conducted at room temperature and included evaluation of: (1) analog input accuracy, (2) digital counter accuracy, (3) fixed and switched voltage accuracy, (4) power consumption, (5) digital output voltage accuracy, and (6) SDI-12 compliance tests. No additional sensors were connected to the Storm during these tests.

Analog input accuracy was evaluated using a calibrated digital power supply,[3] and Direct Current (DC) voltages of 0 volts (V), 2.5 V, and 5 V were connected to each of the Storm's analog input terminals. The input value was compared to the Storm's reported measured voltage and evaluated against the manufacturer's specification for analog input accuracy.

Digital inputs (or digital counter accuracy) were evaluated by connecting a simple push-button switch to each digital input terminal. With the Storm's digital inputs set up as counters, the switch was pressed and released 10 times, with approximately 1 second between presses. The measured count of each digital input was checked to verify that it recorded the correct number of counts.

For the fixed and switched voltage accuracy test, each of the Storm's fixed and switched voltages were measured using a National Institute of Standards and Technology (NIST)-traceable, calibrated multimeter.[4] The 12-V switched voltage output was enabled and disabled in the Storm's software using a PC, and measured in both states.

Power consumption is based on the voltage and current of the device. As the voltage used in this evaluation was fixed, power can be calculated using only current measurements. All power-consumption data were measured by placing a multimeter in series with the Storm power input to measure current. Current was measured while the logger was making a measurement and while the logger was powered but inactive (standby mode).

The 5-V digital outputs were measured with a calibrated multimeter with a 1-kilohm (kΩ) load resistor attached between the output and ground. This results in a current load of 5 mA. Using a PC and the Storm's browser-based GUI, each digital output was set to be on (5 V) or off (0 V). Each output was measured in both states and evaluated against the manufacturer's specification for digital output voltage.

Compliance with SDI-12 Standard Version 1.3 (SDI-12 Support Group, January 2013) was evaluated using a PC and

[2]ESPEC North America, Inc.

[3]Tektronix PS280 DC Power Supply, Tektronix, Inc.

[4]HP 34401A Multimeter, Hewlett-Packard Co.

a SDI-12 verifier, using version 2.21 of the verifier software (NR Systems Inc., 1999) in data logger test mode. The SDI-12 verifier data logger test is an automated procedure that simulates a SDI-12 sensor interacting with the logger. As SDI-12 communication is taking place, the verifier monitors the data and electrical characteristics to verify that the device complies with the requirements described in the SDI-12 standard.

One Storm3-00 data logger, serial number 1056, was evaluated in an environmental test chamber. The environmental test chamber is capable of achieving and accurately maintaining temperatures from −40 to 60 degrees Celsius (°C) and is capable of achieving ±0.3 °C accuracy. The temperature chamber is biennially calibrated and verified using NIST-traceable standards. Operation of the environmental chamber was automated using custom software (LabVIEW).[5] Temperature testing was performed to evaluate the ability of the Storm 3 to log data over its full, specified temperature range. The chamber temperature was cycled between −40 and 60 °C, completing three temperature cycles over the course of the test (fig. 4). The cycles consisted of "ramp" periods during which the chamber was transitioning between temperatures and "soak" periods, in which the temperature was held at a constant value to allow the device under test to equilibrate to the new temperature. During ramp periods, the rate of temperature change was 1 °C/minute. Soak periods at intermediate temperatures were 120 minutes. Soak times at maximum and minimum temperatures were 240 minutes.

Table 3 lists the sensors that were logged during temperature testing. The test included single and multiparameter SDI-12 sensors, an analog voltage input, and a digital switch. The sensors were selected to include the instrument types used at a typical USGS hydrologic data-collection site. All SDI-12 sensors were connected to the data logger through a custom SDI-12 bus box. The digital push-button switch was used to simulate a tipping-bucket rain gage. The switch was used to simulate several tips at room temperature, but this function was not tested at high or low extreme temperatures. The Storm was placed inside the environmental chamber and connected with a serial cable to a WaterLOG/Xylem Inc. H-2221-V2 (WaterLOG/Xylem Inc., 2014b) GOES transmitter that was placed outside the chamber. The Storm was configured to log data from each sensor at 5-minute intervals. The data were transmitted at 10-minute intervals at a rate of 300 baud. The data from this phase of testing were transmitted to a local radio frequencies (RF) receiver, and a dummy load was connected to the H-2221's antenna output. The transmitted RF signal was received by a Microcom GOES Transmitter Test Set TS-101-GOES (Microcom Design Inc., n.d.) and the data were recorded on an attached laptop. Transmissions were monitored for data accuracy.

