Effective Use of Real Time Water Quality Data in an Early Warning System

Data Management, Data Analysis, and Compliance Considerations

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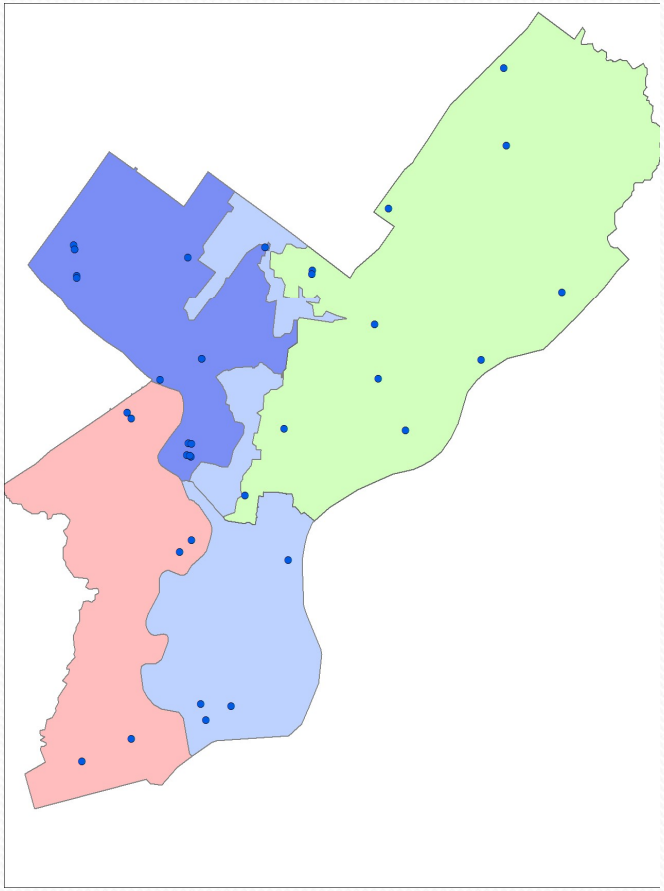
Purpose

- Explore data management and analysis of an online water quality monitoring (OWQM) system
- Identify potential challenges in using this data for compliance monitoring
- Majority of drinking water distribution system online monitoring are not designed with compliance monitoring as a priority or even as a consideration

Overview of PW's OWQM System

- 36 OWQM sites throughout the city
- Up to 9 parameters at any given site: primary and redundant total chlorine, conductivity, oxidation reduction potential (ORP), pH, pressure, temperature, turbidity, UV254 (measure of organic carbon)
- 2 minute data generation



Map of Philadelphia's OWQM Sites

OWQM Tools used for Data Collection, Management, and Analysis

ClearSCADA

Dashboard

Bluebox

WISKI®

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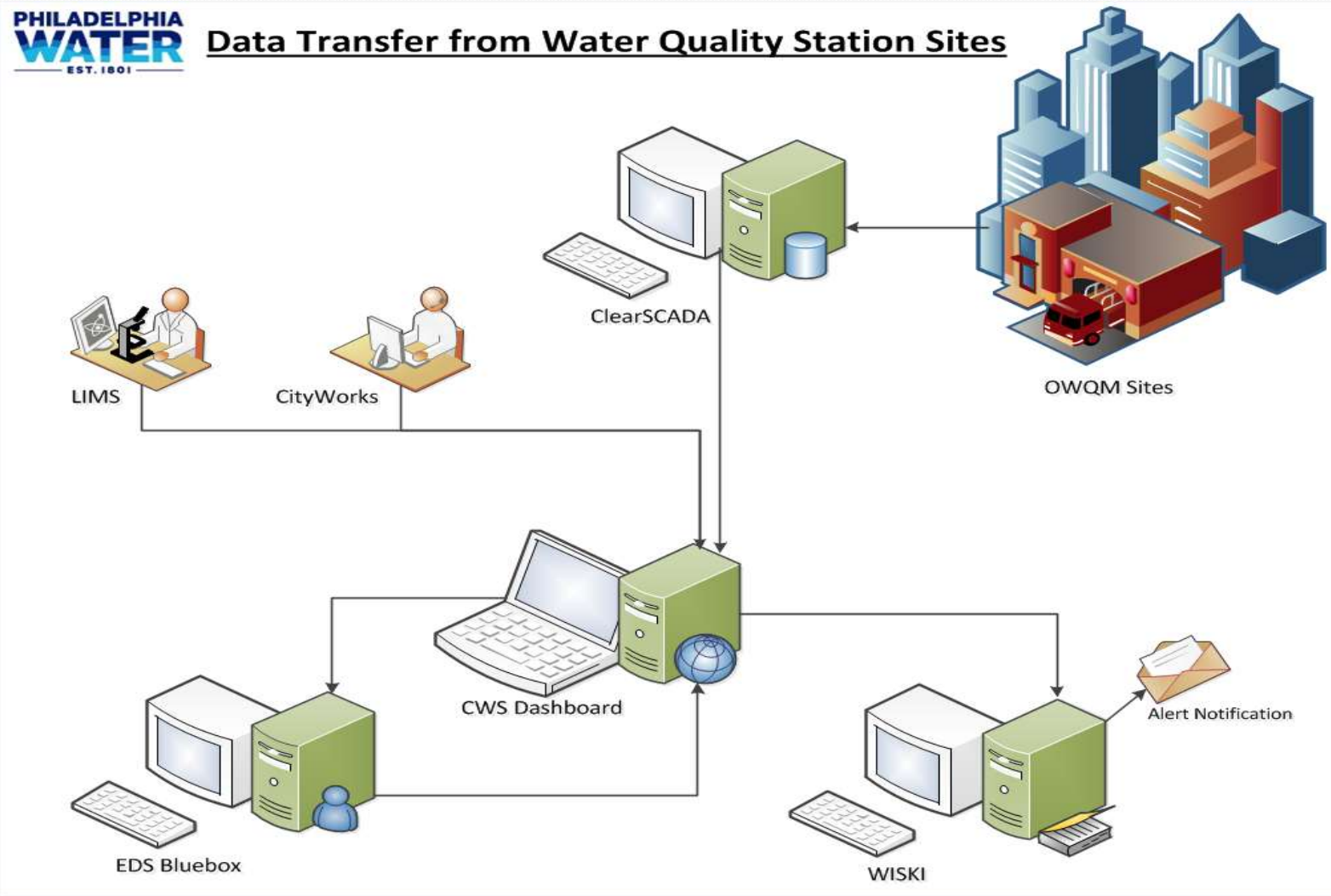
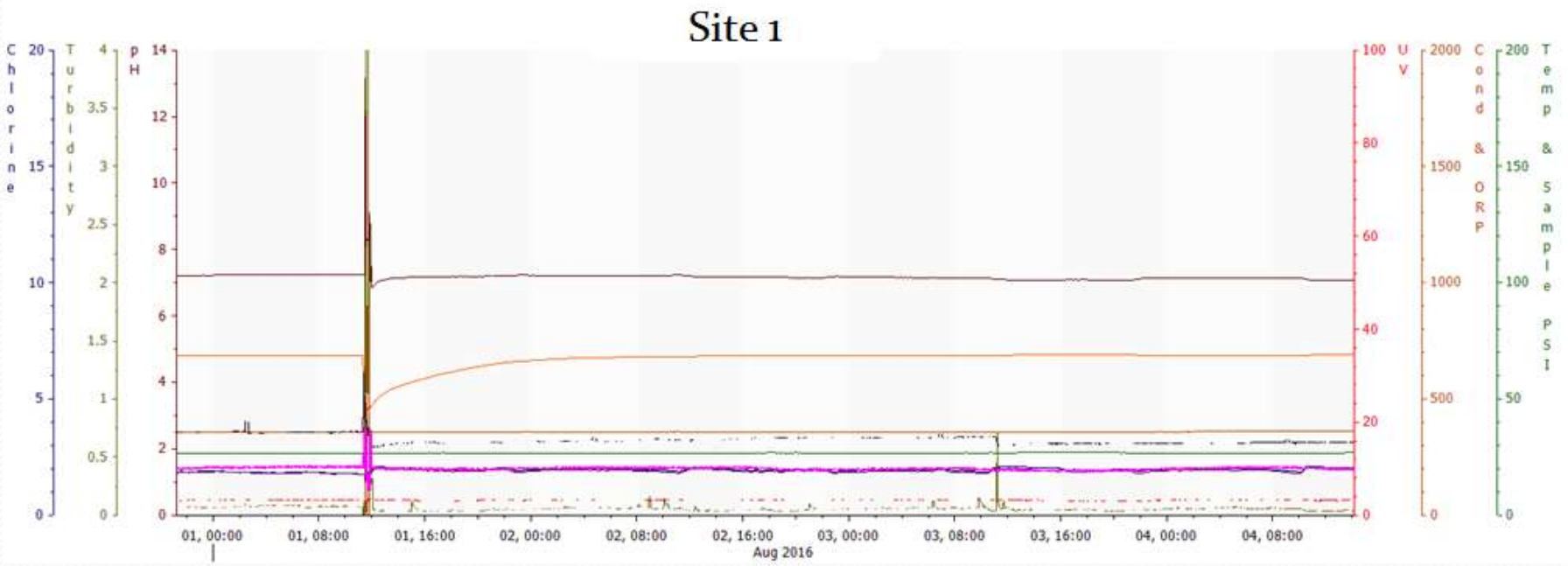


