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Odor Monitoring at the New Orleans East Bank Wastewater Treatment Plant

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Odor Monitoring at the New Orleans East Bank Wastewater Treatment Plant

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

M.S.
In
Engineering (Civil and Environmental)

By

Felicia Figinsky

B.S. University of Texas at Austin, 2009

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This Thesis is dedicated to my wonderful husband, Chris Bergeron, and my mother, Maryellen Figinsky, for their continued support and reassurance.

Acknowledgments Page

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Abstract

Hydrogen Sulfide is a corrosive, odorous, and hazardous gas that can cause issues for wastewater collection systems and treatment plants. When evaluating hydrogen sulfide concentrations it is important to consider the source, odor causing mechanism, and its level of toxicity. In this study, continuous hydrogen sulfide monitoring was performed for 8 locations within the New Orleans East Bank Wastewater Treatment Plant for a span of 5 months. Hot spots within the plant are located and data analysis is performed based on daily and hourly averages of hydrogen sulfide concentrations. The data was configured to show peak hydrogen sulfide concentrations at specific time intervals throughout the day.

Keywords: Wastewater treatment, hydrogen sulfide, odor control, monitoring

1. INTRODUCTION

1.1 Municipal Services

Municipal services provide the community with basic services or facilities that citizens pay for with taxes and fees. Ranging from sanitation and streets to public parks and libraries, these services are expected by citizens and provided by a city's local government.

Sanitation facilities serve the community by supplying citizens with clean drinking water, removing storm water, and treating waste and wastewater. These facilities guard citizens against health concerns and protect the community's natural water bodies.

1.2 Wastewater Treatment Process

The wastewater treatment process is meant to mimic the processes that occur in nature. The engineered treatment practices ensure that the effluent can make national quality standards. These processes can be classified into pretreatment, primary treatment, secondary treatment, and tertiary treatment. Wastewater solids are classified into inorganic solids and organic solids. The inorganic solids are removed though primary treatment and the organic solids are removed through secondary treatment.

Pretreatment is primarily used to remove larger, inorganic solids. This extra step will provide protection to the wastewater treatment equipment in the next stage of treatment. Pretreatment may also reduce preventive maintenance costs since less sand and silt will be entering primary and secondary treatment.

Primary treatment removes the solids that float or settle. Typically 60 to 70% of suspended solids are removed during this process. Bar screens and grit chambers are typical equipment used in primary treatments.

Secondary treatment is used to remove any leftover inorganic solids and to breakdown organic solids. The organic solids are introduced to micro-organisms that feed on the solids. These microorganisms are closely monitored and recycled as they constantly reproduce and die off. The biological processes take place in activated sludge or trickling filters. On average, 85% of BOD and suspended solids can be removed in this phase of treatment.

Tertiary treatment is used when secondary treatment is not adequate or if the discharge is going into a sensitive water body. Tertiary treatment can include biological and chemical treatment followed by filtration. Figure 1 shows the primary, secondary, and tertiary processes (Kommalapati, 2015).

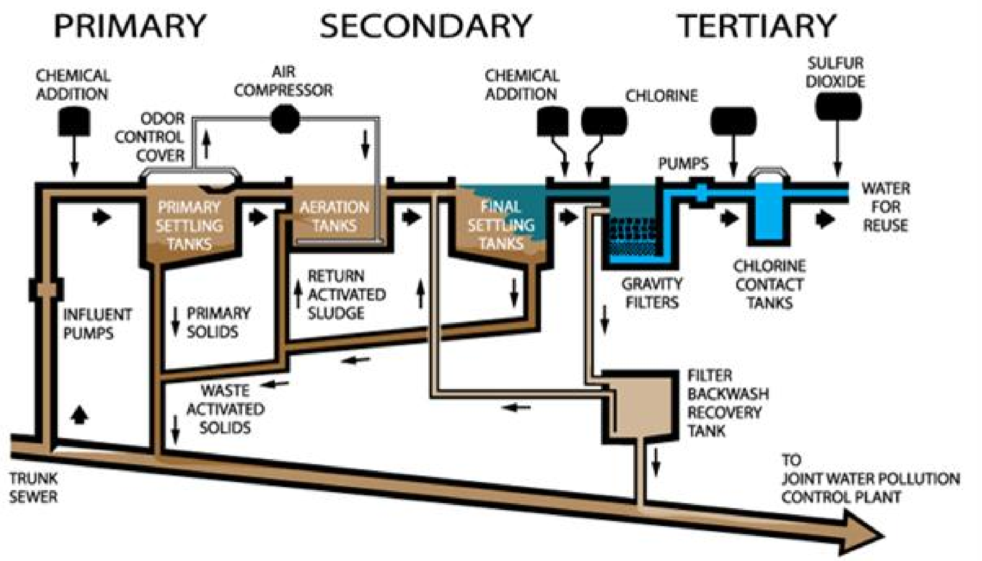


Figure 1: Wastewater Treatment Process Diagram ("Sanitation Districts")

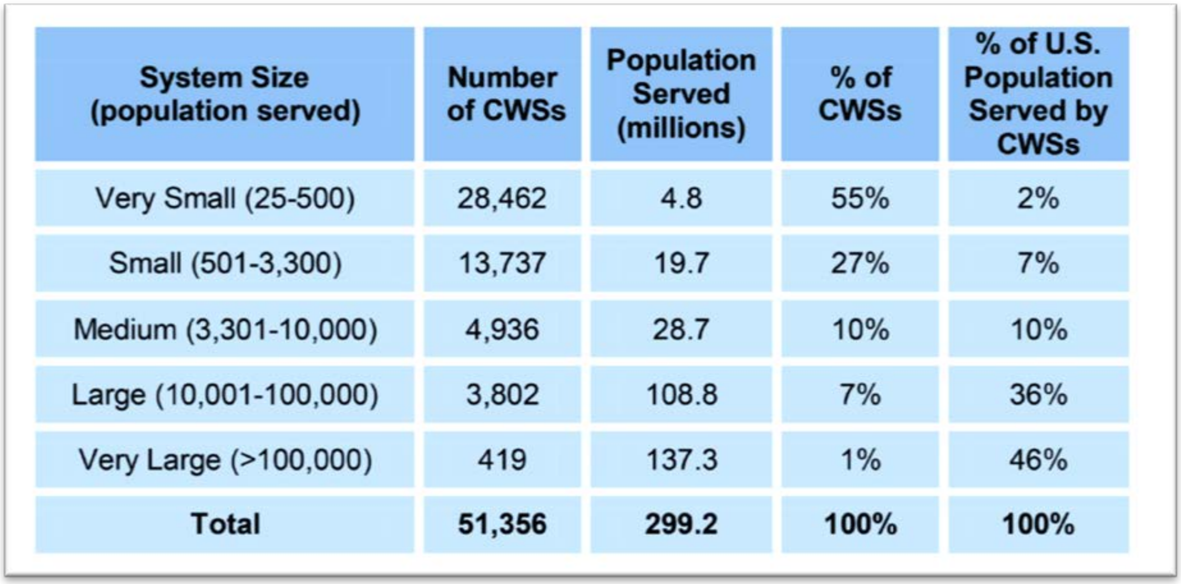
The two main products from a wastewater treatment plant are the effluent and solids. The solids can be treated on-site or trucked off site to a sanitary landfill, while effluent is discharged into a receiving stream or body of water.

Sludge disposal options include land application, dewatering and incineration, or dewatering and landfilling (Kommalapati, 2015).

1.3 Wastewater Treatment Facilities

Table 1 shows the population distribution for United States water systems. The chart shows the number of community water systems (CWS) and population served per the size of the water system. Larger water systems serve a larger population, but have fewer community water systems. Louisiana has a total of 153,511 permitted wastewater treatment plants as of 2001. Approximately 45,625,000,000 gallons of wastewater per year are treated in the state of Louisiana ("On-site Wastewater Program").

Table 1: Population distribution for US water systems (“Center for Sustainable Systems”, 2015)



System Size (population served)	Number of CWSs	Population Served (millions)	% of CWSs	% of U.S. Population Served by CWSs
Very Small (25-500)	28,462	4.8	55%	2%
Small (501-3,300)	13,737	19.7	27%	7%
Medium (3,301-10,000)	4,936	28.7	10%	10%
Large (10,001-100,000)	3,802	108.8	7%	36%
Very Large (>100,000)	419	137.3	1%	46%
Total	**51,356**	**299.2**	**100%**	**100%**

2. BACKGROUND

2.1 Wastewater Collection Systems

The wastewater collection system is an integral part of the treatment process, comprising of pump stations, force mains, and gravity sewers. Sewer collections systems rely partially on pumping stations to propel the influent through force mains to the pumping stations, then gravity to force the influent to the treatment plant. Some sewer systems only rely on gravity to transport the influent. These collection systems have to be properly maintained and managed to prevent sewer overflows and provide influent to the treatment plant. The condition of the collection system can affect the efficiency and productivity of the treatment plant downstream. For instance, increased transport time, periods of stagnant water, and high temperatures can affect the quality of the influent the plant receives.

2.2 Wastewater Treatment Equipment

Wastewater treatment facilities are designed based on the quality of the influent and the size of the population served. Their purpose is to take influent, remove the solids, pathogens, and bacteria, and produce effluent suitable for disposal into a body of water or receiving stream. This final effluent must be disposed into a body of water with minimum environmental effects. To achieve this goal, treatment facilities incorporate biological, physical, and chemical treatment processes.

The first step is primary treatment, where the inorganic solids are removed through physical treatment processes. These processes are located in the headworks of the plant and include bar screens and grit basins. Bar screens are used to capture the large particles found in the influent like rocks, rags, bottles, sanitary items, and solids. Inorganic particles such as sand, wood, or gravel are known as grit and can be removed in grit basins. Grit basins use centrifugal force to separate the grit from the influent.

Secondary treatment is used to remove the colloidal particles and dissolved organics that cannot be removed through physical processes. To accomplish this, influent is pumped through an aerated bioreactor, used to grow the indigenous, aquatic organisms that feed on the organic compounds. Bacteria and protozoa consume the organic solids and constantly reproduce and die off. This process produces a large amount of solids that get transported to a secondary clarifier where the settable microorganisms are separated from the wastewater. The solids are recycled through the system again or are discarded. Tertiary treatment can include disinfection before the effluent is discharged (Kommalapati, 2015).

2.3 Odor Challenges

Odor issues can be a problem for wastewater treatment plants located around urban or residential areas. Having an odorous plant can lead to legal problems. The substances causing these odors are either gaseous inorganics or volatile organic compounds with a molecular weight of 30 to 150 g /mole. These substances can be a result of anaerobic decomposition of organic matter containing sulfur or nitrogen. When the wastewater decomposes, the inorganic gases produced likely include sulfide, ammonia, carbon dioxide, and methane. The organic vaporous substances producing the most odor include indoles, skatoles, mercaptans, and nitrogen-bearing organics.

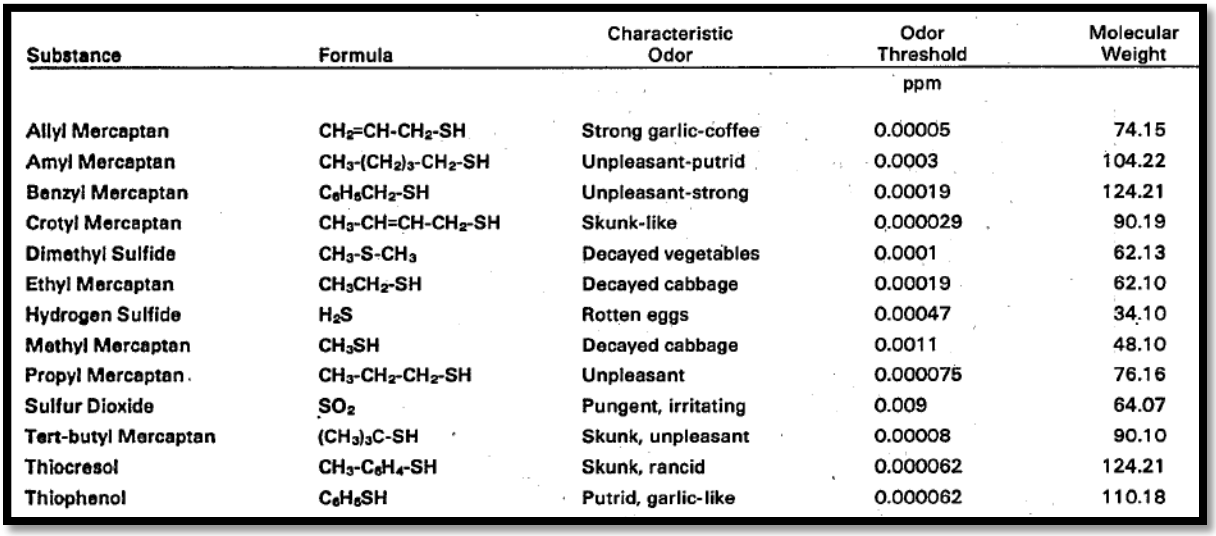
Hydrogen sulfide is the most common odorous gas produced during wastewater decomposition. It has a characteristic rotten egg smell, and is extremely toxic, and is corrosive to metals such as iron, zinc, copper, lead, and cadmium. Under the right conditions, sulfuric acid can be formed from hydrogen sulfide, which can easily corrode lead based paint, concrete, metals, and other materials.

When wastewater first enters the plant at the influent pump station wet well, the raw sewerage first has contact with the air. The sewerage will then travel to the primary clarifier or the head works to remove the large inorganic solids. This allows for the vaporization of odors due to the turbulence as the wastewater cascades over weirs and through narrow channels. The head works, primary and secondary clarifiers, aerobic digesters, solids thickening tanks, solids drying beds, and solids loading areas are likely to produce odorous vapors. Cleaning any of these areas can also produce large, yet brief periods of odor (EPA, 1985).

2.4 Odor Causing Mechanism

Most odors in a wastewater treatment plant are due to the presence of sulfur-bearing compounds. Compounds with a lower molecular weight have a higher volatility and risk of being emitted to the atmosphere. Substances with higher molecular weights tend to not be as odorous, volatile, or soluble. Table 2 lists several of these odor causing compounds and their respective molecular weights (EPA, 1985).

Table 2: Odorous sulfur compounds in wastewater (EPA, 1985)



Substance	Formula	Characteristic Odor	Odor Threshold	Molecular Weight
			ppm	
Allyl Mercaptan	CH_2=CH-CH_2-SH	Strong garlic-coffee	0.00005	74.15
Amyl Mercaptan	CH_3-$(CH_2)_3$-CH_2-SH	Unpleasant-putrid	0.0003	104.22
Benzyl Mercaptan	$C_6H_5CH_2$-SH	Unpleasant-strong	0.00019	124.21
Crotyl Mercaptan	CH_3-CH=CH-CH_2-SH	Skunk-like	0.000029	90.19
Dimethyl Sulfide	CH_3-S-CH_3	Decayed vegetables	0.0001	62.13
Ethyl Mercaptan	CH_3CH_2-SH	Decayed cabbage	0.00019	62.10
Hydrogen Sulfide	H_2S	Rotten eggs	0.00047	34.10
Methyl Mercaptan	CH_3SH	Decayed cabbage	0.0011	48.10
Propyl Mercaptan	CH_3-CH_2-CH_2-SH	Unpleasant	0.000075	76.16
Sulfur Dioxide	SO_2	Pungent, irritating	0.009	64.07
Tert-butyl Mercaptan	$(CH_3)_3$C-SH	Skunk, unpleasant	0.00008	90.10
Thiocresol	CH_3-C_6H_4-SH	Skunk, rancid	0.000062	124.21
Thiophenol	C_6H_5SH	Putrid, garlic-like	0.000062	110.18

Most of the odor complaints from a wastewater treatment plant are due to the reduction of sulfate to hydrogen sulfide under anaerobic conditions. The follow reactions describe this process:

Reaction 1: $SO_4^{2-} + 2C + 2H_2O \xrightarrow{anaerobic\ bacteria} H_2S + 2HCO_3^-$

Reaction 2: $S^- + 2H^+ \xrightarrow{anaerobic\ bacteria} H_2S$

Reaction 3: $SO_4^{2-} + 10H^+ \xrightarrow{anaerobic\ bacteria} H_2S + 4H_2O$

The organic matter in reaction 1 undergoes biochemical oxidation and hydrogen atoms are removed. These hydrogen atoms are eventually converted to hydrogen acceptors through several more biochemical reactions. During anaerobic conditions, sulfate can be an acceptor of the hydrogen producing odorous hydrogen sulfide (Edwards, 2002).

2.5 Hydrogen Sulfide

The sulfate ion (SO4-) is the most common anion in natural water and occurs frequently during rainfall in urban areas. Sulfur concentrations in wastewater can vary greatly, ranging from a few milligrams per liter (mg/l) to hundreds of milligrams per liter. Hydrogen sulfide is a colorless gas that can be detected by the human nose at concentrations as low as $4.7 * 10^{-4}$ ppm. It is toxic at high doses, corrosive to metals, and explosive at concentrations ranging from 4.3 to 45.5 percent in air. At normal temperatures found in wastewater, the solubility of hydrogen sulfide varies from 3,000 to 4,000 mg/l, decreasing slightly with increasing temperature. All sulfur compounds, inorganic or organic, have a potential for sulfur release to the atmosphere under the right conditions. For domestic wastewater, the main contributor to sulfide is sulfate. The sulfur cycle is shown in Figure 2 (EPA, 1985).

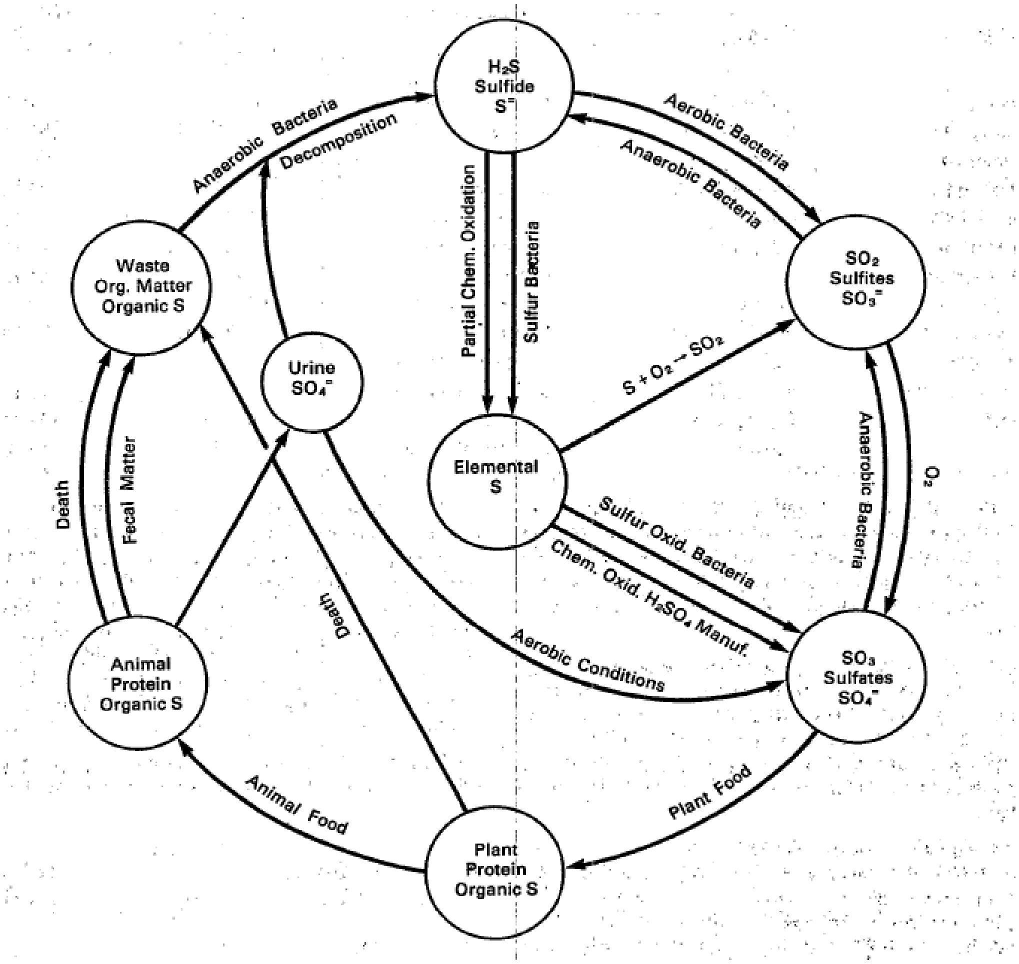


Figure 2: The sulfur cycle (EPA, 1985)

The rate at which sulfide is produced by wastewater depends on several environmental conditions including sulfate concentration, dissolved oxygen, metals present, temperature, stream velocity, surface area, and detention time (EPA, 1985).

2.6 Toxicity of Hydrogen Sulfide

Toxic, heavier than air, and existing in higher concentrations in the lower portion of manholes, hydrogen sulfide is a danger to sewer system workers. It is a colorless gas that has a distinctive rotten egg smell at lower concentrations, but can impair the sense of smell at higher concentrations. At high hydrogen sulfide concentrations unconsciousness occurs quickly, and eventually death if a rescue plan is not in place. This situation has occurred from concentrations of 300 ppm by volume of air in enclosed, turbulent environments from wastewater with 2 mg/l of dissolved sulfide. Figure 3 below shows the toxicity of hydrogen sulfide as varying concentrations.

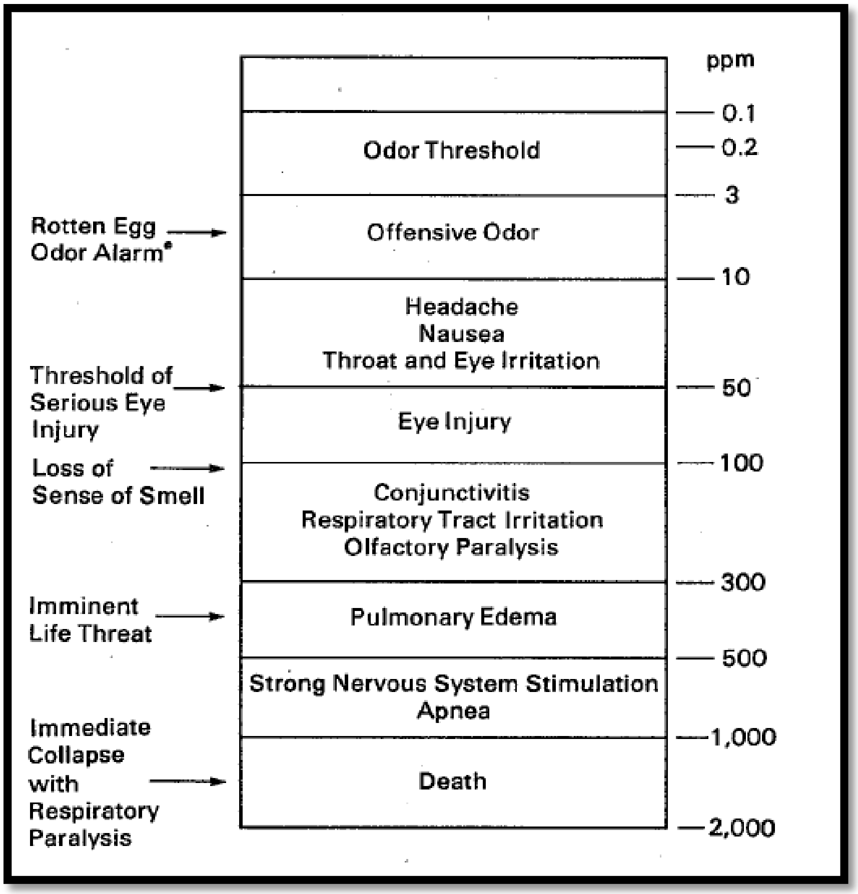


Figure 3: Toxicity of Hydrogen Sulfide (EPA, 1985)

The Occupational Safety and Health Administration (OSHA) has provided limits for hydrogen sulfide exposure. The acceptable ceiling concentration of hydrogen sulfide is 20 ppm for 15 minutes of exposure, and 50 ppm for a maximum one time exposure during an 8-hour work shift. The National Institute of Occupational Safety and Health (NIOSH) lists an exposure limit of 10 ppm for 10 minutes during an 8-hour work shift (EPA, 1985).

2.7 Corrosiveness of Hydrogen Sulfide

Corrosion can occur through direct chemical corrosion by oxidation or hydrogenation. Oxidation is the most common form of corrosion. Oxygenation corrosion can be spotted though the formation of rust. Corrosion occurs through the exchange of electrons between the metal and free oxygen. These metal oxides newly formed are more chemically stable and the as they build up on the metal surface the reaction slows.

With no aeration and high temperature and pressure, water is reduced to its ions, and hydrogenation may occur if metal is immersed in this water. The hydrogen can then penetrate the lattice surface of the metal and react with its internal structure. The internal structure is then subject to internal pressure and possible splitting.

Hydrogen sulfide and sulfur dioxide are corrosive independently and collectively after reacting with water and oxygen to form sulfuric acid. Hydrogen sulfide corrosion will take place under the following conditions: sulfides exist in the wastewater, sulfides exit the liquid phase into the gas phase, hydrogen sulfide is oxidized to sulfuric acid, and the acid attacks the moist, exposed surfaces of cement or metal. Hydrogen sulfide will degrade all metallic structures of a wastewater treatment plant such as gratings, walkways, steel tanks, and equipment such as bar screens, and grit cyclones. It will also directly react with copper to produce black copper sulfate, a poor electrical conductor.

Corrosion in a sewer pipeline is not uniform due to varying factors including air currents, chemical concentrations, and exposure to water. Once hydrogen sulfide is present in a sewer line, it can form sulfuric acid as described above. Sulfuric acid is responsible for most of the corrosion in sewer pipelines, and occurs predominantly at the crown of the pipe. Corrosion at the sewer water line is often severe due to intermittent washing in this zone that cleans away decomposition products and exposes new concrete. The corrosion distribution normally seen in a sewer pipeline is shown in Figure 4 below (EPA, 1985).

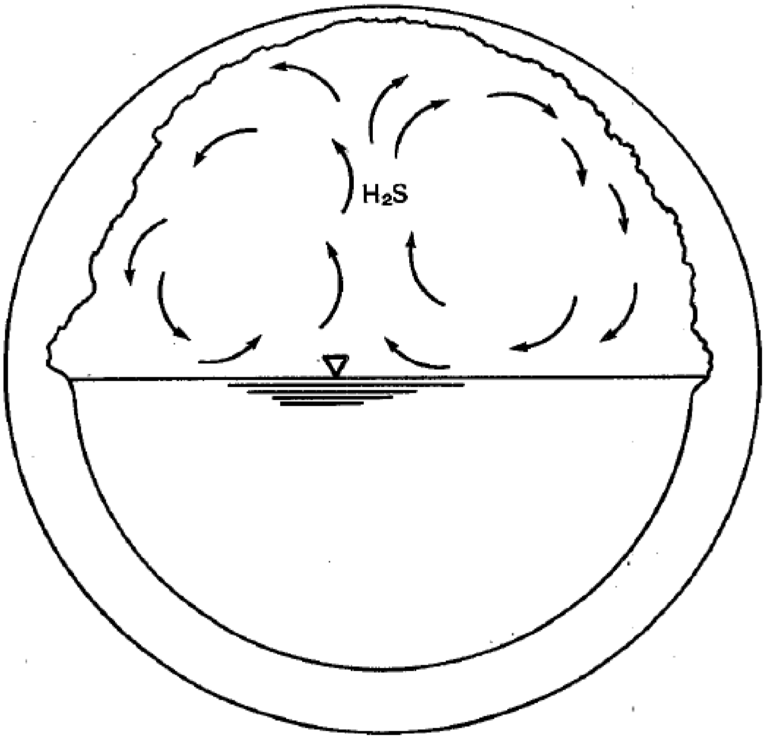


Figure 4: Hydrogen Sulfide Distribution in a Pipeline (EPA, 1985)

Hydrogen sulfide will also react with iron to produce ferrous sulfide. Iron could be present in sewer pipes or septic tanks. Under anaerobic conditions, sulfate reducing bacteria will produce hydrogen sulfide. The hydrogen sulfide reacts with any iron present to form ferrous sulfide, a black precipitate. Iron salts are sometimes used as treatment to remove sulfide in wastewater (Harshman, 2000).

3. SCOPE OF WORK

3.1 Overall Objective

The overall objective of this thesis is to develop an understanding of the average and maximum hydrogen sulfide concentrations at several locations within a wastewater treatment plant through continuous air monitoring.

3.2 Specific Objectives

1. Identify a suitable wastewater treatment plant.
2. Identify ambient air monitors suitable for measurement of low levels of hydrogen sulfide.
3. Identify the number of ambient air monitors necessary.
4. Determine the best location throughout the plant for each ambient air monitor.
5. Perform continuous ambient air monitoring.
6. Identification of hot spots within the wastewater treatment plant.
7. Perform data analysis based on daily and hourly averages of hydrogen sulfide.
8. Construct graphs to display the daily hydrogen sulfide concentrations versus temperature and rainfall.
9. Configure data to show the hydrogen sulfide concentration at specific peak flow time intervals.
10. Recommend strategies for odor management.

4. METHODS AND MATERIALS

4.1 Site Selection

Constructed in 1973, the Sewerage and Water Board of New Orleans (SWBNO) East Bank Wastewater Treatment Plant (EBWWTP) services the east bank of Orleans Parish. After its facility upgrade in 1980, the plant can treat up to 122 million gallons of effluent a day. While the sludge is incinerated, if this method is unavailable, landfill disposal is an alternative method of disposal. Effluent is discharged to the Mississippi River. Owned by the SWBNO, the plant is operated by Veolia Water North America, a private contractor. The plant is located near the Orleans and St. Bernard parish line in the Lower 9th Ward.

Preliminary treatment starts with three sewage force mains leading into the plant headworks. Six (6) mechanical bar screens and six (6) aerated grit chambers start the process. The headworks have a capacity of 940,000 gallons with a detention time of five (5) minutes under normal flow. Incoming flow then travels down an aerated influent channel to provide oxygen for the waste. Connected to the influent channel are Return Activated Sludge (RAS) lines, providing both proper mixing and microorganism concentrations.

Secondary treatment biologically converts dissolved organic solids into sludge, carbon dioxide, and water vapor. The covered aeration basins (oxygen reactors) conduct this process by supplying pure oxygen. Submerged in the basins are aeration mixers, facilitating the reaction. The carbon dioxide escapes the system at this point as an off gas. The EBWWTP is equipped with four (4) 2.2 million gallon oxygen reactors, allowing for 1.6 hours of detention time. The oxygen for the reactors is produced by a 70-ton per day Vacuum Swing Absorption (VSA) plant. A back-up 45,000-gallon liquid oxygen tank is filled by truck to then be converted to gas by a vaporizer for use.

Flow then enters one of the seven (7) available clarifiers to allow sludge and flocculent to settle, producing a compliant effluent. At 160 feet in diameter with a 14 foot water depth, each clarifier has a 20,106 square foot surface area. Ten (10) vertical turbine RAS pumps (150 hp, 8-MGD) remove the sludge from the bottom of the clarifiers, transporting it to either the influent channel or the eighth clarifier to be thickened to approximately 5% total solids (TS). The West Bank WWTP's sludge is thickened to 6% TS and hauled to the EBWWTP and mixed with the waste activated sludge (WAS). A 1,000 gpm WAS pump transports the thickened sludge to four, 2-meter Andritz belt presses, of which two are also gravity belt thickeners. These condense the sludge from 4-5% TS to 22-24%, which is then capable of being incinerated or trucked to a landfill. A fluid bed incinerator (FBI), operated by natural gas, biodiesel, or diesel, disposes of the sludge. Since the FBI’s installation in 1978, a new Venturi Scrubber and Continuous Emission Monitoring System have been added. The Venturi Scrubber recovers the particulate matter or ash from the system. Currently under construction is a FEMA-approved alternative method of sludge drying. This process would utilize the waste heat from the FBI to dry the sludge, producing a self-sustaining fuel source. The incinerated sludge ash is slurried to drying beds, which, when dried, is used as industrial fill material.

Chlorine is injected into the effluent channel to disinfect the clear effluent. On site are two 55-ton rail cars, supplying a 45-day supply of chlorine. The chlorine requires a 90-minute detention time at 100 MGD production. The process flow chart for the wastewater treatment process and the sludge drying process is shown in Figure 5 below (SWBNO).

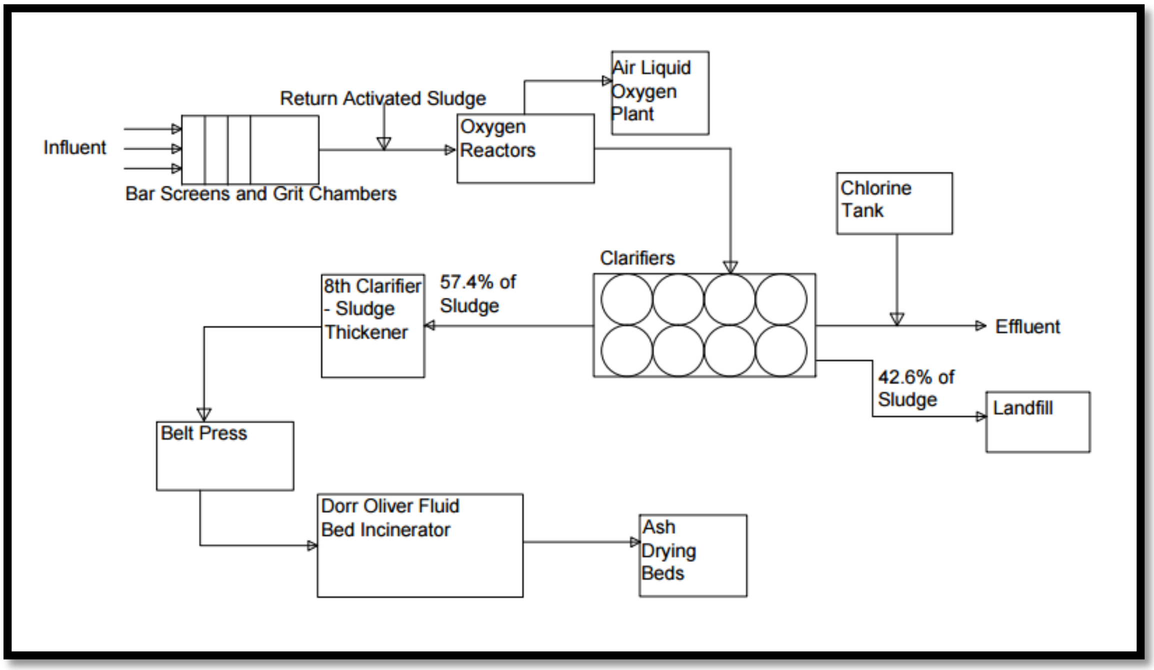


Figure 5: Process Flow Chart for the East Bank Wastewater Treatment Plant

All wastewater treatment plants in Louisiana are regulated by the Louisiana Department of Environmental Quality (LDEQ). The LDEQ enforces the regulations that the Environmental Protection Agency (EPA) enacts. The EBWWTP must submit a Title V permit for air emissions, a National Pollutant Discharge Elimination System (NPDES) permit for liquid discharge, and an annual solid waste report. These reports help the LDEQ regulate pollutants discharged by various companies.

4.2 Experimental Design

Ambient air monitoring is a long term data collection and assessment of pollutant levels in the outside air. Ambient monitoring is performed to assess continuous air pollutant compliance with EPA regulations and provide data for air modeling. The locations for monitoring are determined based on population and high concern areas (“Ambient Air Monitoring”, 2016).

OdaLog Low Range air monitors were used for ambient monitoring since they are capable of collecting data every 10 minutes, 24 hours per day. Eight locations spread throughout the plant were selected based on the type of treatment nearby. These locations were located at the headworks, influent channel, oxygen plant, oxygen reactors 1 and 2, oxygen reactors 3 and 4, secondary clarifiers 1-4, secondary clarifiers 5-8, and chlorine disinfection.

Meteorological monitoring data for temperature and rainfall were also collected to conclude if there are correlations with ambient air concentrations.

4.3 Equipment Selection

The low range OdaLog hydrogen sulfide monitor (Figure 7) is specifically made for the wastewater industry and for logging gas levels over extended periods of time. The device has a hydrogen sulfide measurement range of 0.00 to 2.00 ppm and an accuracy of +/- 10%. Temperatures are also recorded continuously at a range of 32°F to 104°F with a maximum of 6°F change per hour. Data can be logged in varying time intervals ranging from every 10 minutes to 1 hour.

The OdaLog Monitors are battery operated with a central processing unit battery life of 2 months and a pump battery life of 7 days, so batteries were changed and data were collected on a weekly basis ("Odalog Gas Logger", 2016).

Figure 6: OdaLog Air Monitor ("Odalog Gas Logger", 2016)

5. RESULTS AND DISCUSSIONS

5.1 Site Overview and Locations

Table 3 below displays the latitude and longitude for all of the monitoring sites at the EBWWTP.

Table 3: Latitude and Longitude for all Sites

Site Location	Latitude	Longitude
1	N 29^{o}58'39.378"	W 89^{o}59' 51.9288"
2	N 29^{o} 58'39.9036"	W 89^{o}59' 52.26"
3	N 29^{o}58'43.842"	W 89^{o}59' 51.9828"
4	N 29^{o}58'49.5192"	W 89^{o}59' 47.2236"
5	NA	
6	N 29^{o}58'47.622"	W 89^{o}59' 45.8268"
7	N 29^{o}58'43.9536"	W 89^{o}59' 47.7096"
8	N 29^{o}58'39.3816"	W 89^{o}59' 47.976"

The EBWWTP has had no previous hydrogen sulfide monitoring performed. For this reason, it was an ideal location for a new monitoring study. The EBWWTP uses peroxide for odor control. The peroxide and a proprietary catalyst combine to form an OH- hydroxyl free radical that reacts easily with the sulfur in hydrogen sulfide. The byproducts are elemental sulfur, water, oxygen, and a small amount of carbon dioxide. Using peroxide as odor control is a new process for the plant, starting in April 2015. This change had no effect on the hydrogen sulfide concentrations throughout the EBWWTP.

There are a couple of major projects at the EBWWTP that may have affected hydrogen sulfide formation. The project with the most impact is the cleaning of oxygen reactor #1. This project started on March 27, 2015 and continued throughout the entire monitoring period. During this project the reactor was opened, stirred up, and the liquid and grit were pumped out and trucked off site. Site five is located adjacent to oxygen reactor #1, and was the most affected.

The monitors performed well in the field. However, several issues were encountered. The monitor at site eight stopped working April 1st permanently. Therefore, data were only collected from February 11th – April 1st 2015 for site eight. Issues were also encountered when the monitor's batteries prematurely died in the field. The pump batteries are expected to last for seven days; however, it was commonplace to have pump batteries quit after four to five days. The computer batteries would also quit in the middle of a monitoring period and data would be lost for that site.

5.2 Historical Hydrogen Sulfide Analysis

Table 4 below shows the maximum value, minimum value, average, average plus one standard deviation, and average minus one standard deviation for the historical analysis. In the historical analysis, all of the sites are compared based on the hydrogen sulfide concentration and the dates data were collected. The data were then separated and organized according to the time of day concentrations were observed. These times were chosen based on solar radiation strength. Site 1 had the highest average values, and was located by the head works, which contains the bar screens and grit chambers. The high values are due to the fact that this is an open area where raw influent is stirred up and treated by mechanical methods.

Site 3, located near the oxygen reactor, influent channel, and ash drying pits, has the second highest average values. The high values are most likely due to the proximity to the ash drying pits. In these pits ash is pumped as a slurry into the pits, left to dry by evaporation, and trucked to a landfill.

The site with the lowest values is Site 2, placed in the southwest corner of the plant. The monitor was nearby the septage unloading station, the ash drying pits, and the influent channel. All of these areas have the potential for producing hydrogen sulfide; however, Site 2 rarely got any readings over zero ppm. Most likely, the monitor was too far away from all of these potential sources to get any high readings.