Two Storm data loggers—a Storm3-00 with serial number 1077 and a Storm03-03 with serial number 13J101876—were evaluated in an outdoor environment. Outdoor deployment testing was performed at a site next to the HIF building at Stennis Space Center, Mississippi, over 16 weeks, from June 9 to September 30, 2014, to evaluate the Storm in a real-world environment. The Storm, a Power-Sonic[6] 1295 12V, 9.5 Amp-hour lithium-ion battery, a Morningstar SS-6-12-V solar regulator (Morningstar Corporation, 2011), and WaterLOG H-2221-V2 GOES transmitter were mounted inside a fiberglass enclosure that was bolted to a wooden fence (fig. 5). Battery charge was maintained using a 20-watt solar panel mounted on a pole outside the enclosure. Three sensors were mounted to the fence outside the housing and wired into the logger. Table 4 lists the sensors used in the deployment test. These sensors were selected to include the instrument types used at a typical USGS hydrologic data collection site.

Both Storm loggers were programmed to include redundant datasets, meaning that each transmission includes the current measurement and the previous measurement. The two loggers were tested sequentially at the site. Serial number 1077, a Storm3-00, was tested for the first 3 weeks, from June 9 to July 2, 2014. The device was programmed to log data at 15-minute intervals and to transmit the data hourly to GOES satellites using the H-2221 transmitter. The data sent using GOES were verified by monitoring the USGS Emergency Data Distribution Network (EDDN) Web site (http://eddn.usgs.gov/). On July 2, 2014, Serial number 1077 was disconnected and replaced by a Storm03-03 (serial number 13J101876) in the enclosed housing. Serial number 13J101876 was configured to log data from the same sensors and to transmit the data to StormCentral using the internal CDMA modem. A registration code was generated on the StormCentral Web site. The code was programmed into the Storm, linking it to the StormCentral account used for this test. Data were collected and transmitted at 15-minute intervals. During this part of the test, no redundant datasets were transmitted and the H-2221 was disconnected from the battery. This test lasted 13 weeks, from July 2 to September 30, 2014. The data from this logger were monitored on the StormCentral Web site.

[5]System design software by National Instruments Corp.

[6]Power-Sonic Corporation, San Diego, Calif.