Diagram of PW's OWQM data transfer process from Sites to data management software

ClearSCADA

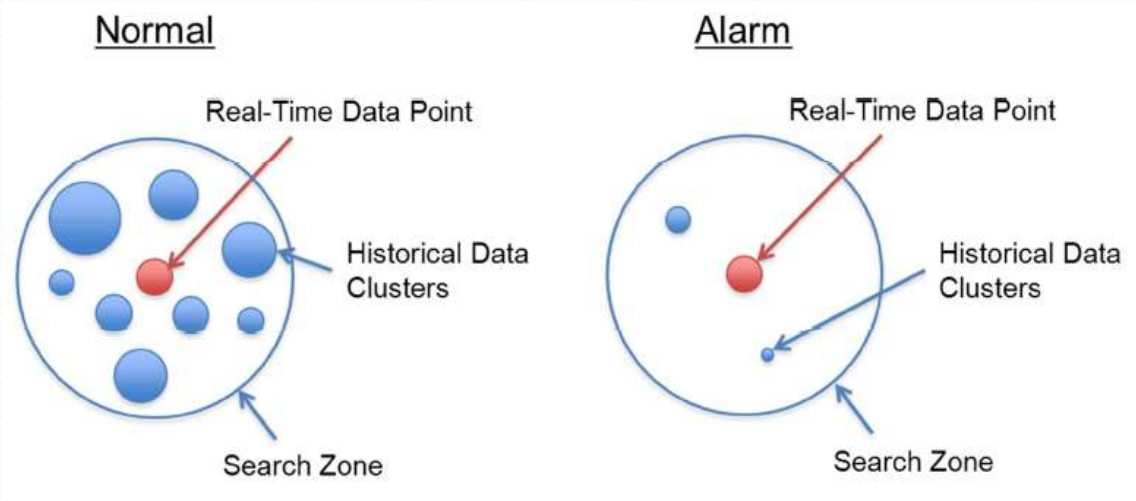
- Produces raw data from all sites at 5-min, 10-min, or longer time intervals
- Used mostly to monitor sensor behavior
- Additional parameter: sample flow (gpm) – used to detect if sensor is out of use