Table 4: Historical Analysis – Sites 1-8

Site Location	**Solar Radiation**	**Timings**	**Historical Analysis**				
			Max Value	Min Value	Avg	Avg +1 SD	Avg -1 SD
Site 1	Slight	6:00AM - 8:20AM	1.15	0	0.21	0.25	0.17
	Moderate	8:20AM - 10:00AM	1.37	0	0.29	0.34	0.24
	Strong	10:00AM - 12:00PM	1.55	0	0.16	0.2	0.12
	Strong	12:00PM - 2:00PM	0.95	0	0.11	0.14	0.08
	Moderate	2:00PM - 3:40PM	1.1	0	0.14	0.17	0.11
	Slight	3:40PM - 6:00PM	1.15	0	0.14	0.17	0.11
	None	6:00PM - 6:00AM	0.91	0	0.13	0.15	0.11
Site 2	Slight	6:00AM - 8:20AM	0.01	0	0	0	0
	Moderate	8:20AM - 10:00AM	0	0	0	0	0
	Strong	10:00AM - 12:00PM	0	0	0	0	0
	Strong	12:00PM - 2:00PM	0	0	0	0	0
	Moderate	2:00PM - 3:40PM	0	0	0	0	0
	Slight	3:40PM - 6:00PM	0	0	0	0	0
	None	6:00PM - 6:00AM	0	0	0	0	0
Site 3	Slight	6:00AM - 8:20AM	0.54	0	0.08	0.09	0.07
	Moderate	8:20AM - 10:00AM	0.33	0	0.05	0.06	0.04
	Strong	10:00AM - 12:00PM	0.18	0	0.03	0.03	0.03
	Strong	12:00PM - 2:00PM	0.2	0	0.03	0.03	0.03
	Moderate	2:00PM - 3:40PM	0.22	0	0.03	0.03	0.03
	Slight	3:40PM - 6:00PM	0.2	0	0.04	0.04	0.04
	None	6:00PM - 6:00AM	0.36	0	0.11	0.12	0.1
Site 4	Slight	6:00AM - 8:20AM	0.18	0	0.01	0.02	0
	Moderate	8:20AM - 10:00AM	0.1	0	0.01	0.01	0.01

	Strong	10:00AM - 12:00PM	0.03	0	0	0	0
	Strong	12:00PM - 2:00PM	0.04	0	0	0	0
	Moderate	2:00PM - 3:40PM	0.04	0	0	0	0
	Slight	3:40PM - 6:00PM	0.05	0	0.01	0.01	0.01
	None	6:00PM - 6:00AM	0.13	0	0.02	0.02	0.02
Site 5	Slight	6:00AM - 8:20AM	0.54	0	0.04	0.05	0.03
	Moderate	8:20AM - 10:00AM	0.4	0	0.03	0.04	0.02
	Strong	10:00AM - 12:00PM	0.29	0	0.02	0.03	0.01
	Strong	12:00PM - 2:00PM	0.22	-0.01	0.02	0.03	0.01
	Moderate	2:00PM - 3:40PM	0.2	0	0.02	0.02	0.02
	Slight	3:40PM - 6:00PM	0.23	0	0.02	0.02	0.02
	None	6:00PM - 6:00AM	0.44	0	0.06	0.07	0.05
Site 6	Slight	6:00AM - 8:20AM	0.11	0	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.12	0	0.01	0.01	0.01
	Strong	10:00AM - 12:00PM	0.07	0	0	0	0
	Strong	12:00PM - 2:00PM	0.05	0	0	0	0
	Moderate	2:00PM - 3:40PM	0.05	-0.01	0	0	0
	Slight	3:40PM - 6:00PM	0.04	0	0	0	0
	None	6:00PM - 6:00AM	0.19	0	0.01	0.01	0.01
Site 7	Slight	6:00AM - 8:20AM	0.24	0	0.03	0.04	0.02
	Moderate	8:20AM - 10:00AM	0.17	0	0.02	0.02	0.02
	Strong	10:00AM - 12:00PM	0.08	0	0.01	0.01	0.01
	Strong	12:00PM - 2:00PM	0.07	0	0.01	0.01	0.01
	Moderate	2:00PM - 3:40PM	0.13	0	0.01	0.01	0.01
	Slight	3:40PM - 6:00PM	0.1	0	0.01	0.01	0.01
	None	6:00PM - 6:00AM	0.17	0	0.03	0.03	0.03
Site 8	Slight	6:00AM - 8:20AM	0.07	0	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.22	0	0.02	0.03	0.01
	Strong	10:00AM - 12:00PM	0.06	0	0.01	0.01	0.01
	Strong	12:00PM - 2:00PM	0.04	0	0.01	0.01	0.01
	Moderate	2:00PM - 3:40PM	0.08	0	0.01	0.01	0.01
	Slight	3:40PM - 6:00PM	0.08	0	0.01	0.01	0.01
	None	6:00PM - 6:00AM	0.05	0	0.01	0.01	0.01

Figures 7 through 13 are the historical analysis graphs for Site 1. According to the graphs below and Table 1, Site 1 recorded the highest hydrogen sulfide concentrations between 8:20 a.m. and 10:00 a.m. It was hypothesized that the strength of the solar radiation would have an obvious effect of the hydrogen sulfide concentrations. However, it is now clear that the influent flow rates into the plant have the most influence on hydrogen sulfide concentrations. There are spikes in hydrogen sulfide concentrations in the morning when people are getting ready for the day and at night while they are getting ready for bed. It is important to note that it can take several hours for the influent to get from the consumer to the EBWWTP.

The other sites also had concentration spikes between 8:20 a.m. and 10:00 a.m. They also have higher hydrogen sulfide concentration readings from 6:00 p.m. to 6:00 a.m. Looking at Site 1, the highest concentration values occurred during the morning and evening hours. Again, this corresponds to the times that people are home and using water to shower, cleaning dishes or washing laundry.

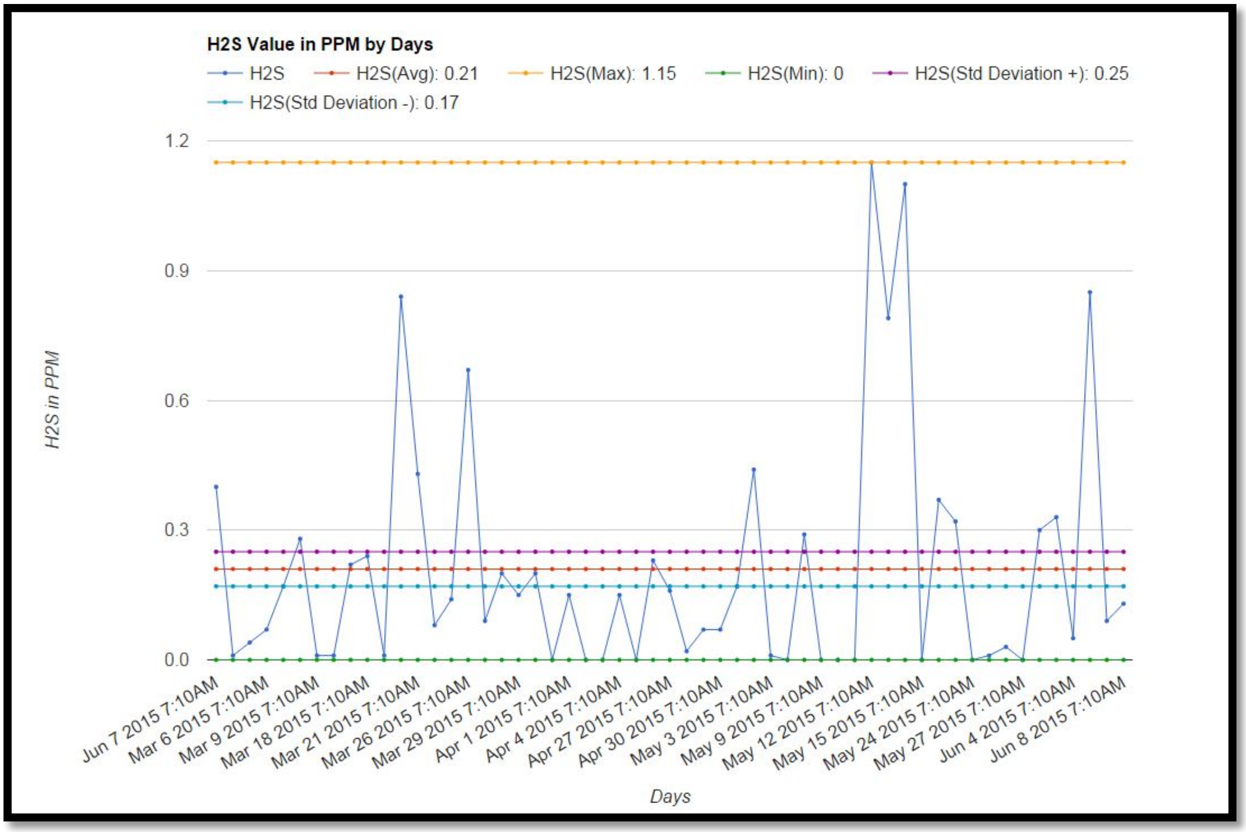


Figure 7: Historical Analysis (6 a.m. – 8:20 a.m.) – Site 1

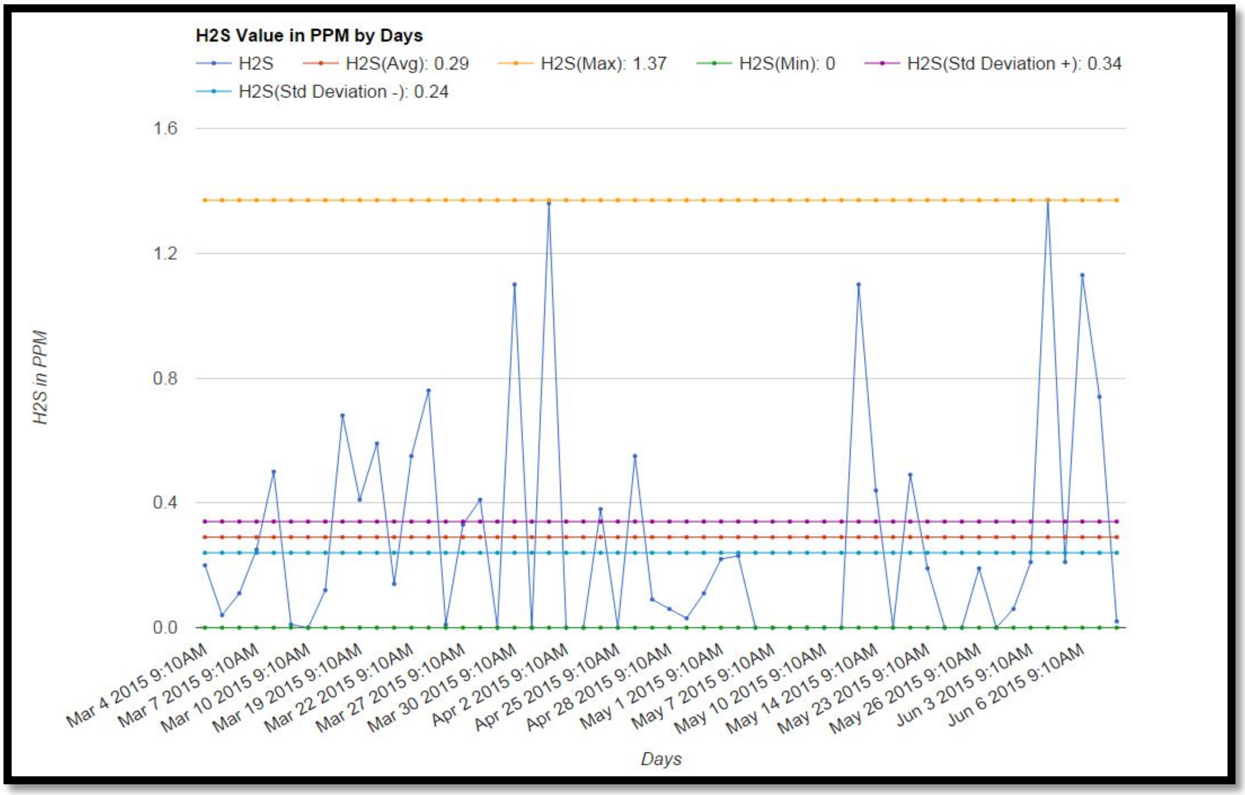


Figure 8: Historical Analysis (8:20 a.m. – 10:00 a.m.) – Site 1

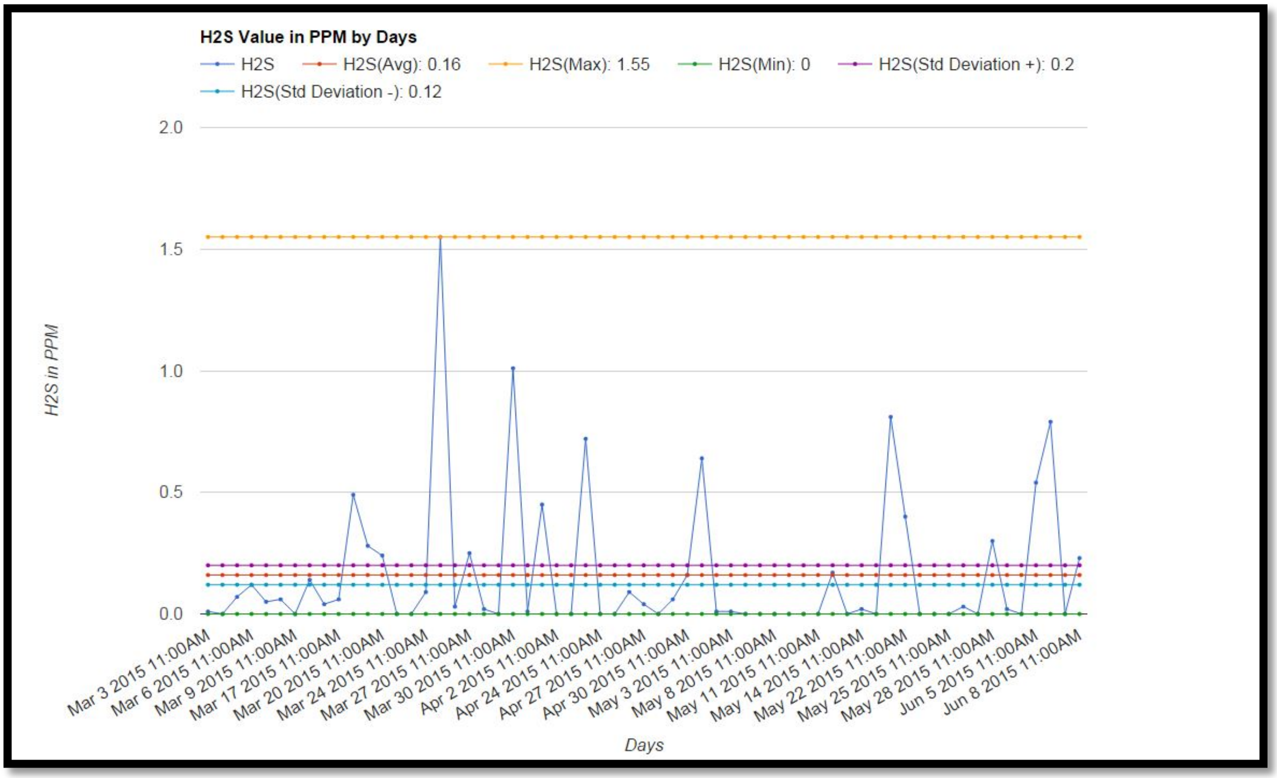


Figure 9: Historical Analysis (10:00 a.m. – 12:00 p.m.) – Site 1

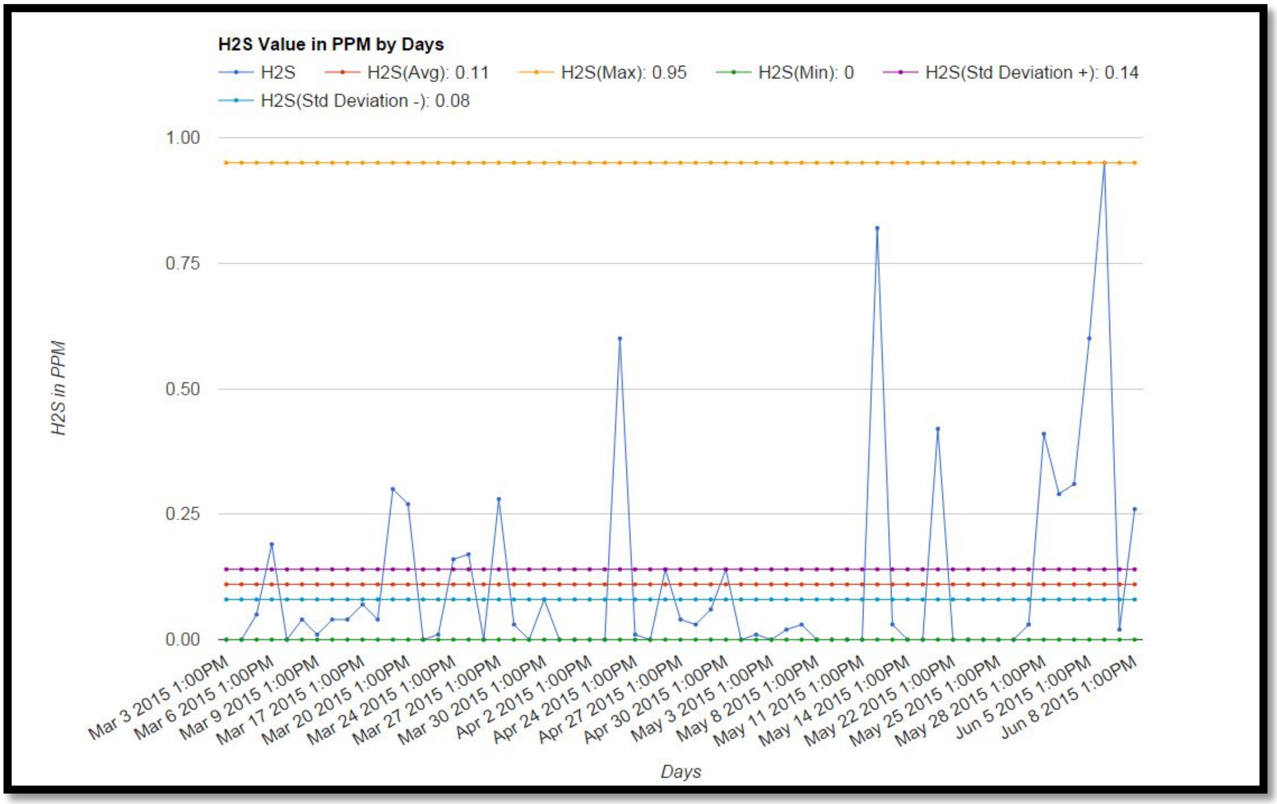


Figure 10: Historical Analysis (12:00 p.m. – 2:00 p.m.) – Site 1

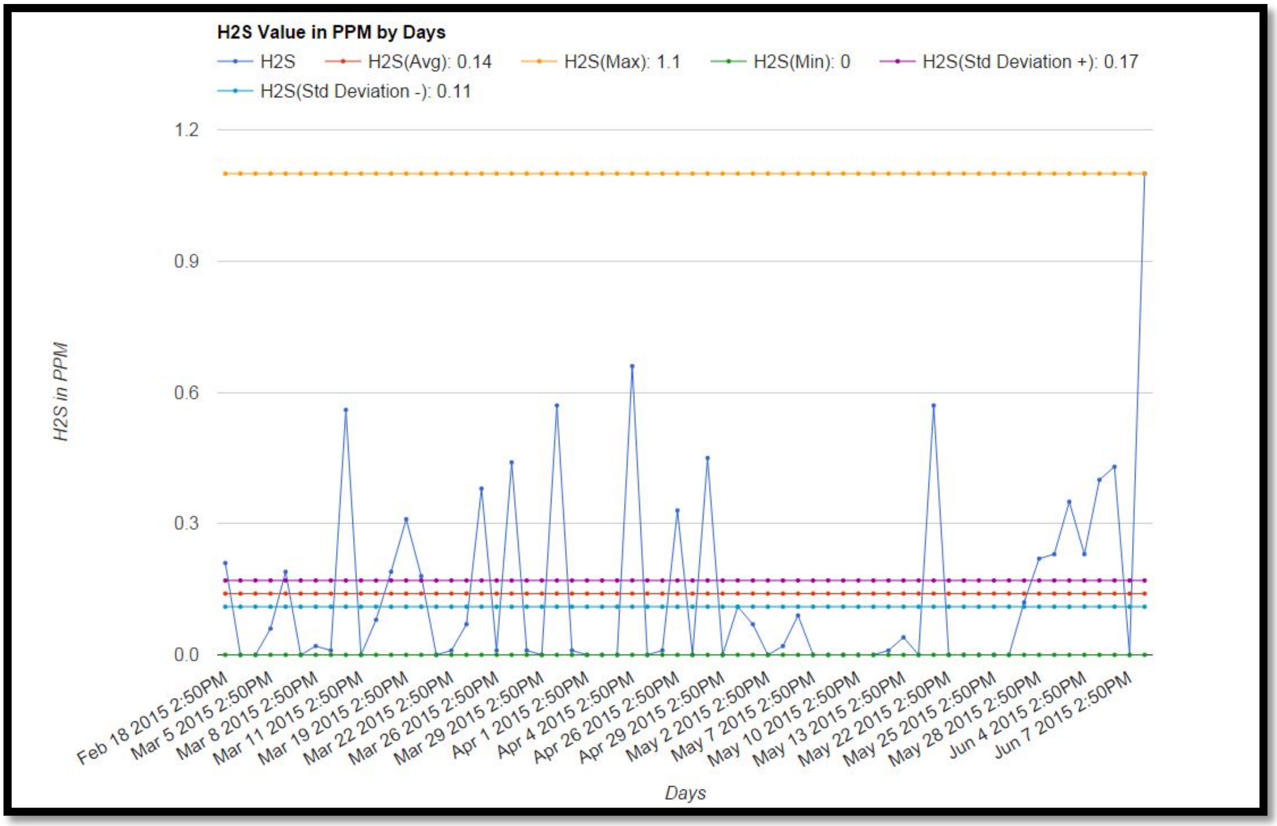


Figure 11: Historical Analysis (2:00 p.m. – 3:40 p.m.) – Site 1

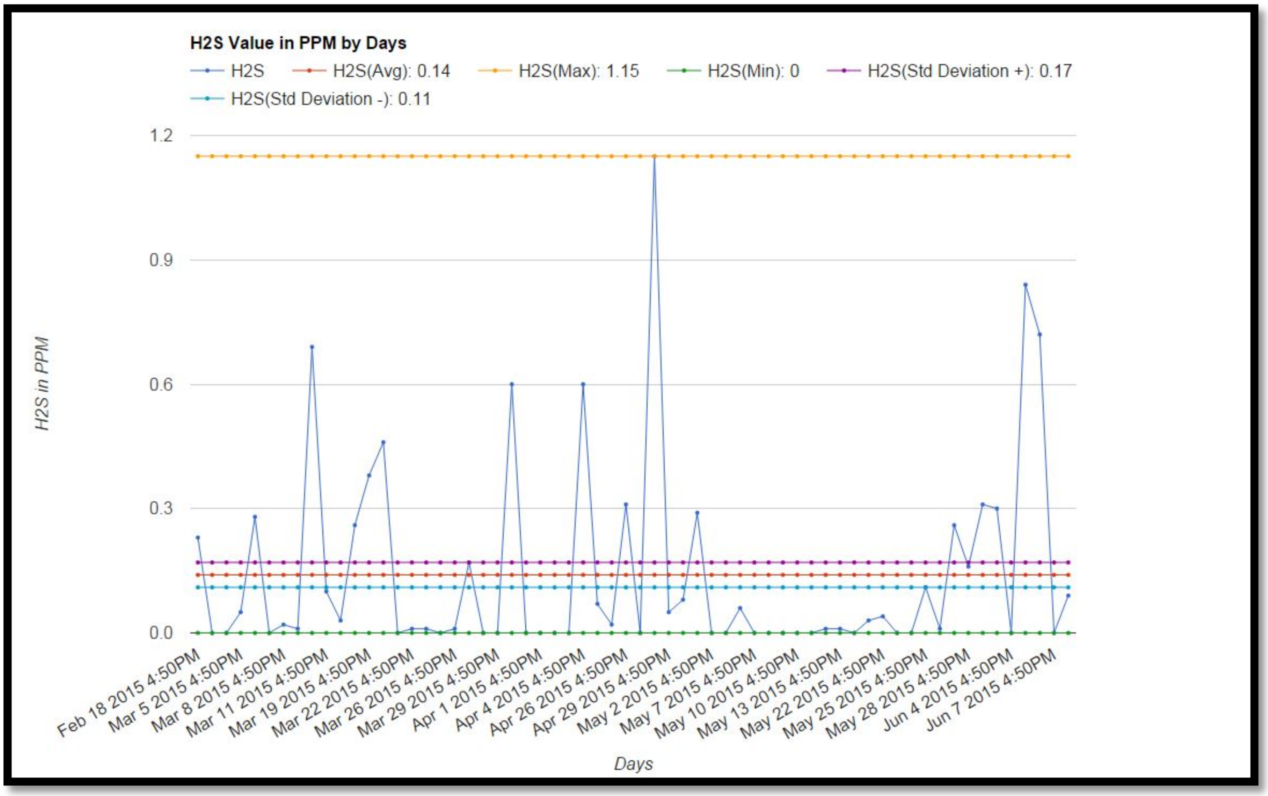


Figure 12: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 1

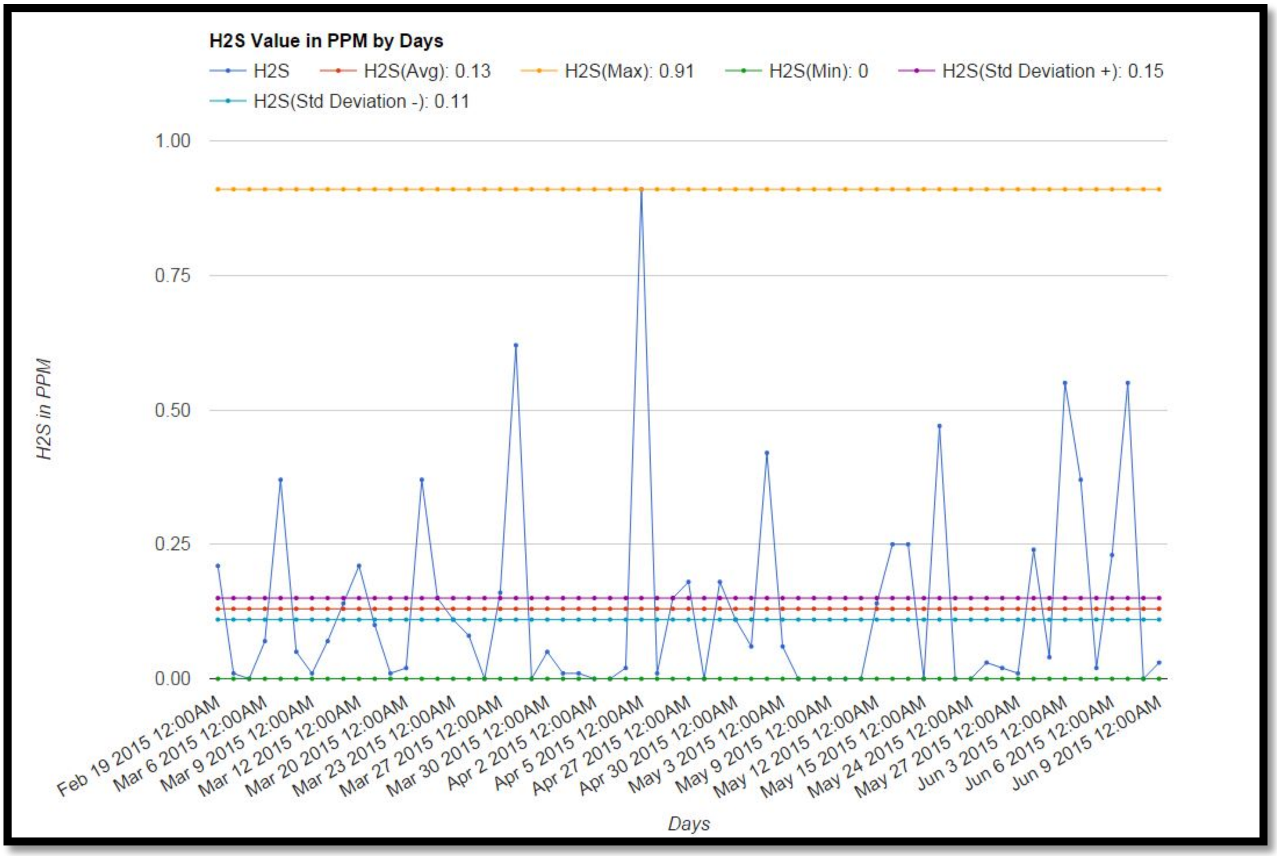


Figure 13: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 1

5.3 Daily Hydrogen Sulfide Analysis for 10 Minute Intervals

Table 5 below shows the maximum value, minimum value, average, average plus one standard deviation, and average minus one standard deviation. The daily analysis was performed by averaging the hydrogen sulfide concentrations for each date observed and comparing them using the time of day based on 10 minute intervals. The day is broken out into seven time ranges based on solar radiation strength.

Site 1 still has the highest hydrogen sulfide concentrations because of its nearness to the head works. The highest concentration for that site occurred between 8:20 a.m. and 10:00 a.m. This still corresponds to the time of highest influent flow into the EBWWTP. Site 2 has the lowest readings, followed by Sites 4 and 6.

According to Table 5, high hydrogen sulfide concentrations occurred mostly between 6:00 a.m. and 10:00 a.m. and between 6:00 p.m. and 6:00 a.m. This corresponds to high influent flow rates coming in the EBWWTP. It should also be recalled that it might take hours for the influent to get from the consumer to the EBWWTP.

Table 5: Daily 10 Minute Analysis – Sites 1-8

Site Location	**Solar Radiation**	**Timings**	**Daily Analysis (10 Minute Intervals)**				
			Max Value	Min Value	Avg	Avg +1 SD	Avg -1 SD
Site 1	Slight	6:00AM - 8:20AM	0.32	0.14	0.22	0.23	0.21
	Moderate	8:20AM - 10:00AM	0.39	0.21	0.3	0.31	0.29
	Strong	10:00AM - 12:00PM	0.25	0.12	0.16	0.17	0.15
	Strong	12:00PM - 2:00PM	0.15	0.09	0.12	0.12	0.12
	Moderate	2:00PM - 3:40PM	0.23	0.07	0.14	0.15	0.13
	Slight	3:40PM - 6:00PM	0.18	0.1	0.15	0.15	0.15
	None	6:00PM - 6:00AM	0.24	0.06	0.12	0.12	0.12
Site 2	Slight	6:00AM - 8:20AM	0	0	0	0	0
	Moderate	8:20AM - 10:00AM	0	0	0	0	0
	Strong	10:00AM - 12:00PM	0	0	0	0	0
	Strong	12:00PM - 2:00PM	0	0	0	0	0
	Moderate	2:00PM - 3:40PM	0	0	0	0	0
	Slight	3:40PM - 6:00PM	0	0	0	0	0
	None	6:00PM - 6:00AM	0	0	0	0	0
Site 3	Slight	6:00AM - 8:20AM	0.12	0.06	0.09	0.09	0.09
	Moderate	8:20AM - 10:00AM	0.1	0.04	0.06	0.06	0.06
	Strong	10:00AM - 12:00PM	0.05	0.03	0.04	0.04	0.04
	Strong	12:00PM - 2:00PM	0.03	0.03	0.03	0.03	0.03
	Moderate	2:00PM - 3:40PM	0.04	0.03	0.04	0.04	0.04
	Slight	3:40PM - 6:00PM	0.05	0.04	0.05	0.05	0.05
	None	6:00PM - 6:00AM	0.18	0.05	0.12	0.12	0.12
Site 4	Slight	6:00AM - 8:20AM	0.02	0.01	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.01	0	0.01	0.01	0.01
	Strong	10:00AM - 12:00PM	0.01	0	0	0	0
	Strong	12:00PM - 2:00PM	0.01	0	0	0	0
	Moderate	2:00PM - 3:40PM	0.01	0	0	0	0
	Slight	3:40PM - 6:00PM	0.01	0	0	0	0
	None	6:00PM - 6:00AM	0.03	0	0.02	0.02	0.02
Site 5	Slight	6:00AM - 8:20AM	0.06	0.03	0.04	0.04	0.04
	Moderate	8:20AM - 10:00AM	0.05	0.02	0.04	0.04	0.04
	Strong	10:00AM - 12:00PM	0.03	0.02	0.03	0.03	0.03
	Strong	12:00PM - 2:00PM	0.03	0.02	0.02	0.02	0.02
	Moderate	2:00PM - 3:40PM	0.03	0.01	0.02	0.02	0.02
	Slight	3:40PM - 6:00PM	0.04	0.01	0.02	0.02	0.02
	None	6:00PM - 6:00AM	0.11	0.02	0.07	0.07	0.07
Site 6	Slight	6:00AM - 8:20AM	0.01	0	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.01	0	0.01	0.01	0.01
	Strong	10:00AM - 12:00PM	0.01	0	0	0	0
	Strong	12:00PM - 2:00PM	0.01	0	0	0	0
	Moderate	2:00PM - 3:40PM	0	0	0	0	0
	Slight	3:40PM - 6:00PM	0	0	0	0	0
	None	6:00PM - 6:00AM	0.03	0	0.01	0.01	0.01
Site 7	Slight	6:00AM - 8:20AM	0.05	0.02	0.03	0.03	0.03
	Moderate	8:20AM - 10:00AM	0.03	0.01	0.02	0.02	0.02
	Strong	10:00AM - 12:00PM	0.01	0	0.01	0.01	0.01
	Strong	12:00PM - 2:00PM	0.01	0	0.01	0.01	0.01
	Moderate	2:00PM - 3:40PM	0.01	0	0.01	0.01	0.01
	Slight	3:40PM - 6:00PM	0.01	0	0.01	0.01	0.01
	None	6:00PM - 6:00AM	0.05	0.01	0.03	0.03	0.03
Site 8	Slight	6:00AM - 8:20AM	0.02	0	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.02	0.01	0.02	0.02	0.02
	Strong	10:00AM - 12:00PM	0.01	0	0.01	0.01	0.01
	Strong	12:00PM - 2:00PM	0.01	0	0.01	0.01	0.01
	Moderate	2:00PM - 3:40PM	0.01	0	0.01	0.01	0.01
	Slight	3:40PM - 6:00PM	0.01	0	0.01	0.01	0.01
	None	6:00PM - 6:00AM	0.02	0	0.01	0.01	0.01

In the graphs below Sites 1, 3, and 5 are shown for time intervals of 6:00 a.m. to 8:20 a.m. and 6:00 p.m. to 6:00 a.m. These times were chosen because of high concentrations at each site.

Site 1 is located near the headworks of the EBWWTP. It is the site with the highest hydrogen sulfide concentrations which spike during the morning and even hours. For the 6:00 a.m. to 8:20 a.m. time range, this site had its highest average concentration of 0.32 ppm at 7:15 a.m. It should be noted that the time period of 8:20 a.m. to 10:00 a.m. had the highest average concentration values, but Figure 14 below was chosen for consistency.

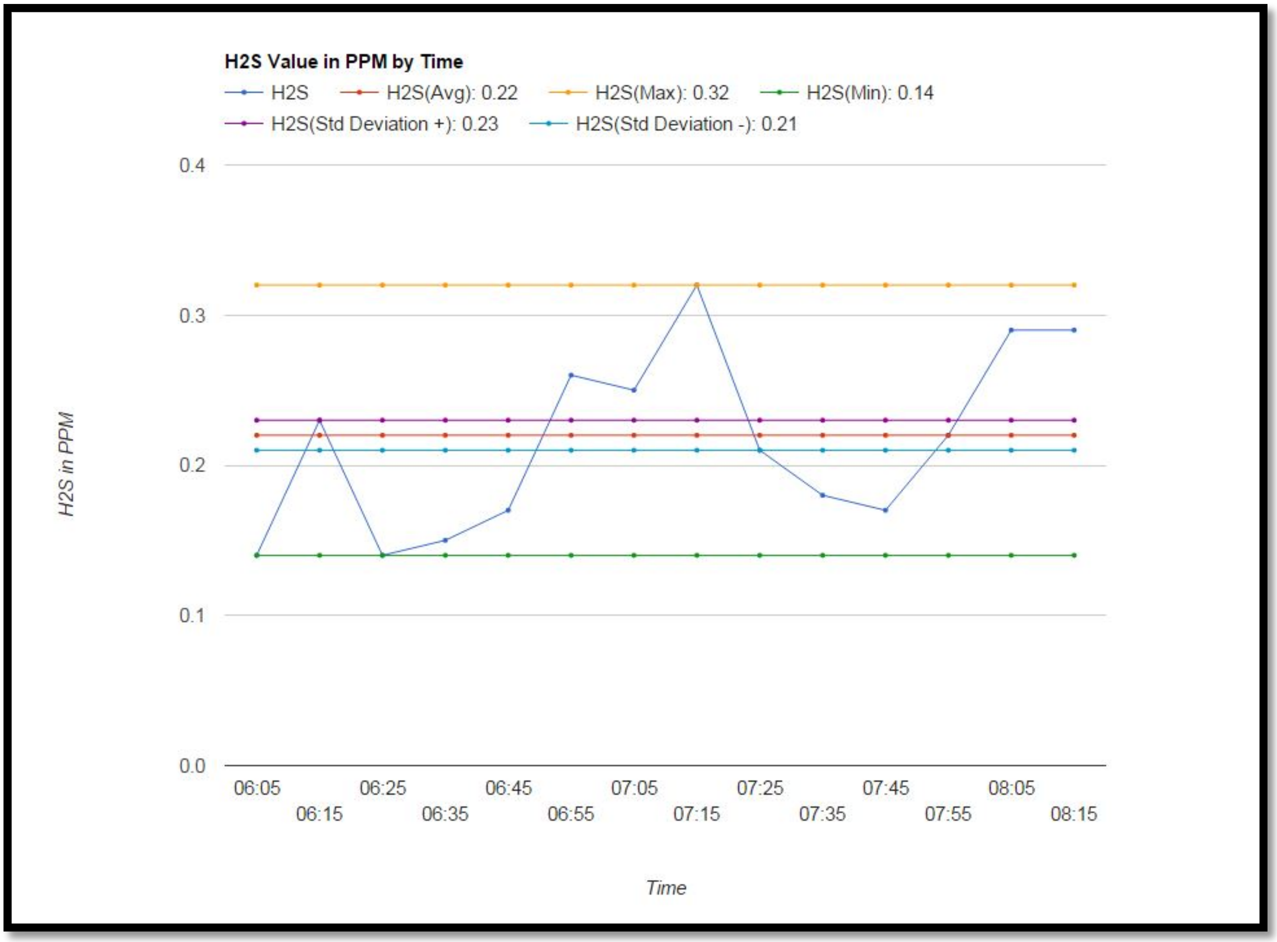


Figure 14: Average Hourly Analysis for 10 Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 1

For the 6:00 p.m. to 6:00 a.m. time range shown in Figure 15 below, the highest concentration was 0.24 ppm at 8:45 p.m. These maximum values correspond with the times the plant would be getting its highest influent flow rates and people would be home using the most water. This site is showing high hydrogen sulfide concentrations earlier than other sites because it is the first stage in treatment. Therefore, the high flows of influent reach Site 1 first.