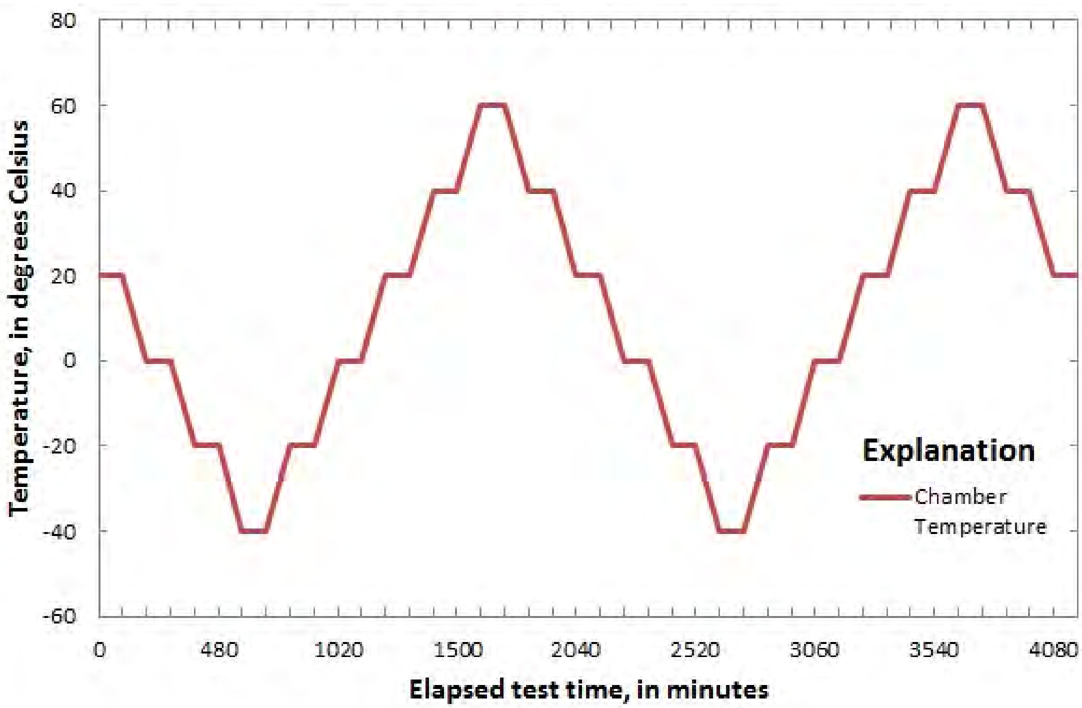

Figure 4. Graph showing temperature profile used during temperature cycling testing for Waterlog/Xylem Incorporated Storm 3 data logger (serial number 1056). Temperatures were applied during logging (5-minute intervals) and transmissions (10-minute intervals).

Table 3. Sensors used during temperature chamber testing of WaterLOG/Xylem Inc. Storm 3-00 data logger (serial number 1056).

Instrument	Type	Serial number	SDI-12 bus address
Handar Model 436 shaft encoder	Single parameter SDI-12	0625	2
Paroscientific PS2 water stage sensor	Single parameter SDI-12	49239	0
HP 6114A precision power supply	Analog	2110A-02381	
Push-button switch, generic, lab stock	Digital counter	None	
Hydrolab Datasonde 4, with attached temperature, conductivity, pH, and dissolved oxygen sensors	Multiparameter SDI-12	35390	1

Figure 5. Photograph showing deployment site used for Waterlog/Xylem Incorporated Storm 3 data logger field test.

Table 4. Sensors used during outdoor deployment testing of WaterLOG/Xylem Inc. Storm 3 data logger at Stennis Space Center, Mississippi, during late summer 2014.

Instrument	Type	Serial number	SDI-12 bus address
RM Young SDI-WS-RMY-2 wind sensor	Multiparameter (2) SDI-12	055114	0
FTS DigiBP SDI-12 pressure sensor	Single parameter SDI-12	055145	1
Hydrological Services TB3 Rain Gauge	Tipping Bucket Rain Gauge	97-895	

Table 5. Results of room temperature bench testing of WaterLOG/Xylem Inc. Storm 3 data logger (serial number 1056) for compliance with selected manufacturer's specifications.

[V, volts; mA, milliAmperes]

Feature/specification	Test	Test result
Analog input accuracy	Voltage inputs at 0, 2.5, and 5 V	Error<0.001 V
Digital counter accuracy	Push button switch, pressed 10 times	10 counts
Power consumption	Standby	~3.98 mA
	During SDI-12 measurement	~55 mA
	With WiFi enabled	~100 mA
Fixed and switched voltage accuracy	+12 V switched	ON: 12.201 V OFF: 0.000 V
	+5 V fixed	ON: 5.002 V OFF: 0.688 mV
Digital output accuracy	Voltage with 5-mA load	Voltage>4.65 V
SDI-12 v1.3 compliance	SDI-12 verifier, version 2.21	PASS

Results

The performance of the three devices was evaluated using the methods described above. Bench testing results are shown in table 5 for the one device tested—serial number 1056. Analog voltages were measured to be accurate to within ± 0.001 volts at the tested voltages of 0, 2.5, and 5 V DC. Power consumption in standby was measured at 3.98 milliamperes (mA). During a measurement, this increased to 55 mA. Both values are about 10 percent higher than the manufacturer's specification, but it is unlikely that this exceedance will have a substantial effect on battery life. Enabling WiFi increased the current draw to approximately 100 mA. Users who intend to leave WiFi enabled should be aware that this may have a significant effect on battery life. During temperature chamber testing on serial number 1056, data were accurately logged and transmitted to the test set. Out of 710 total transmissions, only 1 contained corrupted data. This results in a transmission error rate of 0.14%. Data in the Storm's internal log file were not corrupted or affected by the transmission error.