Time Series graph generated in ClearSCADA from an OWQM station

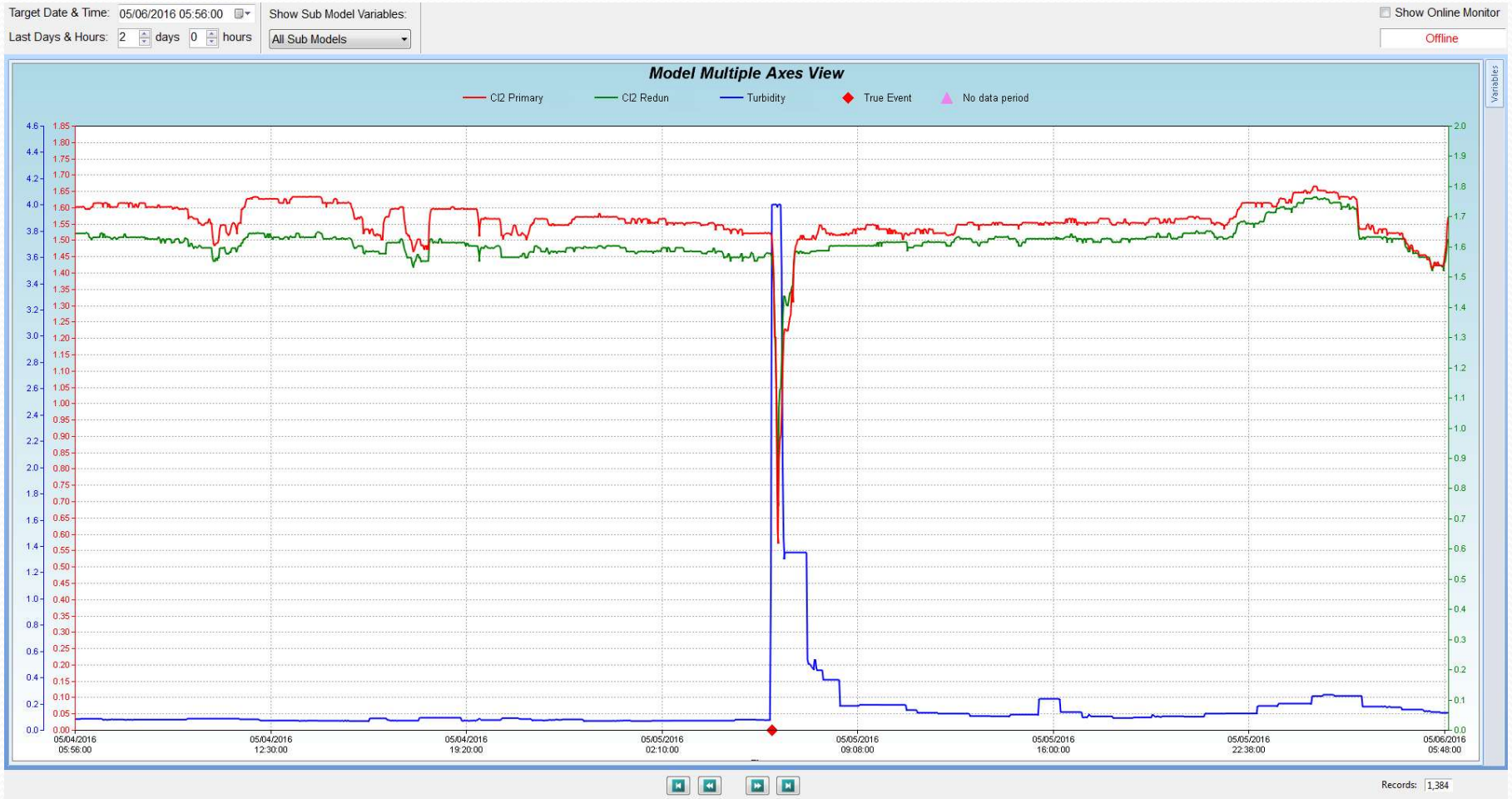
BlueBox

- Event detection system (EDS)
- Data points are grouped into sub-models
- Clustering analysis performed on sub-models
- Alerts are generated using density thresholds within this clustering method



Visual Representation of How BlueBox Generates Alarms

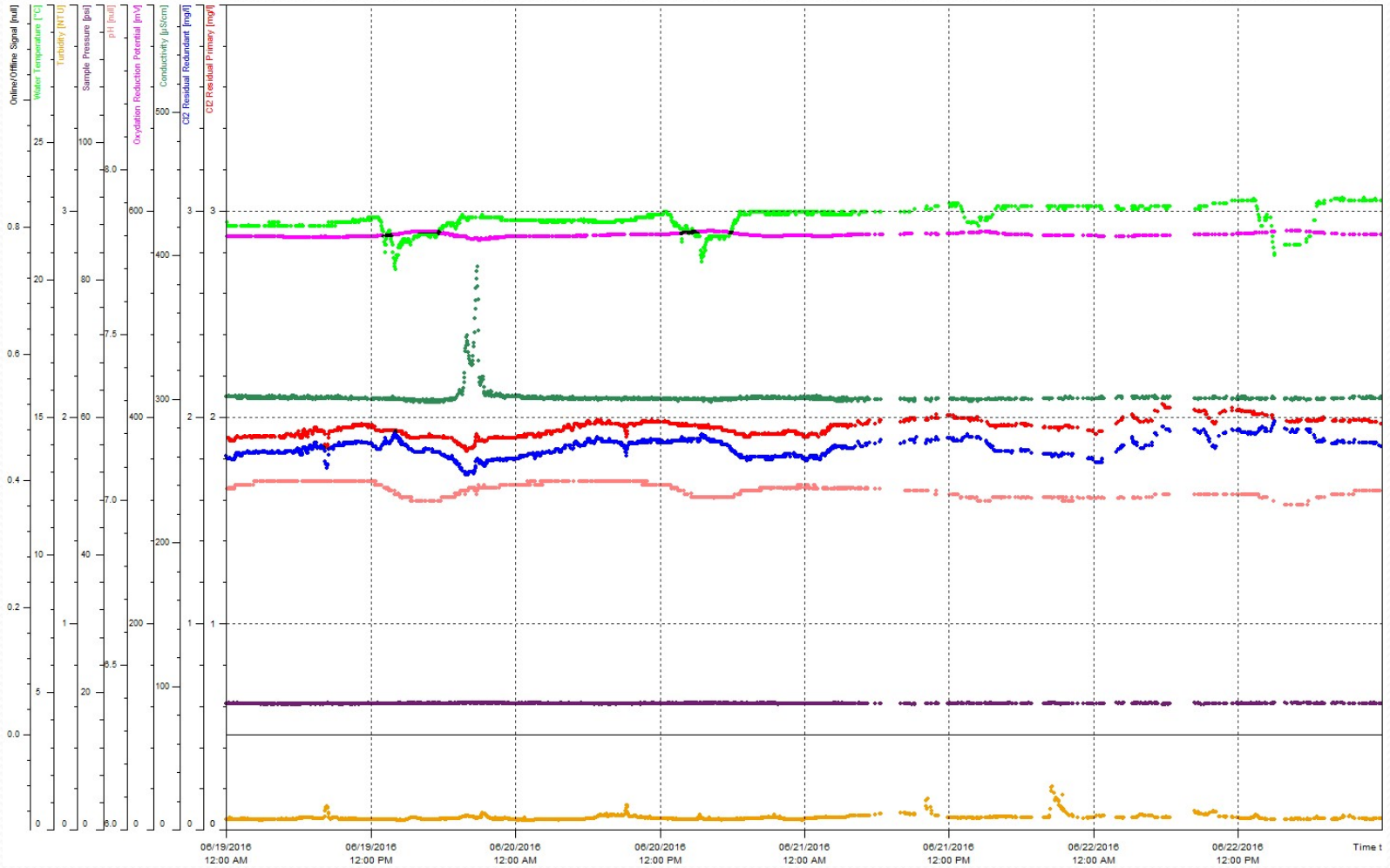
Example of a BlueBox Alarm Situation



BlueBox Alarm in Response to a Water Main Break

WISKI®

- Water Information Systems Kisters, is our data management system
- Validation steps
- Variability in graphical parameters
- Monitored daily



Example of a WISKI Graph Covering 1 Week

Dashboard

- Incorporates data from several sources:
  - EDS (BlueBox)
  - ClearSCADA/WISKI®
  - Laboratory Information Management System (LIMS) – basic lab data
  - Customer complaints
  - ArcGIS