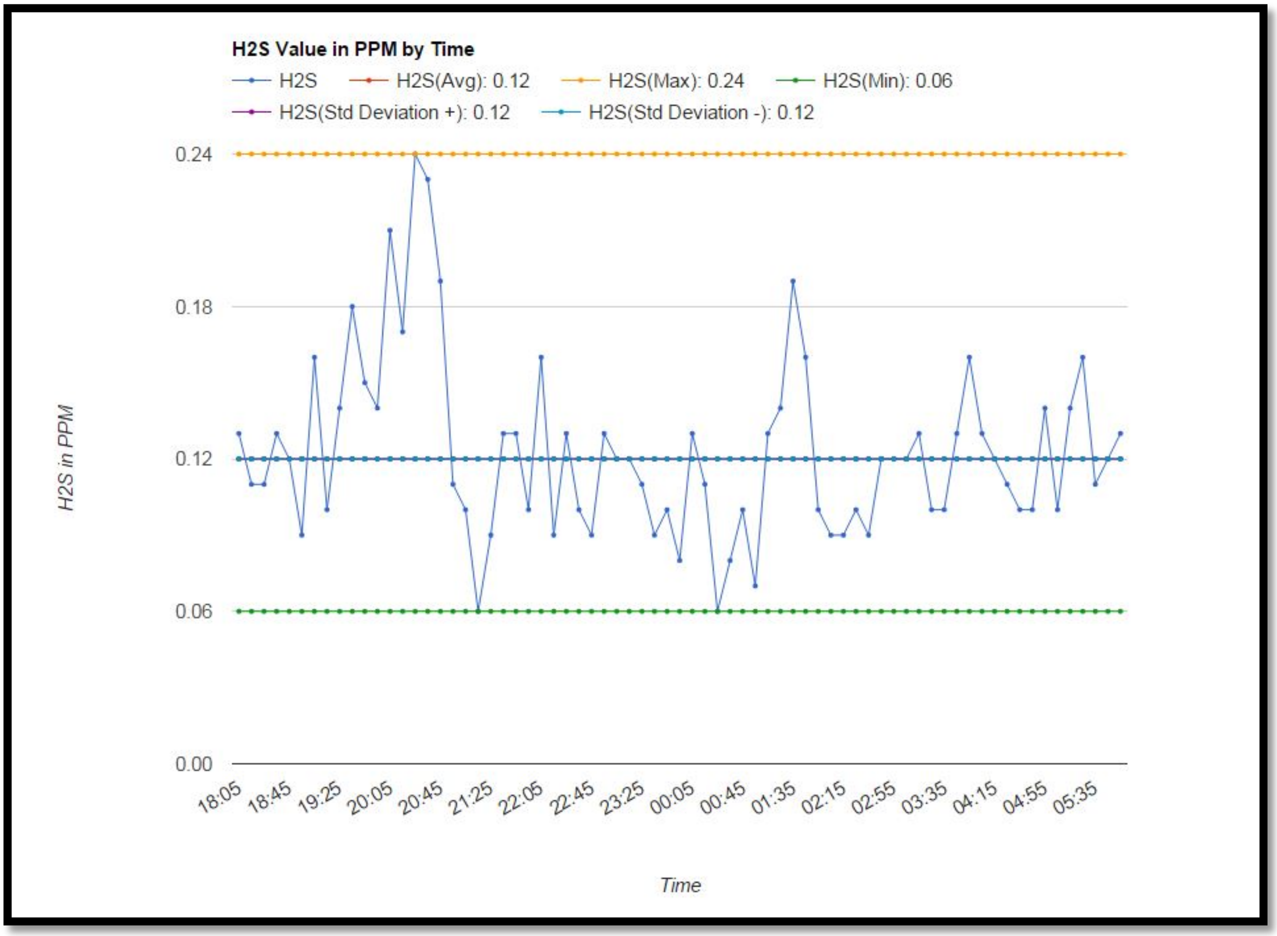


Figure 15: Average Hourly Analysis for 10 Minute Intervals (6:00p.m. – 6:00 a.m.) – Site 1

Site 3 (Figure 16) is located near the oxygen plant and the ash drying pits. It has the second highest hydrogen sulfide concentrations at the EBWWTP. The highest average hydrogen sulfide concentration for the time interval 6:00 a.m. to 8:20 a.m. is 0.12 ppm at 6:45 a.m., 7:35 a.m., and 7:45 a.m. This can be read from Figure 16 below.

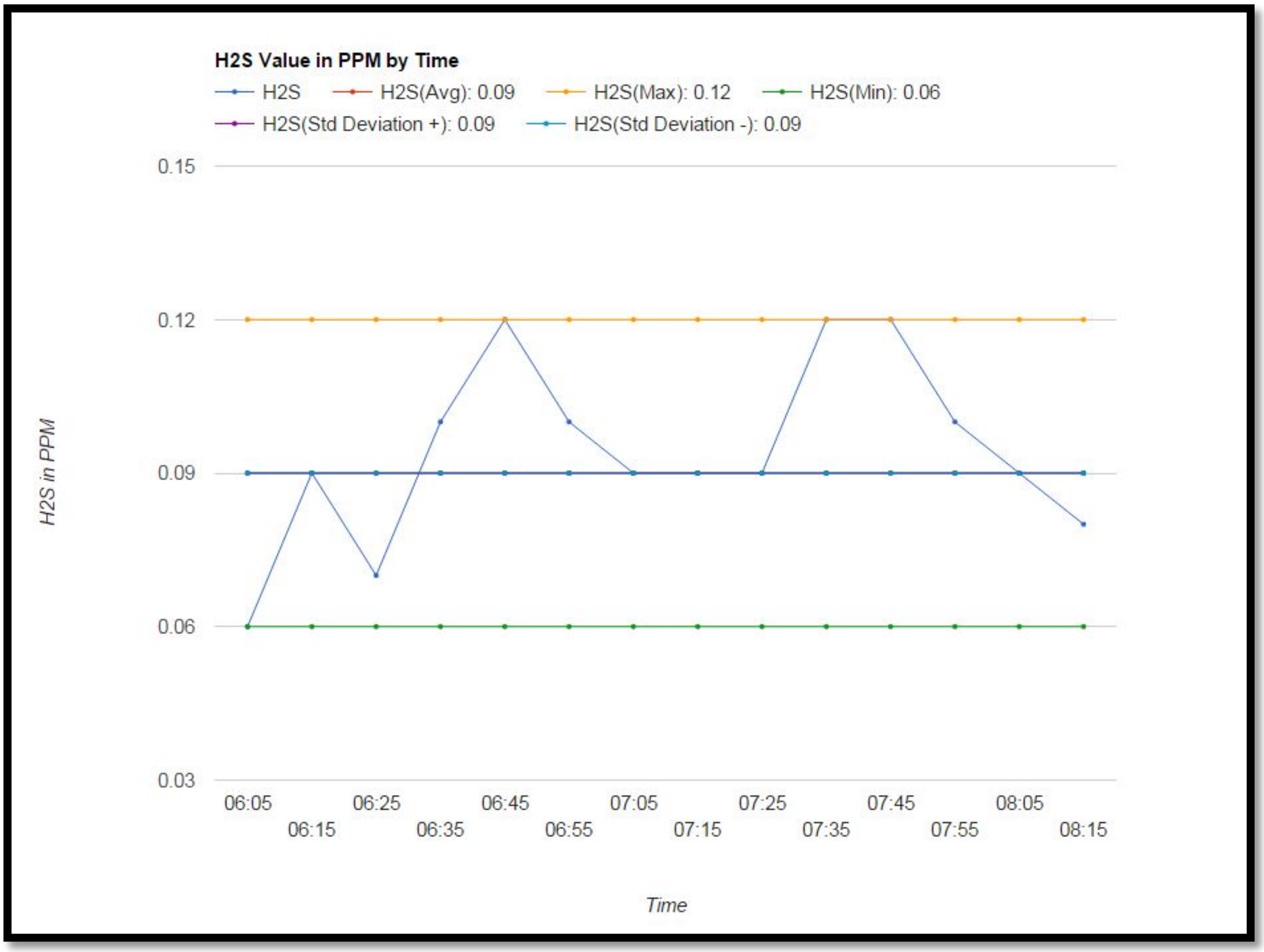


Figure 16: Average Hourly Analysis for 10 Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 3

In Figure 17 below, the concentrations are shown for the time interval 6:00 p.m. to 6:00 a.m. The highest average concentration was 0.18 ppm and was recorded at 10:05 p.m., 10:45 p.m., 12:05 p.m., and 12:45 p.m. This site is achieving high hydrogen sulfide concentrations due to its proximity to the ash drying pits and influent channel. The ash drying pits are continuously filled and emptied throughout the day, so concentrations should not vary with influent flow rates. However, if the odor were coming from the influent channel, concentrations could vary based on influent flow rates which are highest during the morning and evening hours.

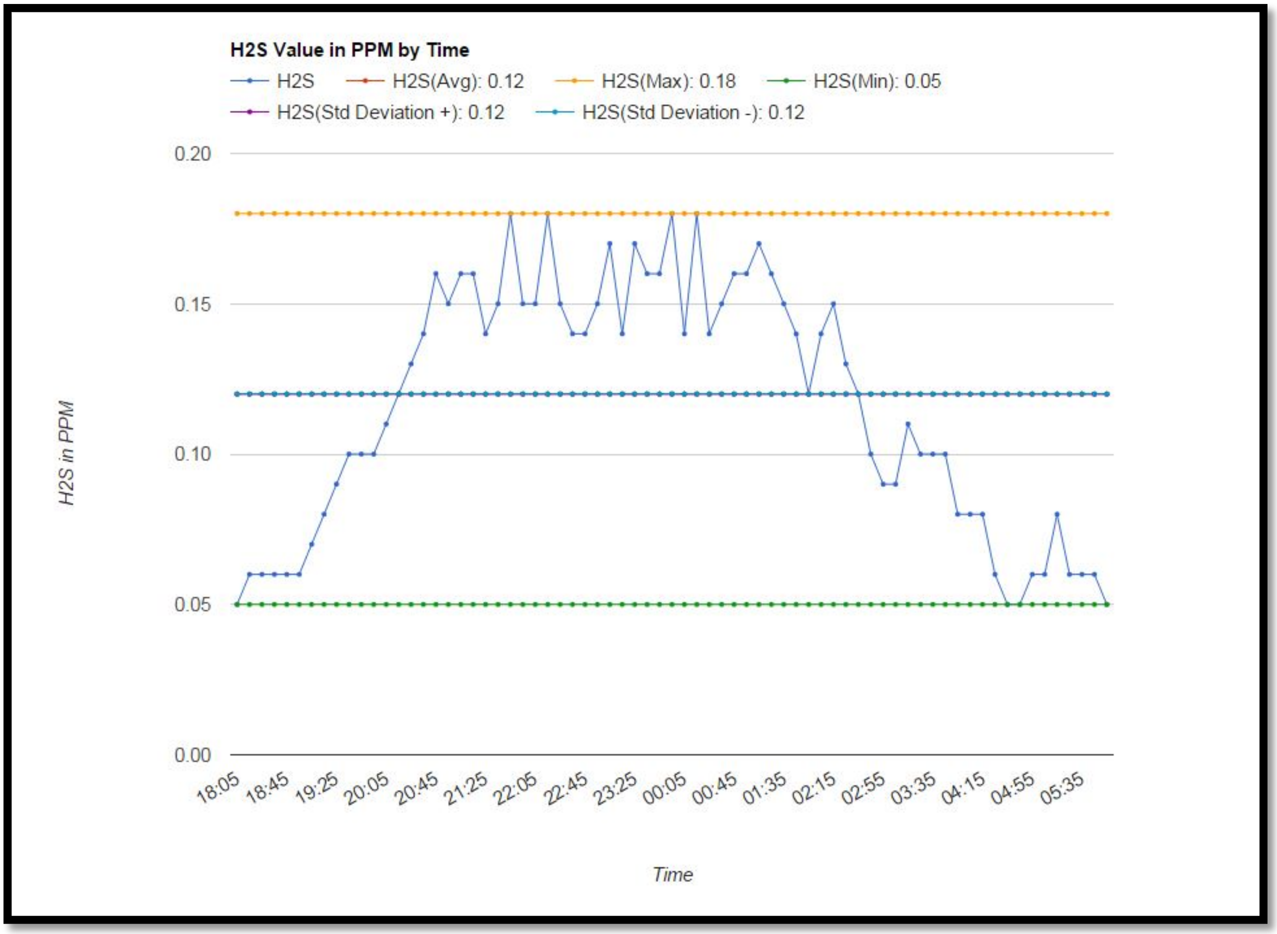


Figure 17: Average Hourly Analysis for 10 Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 3

Figure 18 below shows the average hourly analysis for Site 5 for the time interval of 6:00 a.m. to 8:20 a.m. This site is located near the center of the plant. It is close to the oxygen reactors, the influent channel, and clarifier number four. The maximum concentration was recorded as 0.06 ppm at 8:05 a.m.

Figure 18: Average Hourly Analysis for 10 Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 5

Figure 19 shows the average hourly analysis for Site 5 between 6:00 p.m. and 6:00 a.m. The maximum concentration achieved was 0.11 PPM at 12:45 p.m. and 2:35 a.m. The lowest concentration occurred at 5:45 a.m. with a concentration of 0.02 ppm. It is interesting to note that higher concentrations are coming later in the night as the influent is making its way through the treatment process.

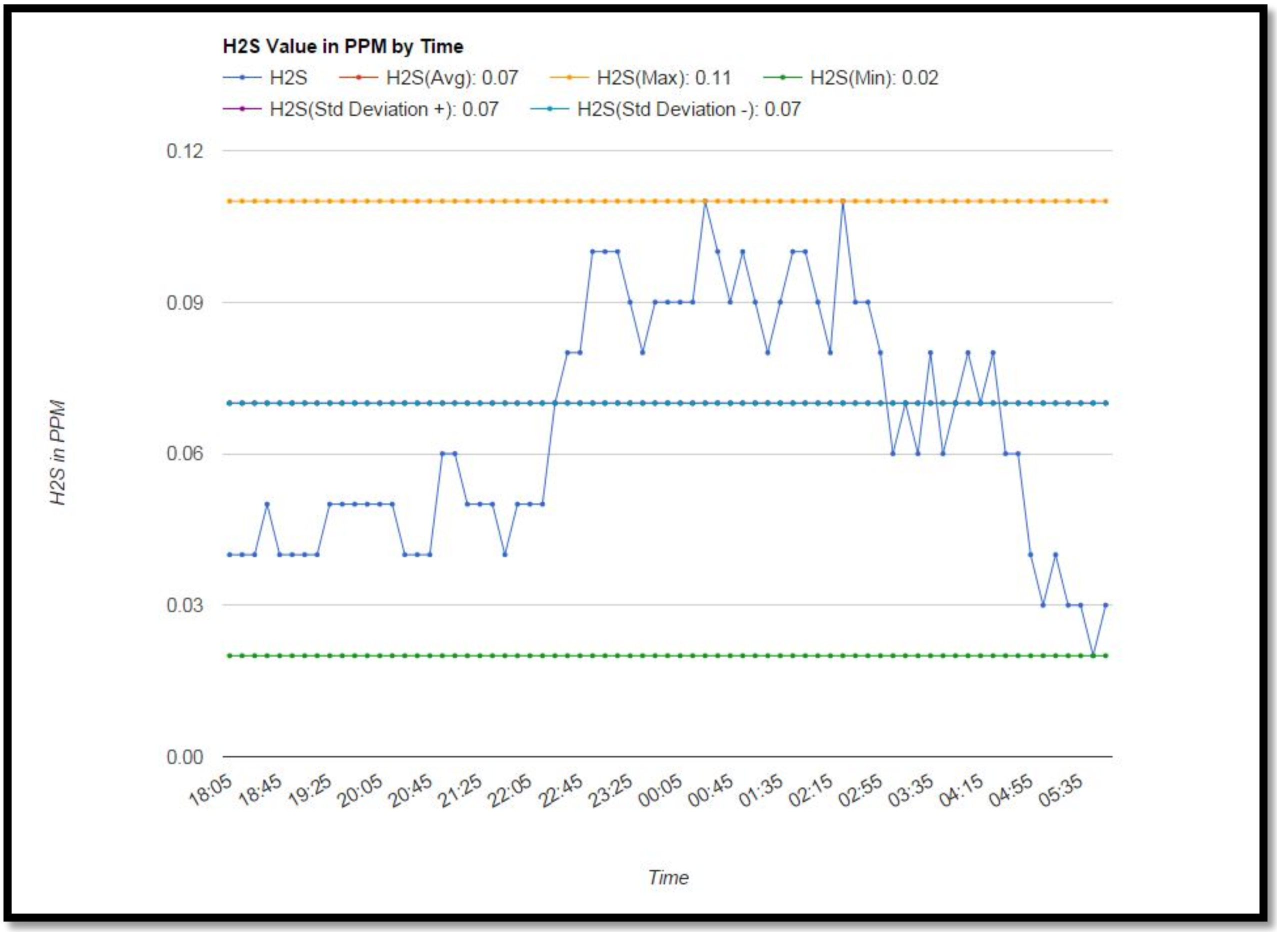


Figure 19: Average Hourly Analysis for 10 Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 5

5.4 Daily Hydrogen Sulfide Analysis for 30 Minute Intervals

Table 6 below displays the maximum value, minimum value, average, average plus one standard deviation, and average minus one standard deviation. The daily analysis was performed by averaging the hydrogen sulfide concentrations for the entire monitoring period and comparing them based on the time of day for 30 minute intervals.

The data in this table is similar to Table 5 since the same analysis was performed but with different time intervals.

Table 6: Daily 30-Minute Analysis – Sites 1-8

Site Location	Solar Radiation	Timings	Daily Analysis (30 Minute Intervals)				
			Max Value	Min Value	Avg	Avg +1 SD	Avg -1 SD
Site 1	Slight	6:00AM - 8:20AM	0.29	0.15	0.22	0.22	0.22
	Moderate	8:20AM - 10:00AM	0.33	0.22	0.28	0.28	0.28
	Strong	10:00AM - 12:00PM	0.2	0.13	0.16	0.16	0.16

	Strong	12:00PM - 2:00PM	0.13	0.1	0.11	0.11	0.11
	Moderate	2:00PM - 3:40PM	0.19	0.09	0.15	0.15	0.15
	Slight	3:40PM - 6:00PM	0.17	0.11	0.14	0.14	0.14
	None	6:00PM - 6:00AM	0.2	0.09	0.12	0.12	0.12
Site 2	Slight	6:00AM - 8:20AM	0	0	0	0	0
	Moderate	8:20AM - 10:00AM	0	0	0	0	0
	Strong	10:00AM - 12:00PM	0	0	0	0	0
	Strong	12:00PM - 2:00PM	0	0	0	0	0
	Moderate	2:00PM - 3:40PM	0	0	0	0	0
	Slight	3:40PM - 6:00PM	0	0	0	0	0
	None	6:00PM - 6:00AM	0	0	0	0	0
Site 3	Slight	6:00AM - 8:20AM	0.11	0.06	0.08	0.08	0.08
	Moderate	8:20AM - 10:00AM	0.08	0.04	0.05	0.05	0.05
	Strong	10:00AM - 12:00PM	0.04	0.03	0.04	0.04	0.04
	Strong	12:00PM - 2:00PM	0.03	0.03	0.03	0.03	0.03
	Moderate	2:00PM - 3:40PM	0.04	0.03	0.04	0.04	0.04
	Slight	3:40PM - 6:00PM	0.05	0.04	0.04	0.04	0.04
	None	6:00PM - 6:00AM	0.16	0.05	0.11	0.11	0.11
Site 4	Slight	6:00AM - 8:20AM	0.02	0.01	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.01	0	0.01	0.01	0.01
	Strong	10:00AM - 12:00PM	0	0	0	0	0
	Strong	12:00PM - 2:00PM	0.01	0	0.01	0.01	0.01
	Moderate	2:00PM - 3:40PM	0	0	0	0	0
	Slight	3:40PM - 6:00PM	0.01	0	0	0	0
	None	6:00PM - 6:00AM	0.03	0	0.02	0.02	0.02
Site 5	Slight	6:00AM - 8:20AM	0.05	0.04	0.04	0.04	0.04
	Moderate	8:20AM - 10:00AM	0.04	0.02	0.03	0.03	0.03
	Strong	10:00AM - 12:00PM	0.03	0.02	0.03	0.03	0.03
	Strong	12:00PM - 2:00PM	0.03	0.02	0.02	0.02	0.02
	Moderate	2:00PM - 3:40PM	0.02	0.01	0.02	0.02	0.02
	Slight	3:40PM - 6:00PM	0.04	0.01	0.03	0.03	0.03
	None	6:00PM - 6:00AM	0.1	0.03	0.06	0.06	0.06
Site 6	Slight	6:00AM - 8:20AM	0.01	0	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.01	0	0.01	0.01	0.01
	Strong	10:00AM - 12:00PM	0.01	0	0	0	0
	Strong	12:00PM - 2:00PM	0	0	0	0	0
	Moderate	2:00PM - 3:40PM	0	0	0	0	0
	Slight	3:40PM - 6:00PM	0	0	0	0	0
	None	6:00PM - 6:00AM	0.03	0	0.01	0.01	0.01
Site 7	Slight	6:00AM - 8:20AM	0.03	0.02	0.02	0.02	0.02
	Moderate	8:20AM - 10:00AM	0.02	0.01	0.01	0.01	0.01
	Strong	10:00AM - 12:00PM	0.01	0.01	0.01	0.01	0.01
	Strong	12:00PM - 2:00PM	0.01	0.01	0.01	0.01	0.01
	Moderate	2:00PM - 3:40PM	0.01	0.01	0.01	0.01	0.01
	Slight	3:40PM - 6:00PM	0.01	0.01	0.01	0.01	0.01
	None	6:00PM - 6:00AM	0.04	0.01	0.03	0.03	0.03
Site 8	Slight	6:00AM - 8:20AM	0.01	0	0.01	0.01	0.01
	Moderate	8:20AM - 10:00AM	0.02	0.01	0.02	0.02	0.02
	Strong	10:00AM - 12:00PM	0.01	0.01	0.01	0.01	0.01
	Strong	12:00PM - 2:00PM	0.01	0	0.01	0.01	0.01
	Moderate	2:00PM - 3:40PM	0.01	0.01	0.01	0.01	0.01
	Slight	3:40PM - 6:00PM	0.01	0	0.01	0.01	0.01
	None	6:00PM - 6:00AM	0.01	0	0.01	0.01	0.01

Figure 20 below shows the average hourly analysis at Site 3 for the time interval of 6:00 a.m. to 8:20 a.m. Site 3 is located near the oxygen plant, influent channel, and the ash drying pits. The maximum hydrogen sulfide concentration is 0.11 ppm and occurs at 7:45 a.m. Figure 21 displays the average hourly concentrations for the time interval of 6:00p.m. to

6:00 a.m. The maximum value is 0.16 ppm and occurs at 11:15p.m., 11:45p.m., and 1:15 a.m. I chose these time periods because they recorded the highest hydrogen sulfide concentrations consistently.

Figure 20: Average Hourly Analysis for 30 Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 3

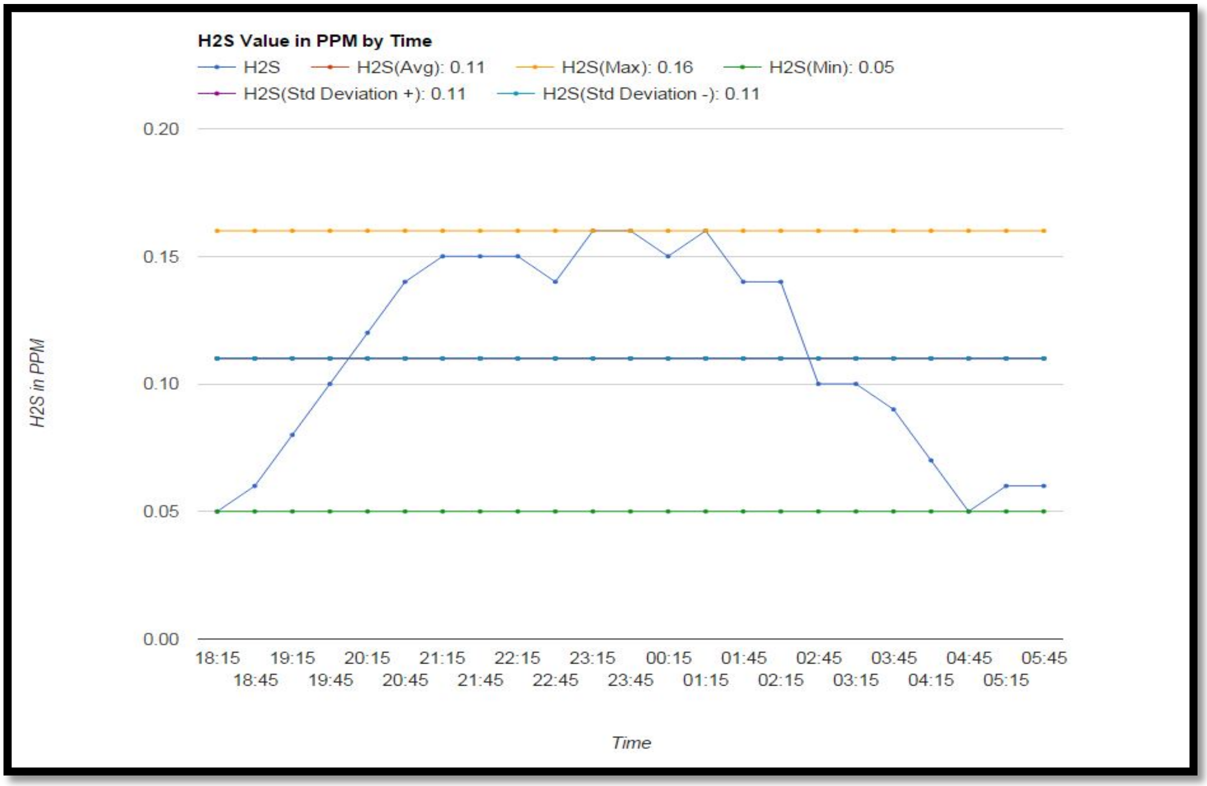


Figure 21: Average Hourly Analysis for 30 Minute Intervals (6:00p.m. – 6:00 a.m.) – Site 3

Figure 22 below shows the average hourly analysis at Site 5 for the time interval of 6:00 a.m. to 8:20 a.m. Site five is located in the middle of the EBWWTP adjacent to the influent channel, oxygen reactors, and clarifier number four. The maximum hydrogen sulfide concentration is 0.05 ppm and occurs at 8:15 a.m. Figure 23 displays the average hourly concentrations for the time interval of 6:00p.m. to 6:00 a.m. The maximum value is 0.1 ppm and occurs at 11:15p.m.

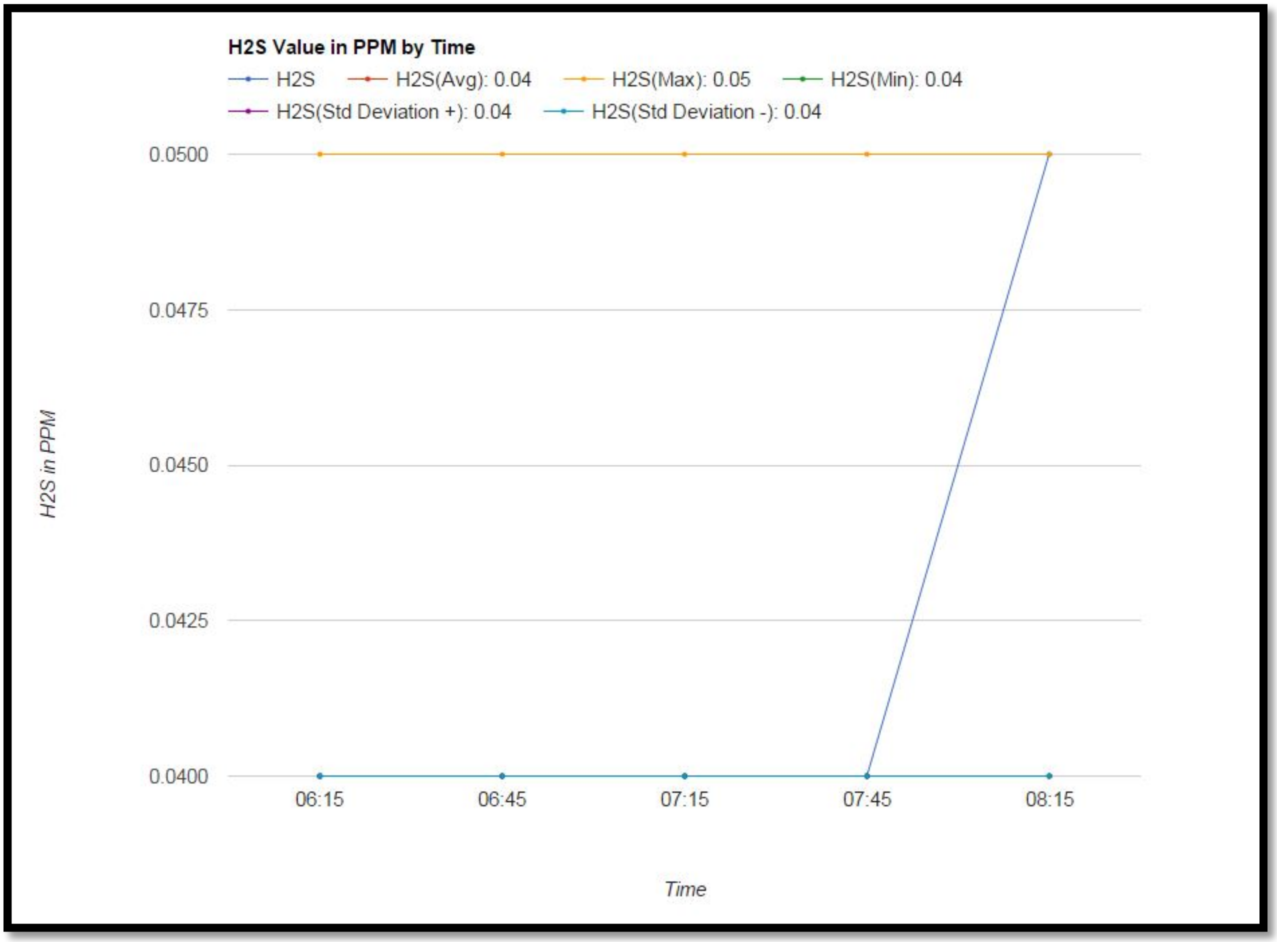


Figure 22: Average Hourly Analysis for 30 Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 5

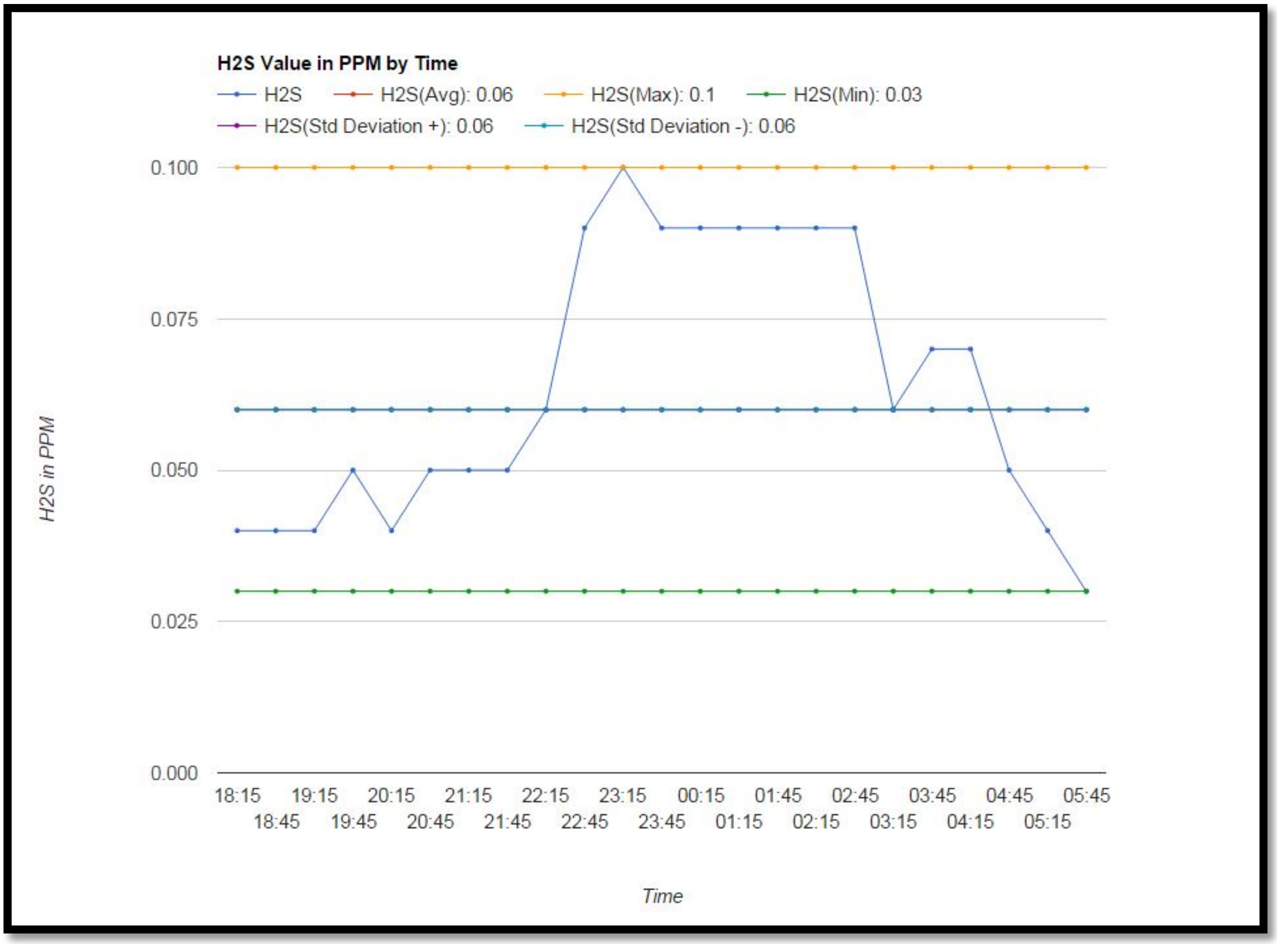


Figure 23: Average Hourly Analysis for 30 Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 5

Figure 24 below shows the average hourly analysis at Site 7 for the time interval of 6:00 a.m. to 8:20 a.m. Site 7 is located adjacent to clarifier number one and three. The maximum hydrogen sulfide concentration is 0.03 ppm and it occurs at 7:15 a.m. and 8:15 a.m. Figure 25 displays the average hourly concentrations for the time interval of 6:00p.m. to 6:00 a.m. The maximum value is 0.04 ppm and occurs at 10:15p.m., 12:15 p.m. and 1:15 a.m. For all three sites displayed, the maximum concentrations occur around the same time periods in the morning and evening. This is due to the higher 30 minute averaging interval used in this analysis.

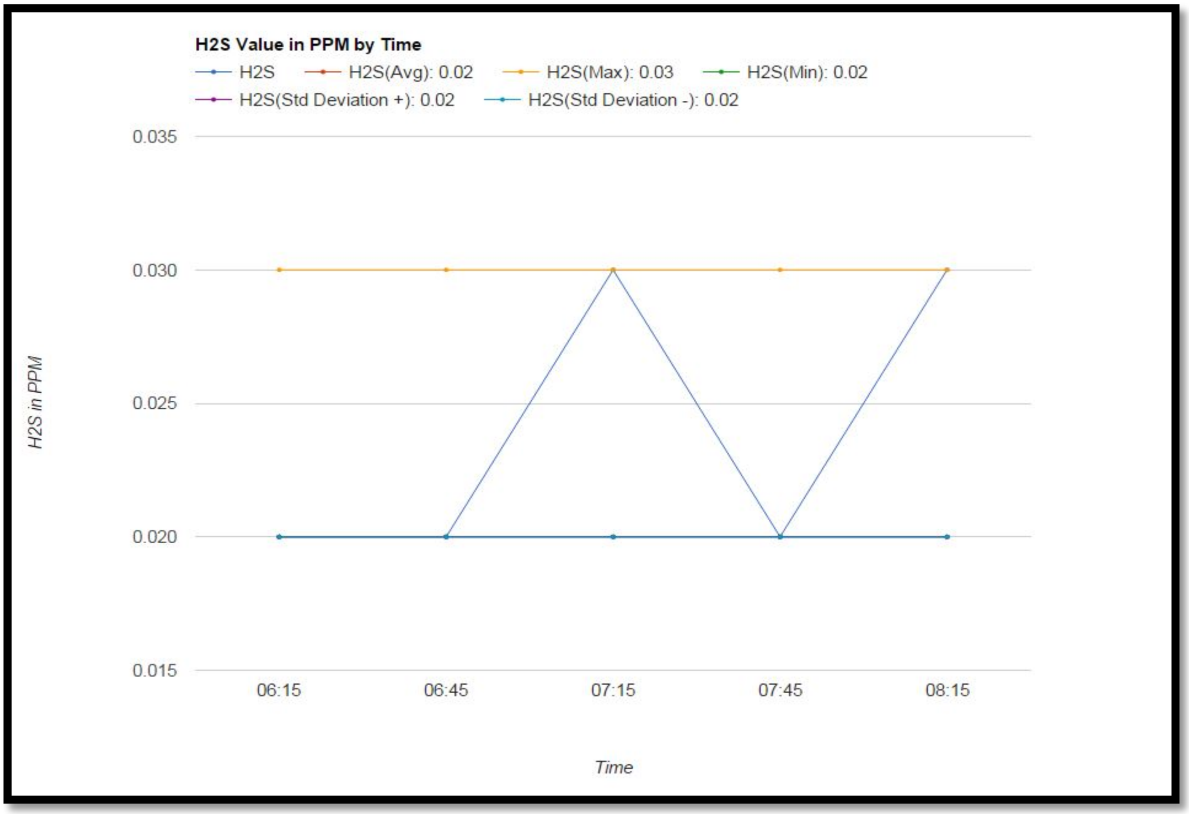


Figure 24: Average Hourly Analysis for 30 Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 7

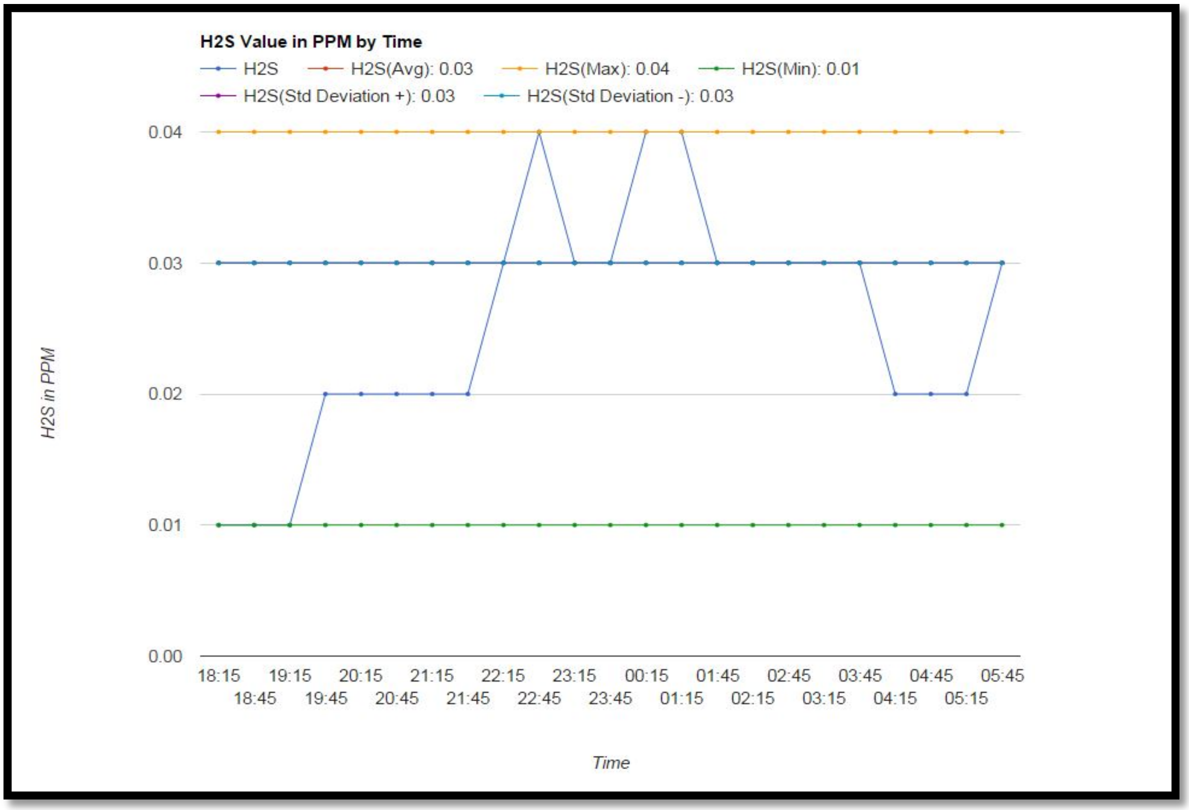


Figure 25: Average Hourly Analysis for 30 Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 7

5.5 Historical Analysis with Precipitation Data

Figures 26 through 28 below were generated by averaging the daily values for all of the hydrogen sulfide concentrations during the entire monitoring period. The graphs are also overlaid with the daily precipitation data shown in inches per day.