The data from deployment testing of serial number 1077 included several errors in logging data from the attached sensors. The logger's event log reported each of these errors as a "sensor timeout" error. Over the course of 3 weeks (June 9 to July 2, 2014), the logger made 475 measurements; 52 of these measurements contained errors, resulting in a total error rate of 10.95 percent. All of the errors occurred between June 15 and July 1, 2014, after the first 6 days of the test. The majority of the errors occurred when recording the FTS DigiBP SDI-12 pressure sensor (37 errors). Fewer errors occurred when recording the RM Young SDI-WS-RMY-2 wind sensor (10 errors) and the Australian Hydrological Services Tipping Bucket Rain Gauge Model TB3 (5 errors).

The data from serial number 13J101876 also contained logging errors, but only for the FTS DigiBP SDI-12 pressure sensor. Out of 8,638 total measurements by the pressure sensor, 252 logging errors occurred, resulting in an error rate of 2.92 percent. Logging of data using StormCentral functioned as described by the manufacturer. Analysis of the data shows a possible link between the logging errors and rainfall (fig. 6). Errors occurred more frequently when the rainfall value recorded by the Hydrological Services TB3 Rain Gauge was increasing or immediately after. Conversely, several intense rainfall events occurred that did not coincide with logging errors, so there is not enough information to draw a conclusion based on this observation. There is also not enough information to conclude whether the errors are the fault of the Storm or of one of the SDI-12 sensors being logged during the test. It is recommended that future tests of data loggers include multiple units with identical instrumentation and configuration so that error sources can be more easily identified.

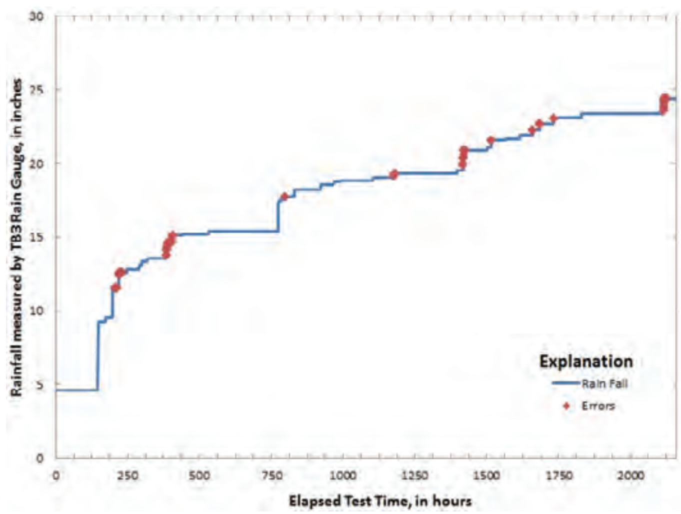

Figure 6. Graph showing comparison of WaterLOG/Xylem Incorporated Storm 3 data logger (serial number 13J101876) logging errors during deployment testing and rainfall measured by Hydrological Services TB3 Rain Gauge. A possible correlation was observed between rainfall events and logging errors; however, the link was inconclusive.

Summary

The WaterLOG/Xylem Incorporated Storm 3 data logger was evaluated to determine if it met the manufacturer's stated specifications and if it was suitable for use in USGS hydrologic data-collection activities. The evaluations included bench testing, temperature chamber testing over the device's full operating temperature range, and deployment testing in an outdoor environment. The device met the manufacturer's stated specifications during nearly all phases of testing, but its power consumption was about 10 percent above the manufacturer's specification. Additionally, enabling WiFi was found to double the power consumption. In addition, several logging errors were encountered during deployment testing, but there was not enough information to determine whether the errors are the fault of the Storm, an attached sensor, or the combined effects of the sensors.

Overall, the Storm's browser-based interface and remote communication make it a suitable choice to consider using for data collection and telemetry at USGS field locations. Users who intend to leave WiFi enabled should be aware that it will have a significant effect on their battery life.

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