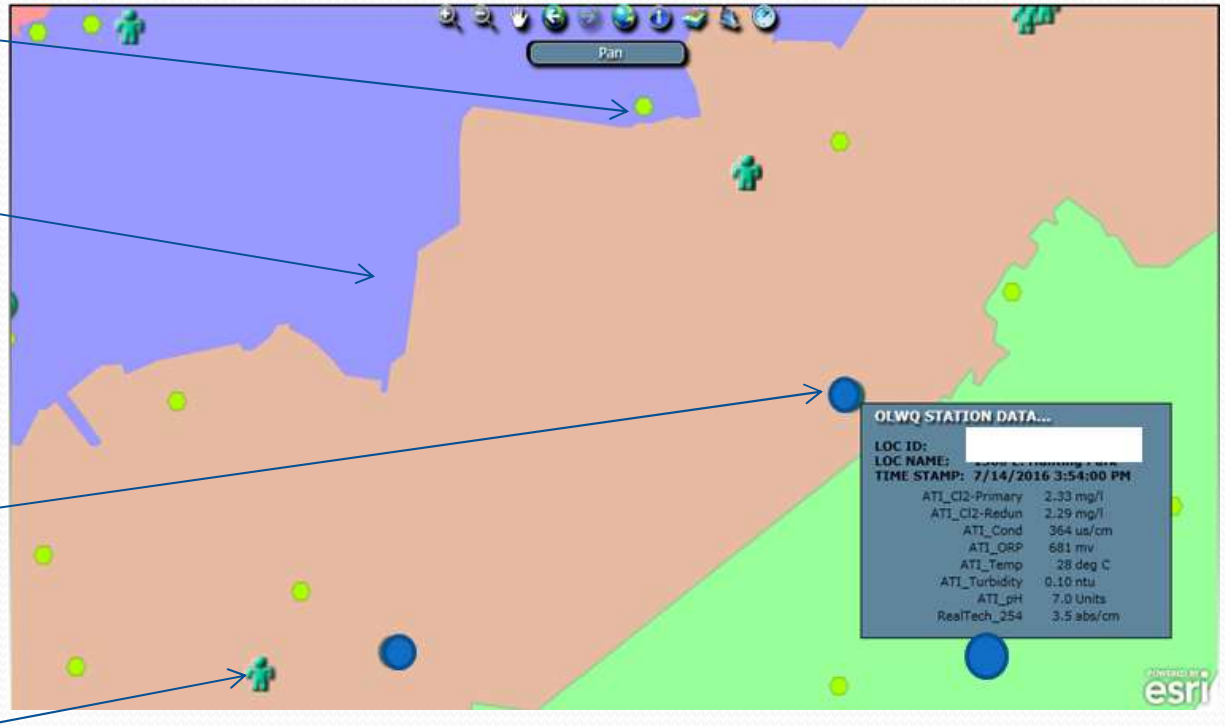
Dashboard - Example

Grab Sample Site Site

GIS Interface

OWQM Site

Customer Complaint



Example of CWS Dashboard Interface

Challenges Faced in OWQM Data Analysis and Management

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System Integration

- In-house program was designed for data transfer
- Different groups manage the different steps in the process:
  - Can create issues when diagnosing and remediating software issues
  - Can make coordinating changes and updates difficult
  - Large amount of staff time required

Event Detection System

- EDS in a historical data management world
  - Finding the right EDS for the system
  - Sophisticated statistical analysis
- Staff Time
  - Every Site/Model is different & can change
  - Reviewing and classifying alerts

Overall Stats	
Total Time (Hours)	673
Avg Time Per Session (HH:MM)	1:14
Avg Time Per Day (HH:MM)	0:35

Hourly Work Load for PW's Event Detection System

Control Limits

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Control Limit Selection

- Continually trying to improve and optimize
- Follows Umberg and Allgeier, 2016
- Currently based on general knowledge
- Percentiles to develop control limits for each individual site
- If percentile is outside of the range of existing control limits, what are other options?

Existing Control Limits

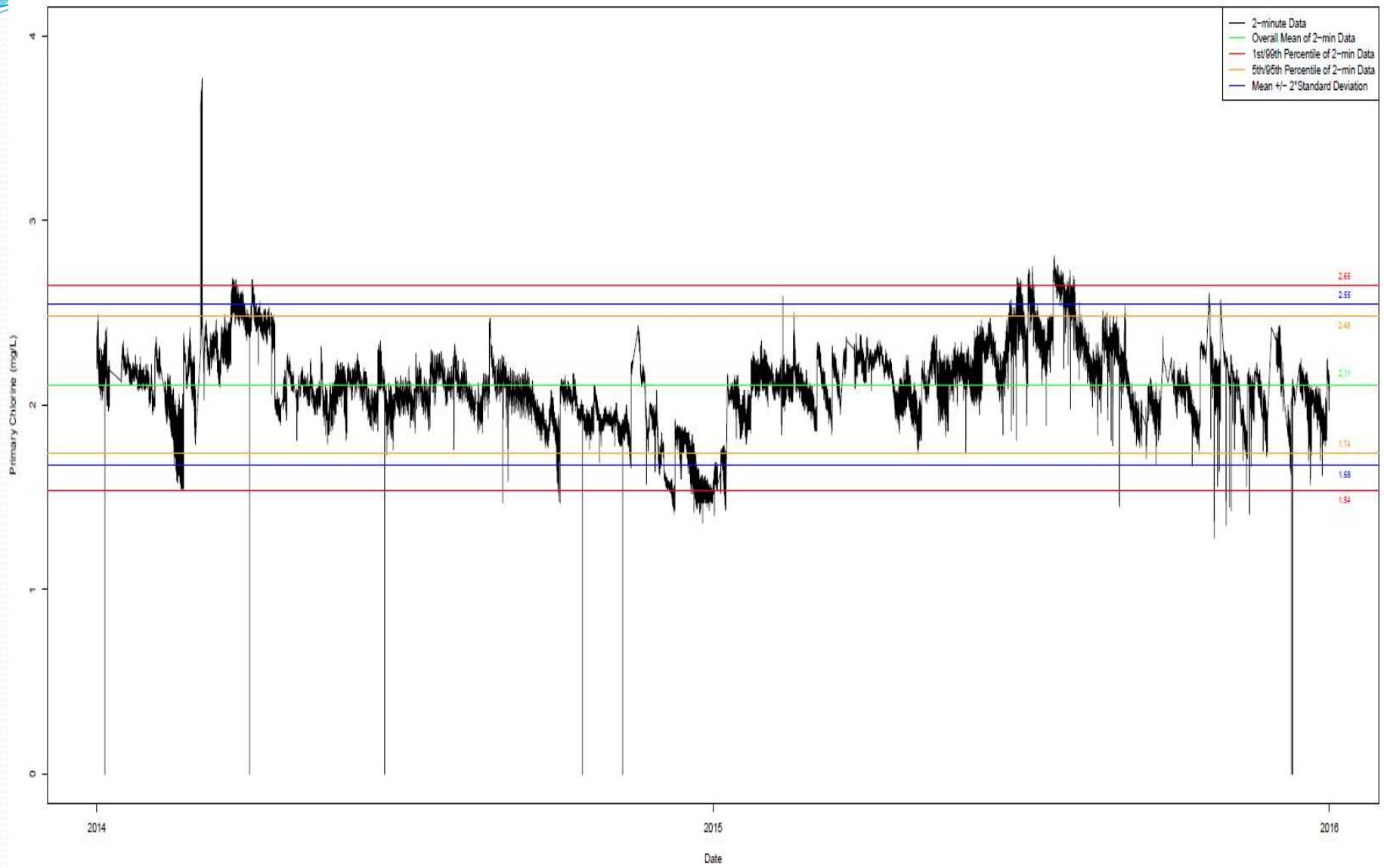
OWQM Parameter	Low Set Point	High Set Point	Units
Primary Total Chlorine	1	3	mg/L
Redundant Total Chlorine	1	3	mg/L
Conductivity	100	1000	µS/cm
Oxidation Reduction Potential (ORP)	100	1000	mV
pH	6.8	7.5	-
Pressure	5	40	PSI
Temperature	5	35	°C
Turbidity	0	0.5	NTU
UV254	0.02	0.1	A/cm
Flow	0.1	1	gpm