The figures below show no clear relationship between precipitation and hydrogen sulfide concentrations. It was hypothesized that rainfall would lower the hydrogen sulfide concentrations, but that does not happen in a consistent pattern.

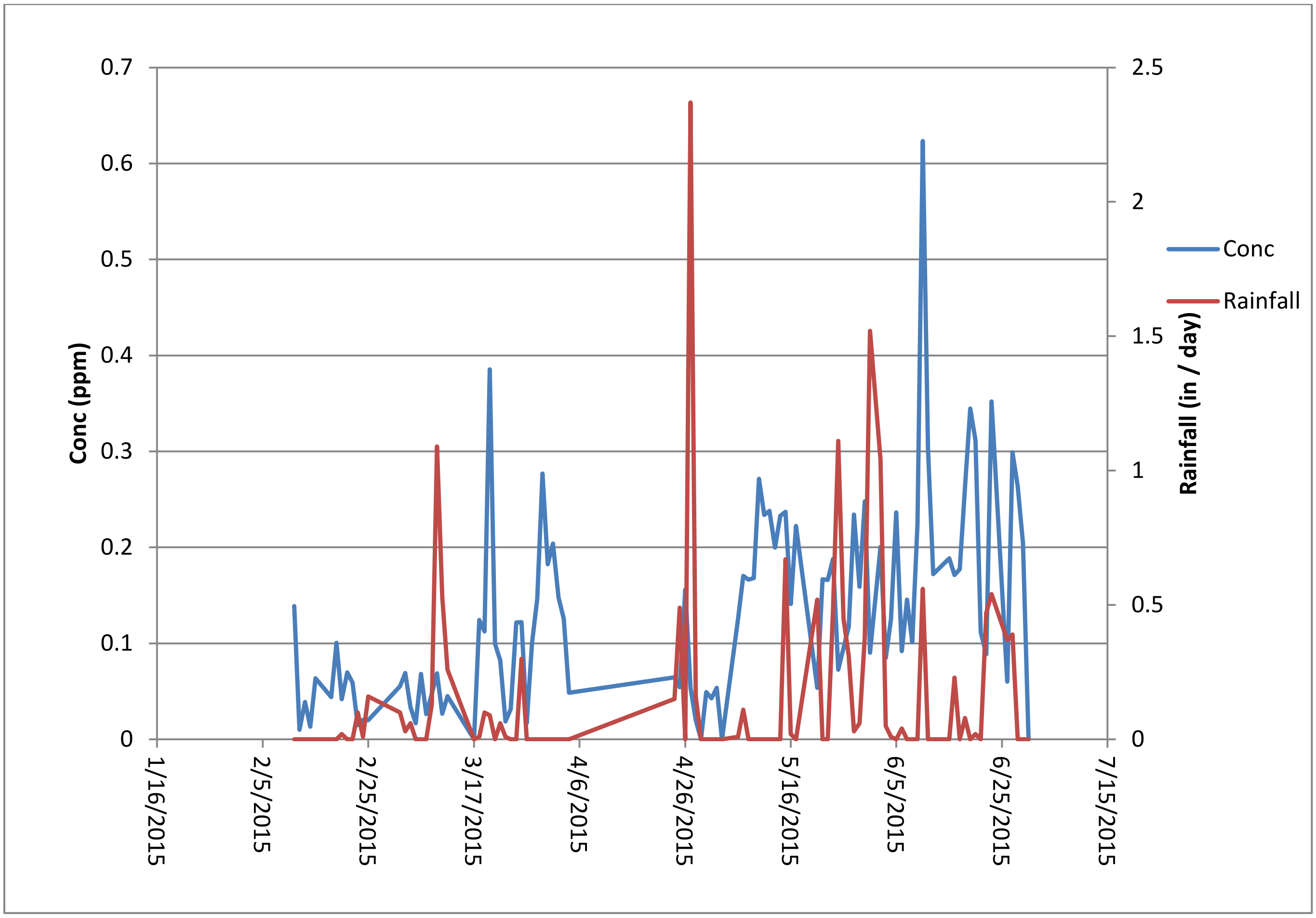


Figure 26: Historical Analysis and Rainfall – Site 3

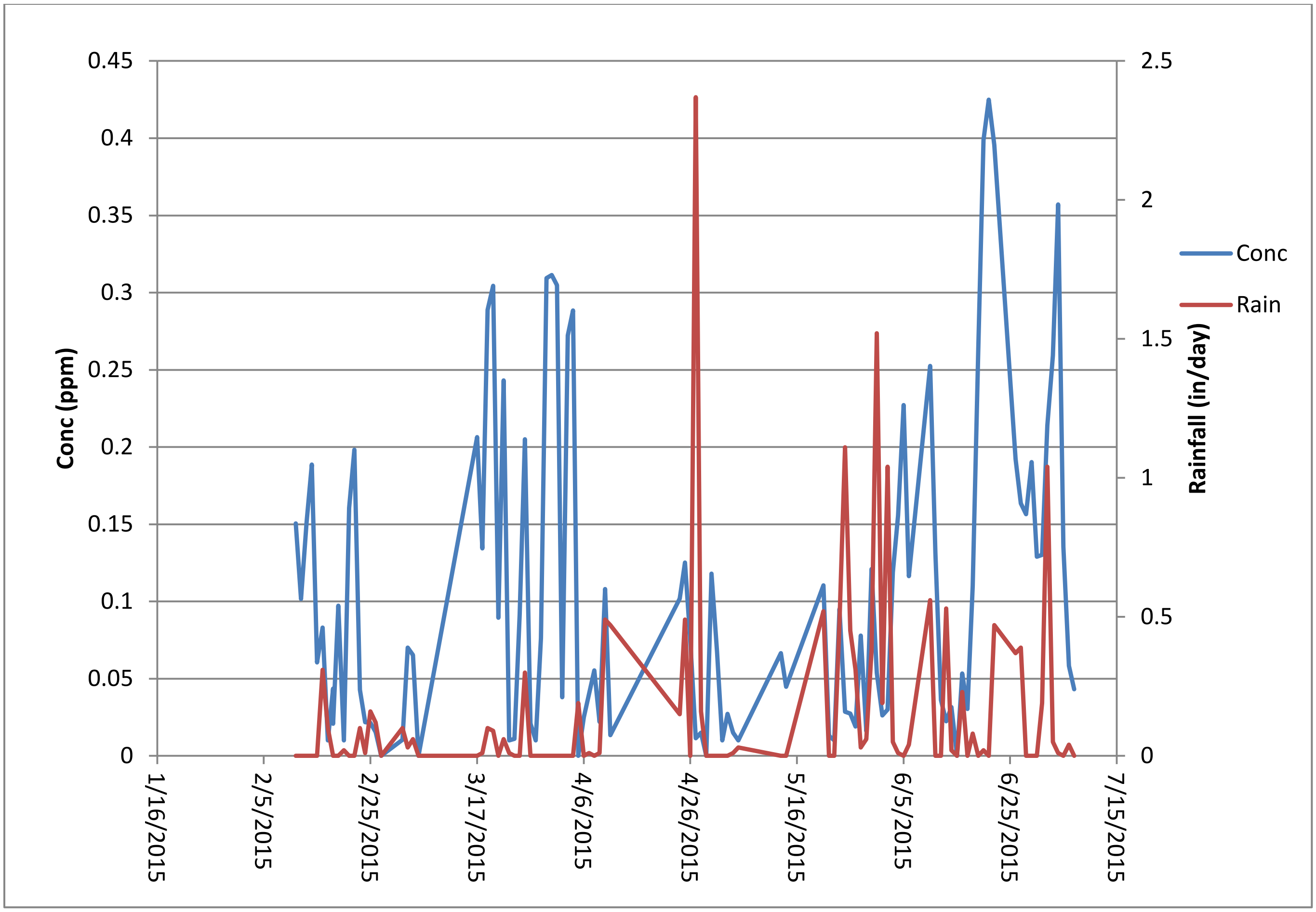


Figure 27: Historical Analysis and Rainfall – Site 5

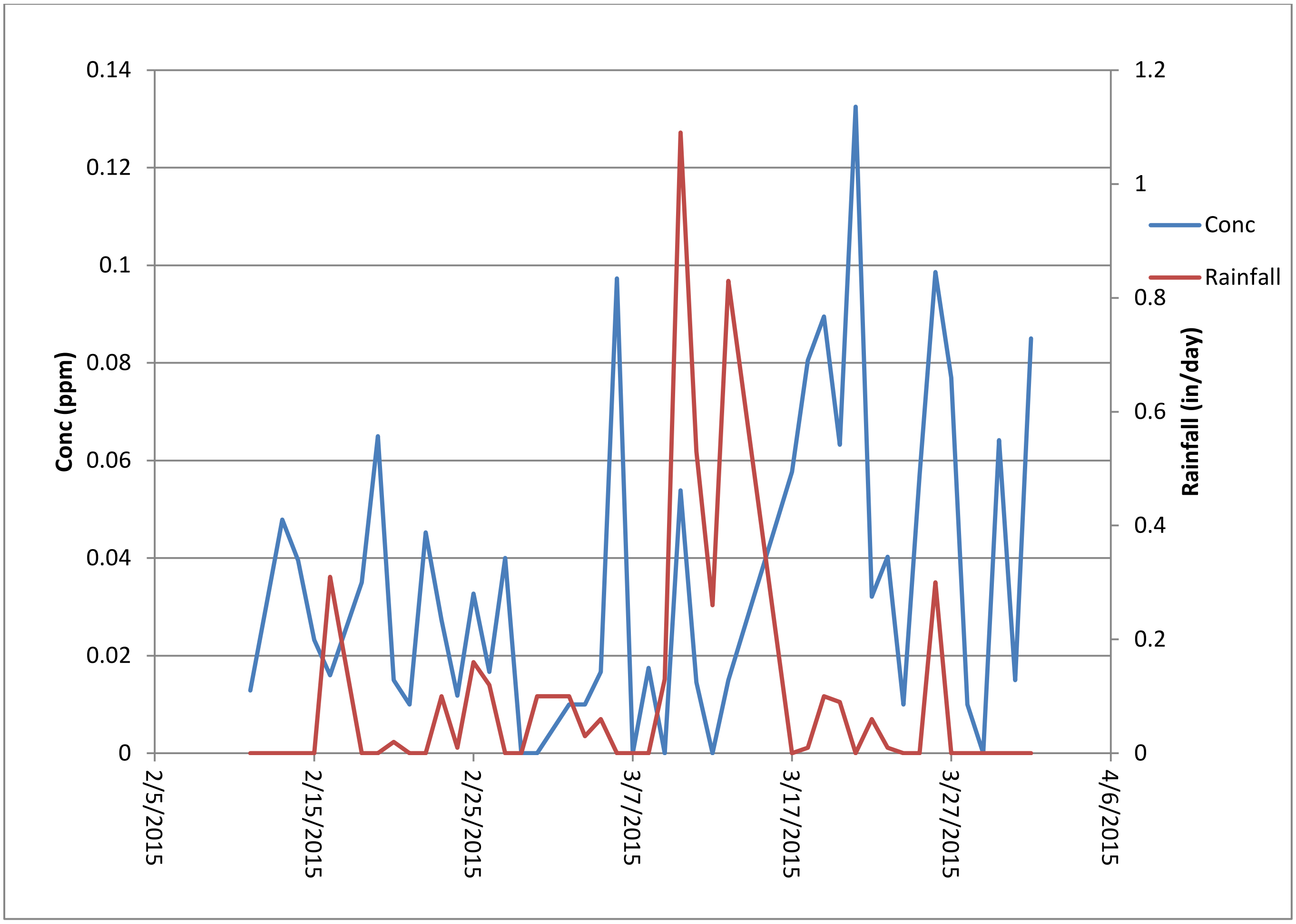


Figure 28: Historical Analysis and Rainfall – Site 8

5.6 Historical Analysis and Temperature

Figures 29 through 31 display the average daily values for each site during the entire monitoring period. These graphs average the entire 24 hour daily monitoring period. The graphs are also overlaid with the average daily temperatures.

Sites 1, 3 and 7 are displayed because their charts clearly show a trend between hydrogen sulfide concentrations and temperature. In Figure 29 there is an obvious trend in temperature between February 2015 and June 2015. There is also a slight increasing trend in concentration, proving there is a direct relationship between temperature and hydrogen sulfide concentrations at the EBWWTP. This direct relationship can also be seen in Figures 30 and 31 below.

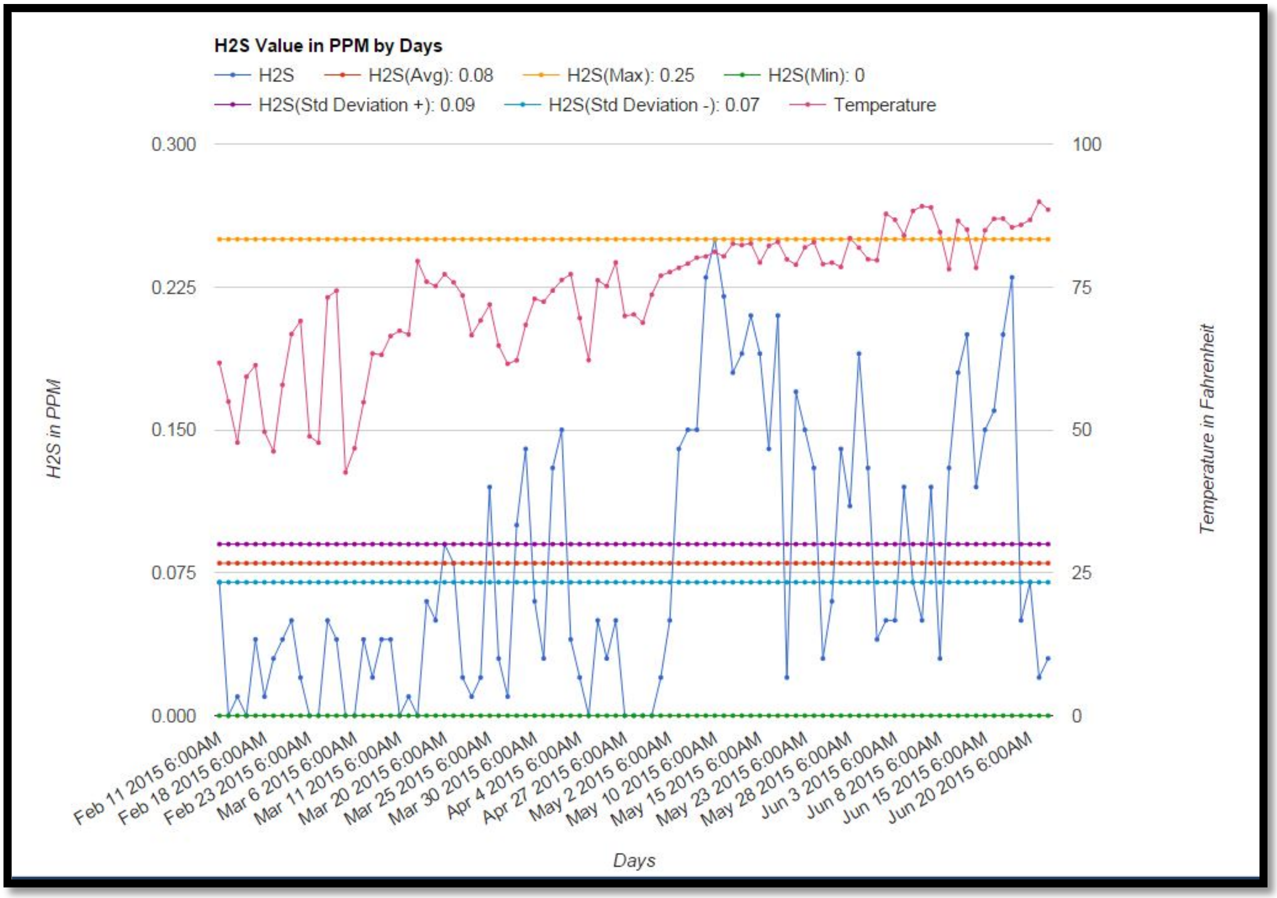


Figure 29: Historical Analysis and Temperature – Site 1

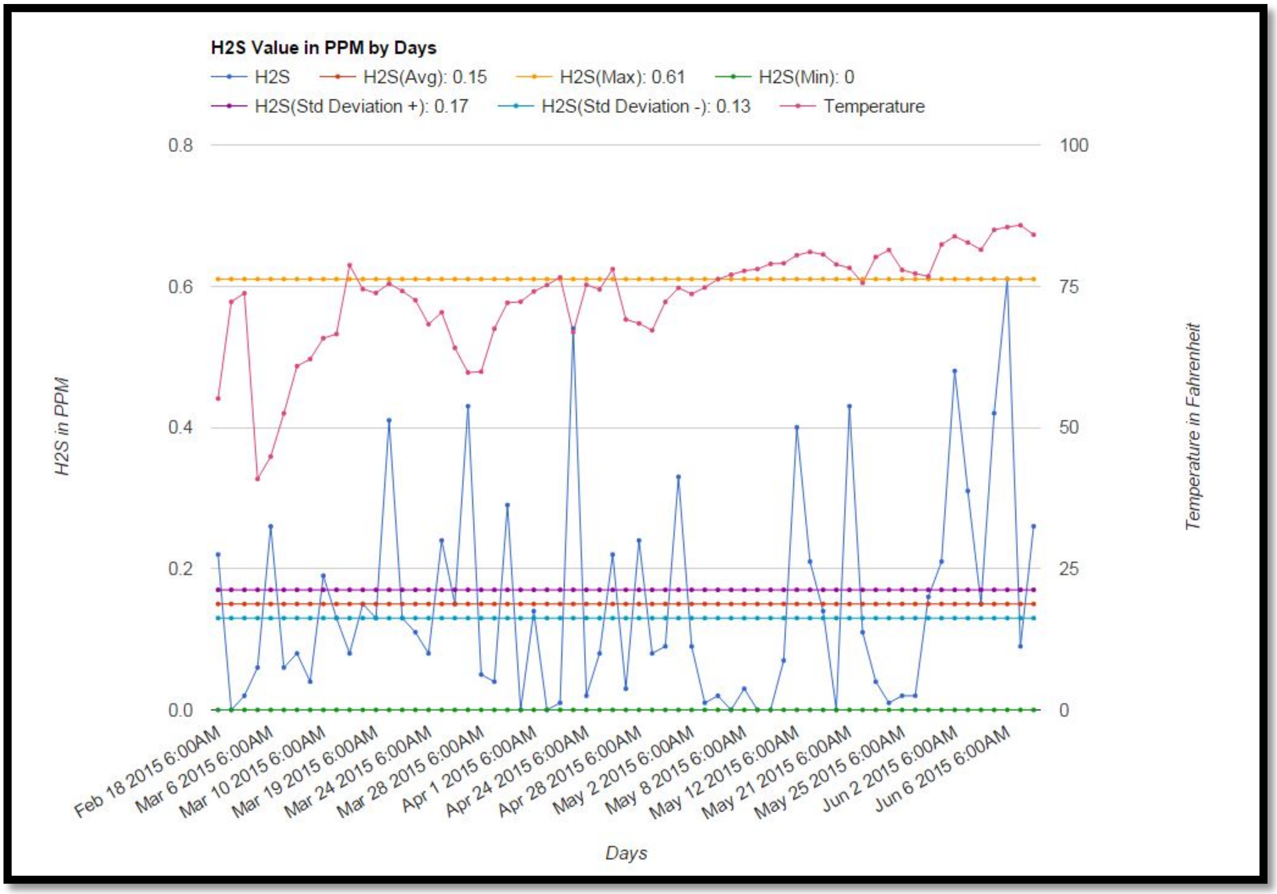


Figure 30: Historical Analysis and Temperature – Site 3

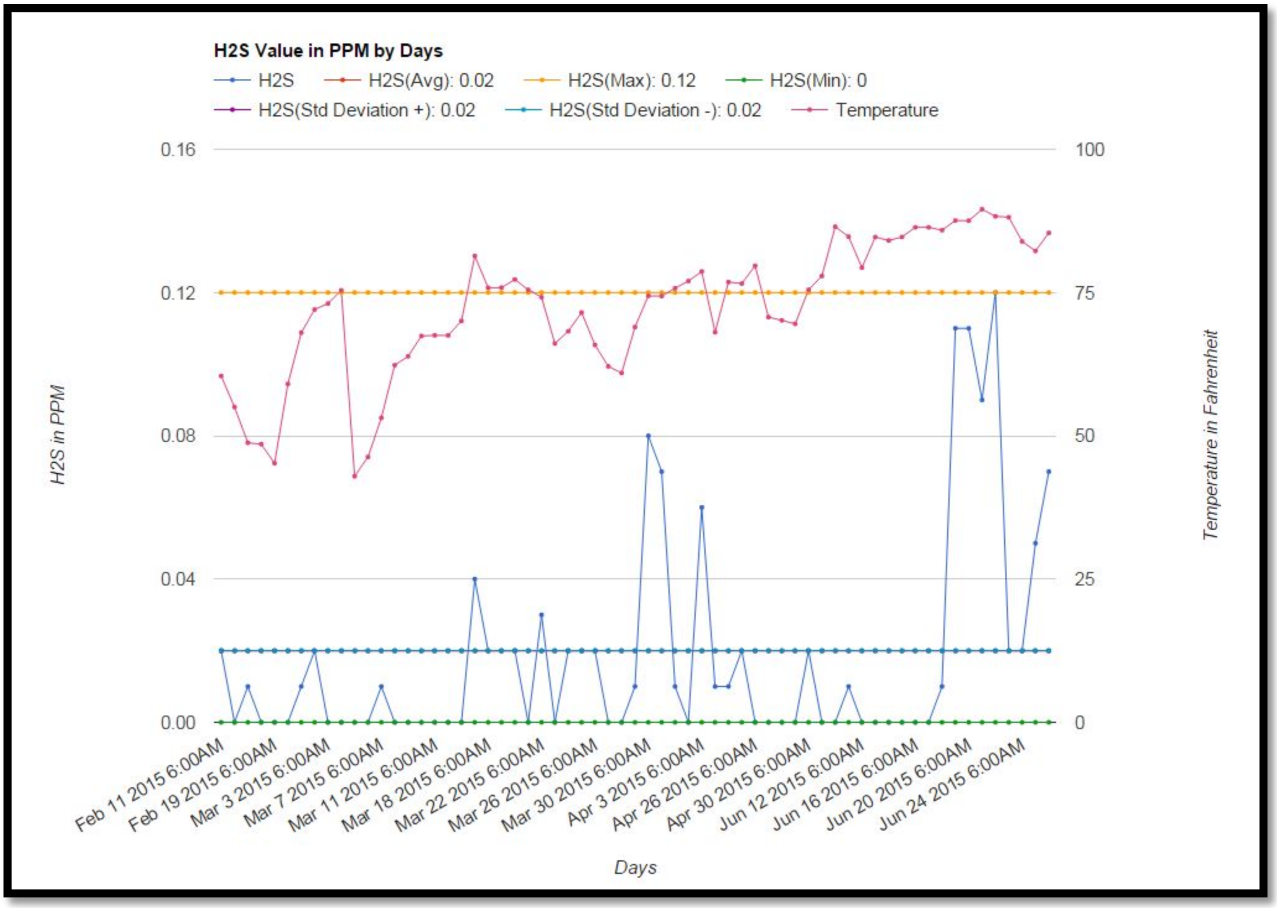


Figure 31: Historical Analysis and Temperature – Site 7

6. DISCUSSION

Anaerobic conditions exist primarily in the sewer transport and collection system. These areas often exhibit the highest odor concentrations due to their lack of oxygen and high organic matter concentrations. Consequently, influent first entering the plant has a very high concentration of odor producing compounds. These compounds must be transferred from the liquid phase to the gaseous phase. This process is accelerated in areas of high turbulence or atmospheric contact.

Based on a study of 26 wastewater treatment plants, Vincent (2001) found that primary settlers, anaerobic sludge-digestion tanks, and anaerobic sludge thickening were the main sources of odor emissions. The EBWWTP has no primary settling; instead the raw sewerage or influent first enters the headworks, consisting of bar screens and grit chambers. Therefore, the highest hydrogen sulfide concentrations at the EBWWTP were found at the headworks due to its turbulent nature and high air/wastewater contact ratio.

The sludge thickening process for the EBWWTP is aerobic in nature. Before incineration, the sludge is thickened in a converted clarifier and routed through 4 belt presses. Typically, anaerobic sludge treatment emits higher concentrations of odorous compounds (Lebrero et al., 2011).

The thickened sludge is incinerated and ash is produced. The incinerator can be a source of odor at the plant if the stack is not tall enough or wind patterns ground the emissions. Odor destruction in an incinerator depends on temperature fluctuations and the chemical content of the sludge. The ash is pumped as a slurry to ash drying pits. The ash drying pits were found to be the second highest source of hydrogen sulfide at the EBWWTP (Sawyer et al., 1960).

7. CONCLUSIONS

Hydrogen sulfide gas is a threat to municipal facilities around the country. The gas is corrosive and dangerous to humans at high concentrations. Without treatment, the gas would become an odor nuisance to surrounding communities and a health hazard to those working at the treatment plant.

The New Orleans East Bank Wastewater Treatment Plant was an ideal place to perform hydrogen sulfide monitoring. During the monitoring period, the plant went through a change in hydrogen sulfide treatment. While the switch to peroxide for odor control did not make a significant impact on the hydrogen sulfide concentrations, it is worth noting. There was also a construction project that impacted the hydrogen sulfide concentrations at the plant. This project mainly impacted Site 5 due to its nearness to the opening and cleaning of oxygen reactor #1.

Out of the eight sites selected for monitoring, Site 1 had the highest hydrogen sulfide concentrations due to its nearness to the head works. Site 3 had the second highest concentrations, located near the ash drying pits. Site 2 was located near the septage unloading station, ash drying pits and the influent channel; however, it received the lowest hydrogen sulfide concentrations. The monitor was most likely placed too far away from these sources to record significant readings.

High hydrogen sulfide readings were recorded during the morning and evening hours. Despite hypothesizing that high concentrations would be dependent on solar radiation, none of the data supported this theory. Instead, it was found that influent flow rates greatly affected the hydrogen sulfide concentrations. Influent flow rates are highest in the morning and evening hours. This corresponds to the time people are using high amounts of water to shower and wash laundry or dishes. These high flows can take several hours to reach the plant, so the high hydrogen sulfide concentrations might not appear until several hours after the typical morning and evening hours. It is also significant to recall that the high influent flow rates will affect the plant in chronological order. Meaning that the earlier stages in treatment will be first to record high hydrogen sulfide concentrations.

The relationship between hydrogen sulfide concentrations and daily precipitation was analyzed and it was hypothesized that high precipitation would lower hydrogen sulfide concentrations. Conversely, no significant pattern was detected.

Temperature and hydrogen sulfide concentrations were also analyzed to test for a positive correlation. Based on several graphs displaying average daily values for each site, it was determined that there is a direct relationship between temperature and hydrogen sulfide concentrations.

8. RECOMMENDATIONS

The most pressing issue found in this study was the high hydrogen sulfide concentrations found at the head works and the ash drying pits at the EBWWTP. These concentrations were still well within OSHA standards and pose no threat to human health. However, concentrations this high can cause a threat to the plant by way of corrosion.

While it may never be possible to completely rid a wastewater treatment plant of hydrogen sulfide gas, efforts can be made to reduce the levels. Currently the plant uses peroxide the treat hydrogen sulfide. The peroxide is injected into the influent line just before reaching the headworks. The reaction time is 2 to 3 minutes and the process is only viable for 3 hours.

To reduce the odor at the headworks, it is recommended that the plant inject the peroxide further upstream from the plant. It appears that the peroxide might not have sufficient contact time before the effluent enters the headworks. An analysis of peroxide injection concentration should also be performed to determine the correct dose.

The hydrogen sulfide concentrations at the ash drying pits are not affected by the plant's peroxide treatment. The ash is produced from an on-site fluidized bed incinerator. By the time the sludge reaches the incinerator, the peroxide is no longer reactive. It is recommended that the plant use additional odor treatment for the ash. A second dose of peroxide could be injected directly into the ash slurry pipeline.

Subsequent analysis and modeling should be performed with the current data. Modeling would show the movement and layout of the hydrogen sulfide plum at the EBWWTP. This would help the plant further locate their problem areas and peak hydrogen sulfide concentration times.

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Appendix

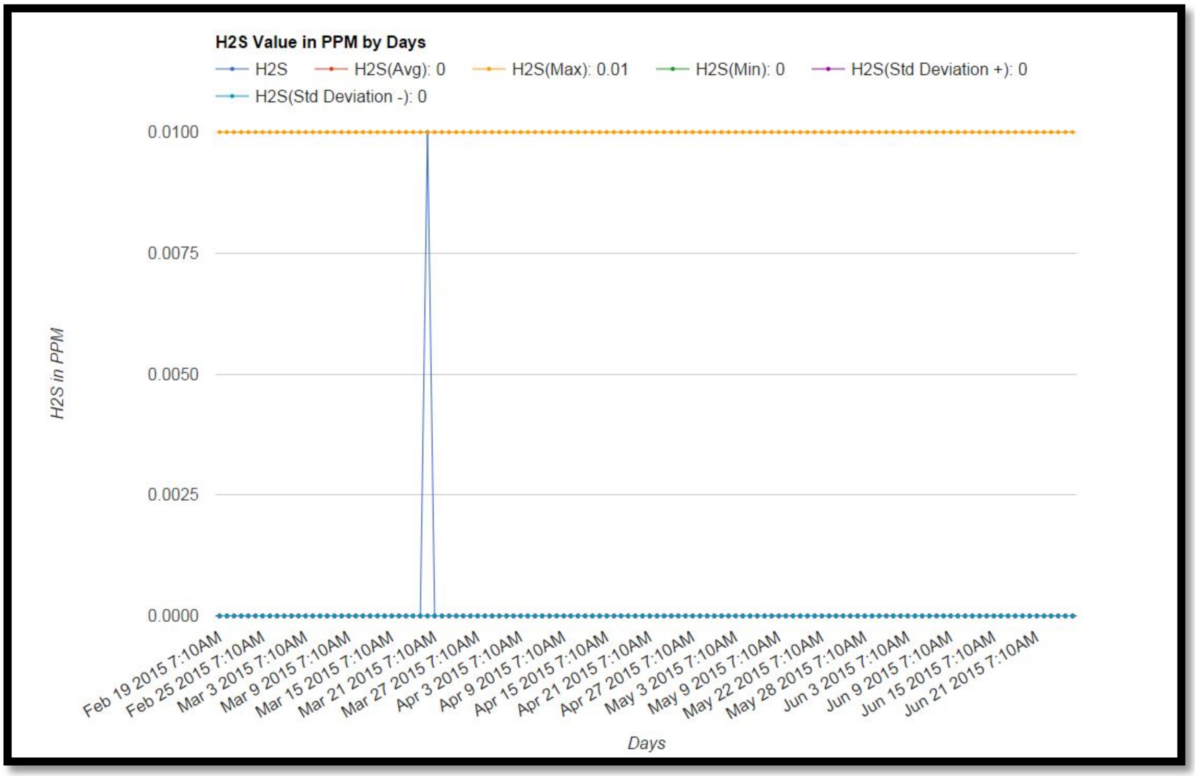


Figure A-1: Historical Analysis (6:00 a.m. – 8:20 a.m.) – Site 2

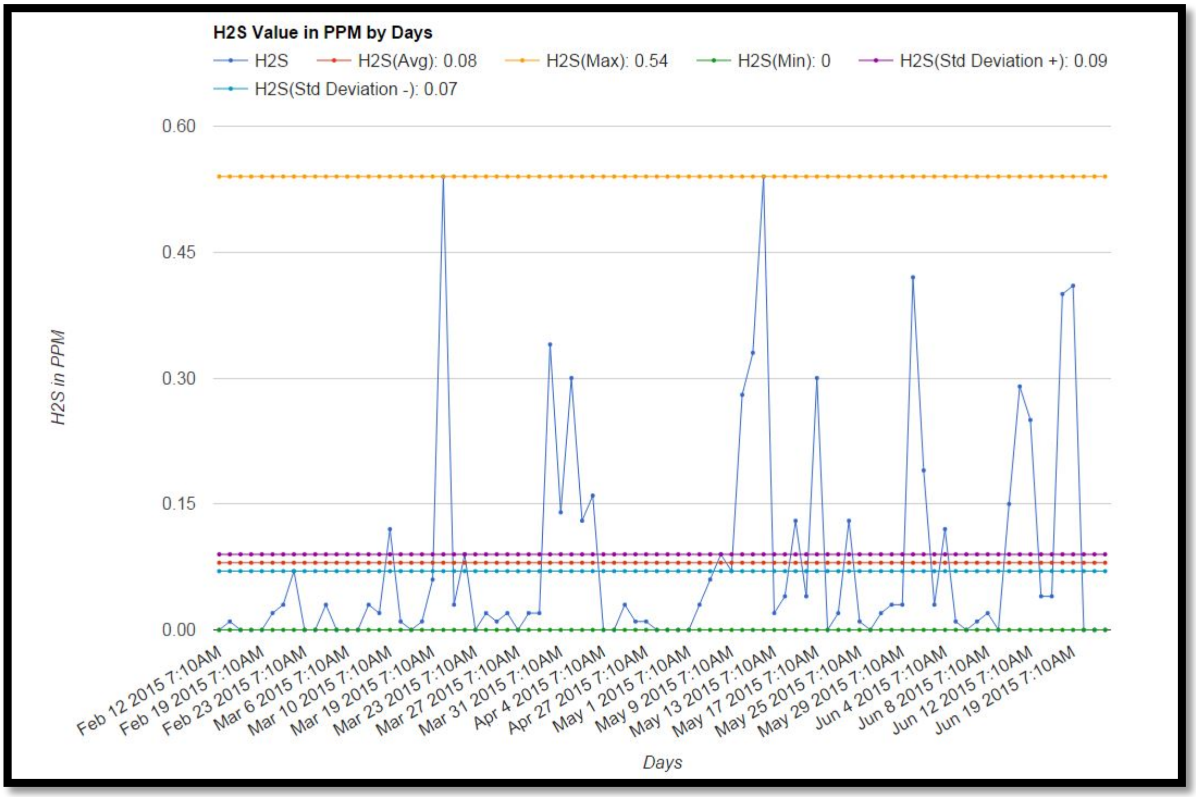


Figure A-2: Historical Analysis (6:00 a.m. – 8:20 a.m.) – Site 3

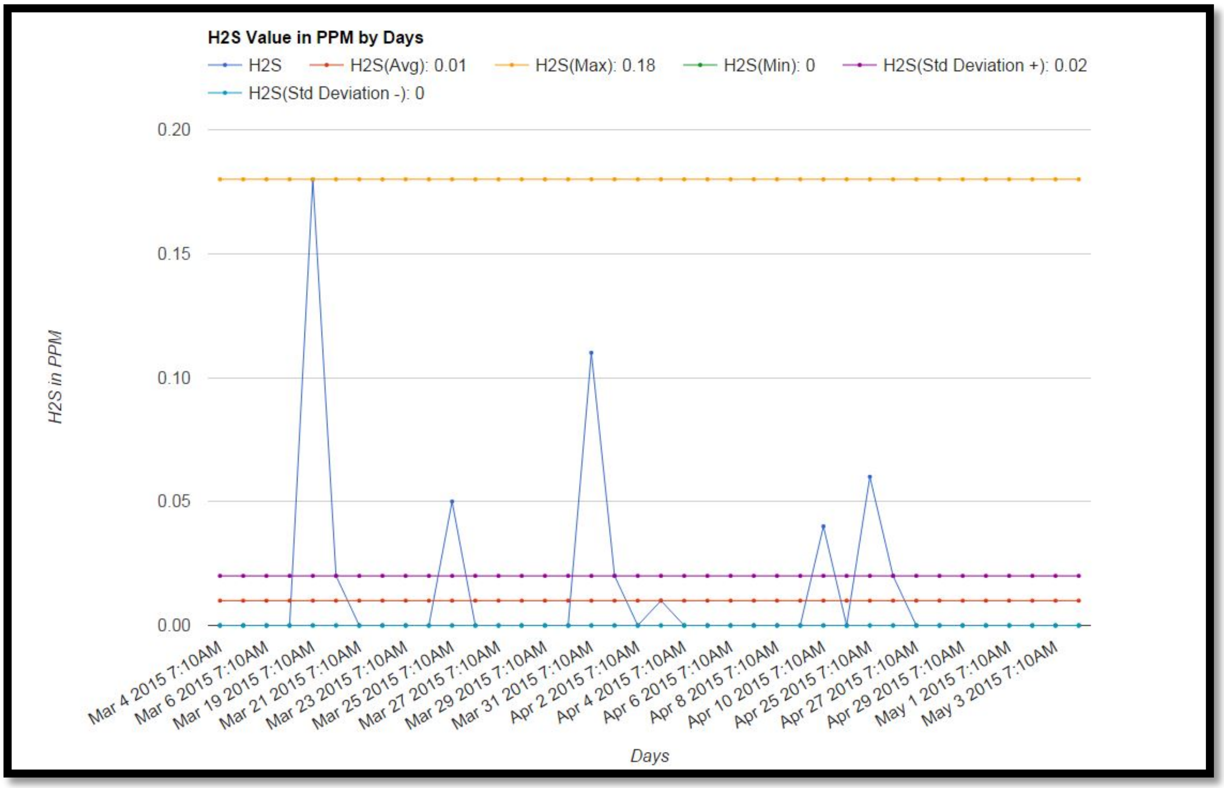


Figure A-3: Historical Analysis (6:00 a.m. – 8:20 a.m.) – Site 4

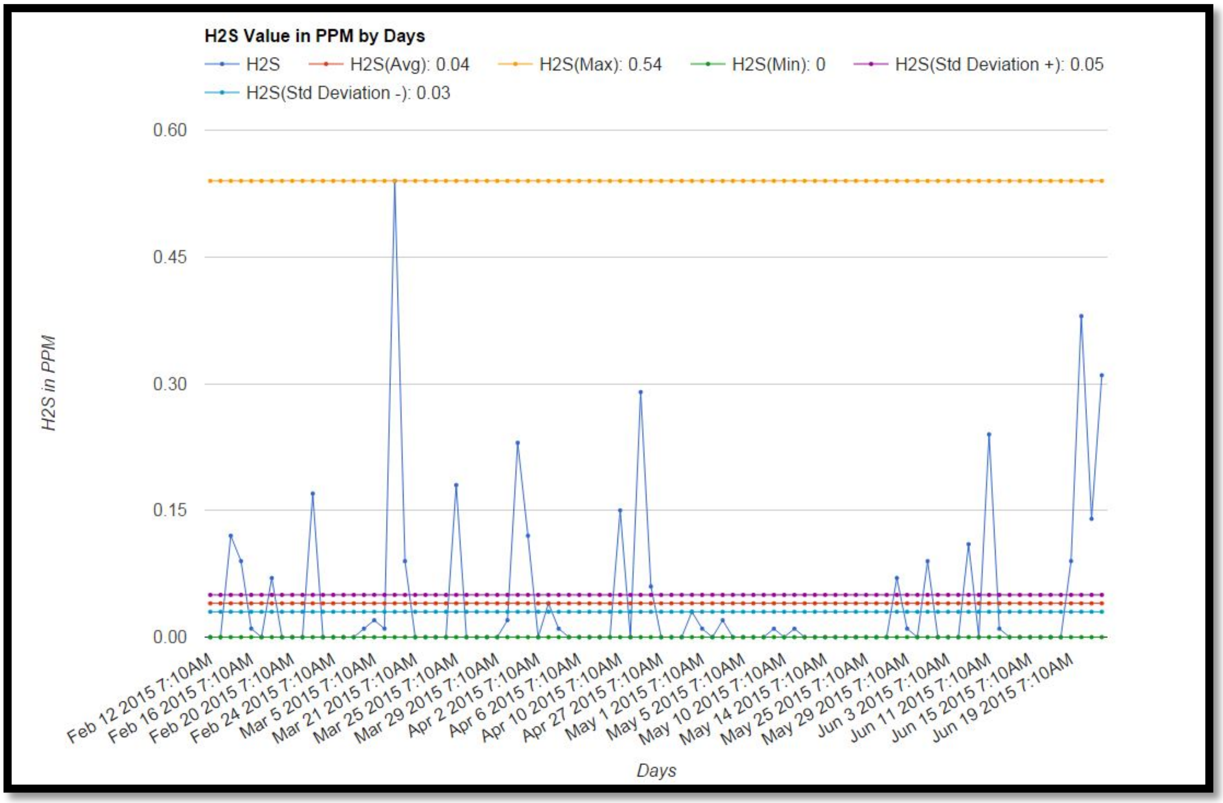


Figure A-4: Historical Analysis (6:00 a.m. – 8:20 a.m.) – Site 5

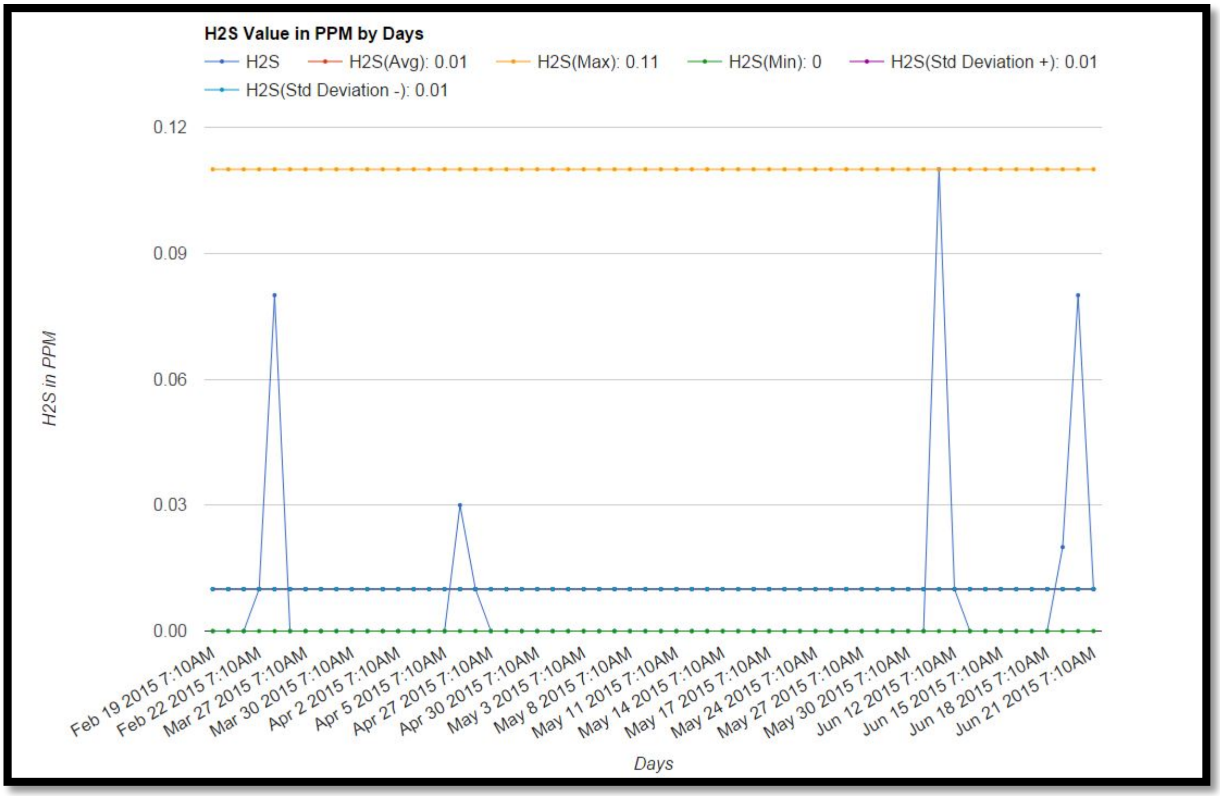


Figure A-5: Historical Analysis (6:00 a.m. – 8:20 a.m.) – Site 6

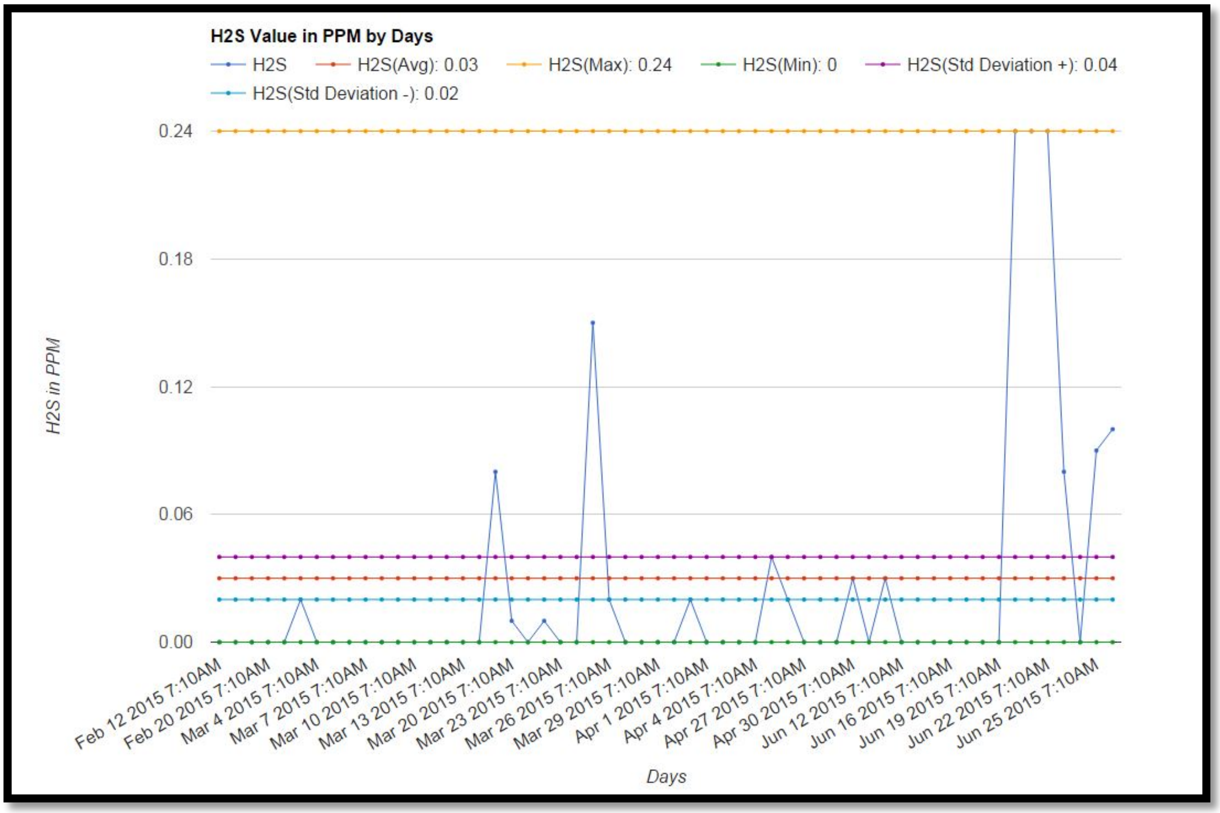


Figure A-6: Historical Analysis (6:00 a.m. – 8:20 a.m.) – Site 7

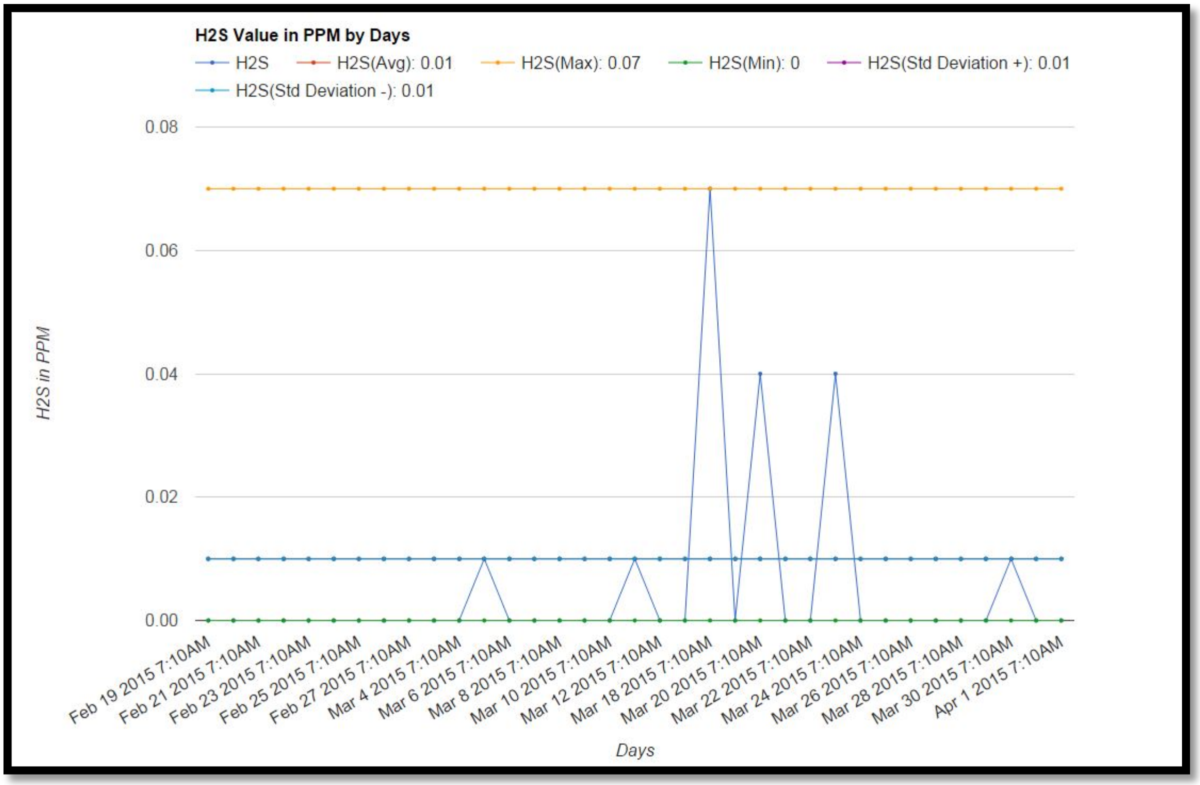


Figure A-7: Historical Analysis (6:00 a.m. – 8:20 a.m.) – Site 8

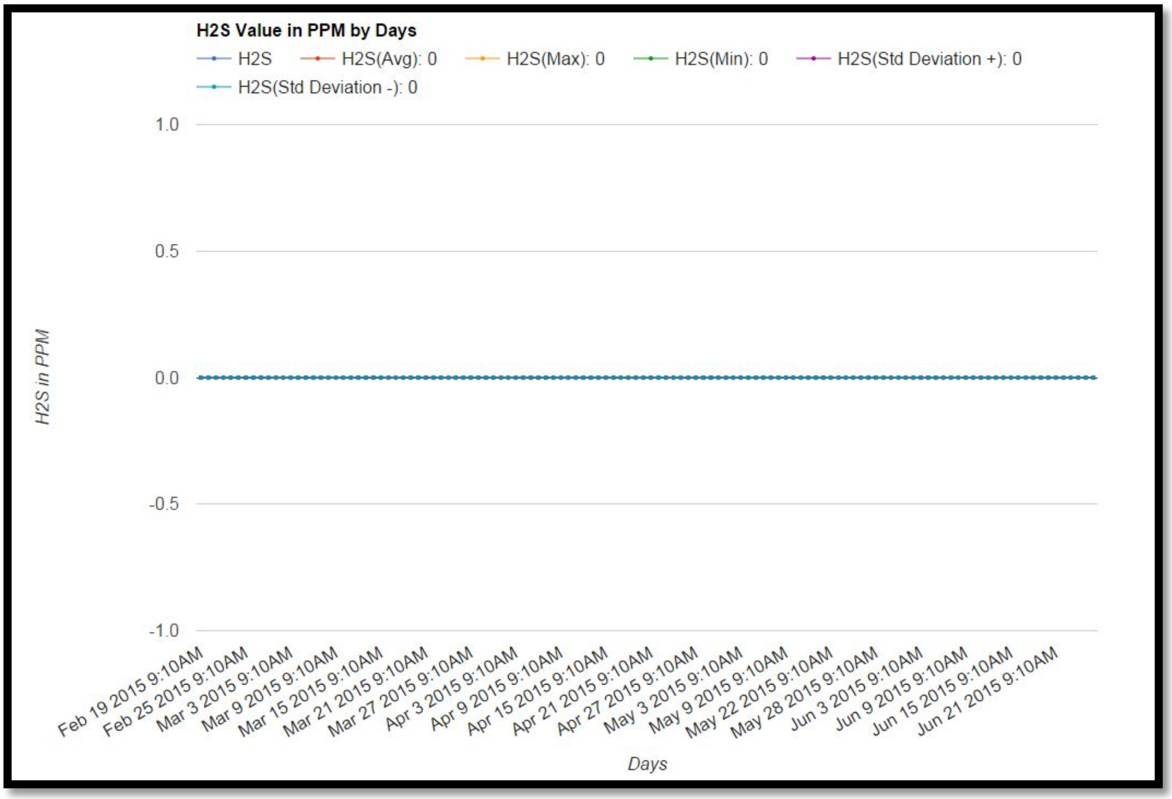


Figure A-8: Historical Analysis (8:20 a.m. – 10:00 a.m.) – Site 2

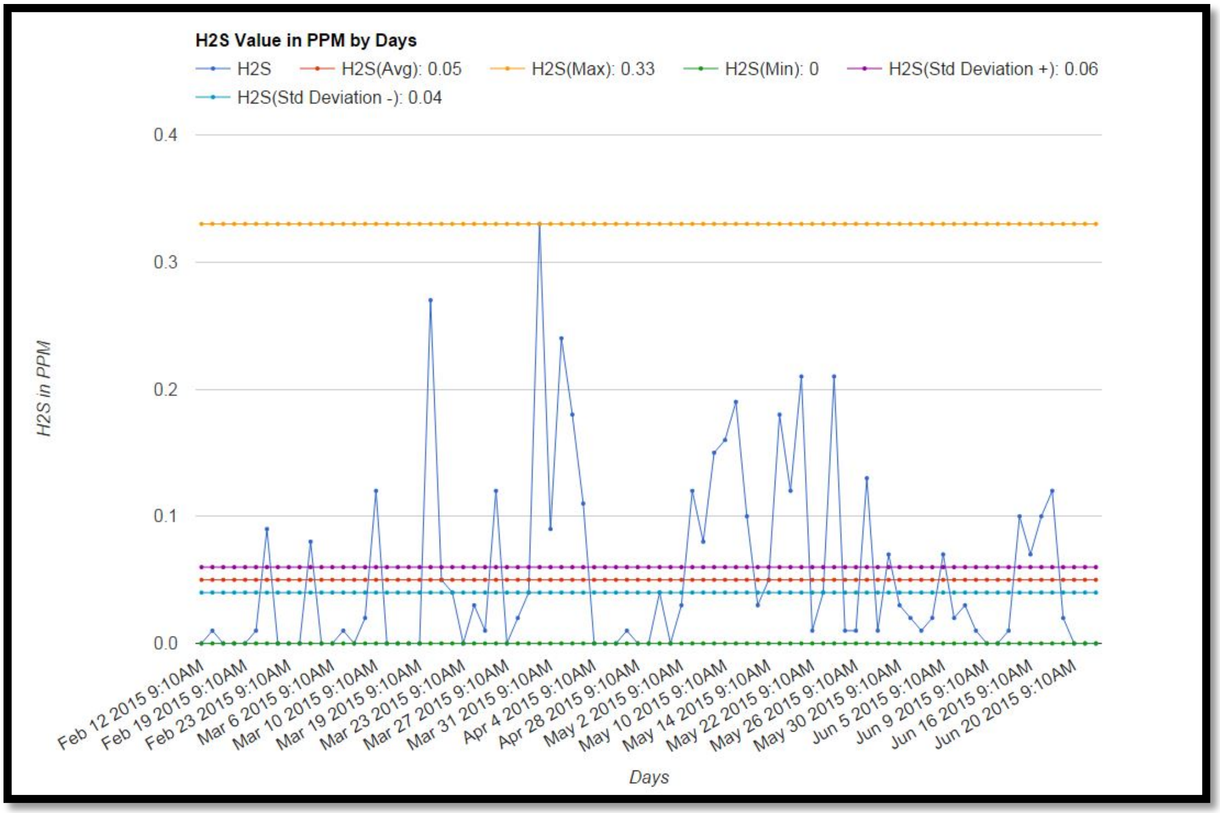


Figure A-9: Historical Analysis (8:20 a.m. – 10:00 a.m.) – Site 3

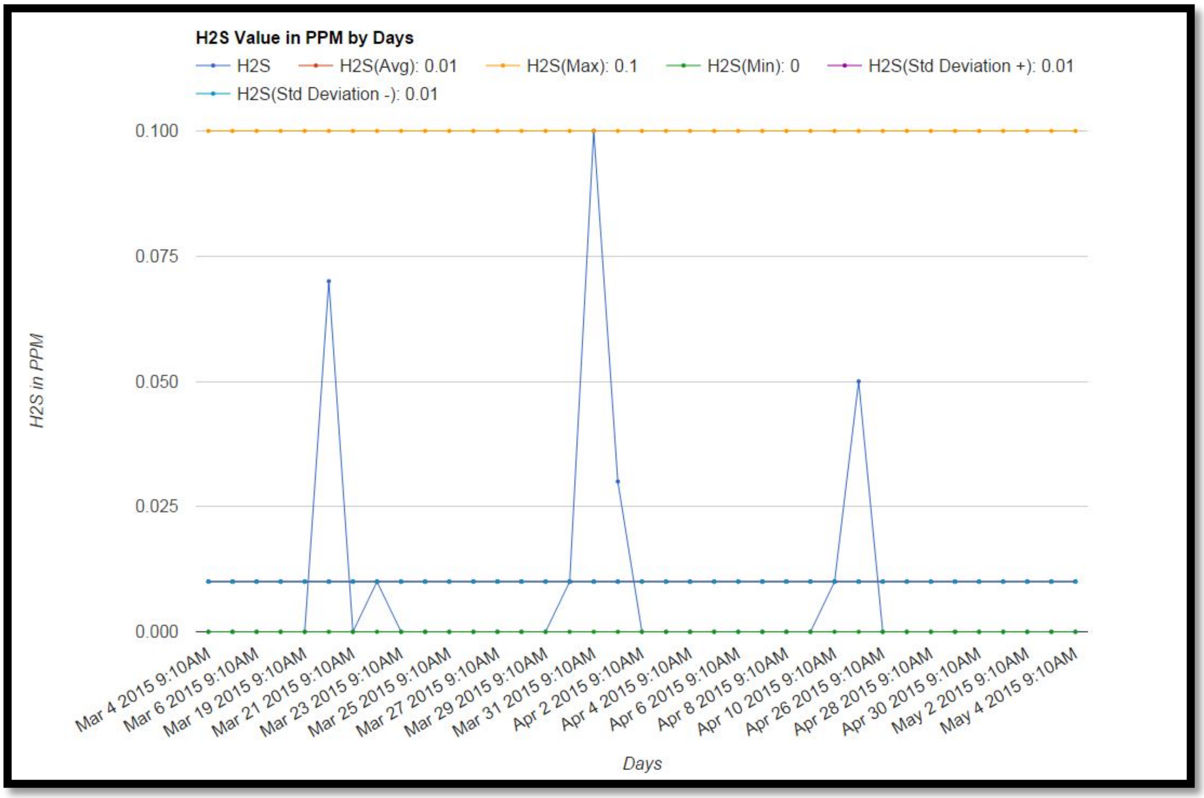
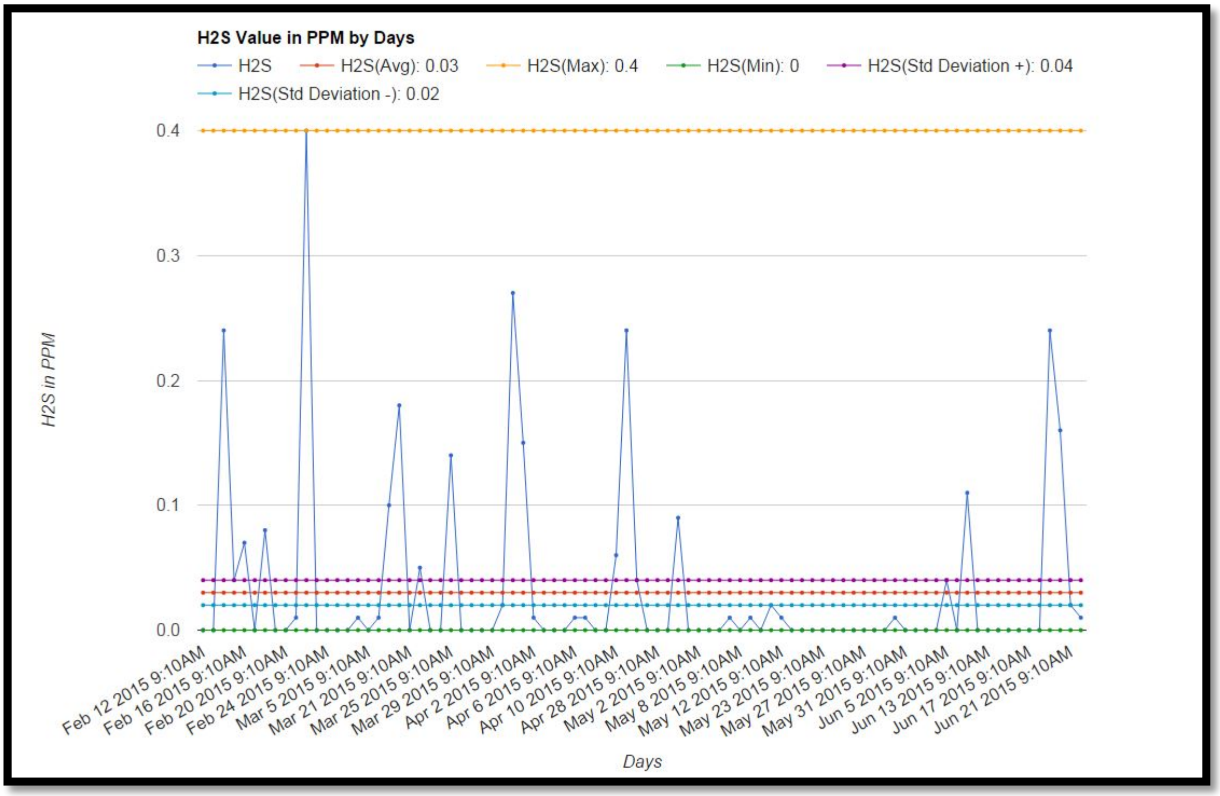


Figure A-10: Historical Analysis (8:20 a.m. – 10:00 a.m.) – Site 4



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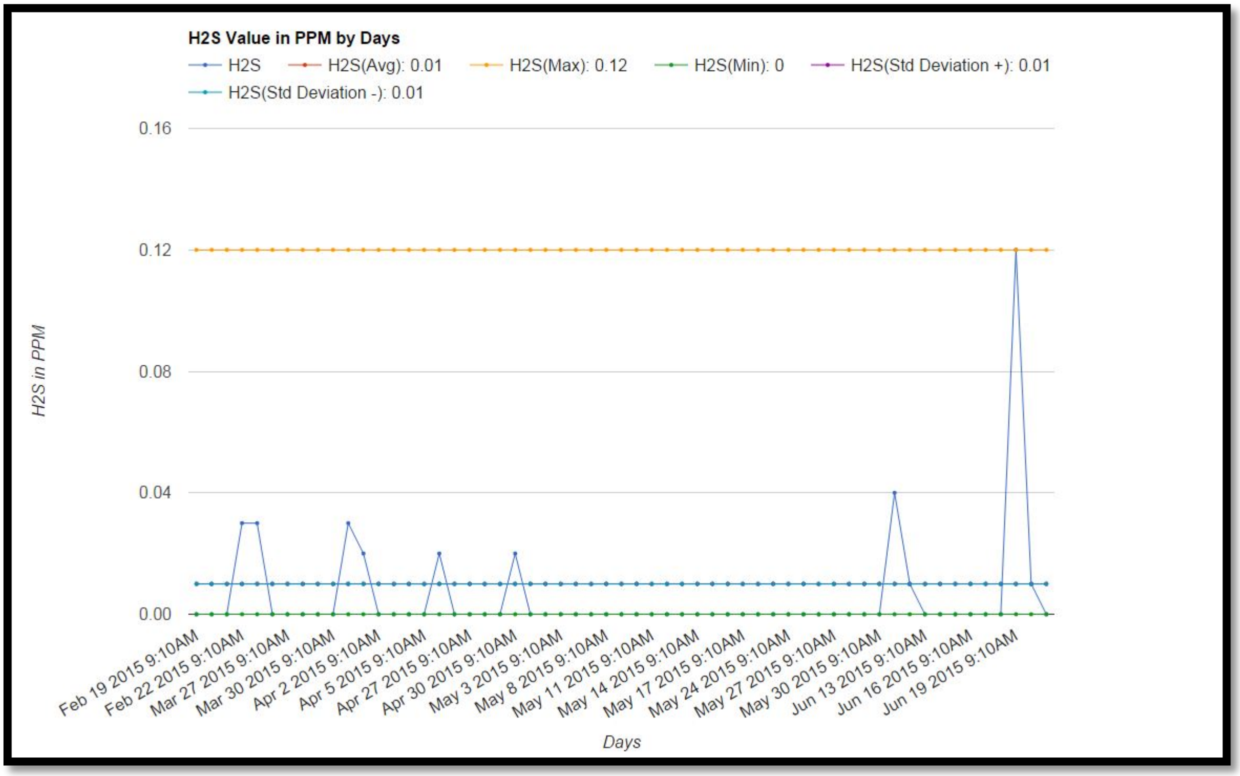


Figure A-12: Historical Analysis (8:20 a.m. – 10:00 a.m.) – Site 6

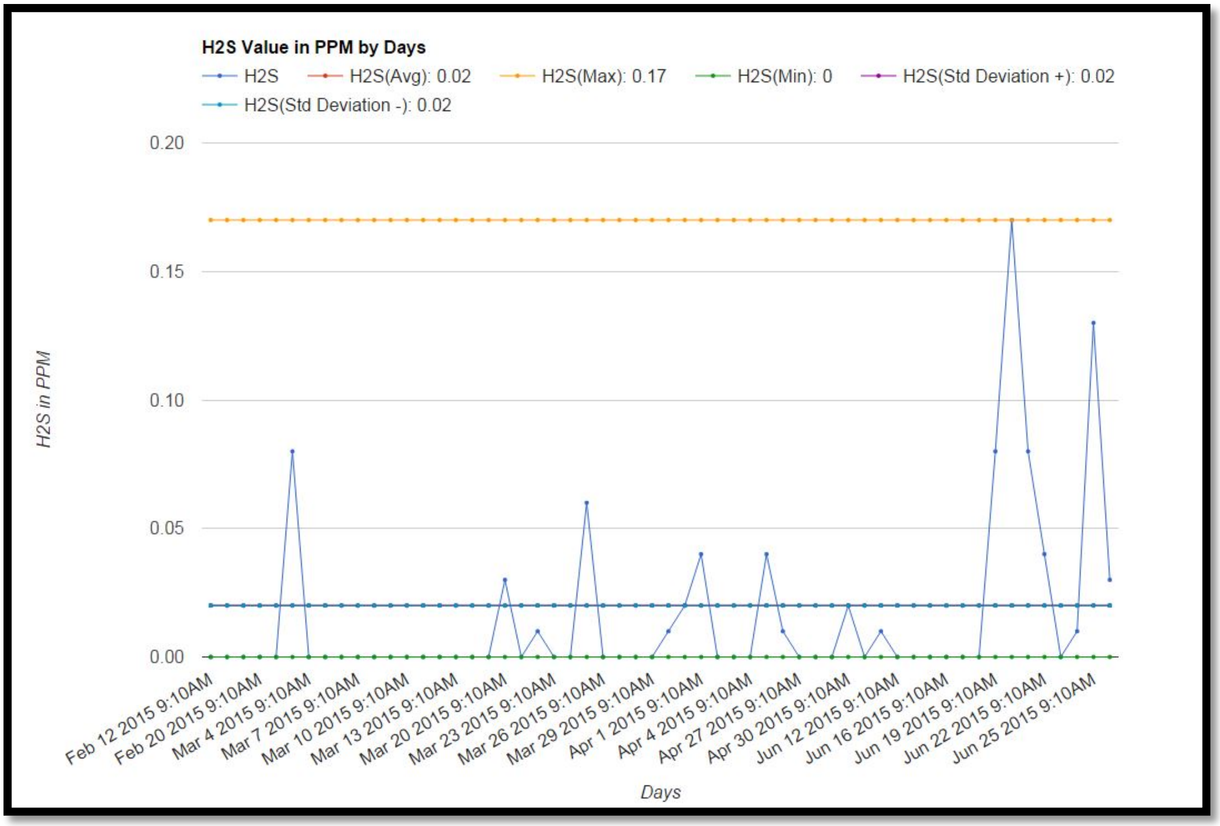


Figure A-13: Historical Analysis (8:20 a.m. – 10:00 a.m.) – Site 7

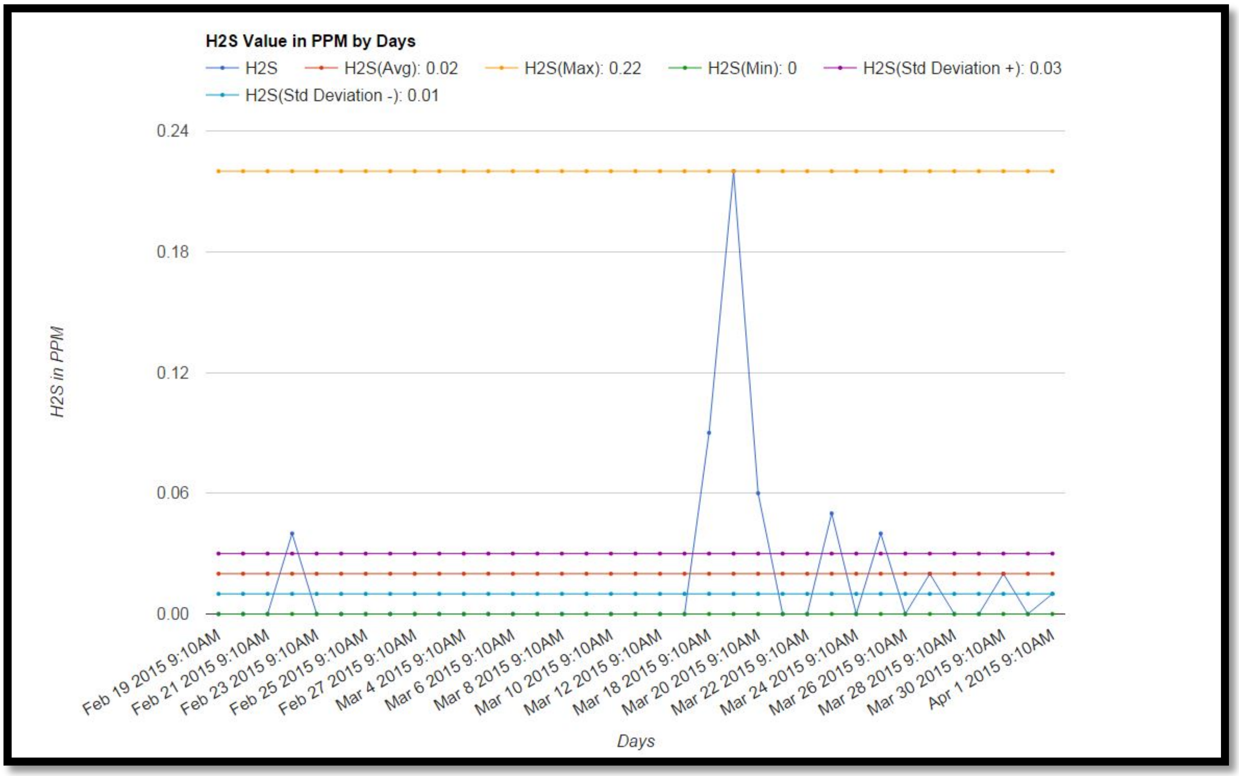


Figure A-14: Historical Analysis (8:20 a.m. – 10:00 a.m.) – Site 8

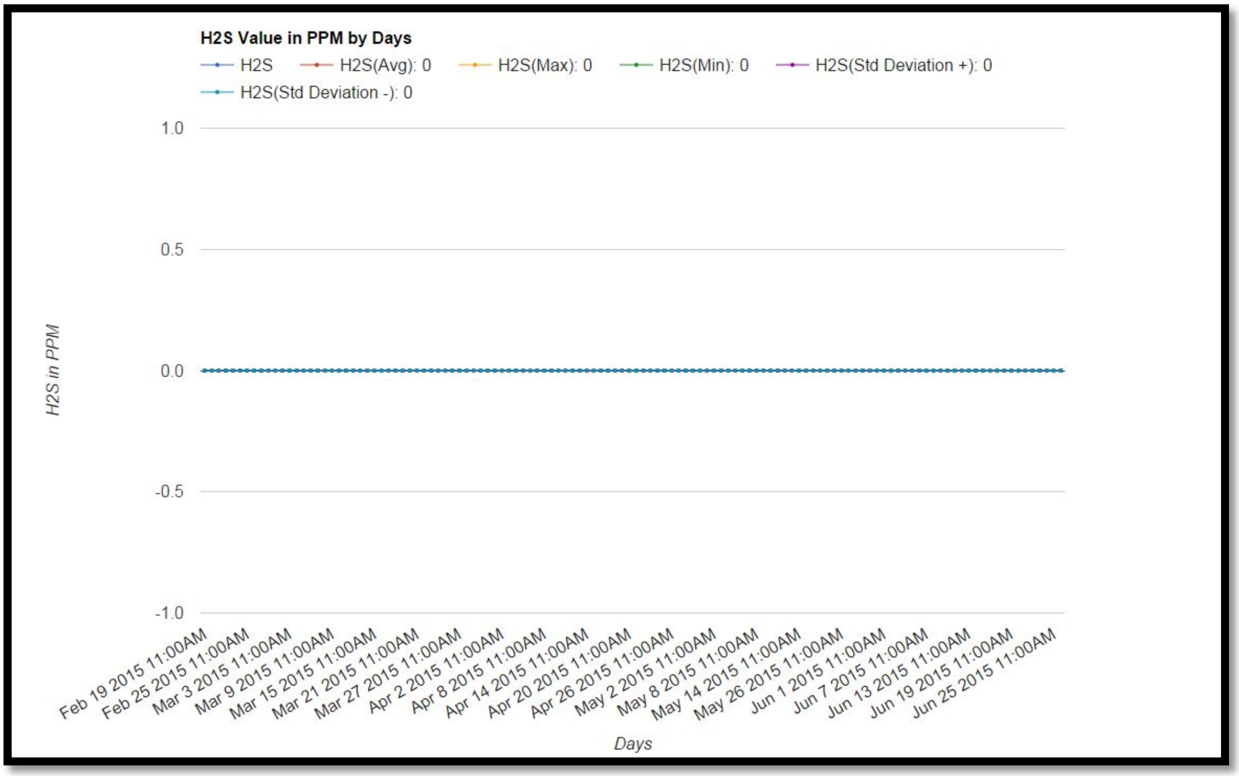
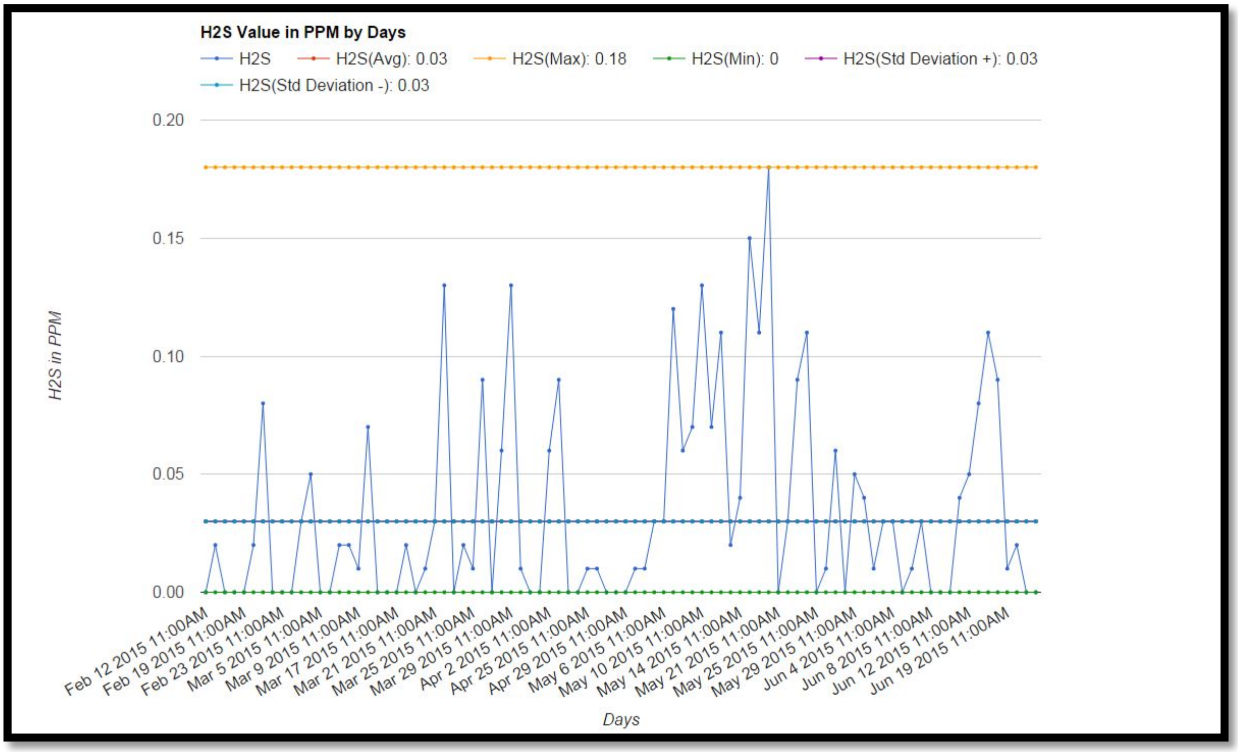