Existing Control Limits for all Sites

Control Limits - Percentiles

Site 1			
OWQM Parameter	Low Set Point	High Set Point	Units
Primary Total Chlorine	1.54	2.65	mg/L
Redundant Total Chlorine	1.48	2.62	mg/L
Conductivity	266	719	µS/cm
Oxidation Reduction Potential (ORP)	250	712	mV
pH	6.93	7.44	-
Pressure	17.68	35.02	PSI
Temperature	6.72	26.67	°C
Turbidity	0.007	0.11	NTU
UV254	0.021	0.043	A/cm
Flow	0.1	1	gpm

Proposed Control Limits for Site 1 based on Percentiles

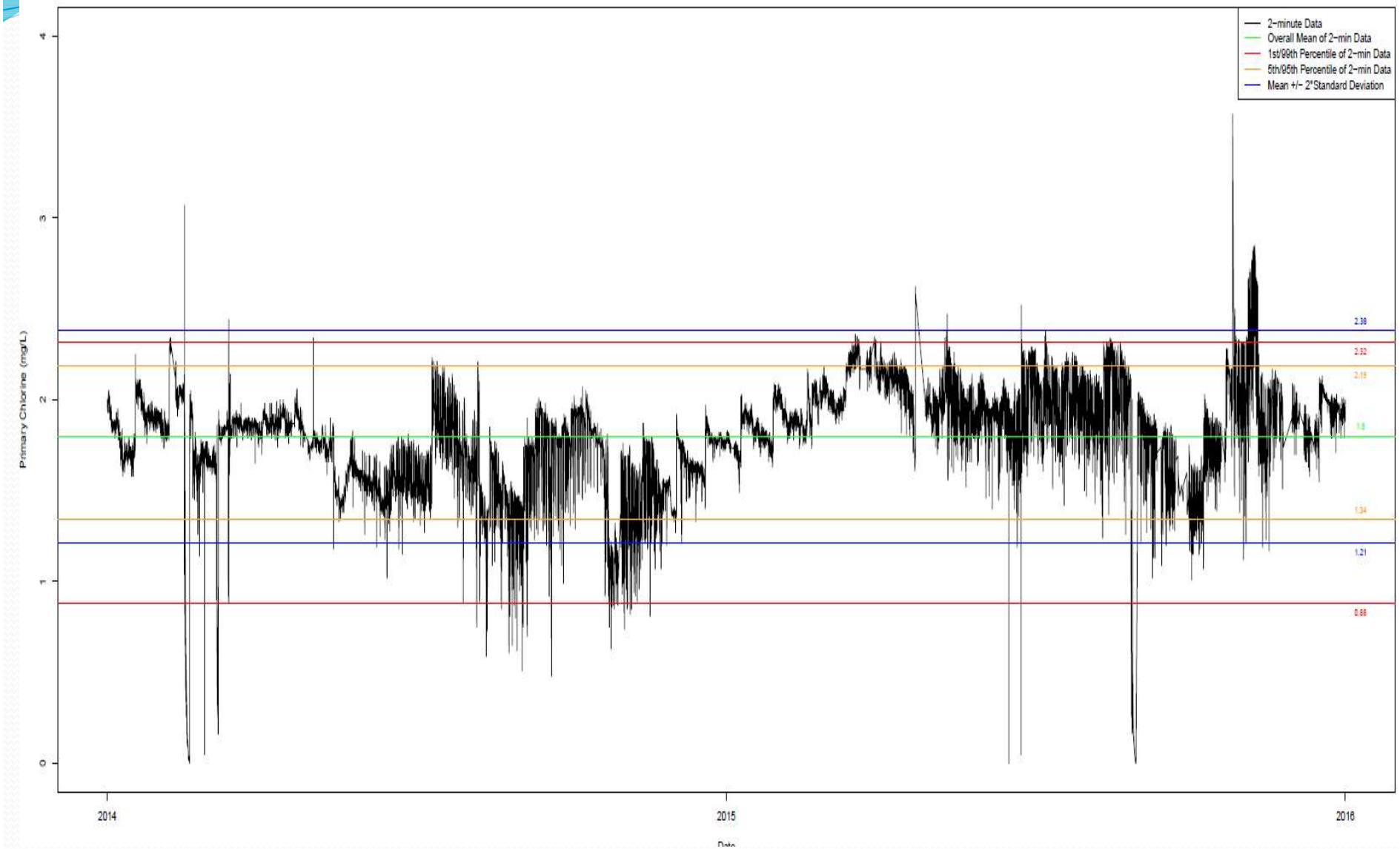


Total Chlorine data from 1/1/14-12/31/15 for site 1

Control Limits - Percentiles

Site 2			
OWQM Parameter	**Low Set Point**	**High Set Point**	**Units**
Primary Total Chlorine	0.88	2.32	mg/L
Redundant Total Chlorine	0.69	2.28	mg/L
Conductivity	256	743	µS/cm
Oxidation Reduction Potential (ORP)	454	682	mV
pH	6.83	7.41	-
Pressure	39.51	49.9	PSI
Temperature	6.31	29.17	°C
Turbidity	0.018	1.004	NTU
UV254	0.023	0.043	A/cm
Flow	0.1	1	gpm

Proposed Control Limits for Site 2 based on Percentiles



Total Chlorine data from 1/1/14-12/31/15 for site 2

Percentiles Outside of Existing Range

Site	Parameter	1st Percentile	5th Percentile	95th Percentile	99th Percentile	Number of Data Points
2	Primary Chlorine	**0.88**	1.34	2.19	2.32	388885
2	Redundant Chlorine	**0.69**	1.34	2.14	2.28	351021
2	Conductivity	256	284	633	743	400460
2	ORP	454	617	676	682	341074
2	pH	6.83	6.91	7.33	7.41	293016
2	Pressure	39.51	41.13	48.68	49.90	473280
2	Temperature	6.31	7.42	28.15	29.17	281378
2	Turbidity	0.018	0.034	**0.427**	**1.004**	453994
2	UV	0.0232	0.0247	0.0353	0.0430	427044

Percentiles of overall data for Site 2

Site	Parameter	Stat	1st Percentile	5th Percentile	95th Percentile	99th Percentile	Number of Days Total	Number of Days with Data
2	Primary Chlorine	Daily Mean	**1.06**	1.38	2.14	2.28	729	709
2	Redundant Chlorine	Daily Mean	**1.06**	1.38	2.12	2.21	729	708
2	Conductivity	Daily Mean	260	284	606	691	729	714
2	ORP	Daily Mean	347	618	678	682	729	713
2	pH	Daily Mean	6.86	6.91	7.33	7.39	729	676
2	Pressure	Daily Mean	40.04	41.48	48.06	49.07	729	714
2	Temperature	Daily Mean	6.61	7.43	28.08	28.85	729	713
2	Turbidity	Daily Mean	0.023	0.048	**0.393**	**0.860**	729	710
2	UV	Daily Mean	0.024	0.025	0.035	0.042	729	714