Figure A-15: Historical Analysis (10:00 a.m. – 12:00 p.m.) – Site 2



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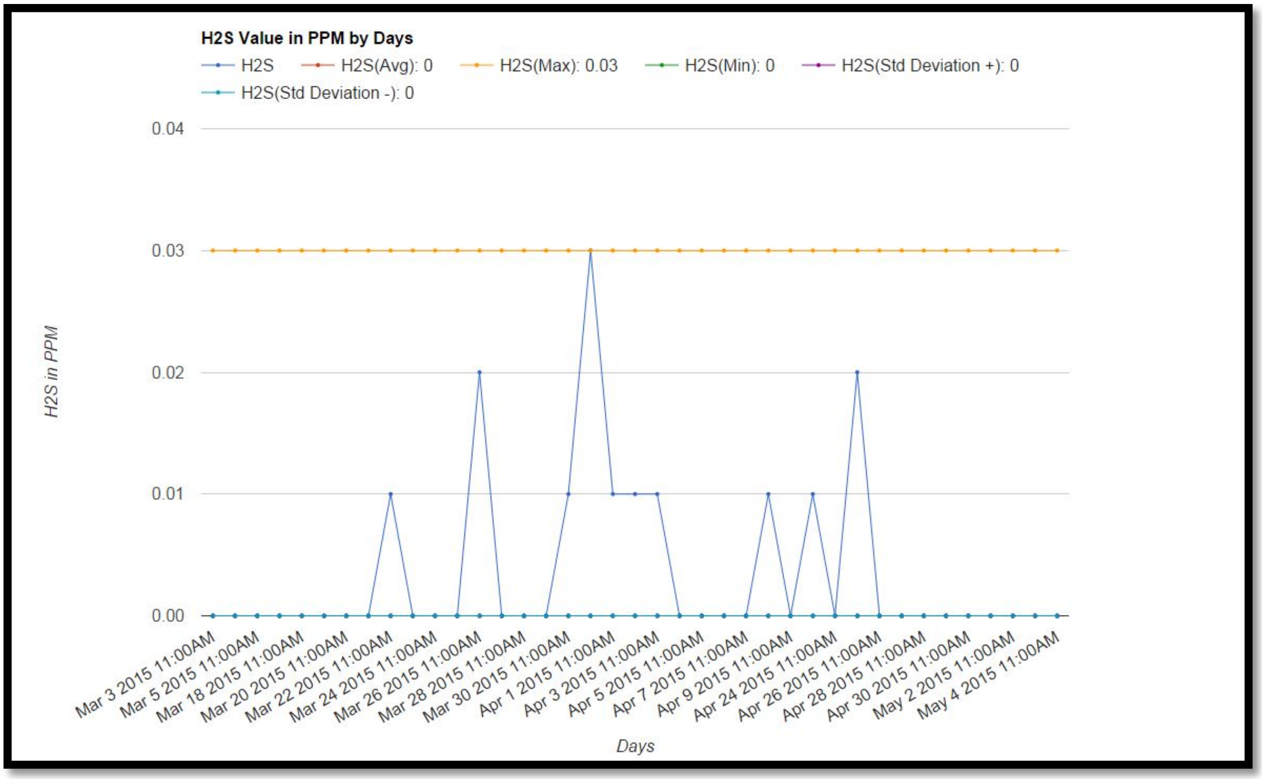


Figure A-17: Historical Analysis (10:00 a.m. – 12:00 p.m.) – Site 4

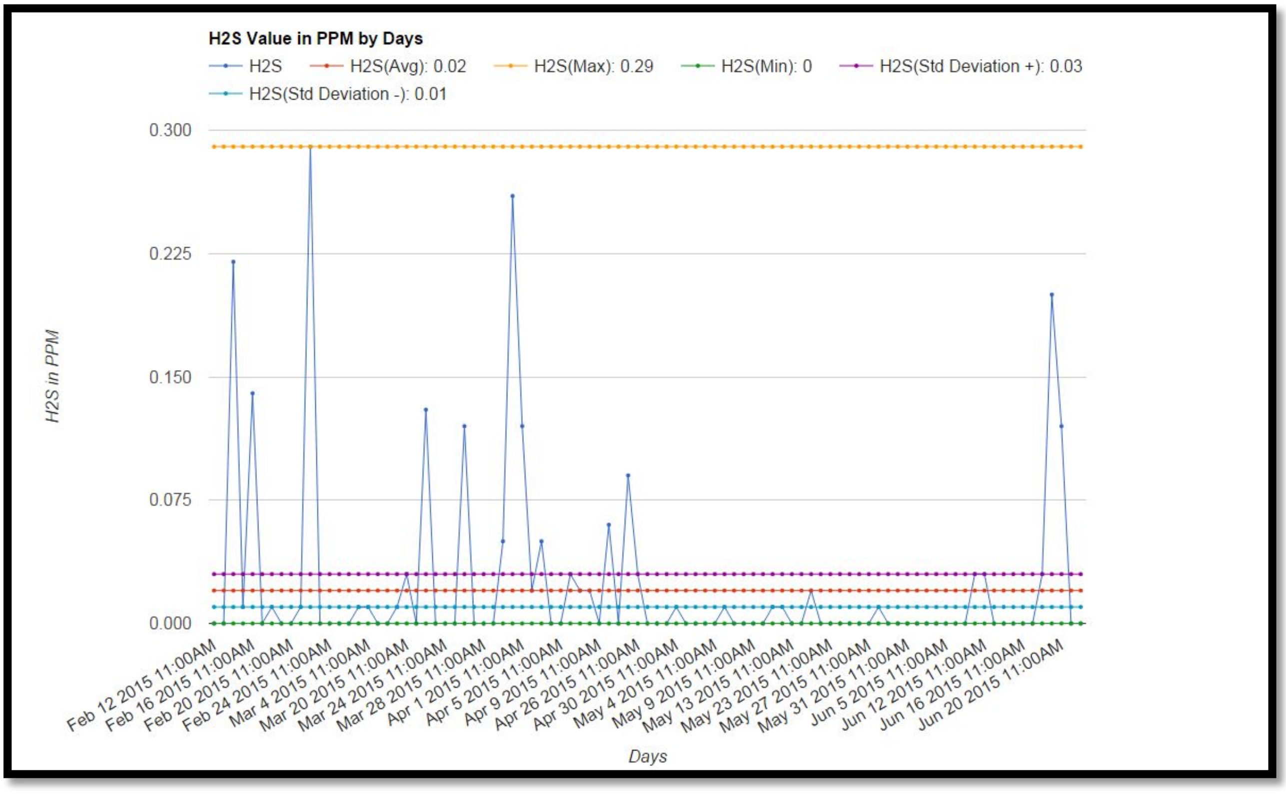


Figure A-18: Historical Analysis (10:00 a.m. – 12:00 p.m.) – Site 5

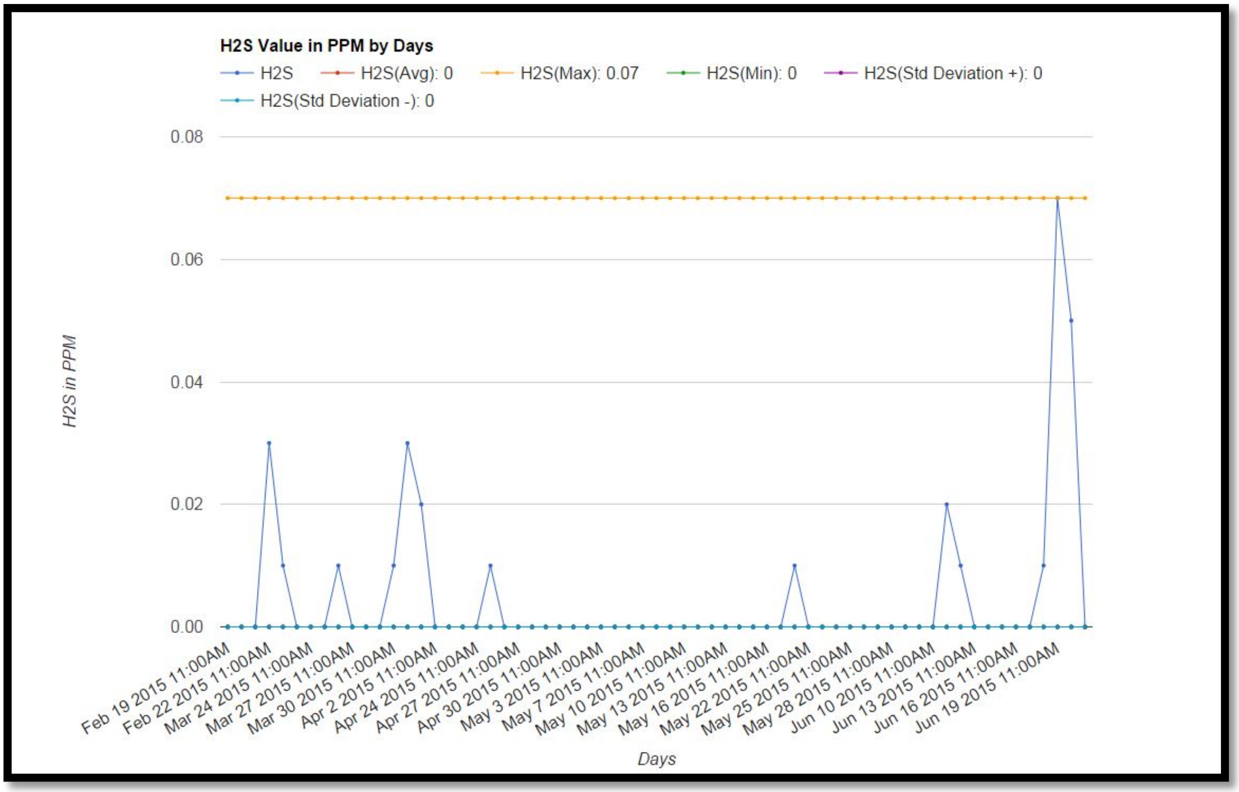
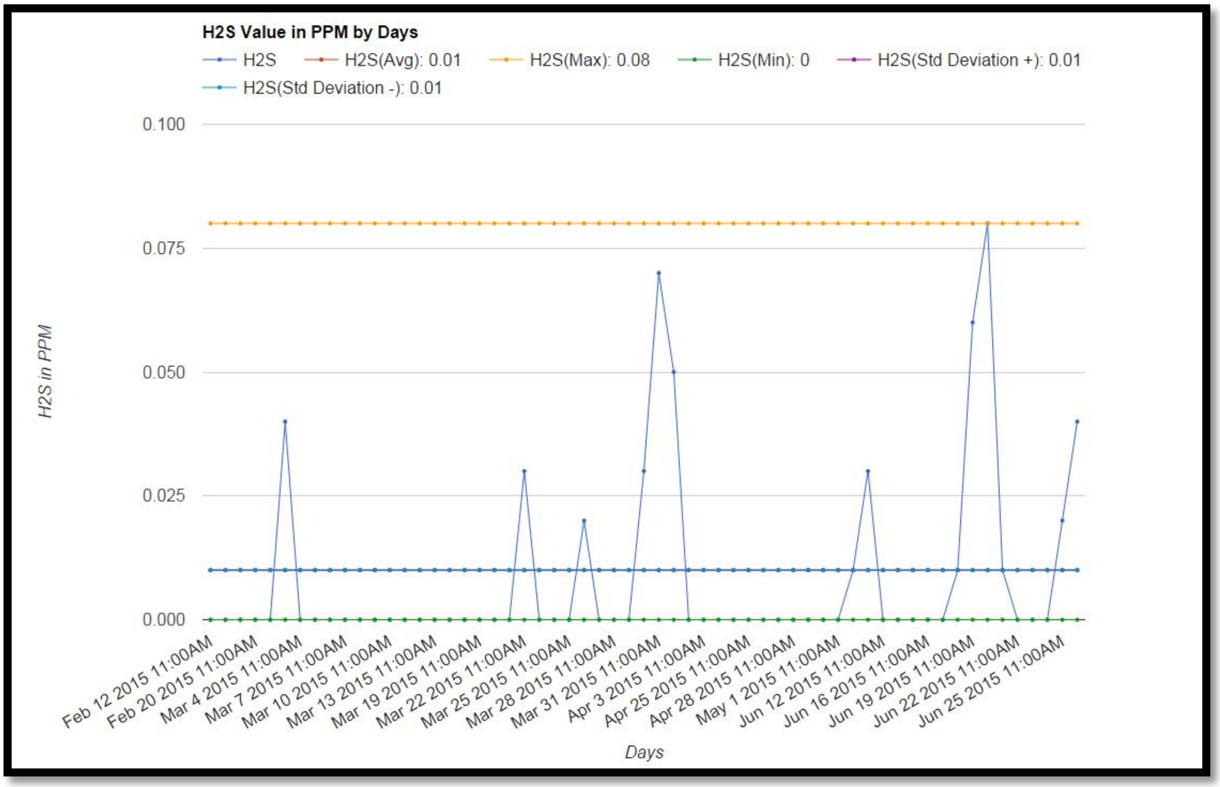


Figure A-19: Historical Analysis (10:00 a.m. – 12:00 p.m.) – Site 6



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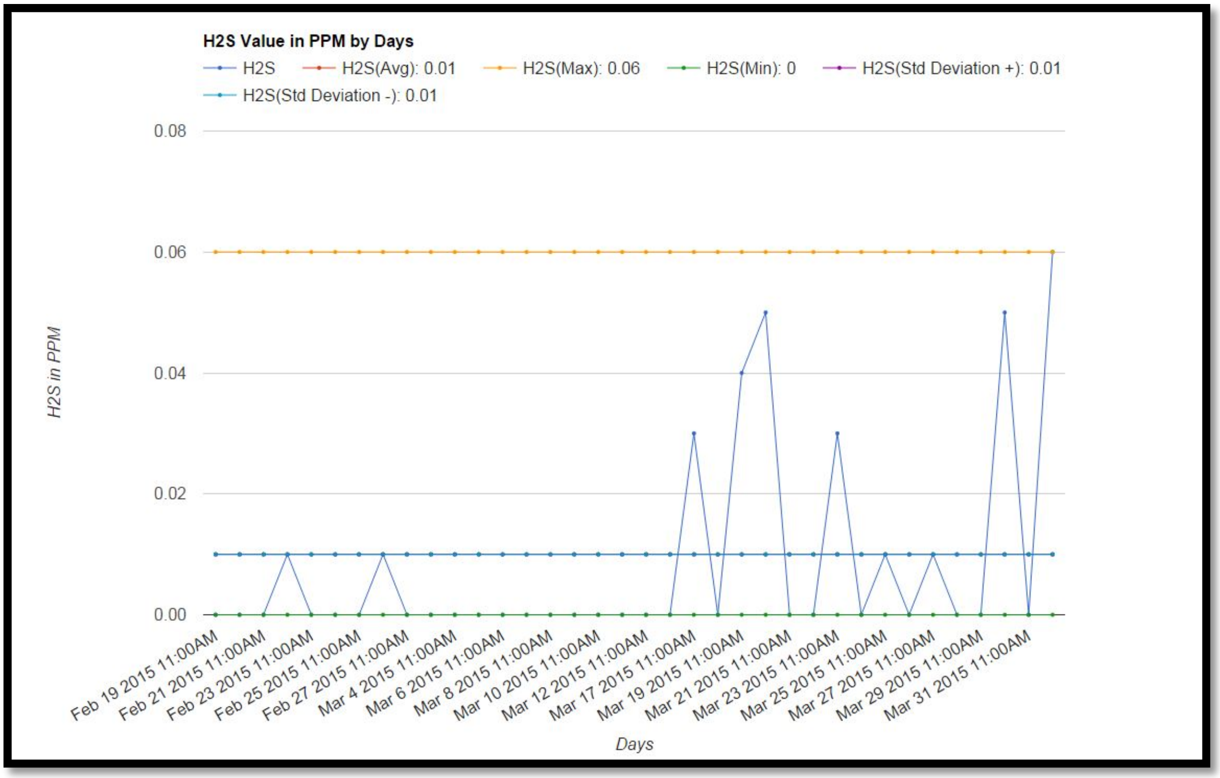


Figure A-21: Historical Analysis (10:00 a.m. – 12:00 p.m.) – Site 8

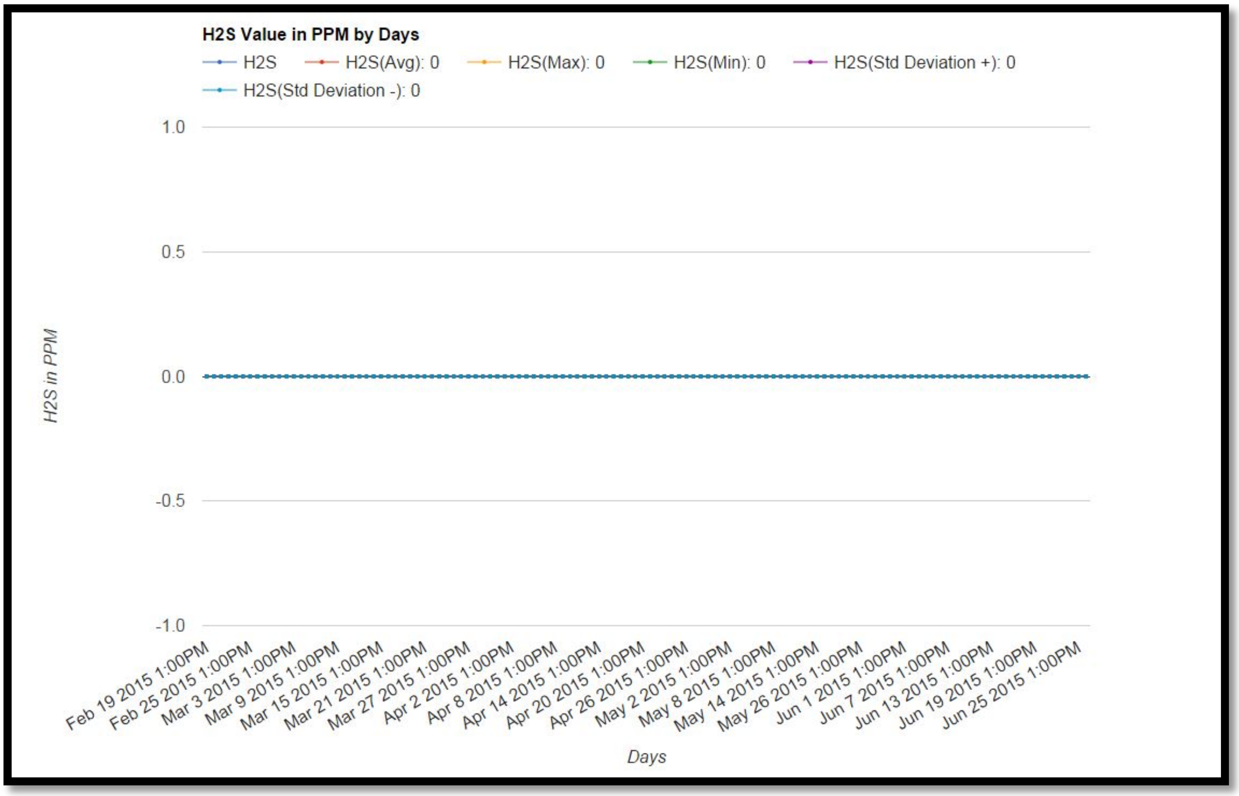
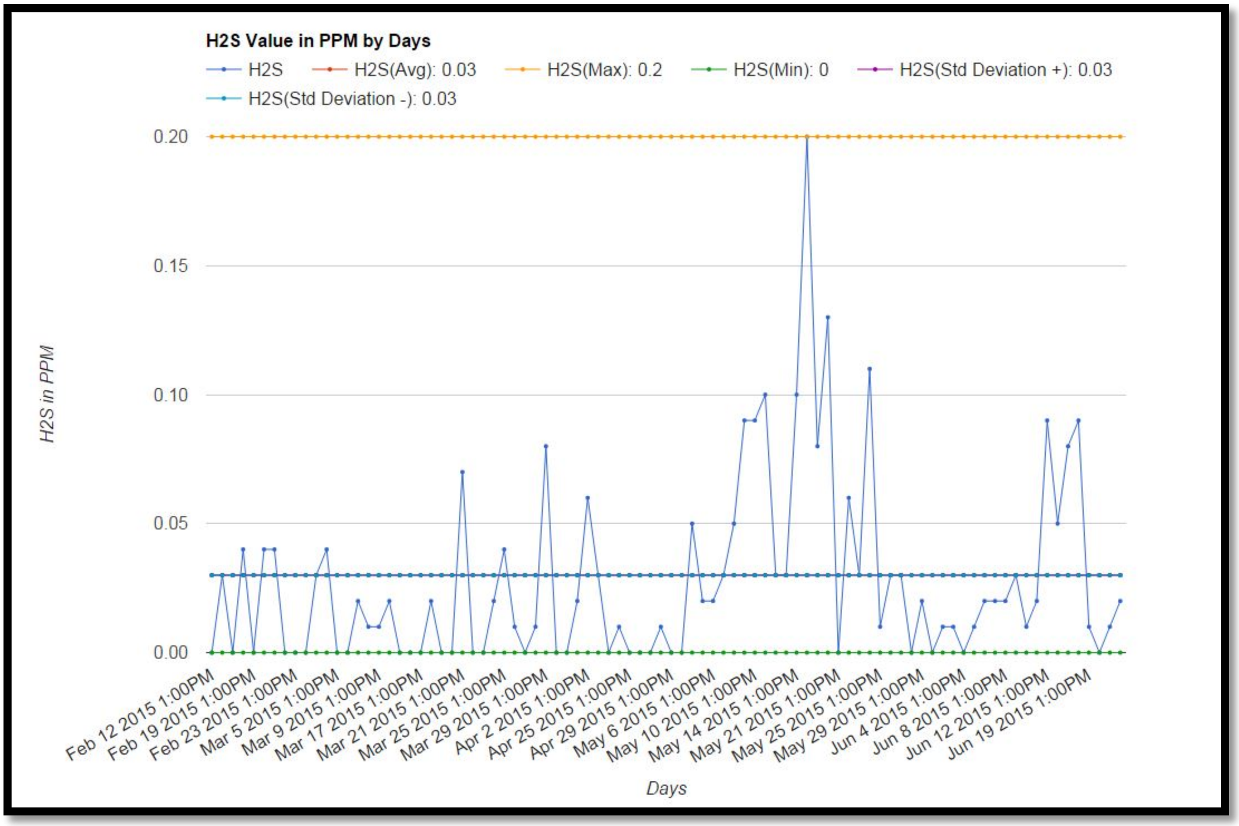


Figure A-22: Historical Analysis (12:00 p.m. – 2:00 p.m.) – Site 2



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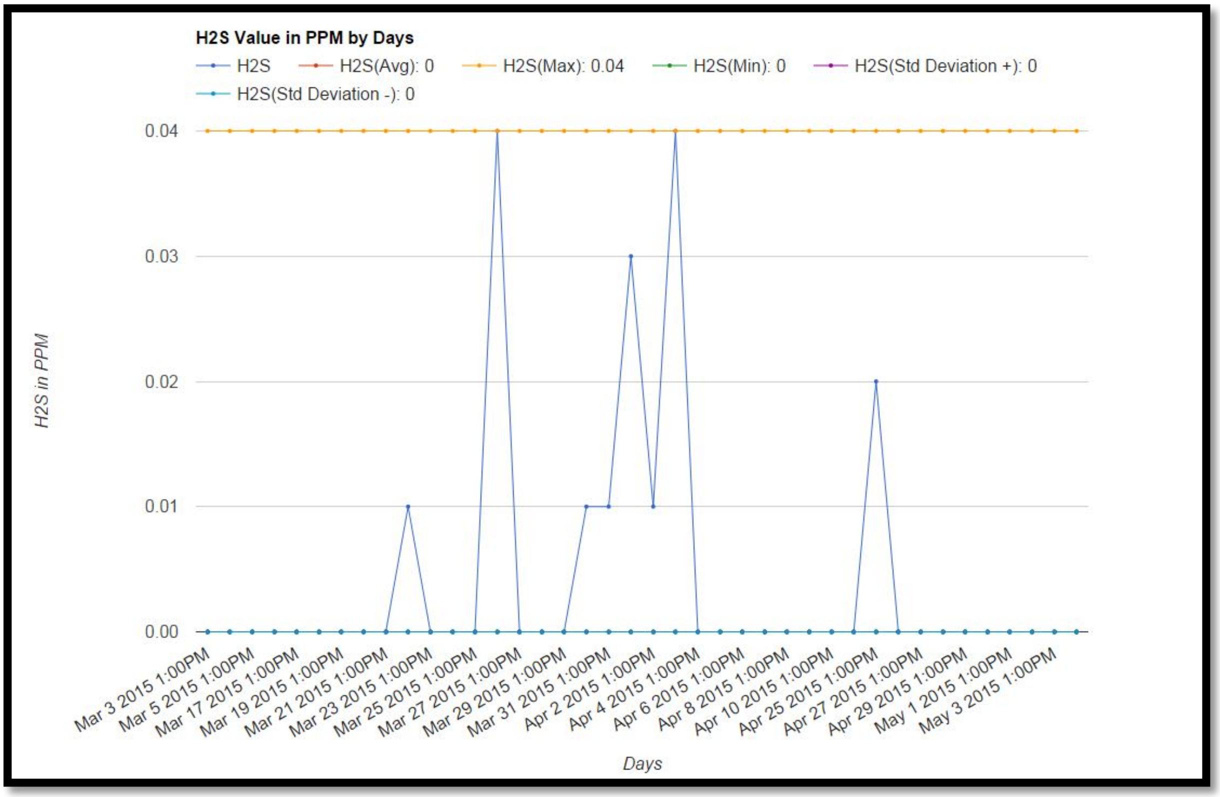


Figure A-24: Historical Analysis (12:00 p.m. – 2:00 p.m.) – Site 4

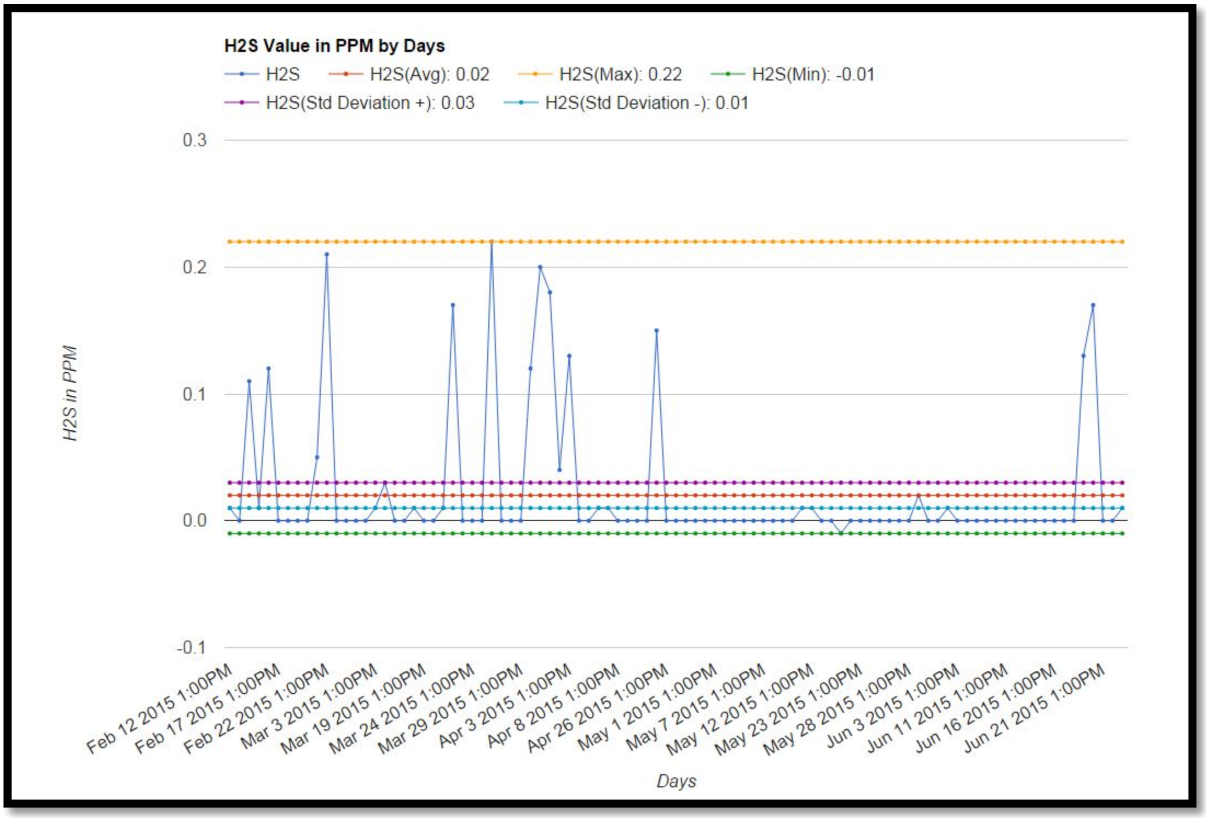
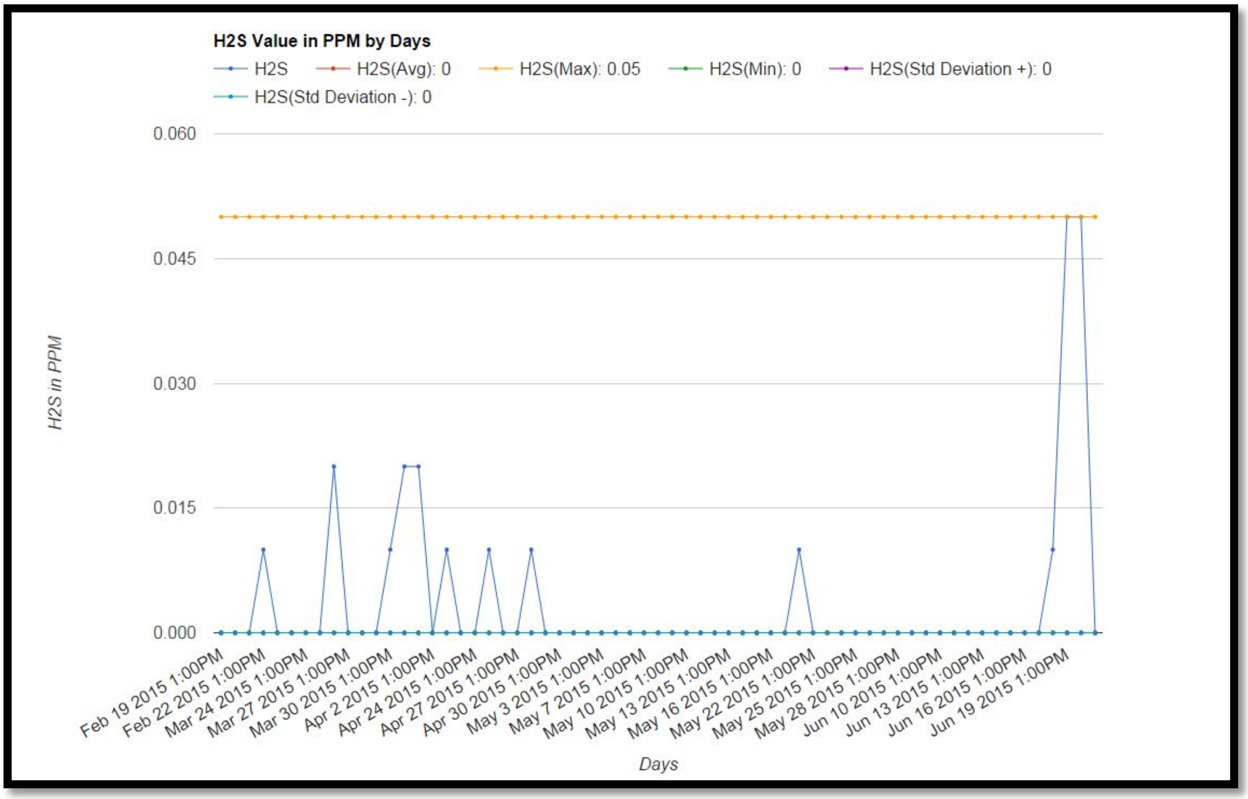


Figure A-25: Historical Analysis (12:00 p.m. – 2:00 p.m.) – Site 5



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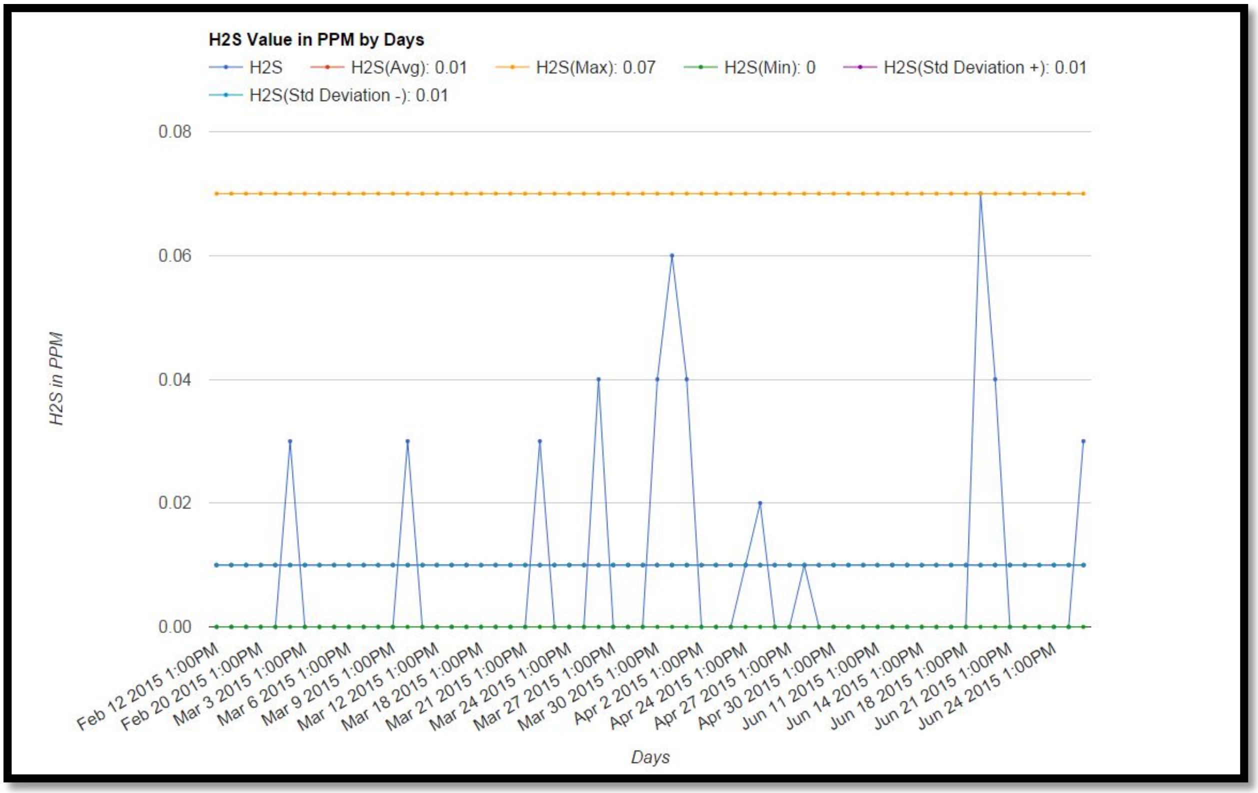

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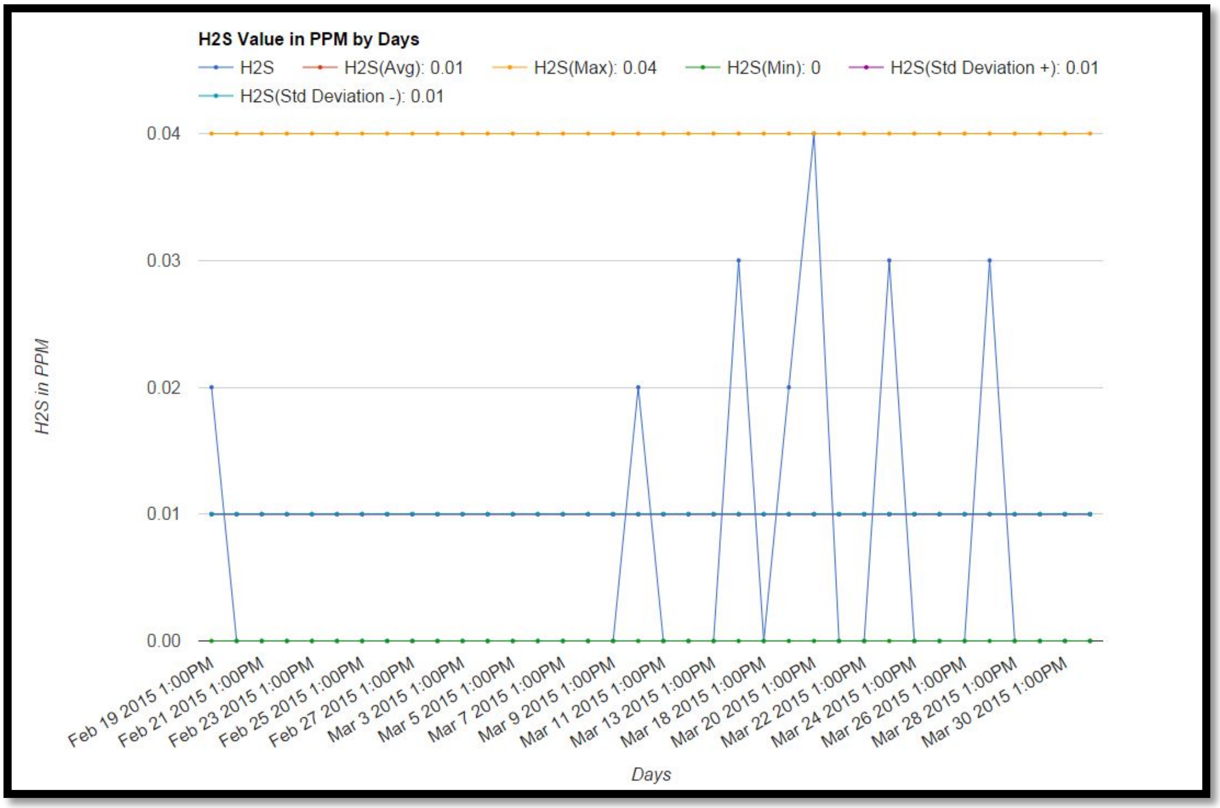

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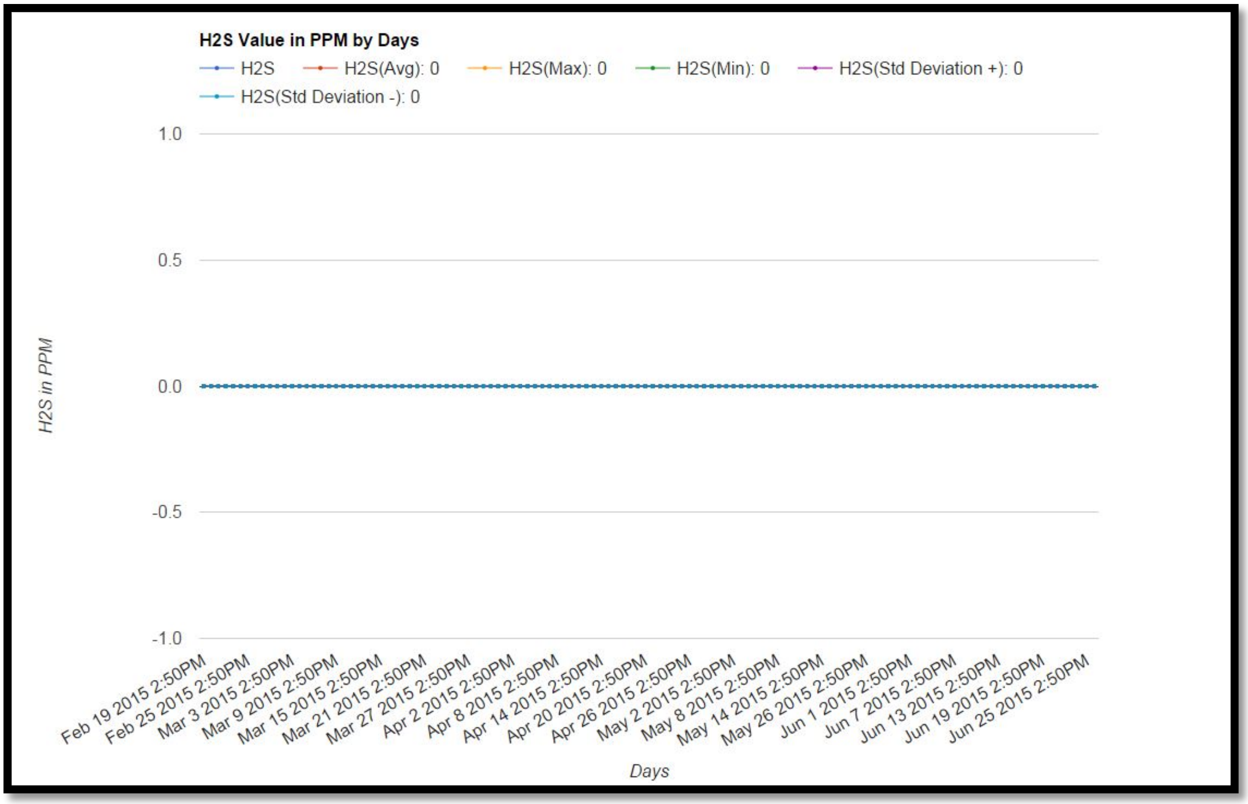