Percentiles of Daily Means for Site 2

Control Limits - Percentiles

Site 2			
OWQM Parameter	**Low Set Point**	**High Set Point**	**Units**
Primary Total Chlorine	**1.06**	2.32	mg/L
Redundant Total Chlorine	**1.06**	2.28	mg/L
Conductivity	256	743	µS/cm
Oxidation Reduction Potential (ORP)	454	682	mV
pH	6.83	7.41	-
Pressure	39.51	49.9	PSI
Temperature	6.31	29.17	°C
Turbidity	0.018	**0.427**	NTU
UV254	0.023	0.043	A/cm
Flow	0.1	1	gpm

Revised proposed control limits for Site 2

Precision and Accuracy of Data

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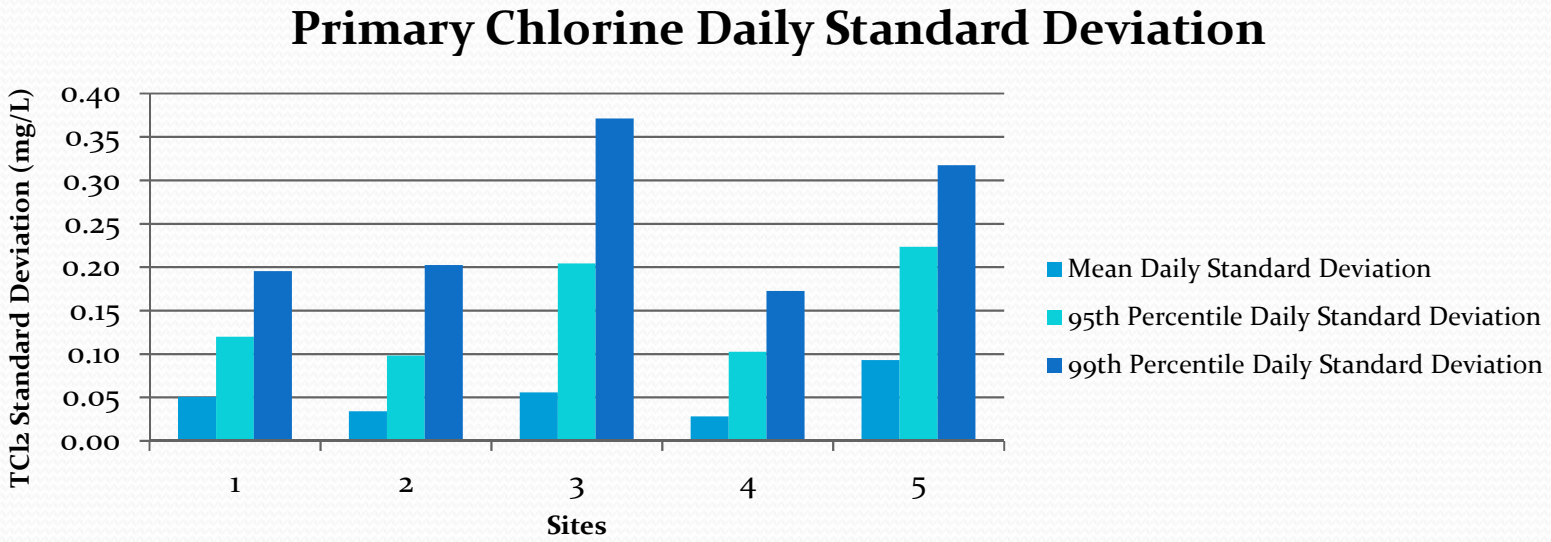
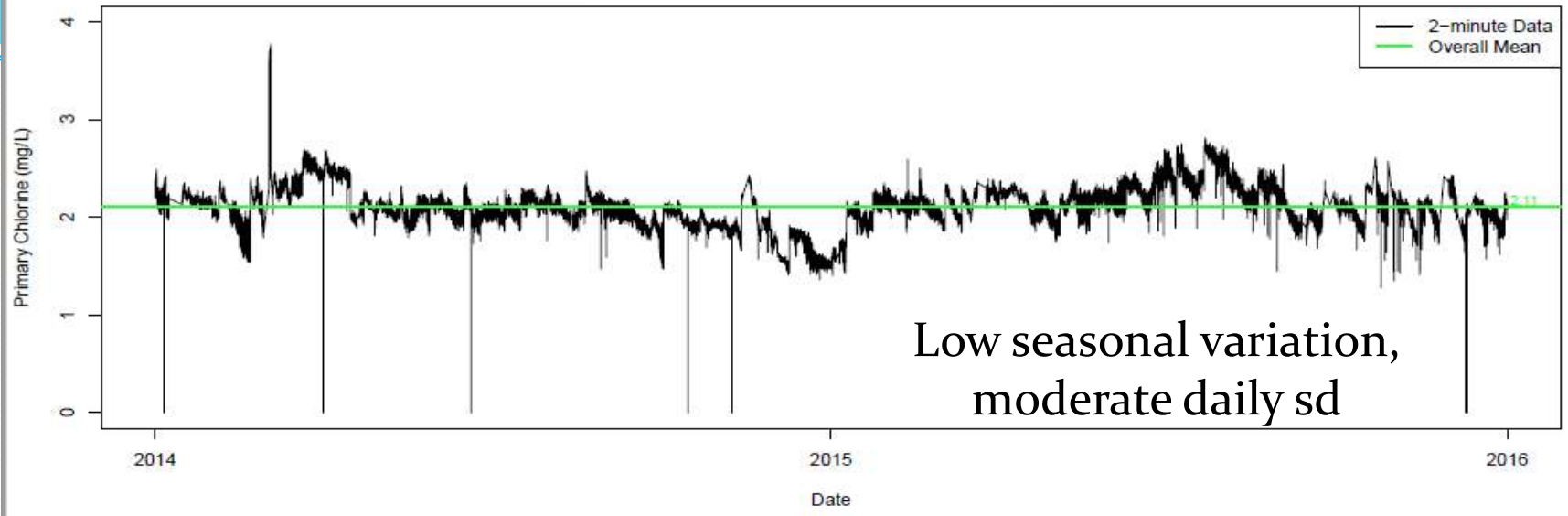
Precision

- Def – The measure of agreement among repeated measurements of the same parameter and same sensor under substantially similar conditions
- Hard to quantify in a complex water matrix
- Compare daily standard deviations of data from different sites

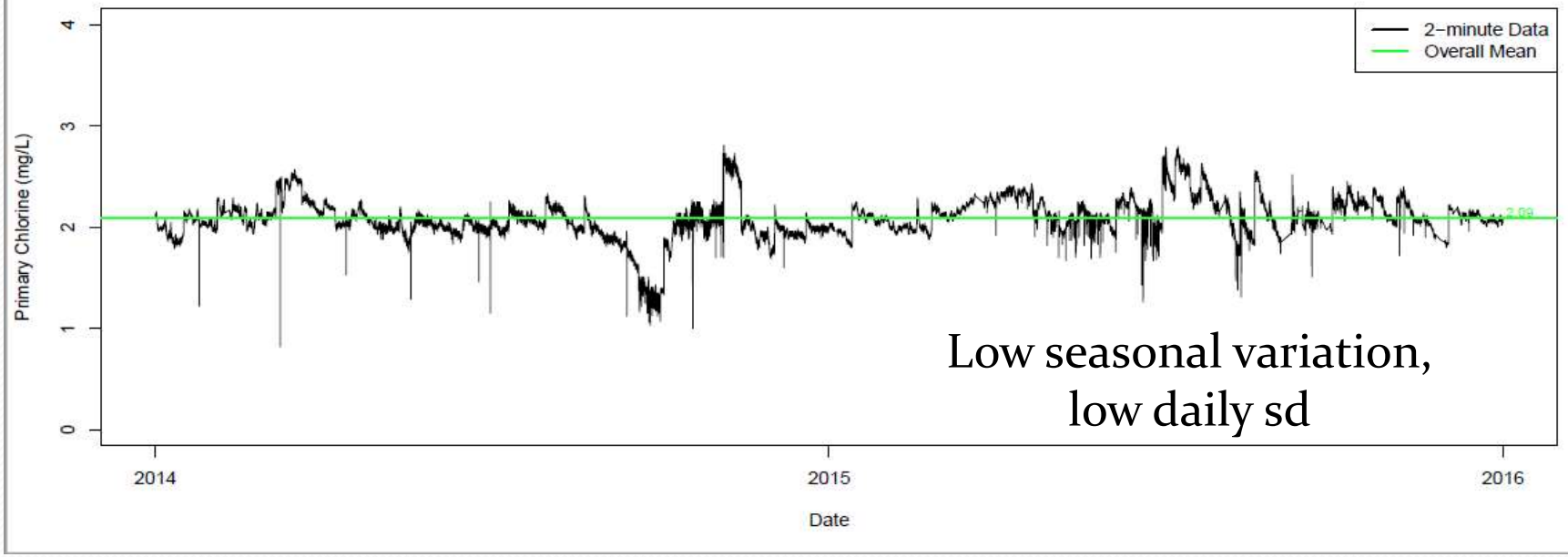


Site Comparisons of Daily Standard Deviations

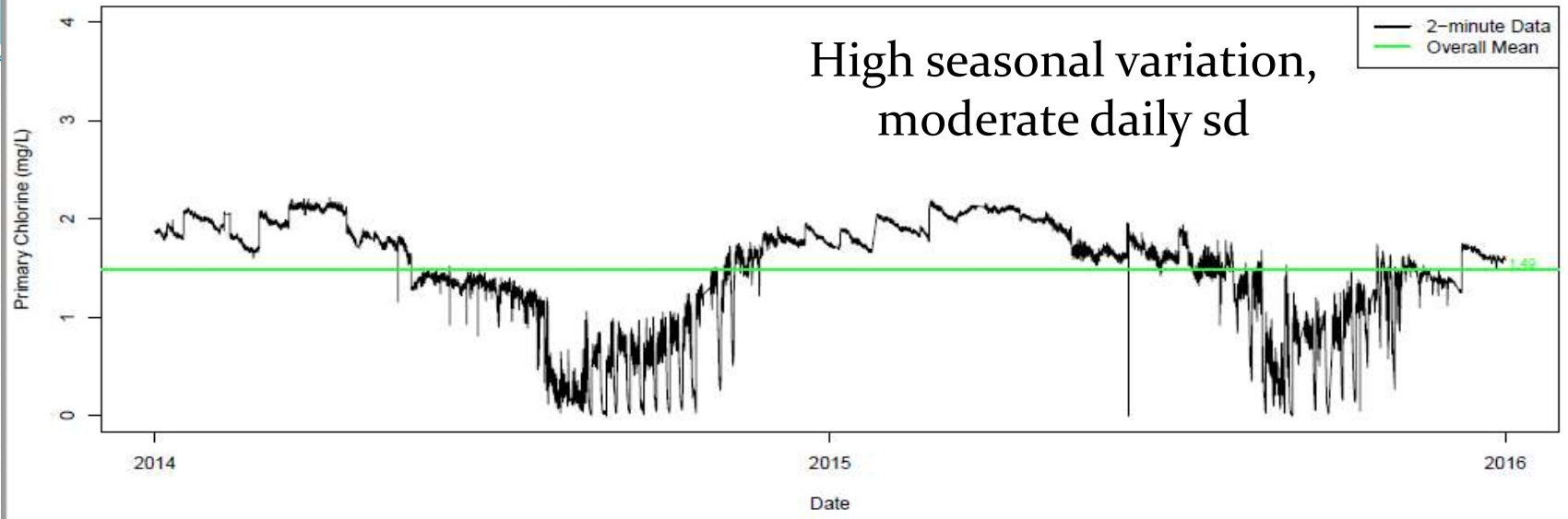
Site 1


2−minute Data
Overall Mean
Primary Chlorine (mg/L)
0
1
2
3
4
2014
2015
2016
Date
Low seasonal variation,
moderate daily sd