Figure A-29: Historical Analysis (2:00 p.m. – 3:40 p.m.) – Site 2

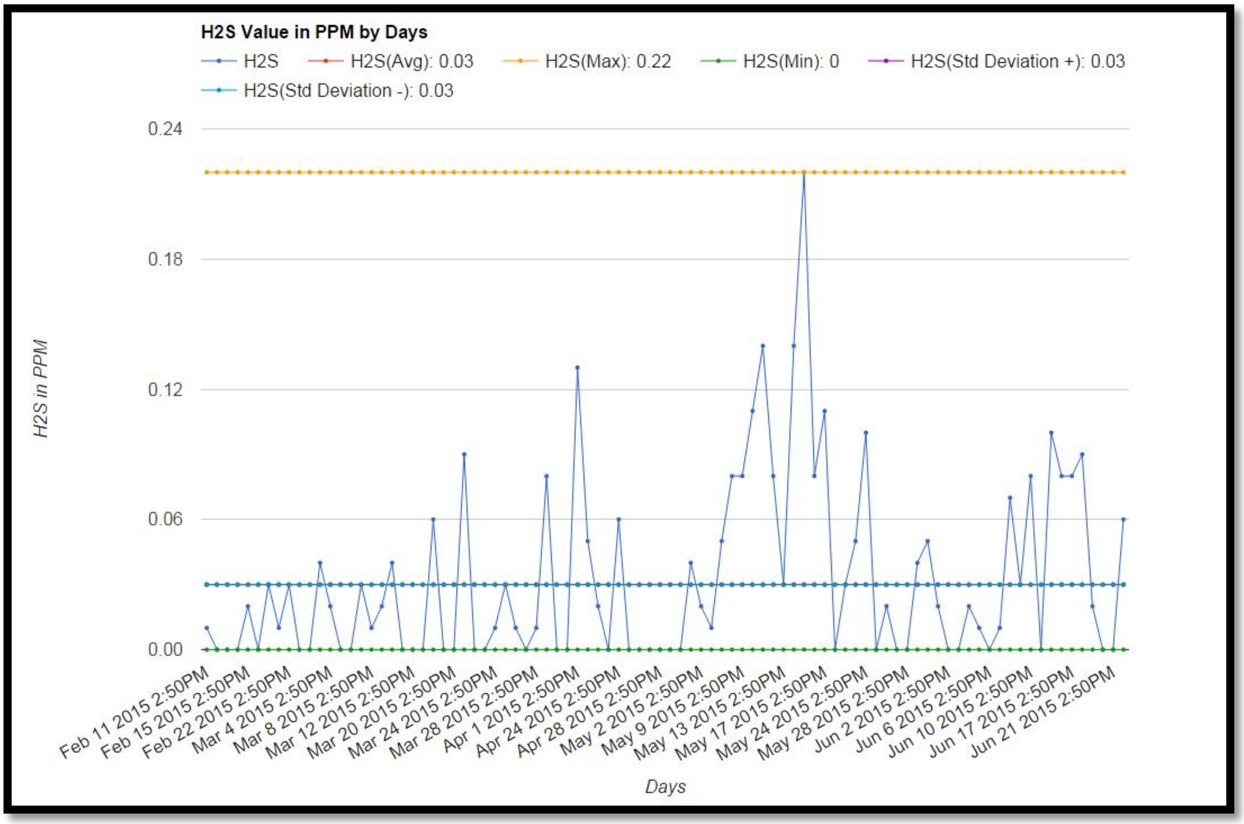
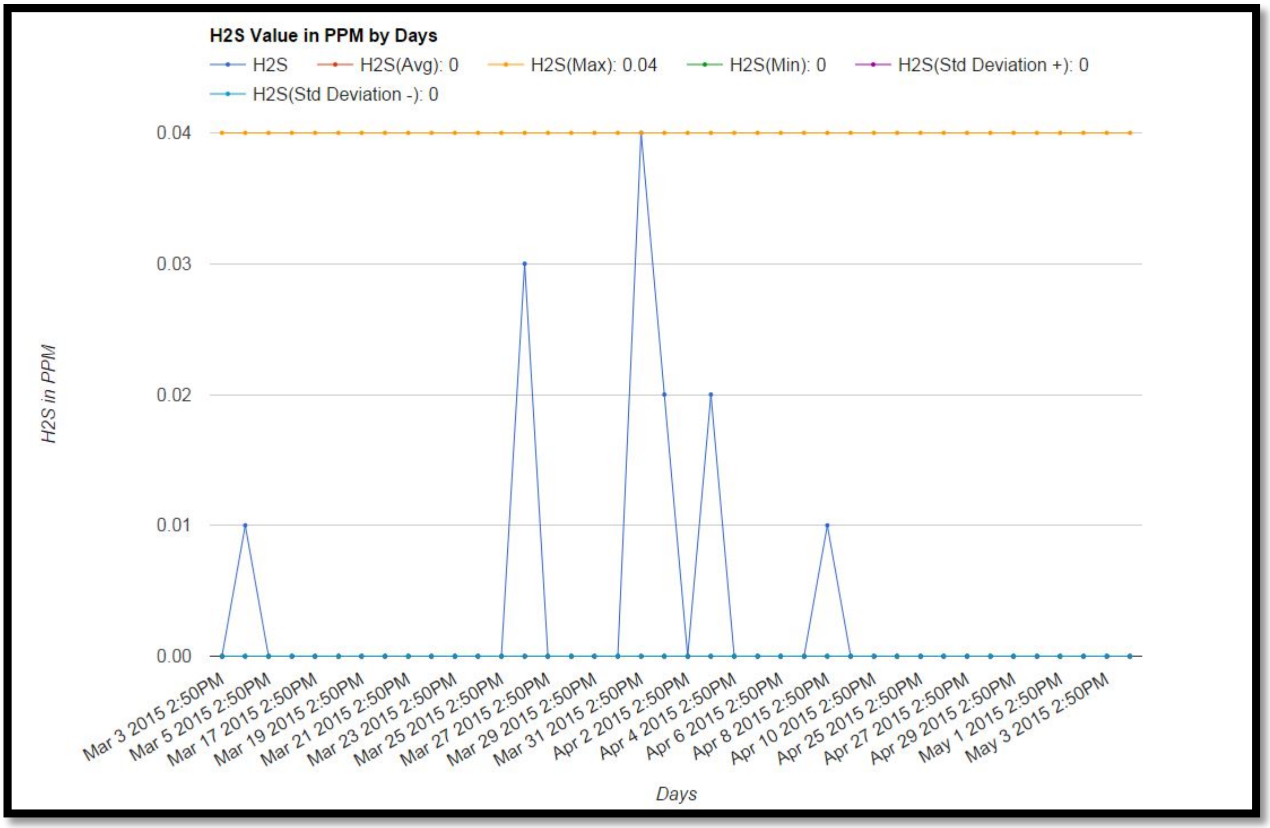


Figure A-30: Historical Analysis (2:00 p.m. – 3:40 p.m.) – Site 3



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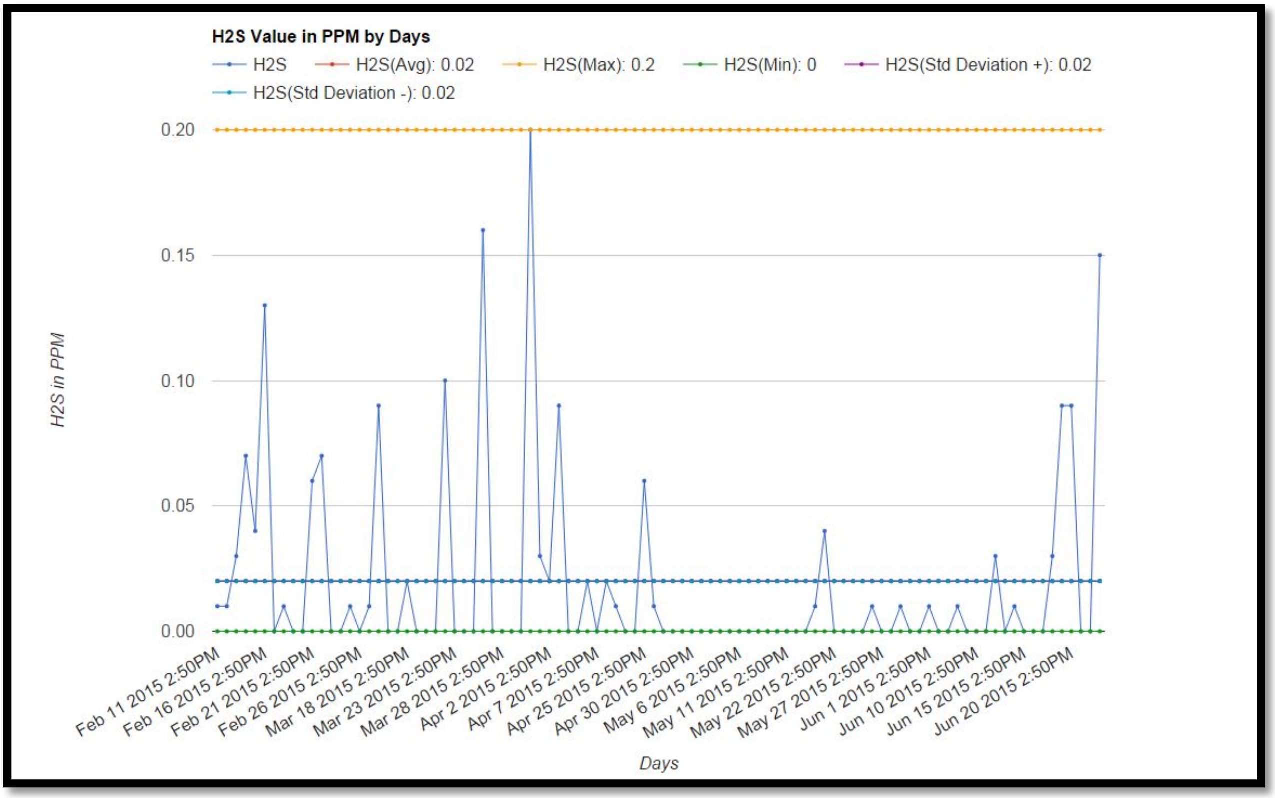