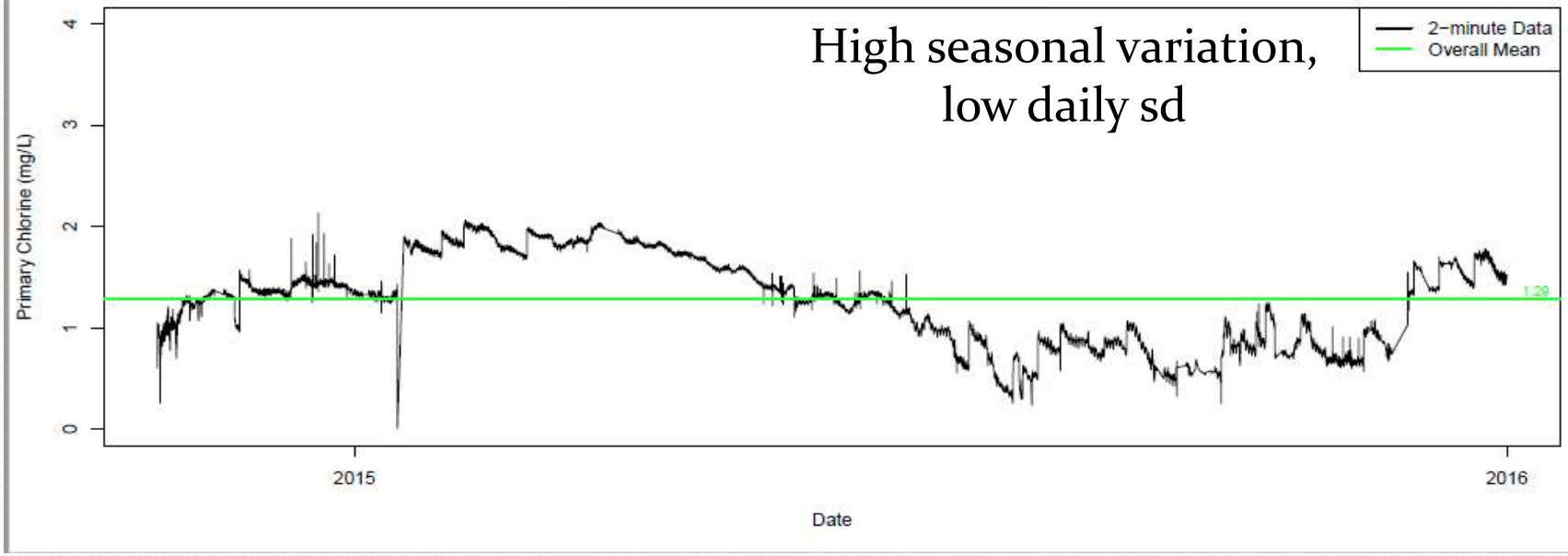
Site 2

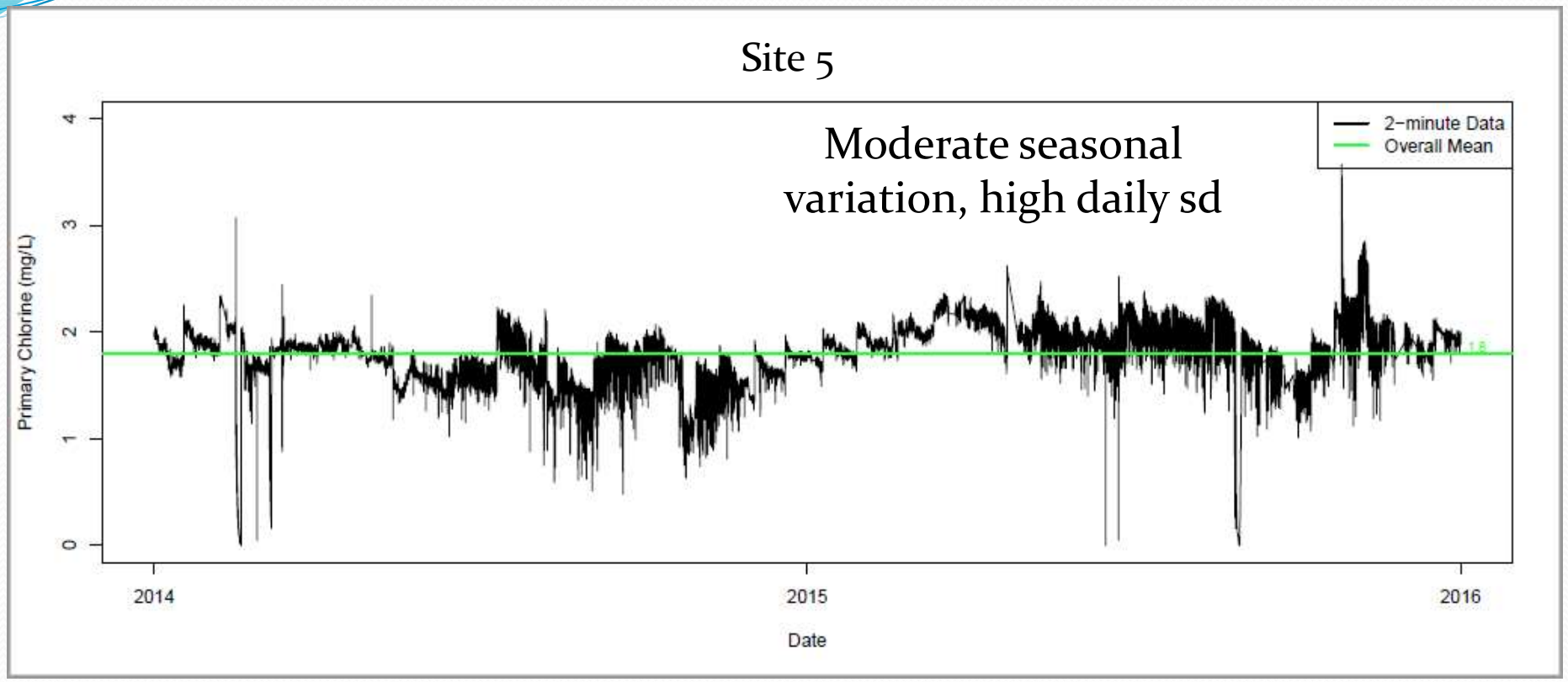

2−minute Data
Overall Mean
Primary Chlorine (mg/L)
0
1
2
3
4
2014
2015
2016
Date
Low seasonal variation,
low daily sd

Site 3


High seasonal variation,
moderate daily sd
2−minute Data
Overall Mean
Primary Chlorine (mg/L)
0
1
2
3
4
1.49
2014
2015
2016
Date

Site 4


High seasonal variation,
low daily sd
2−minute Data
Overall Mean
Primary Chlorine (mg/L)
0
1
2
3
4
1.29
2015
2016
Date



Graphical representation of Total Chlorine data points from 1/1/14-12/31/15 for 5 different sites showing varying degrees of sensor precision

Accuracy

- Def – The degree of difference between the measured and true values
- Chlorine
  - User-defined acceptance range of +/- 0.20 mg/L
  - Lab samples have an acceptance range of +/- 10%
- Bias – Online Sensors show a slight bias to be less than grab samples

Accuracy and Bias – June 2016

Online Sensor Accuracy Compared to Grab Sample Results - June 2016					
# of grab samples total	# of grab samples with corresponding online data	# of samples with difference > 0.2 mg/L	% of samples with difference >0.2 mg/L	# of samples with difference > combined acceptance range	% of samples with difference > combined acceptance range
480	442	232	53%	63	14%

Number of Samples Total	# of grab samples with corresponding online data	Average Bias between Grab Samples and Online Sensors	Average Percent Accuracy of Online Values to Grab Samples	Average Difference between Grab Data and Online Sensors (mg/L)
480	442	8%	89%	0.18

Online Sensor Accuracy for June 2016

Should Real Time Water Quality Data be Used for Compliance Monitoring?

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Considerations

- Extremely large amounts of data – 720 data points per parameter per site per day
- Chain of custody for online data?
- Framework of regulation – sensor, data transfer, results, or overall system?
- Calibration issues

Considerations

- Accuracy/Precision – Lab Samples vs Online Sensors
- Initial purpose of OWQM sensors
- Discourage systems from establishing OWQM
- Process Control vs Process Management

Conclusions

- Acceptable for early warning and system knowledge
- Precision and accuracy must be continuously addressed
- Set points potentially an effective alternative or companion to complicated warning systems
- Compliance may not be a good use for OWQM

For More Information

- Umberg, Katie, and Steven Allgeier. "Parameter Set Points: An Effective Solution for Real-Time Data Analysis." *Journal AWWA* 108.1 (2016): E60-66. *American Water Works Association*. Jan. 2016. Web.

Questions?