Figure A-32: Historical Analysis (2:00 p.m. – 3:40 p.m.) – Site 5

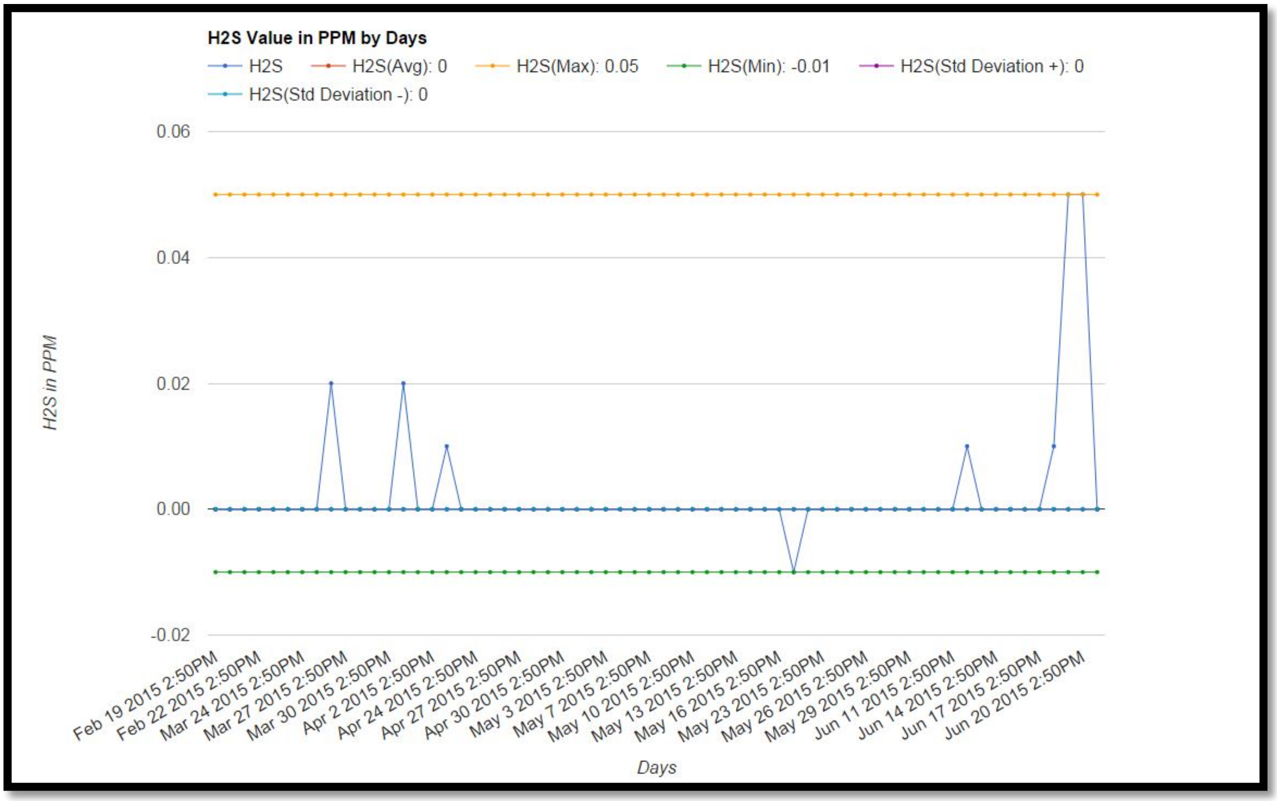

Figure A-33: Historical Analysis (2:00 p.m. – 3:40 p.m.) – Site 6

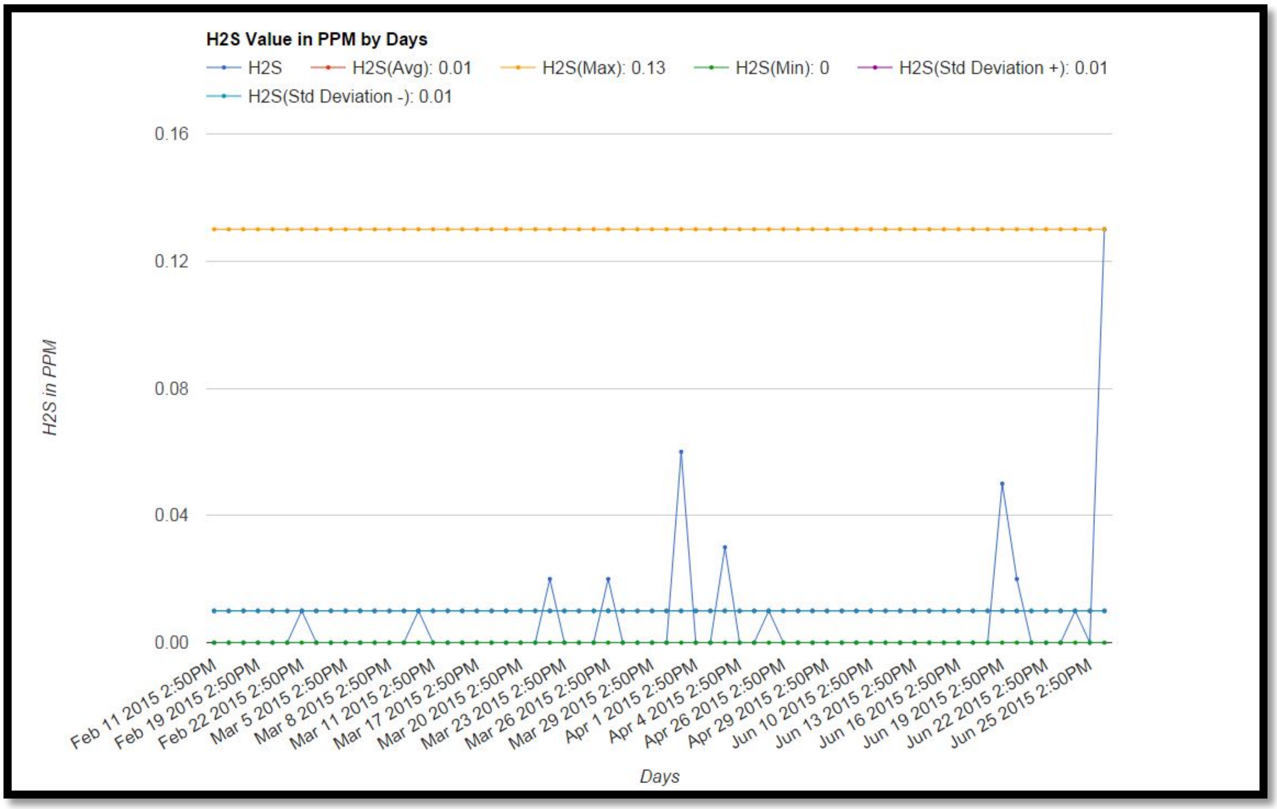

Figure A-34: Historical Analysis (2:00 p.m. – 3:40 p.m.) – Site 7

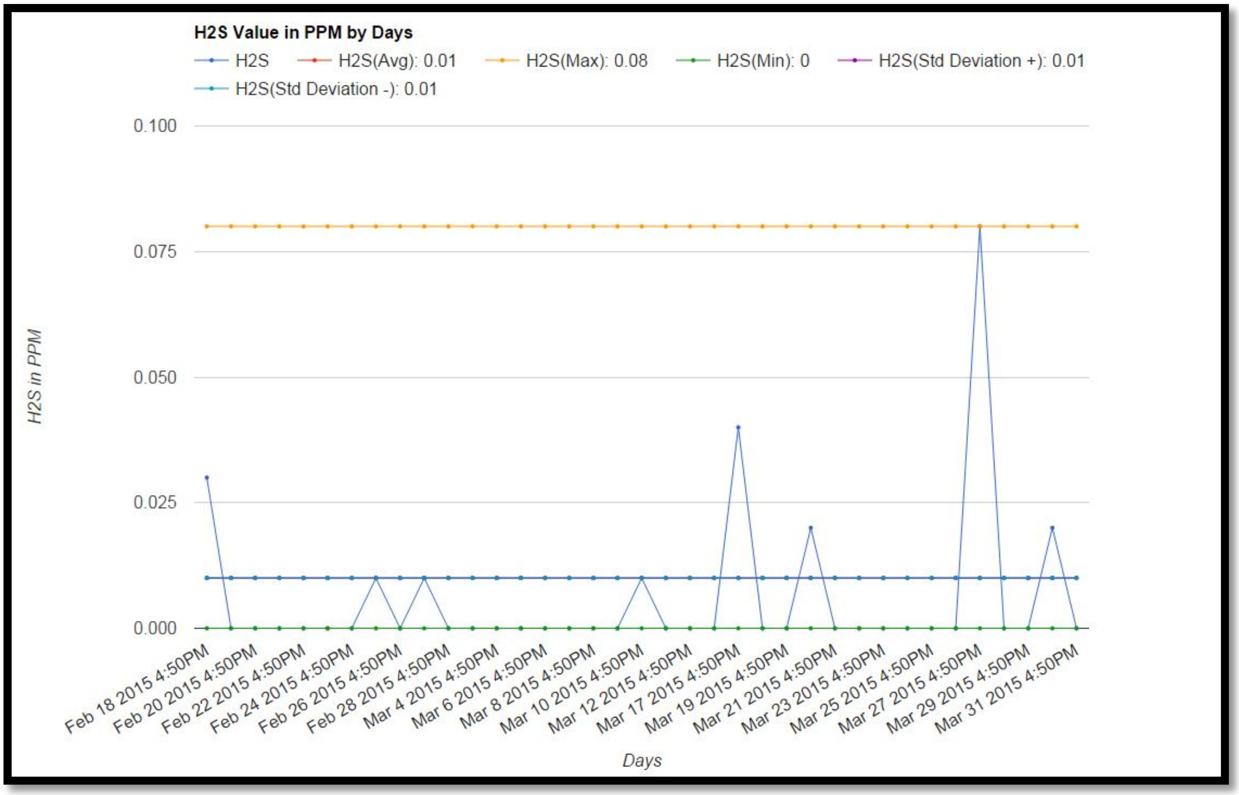

Figure A-35: Historical Analysis (2:00 p.m. – 3:40 p.m.) – Site 8

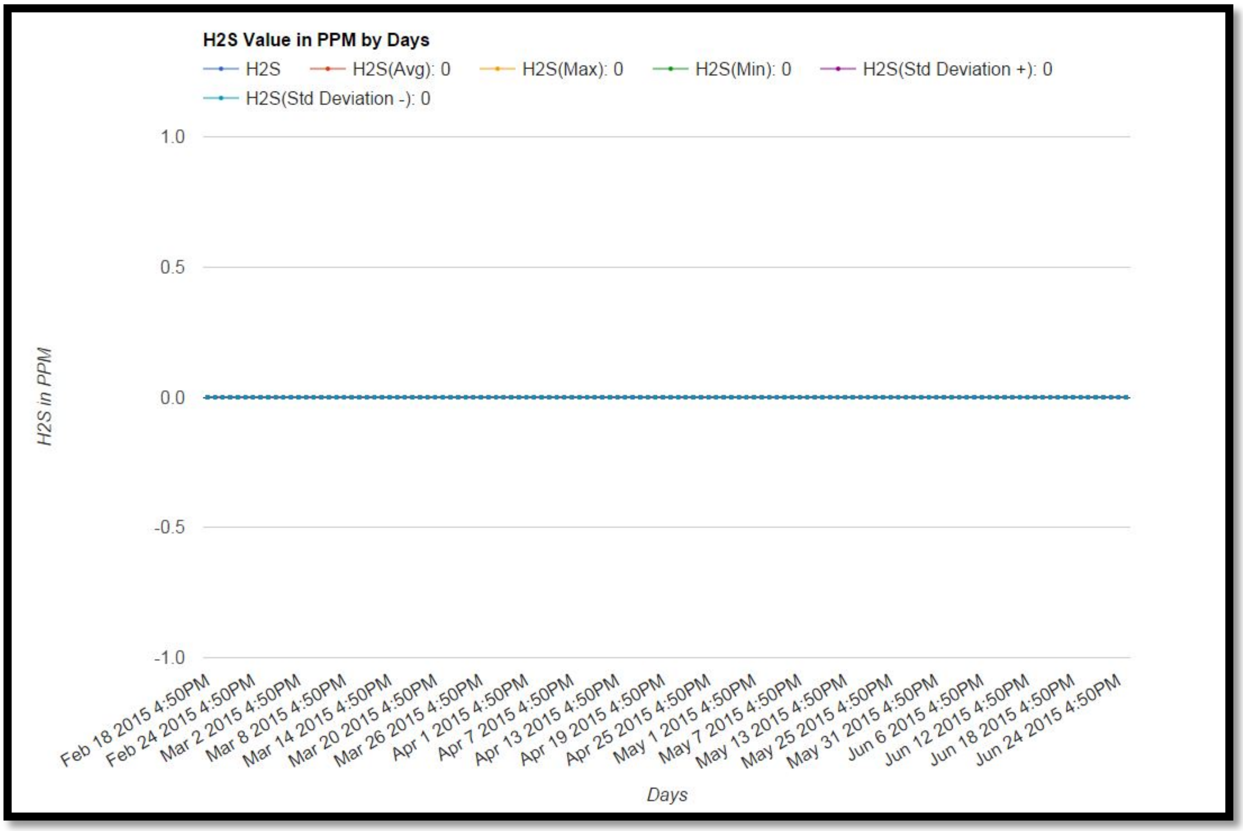

Figure A-36: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 2

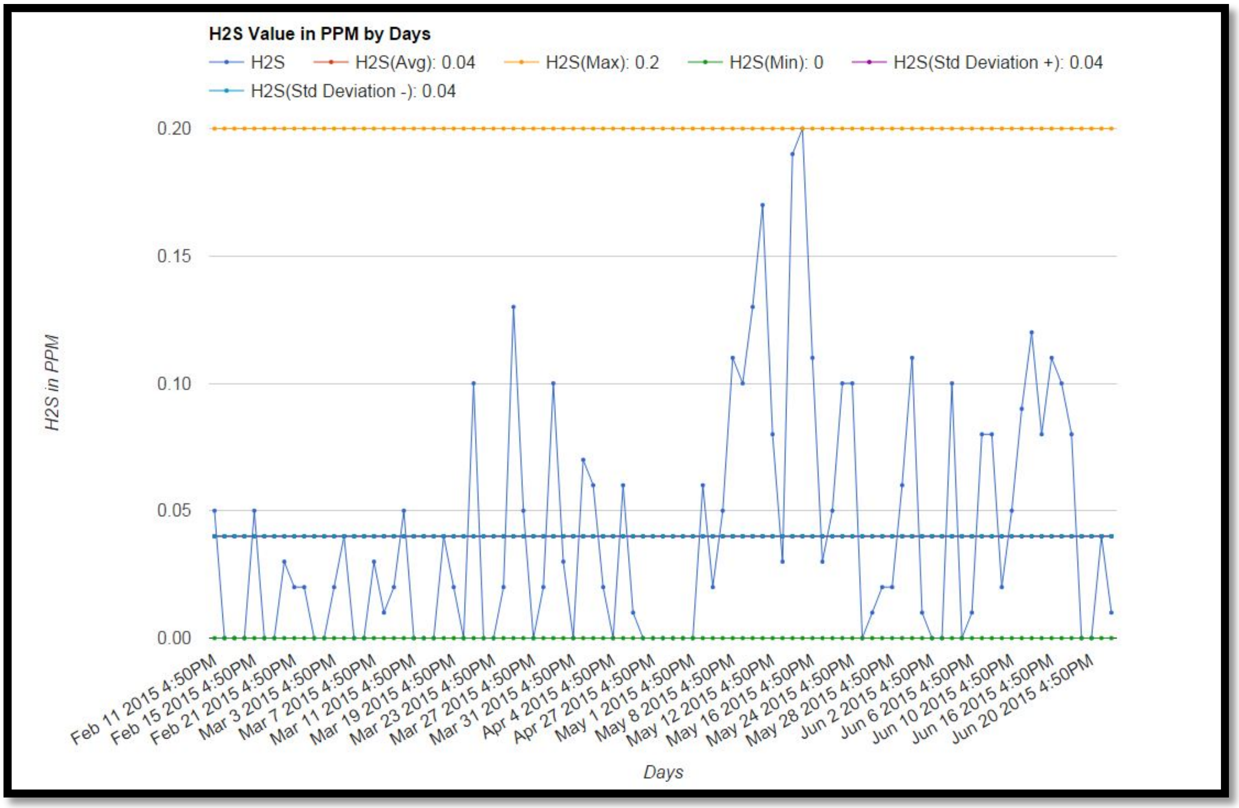

Figure A-37: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 3

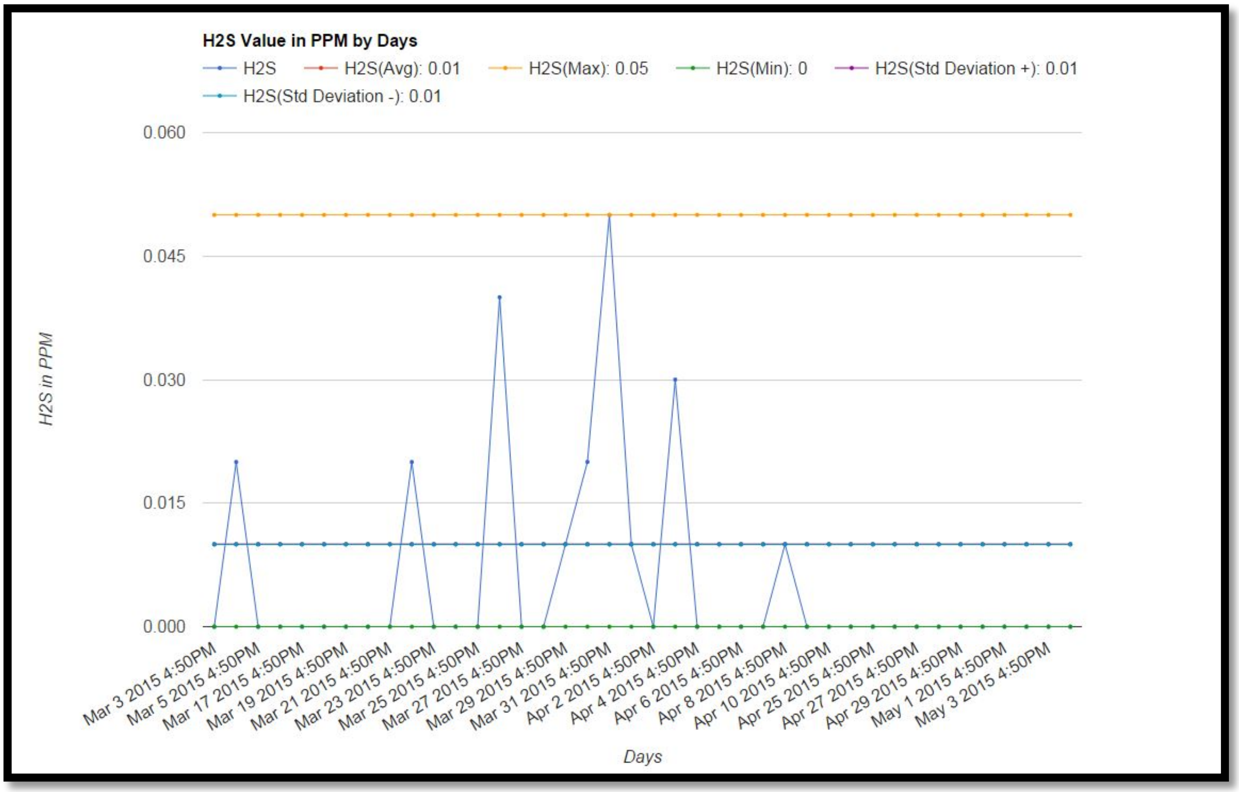

Figure A-38: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 4

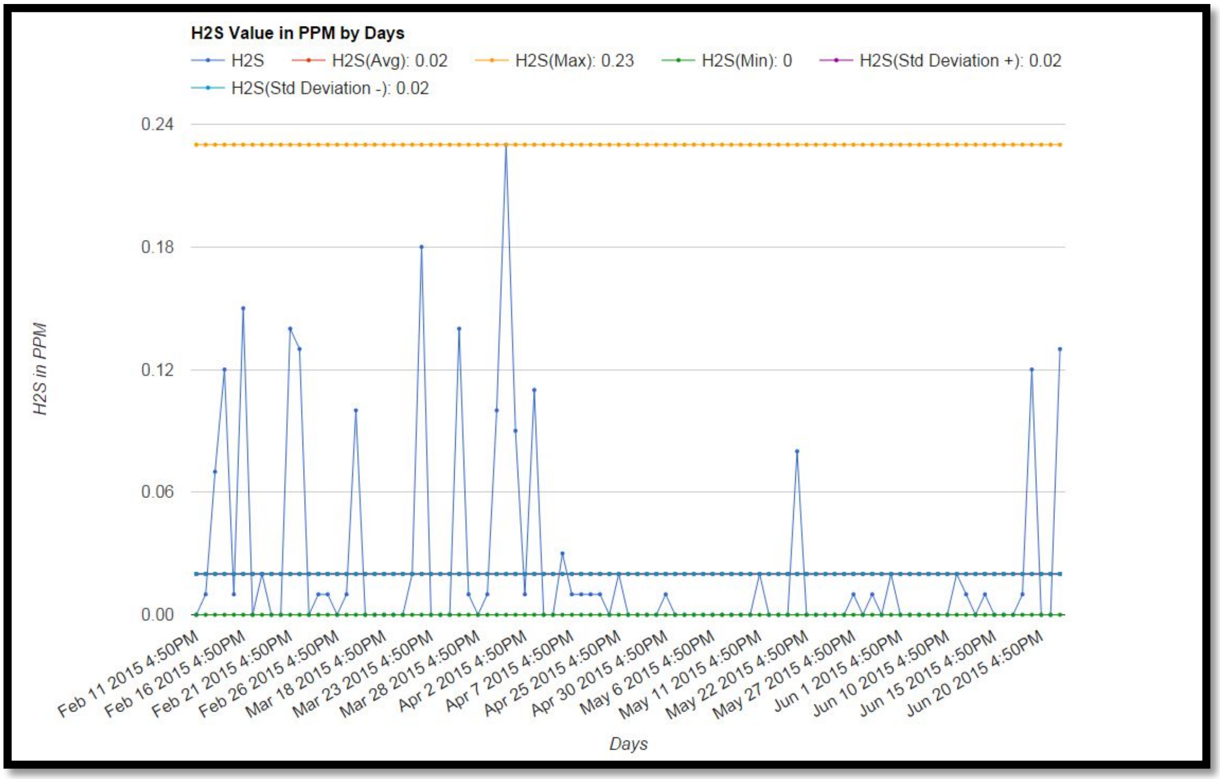

Figure A-39: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 5

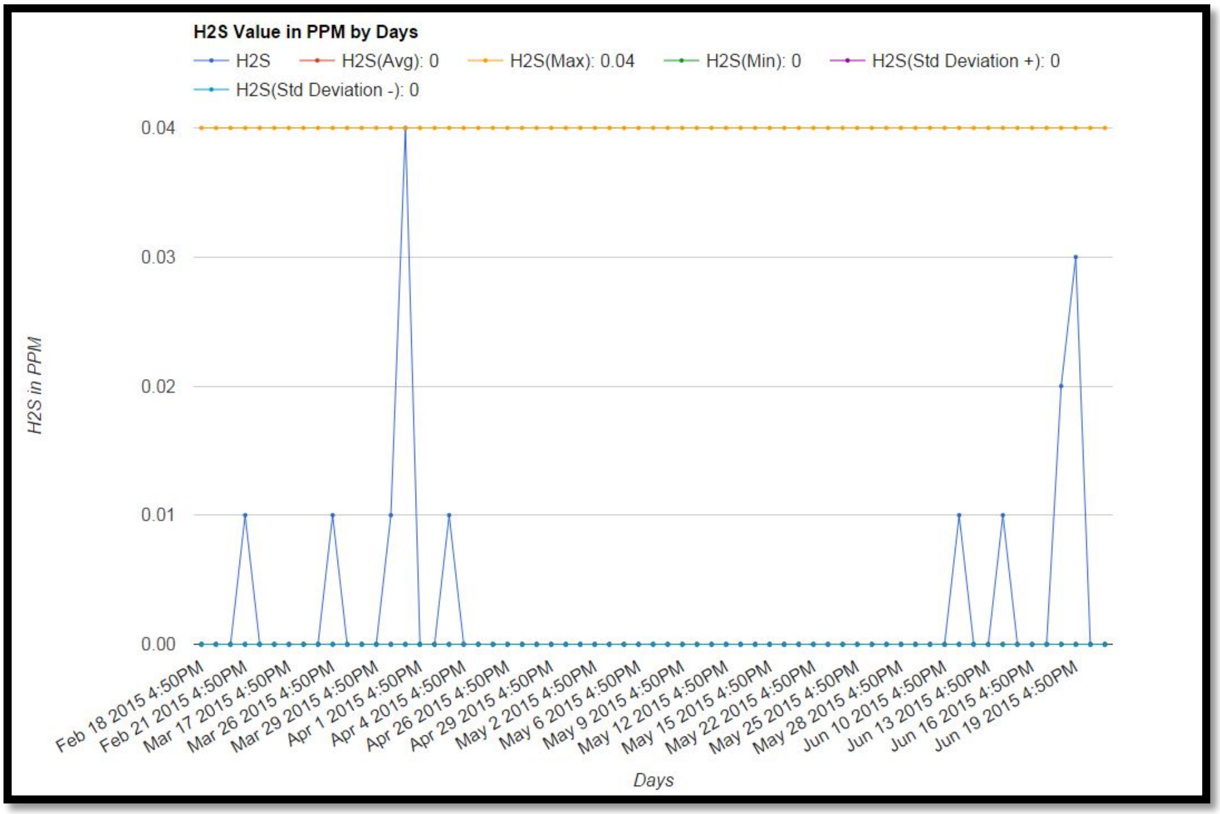

Figure A-40: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 6

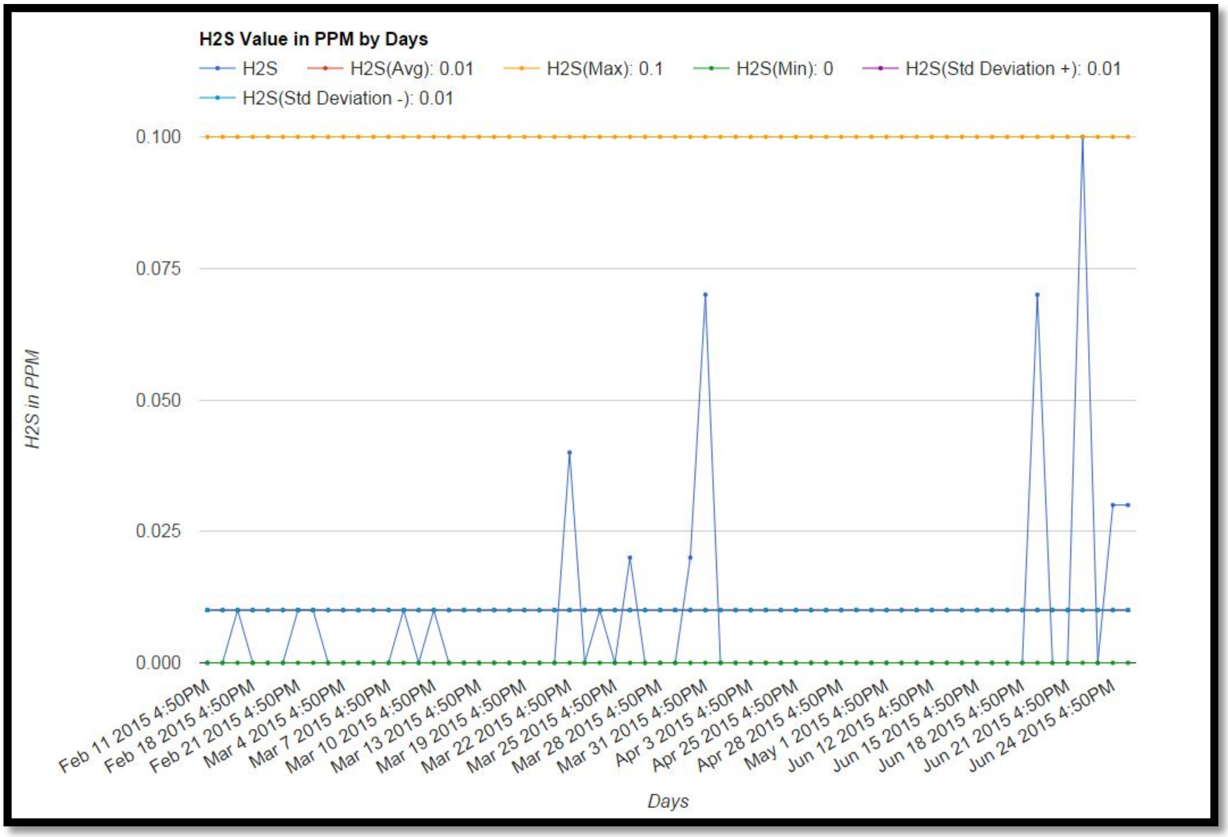

Figure A-41: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 7

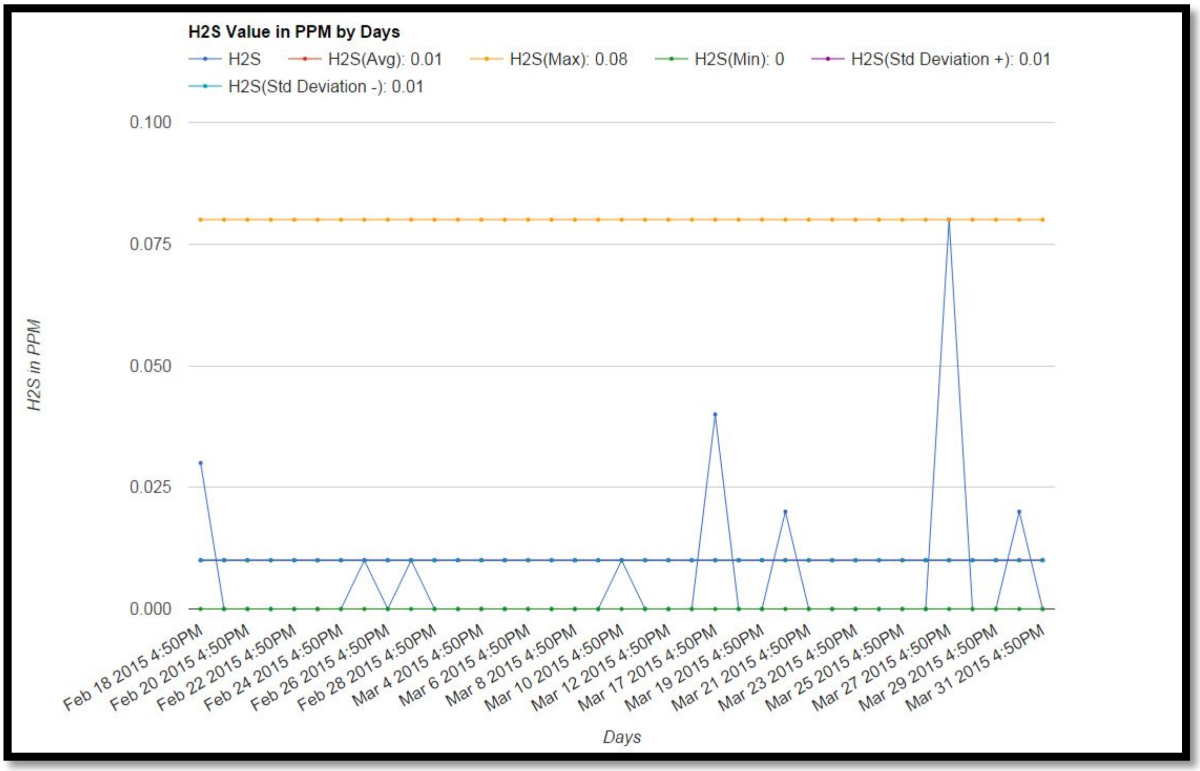

Figure A-42: Historical Analysis (3:40 p.m. – 6:00 p.m.) – Site 8

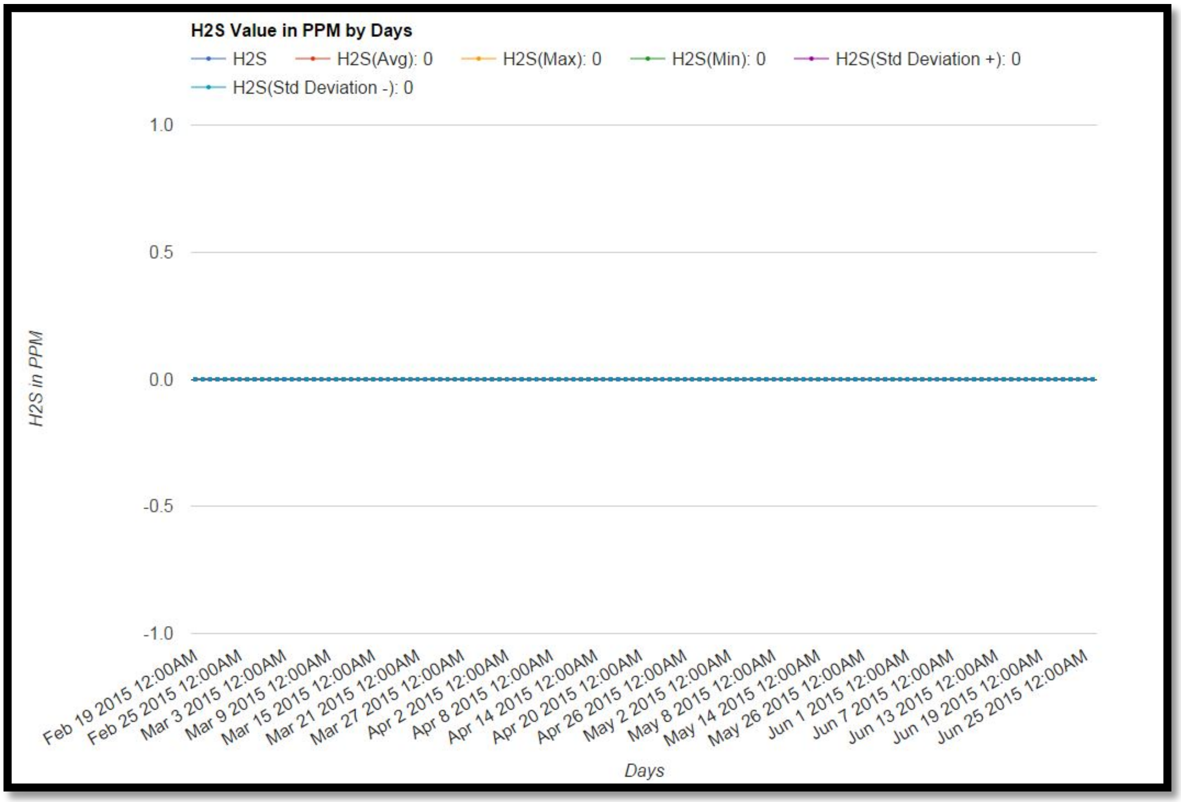

Figure A-43: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 2

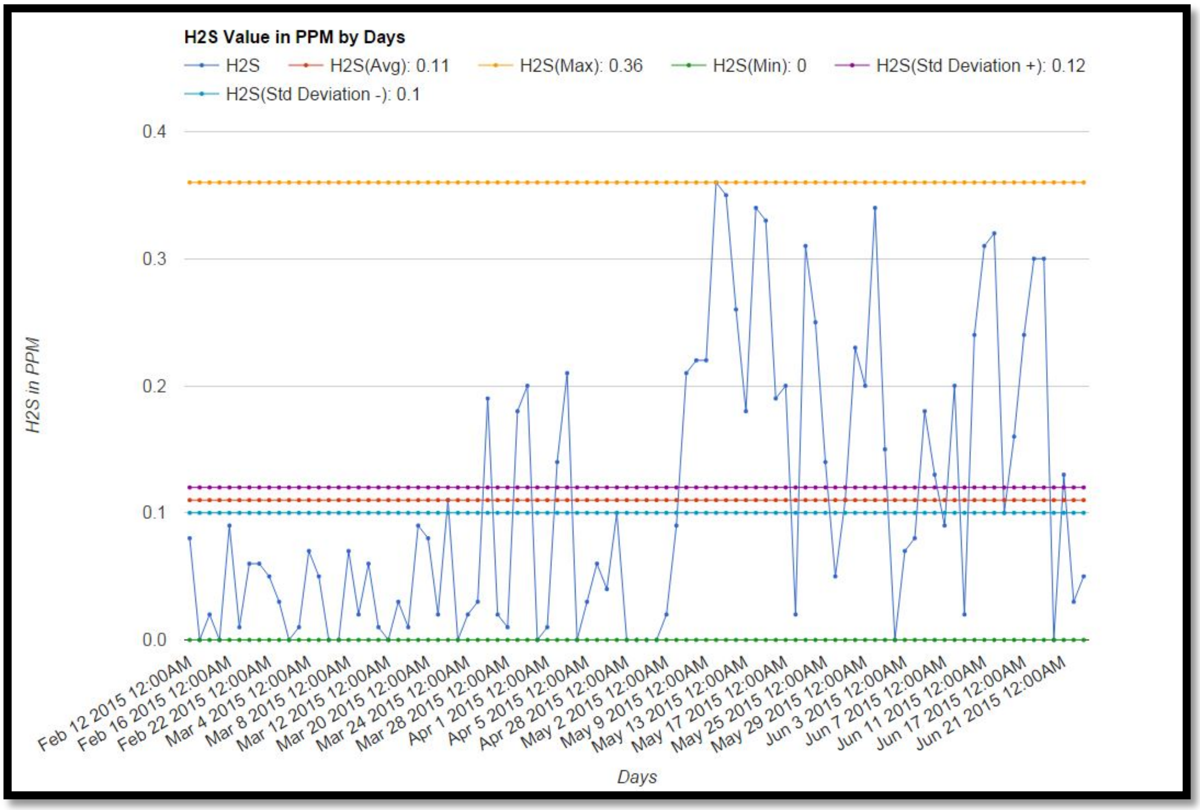

Figure A-44: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 3

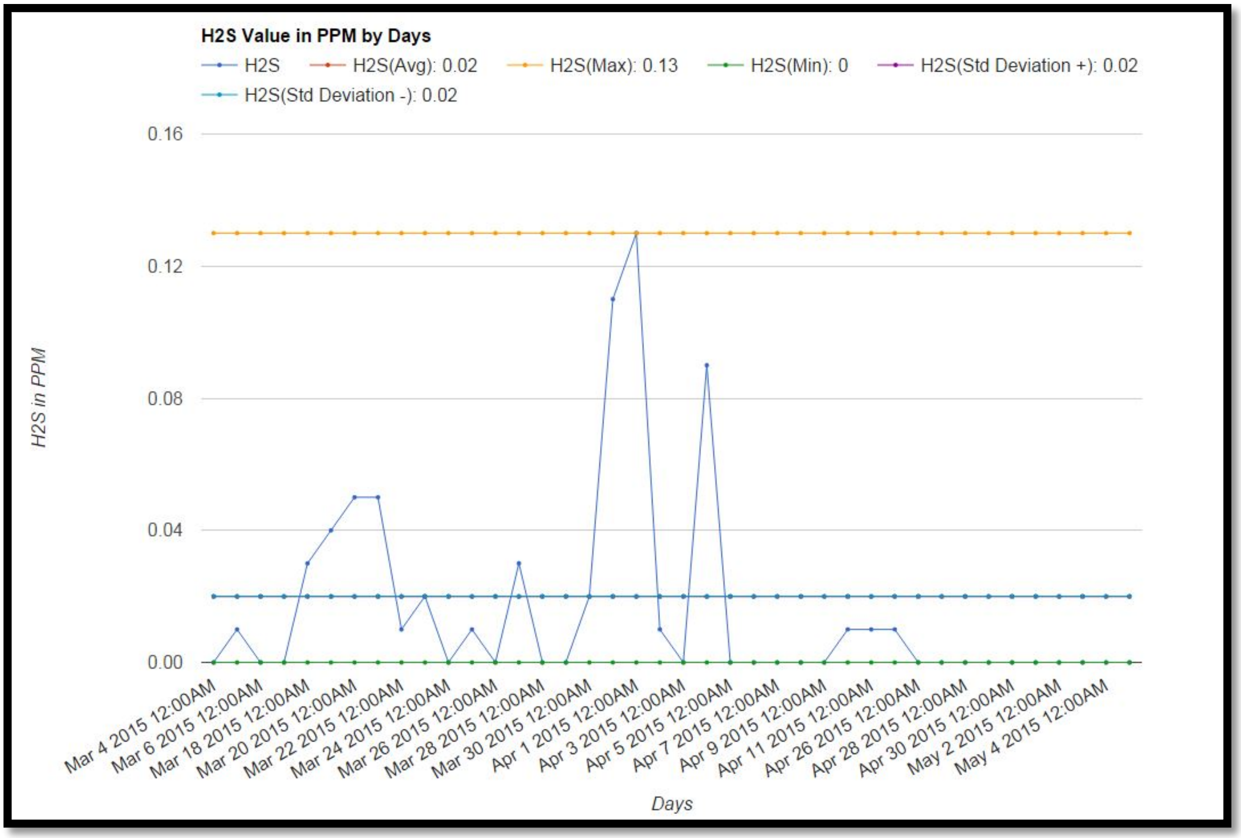

Figure A-45: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 4

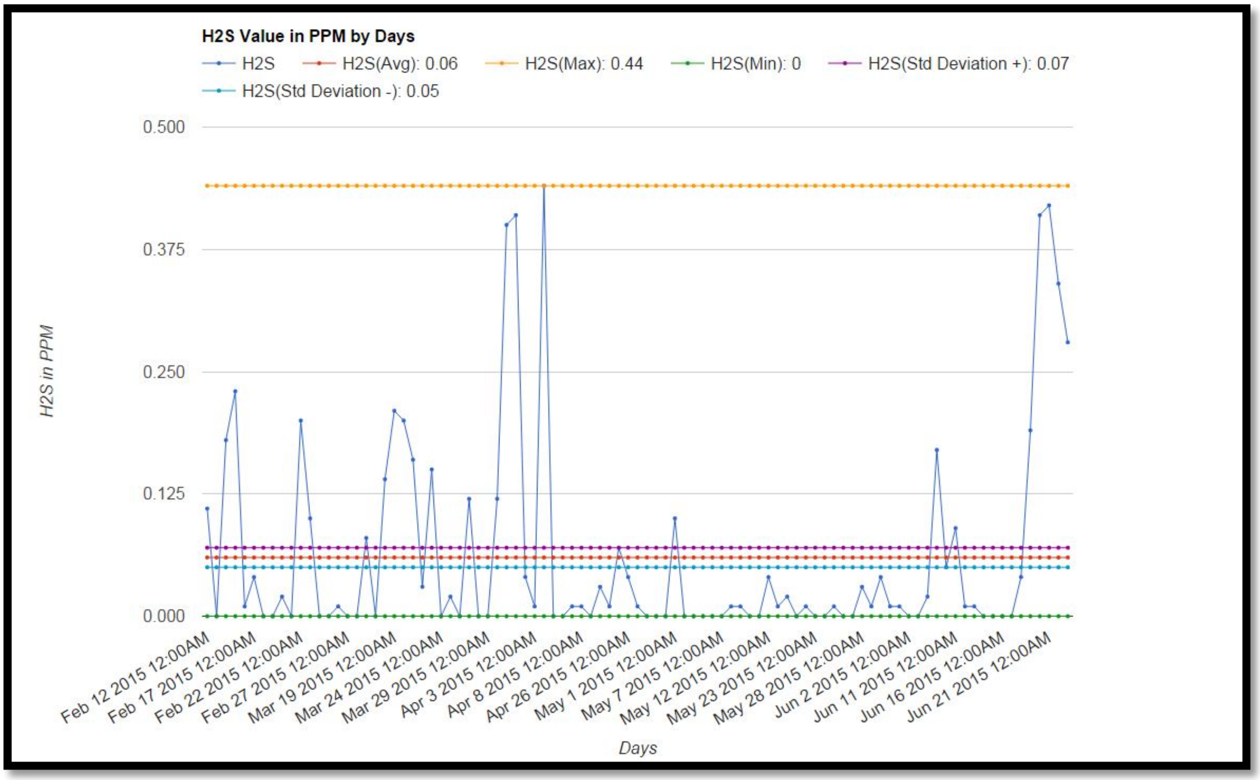

Figure A-46: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 5

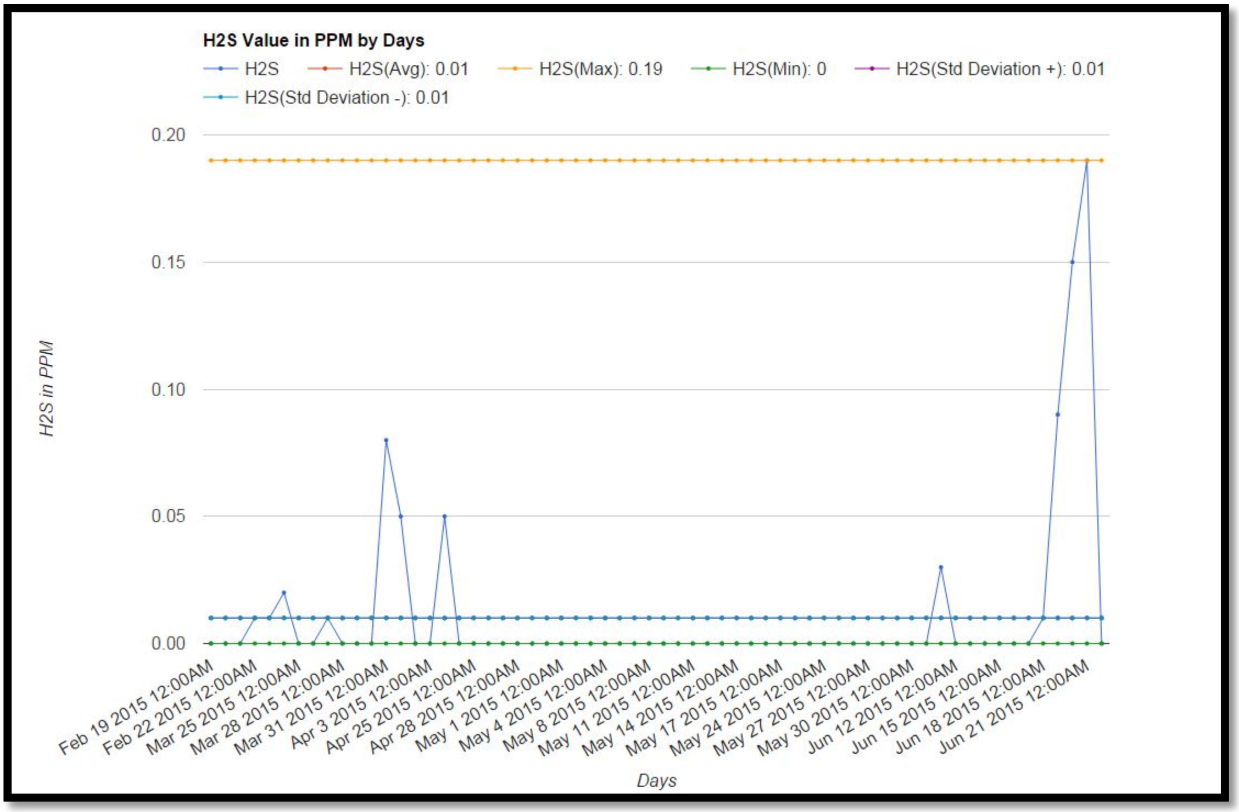

Figure A-47: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 6

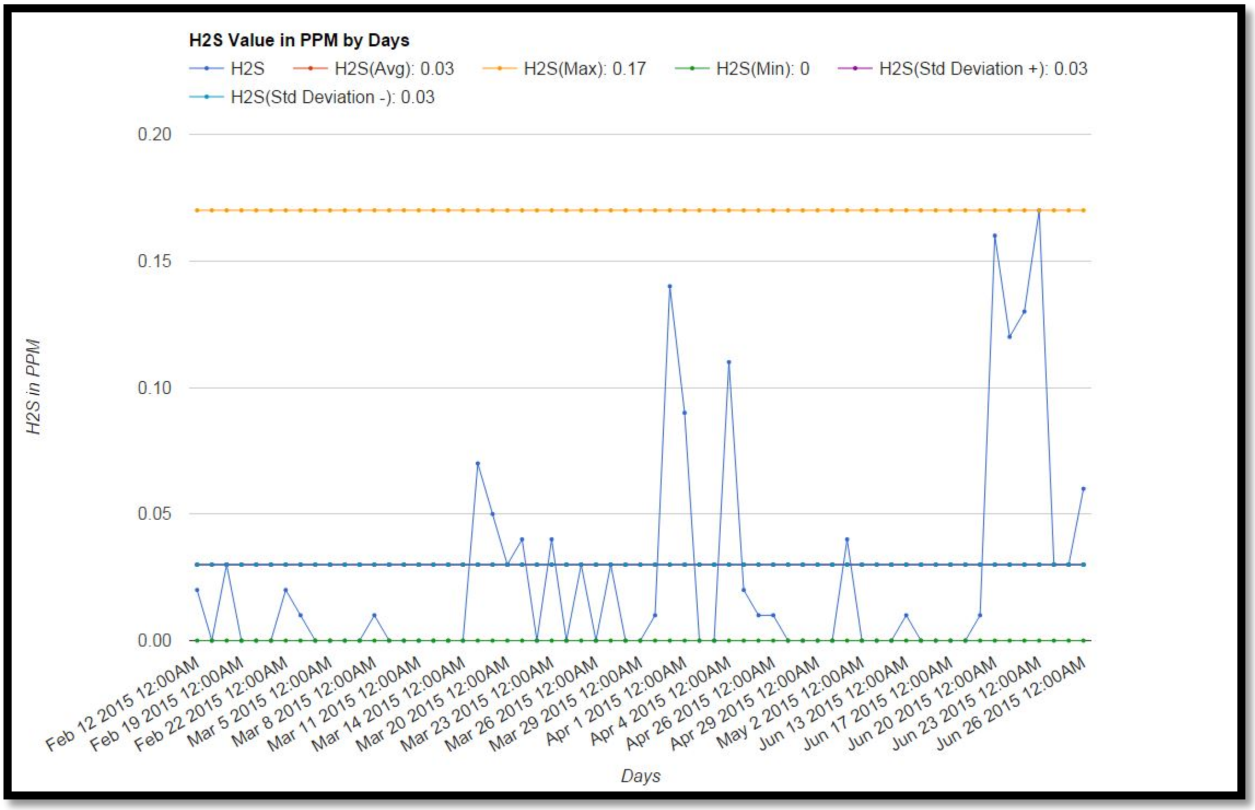

Figure A-48: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 7

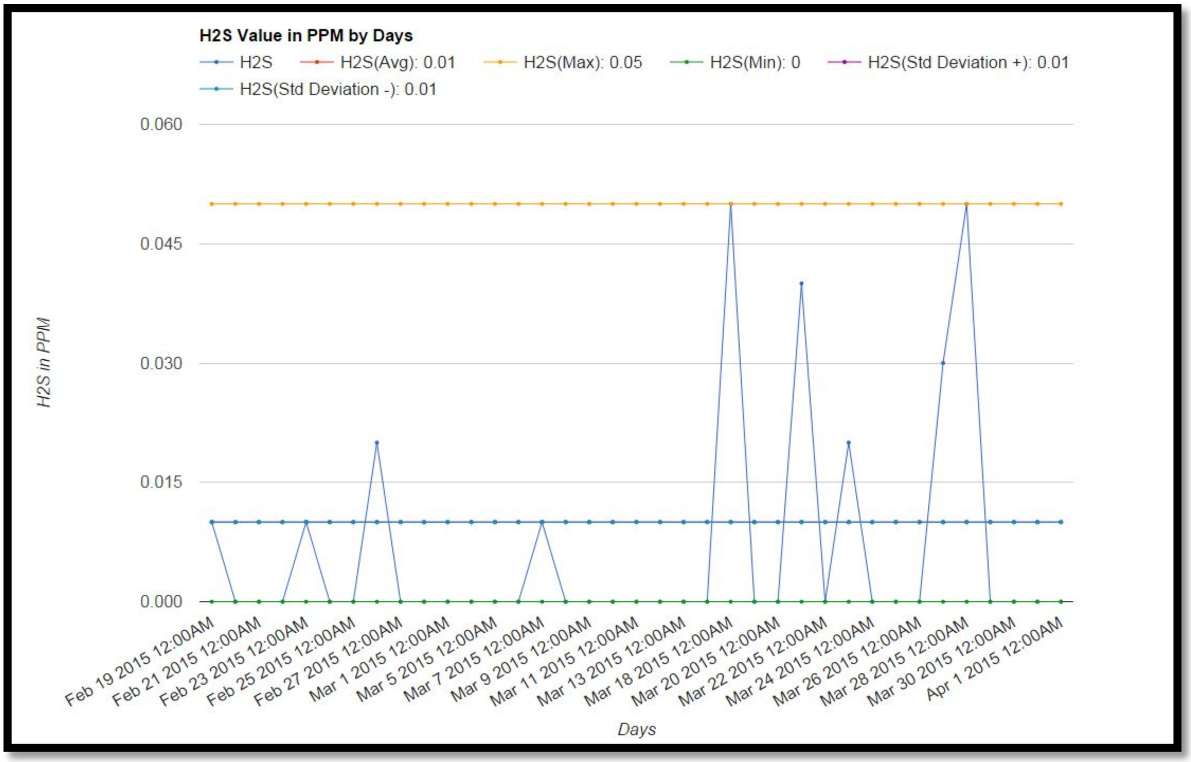

Figure A-49: Historical Analysis (6:00 p.m. – 6:00 a.m.) – Site 8

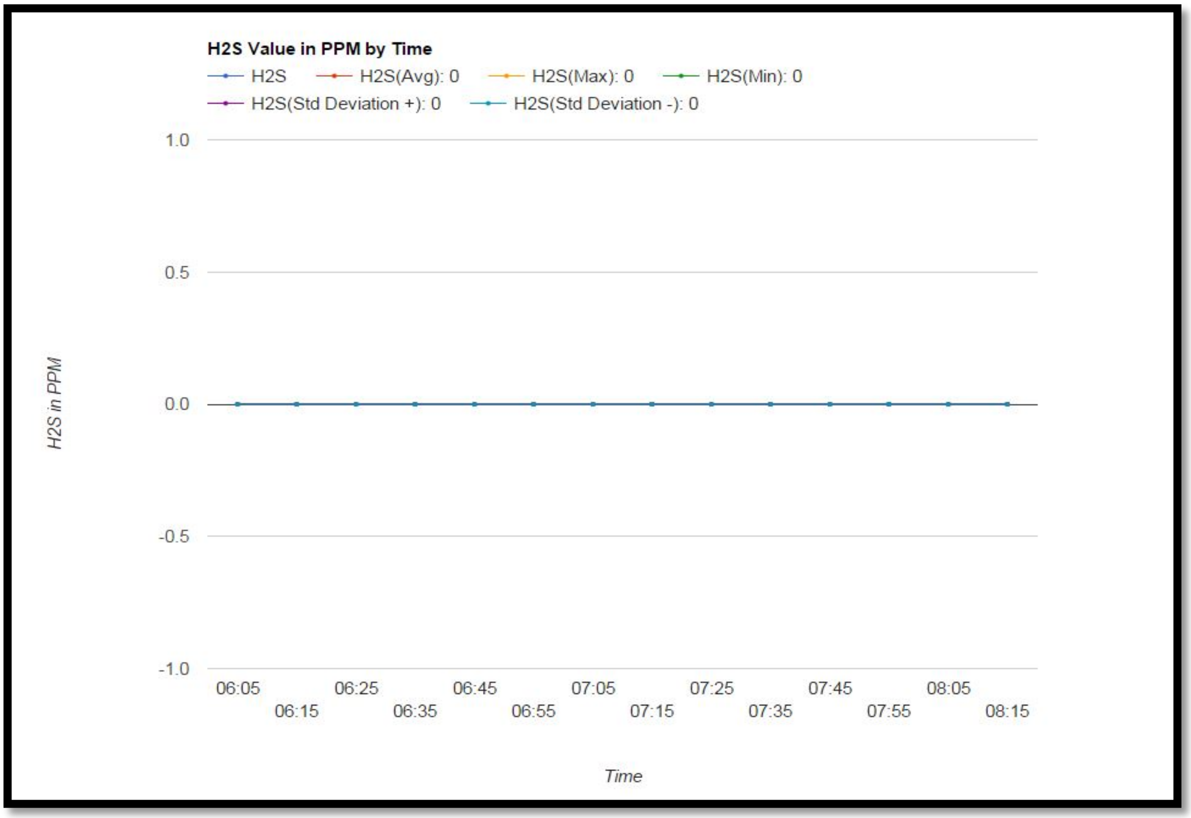

Figure A-50: Average Hourly Analysis for 10-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 2

Figure A-51: Average Hourly Analysis for 10-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 4

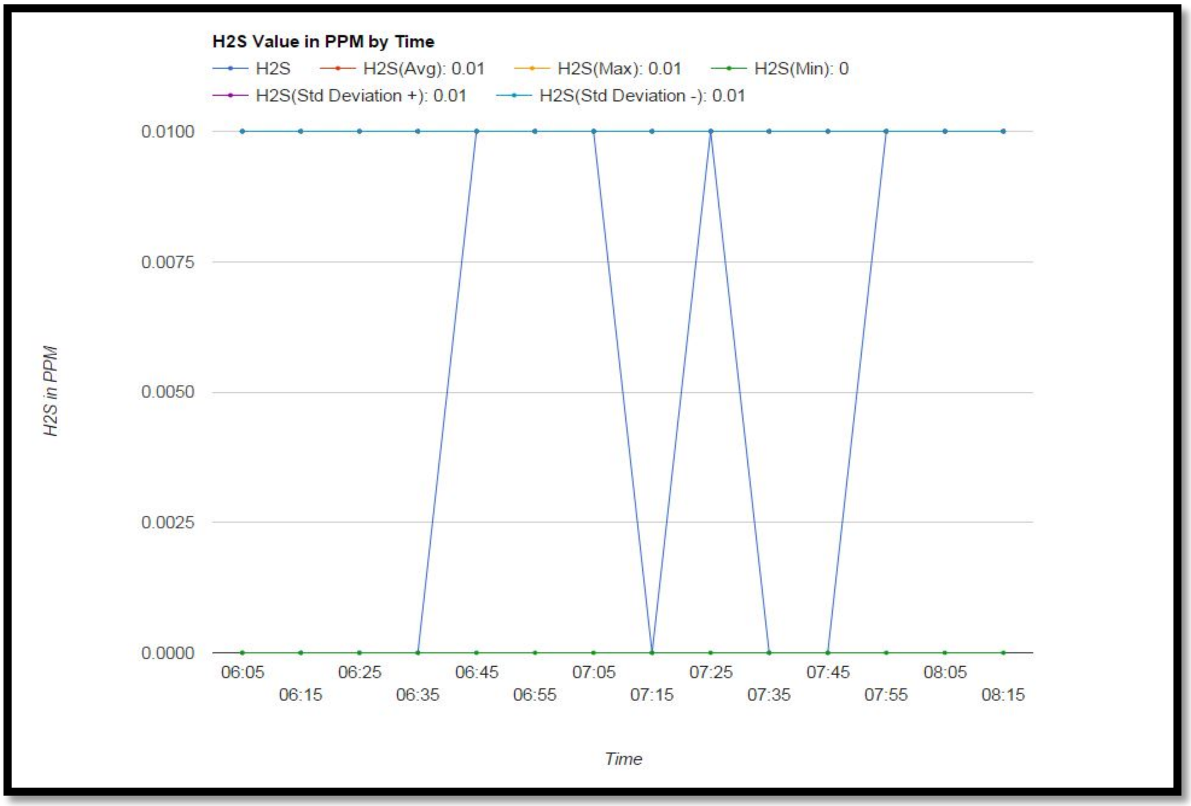

Figure A-52: Average Hourly Analysis for 10-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 6

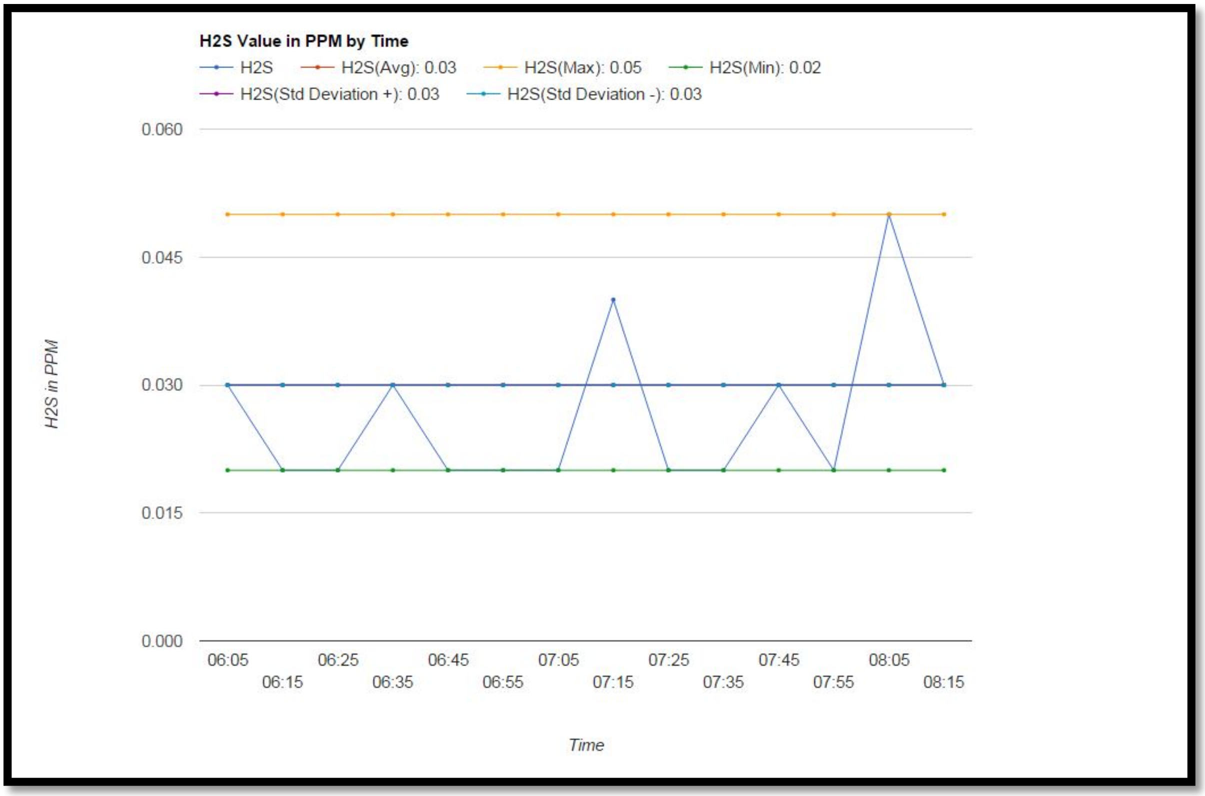

Figure A-53: Average Hourly Analysis for 10Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 7

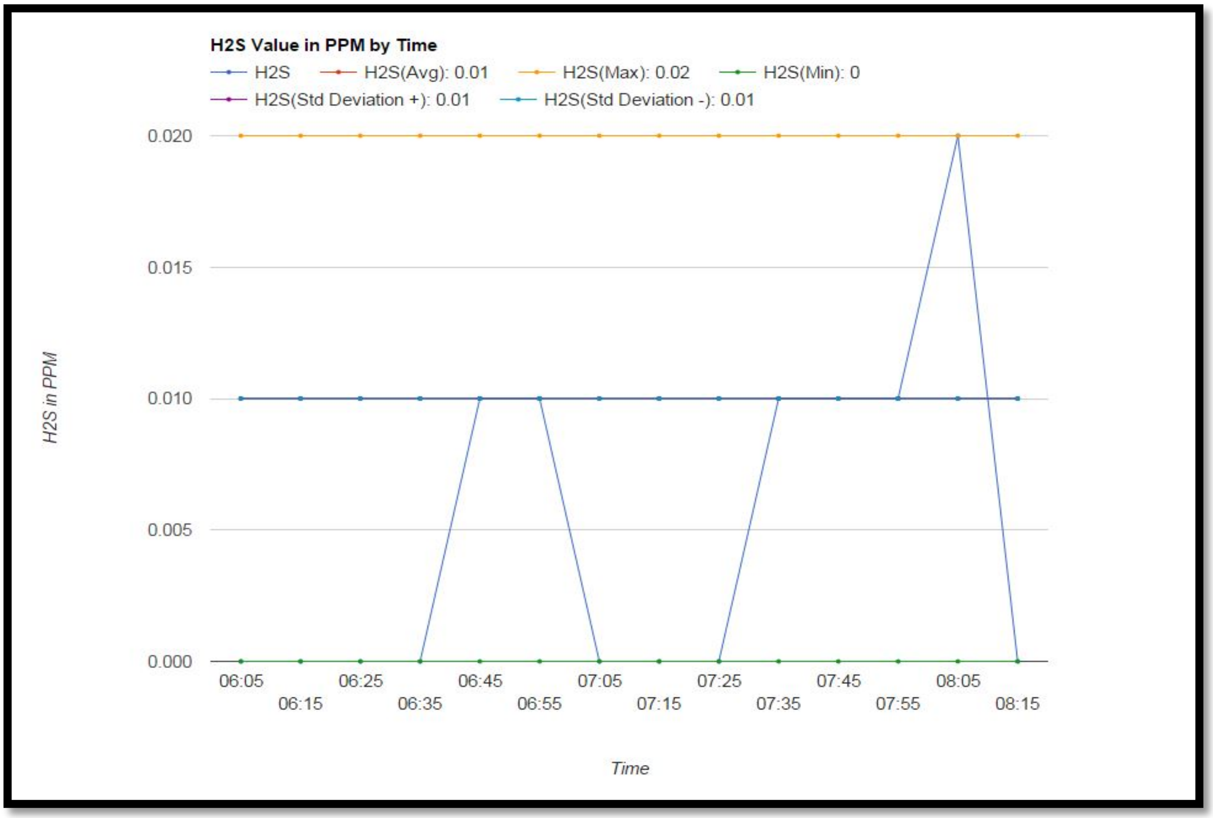

Figure A-54: Average Hourly Analysis for 10-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 8

Figure A-55: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 1

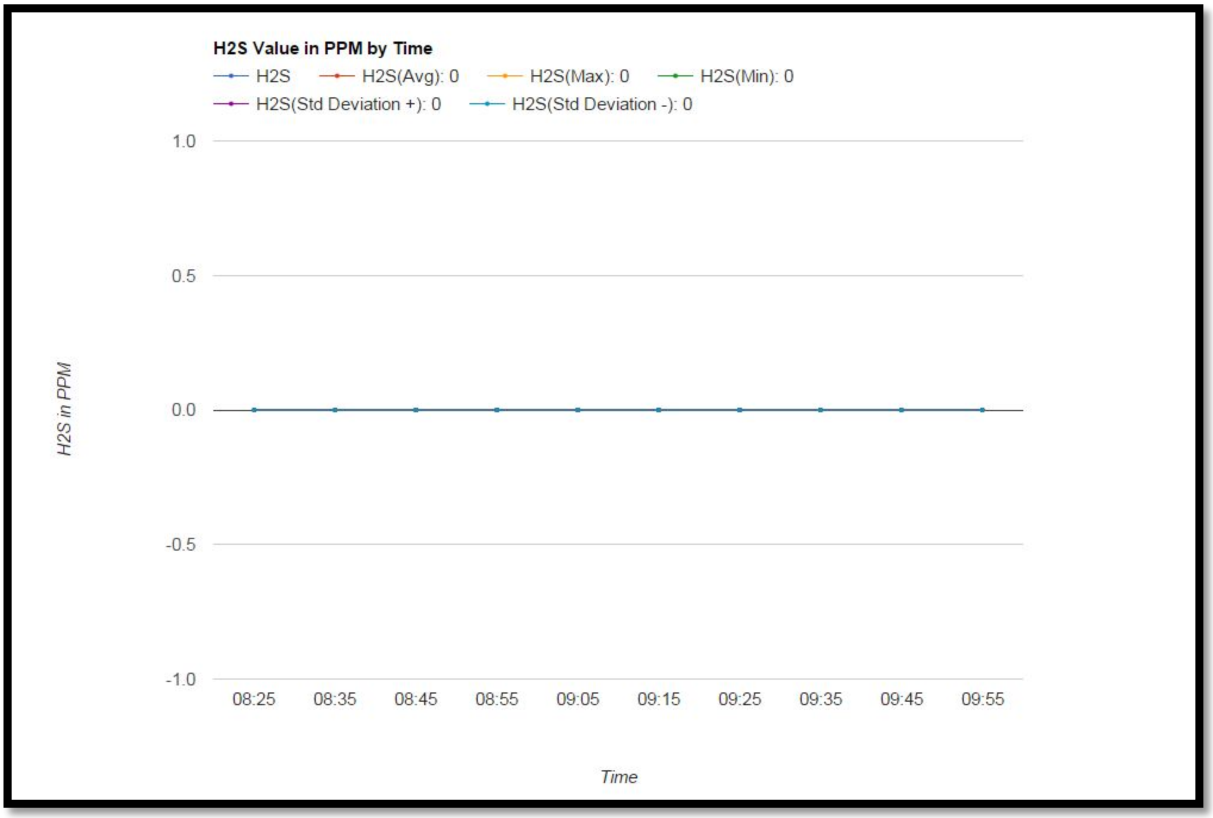

Figure A-56: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 2

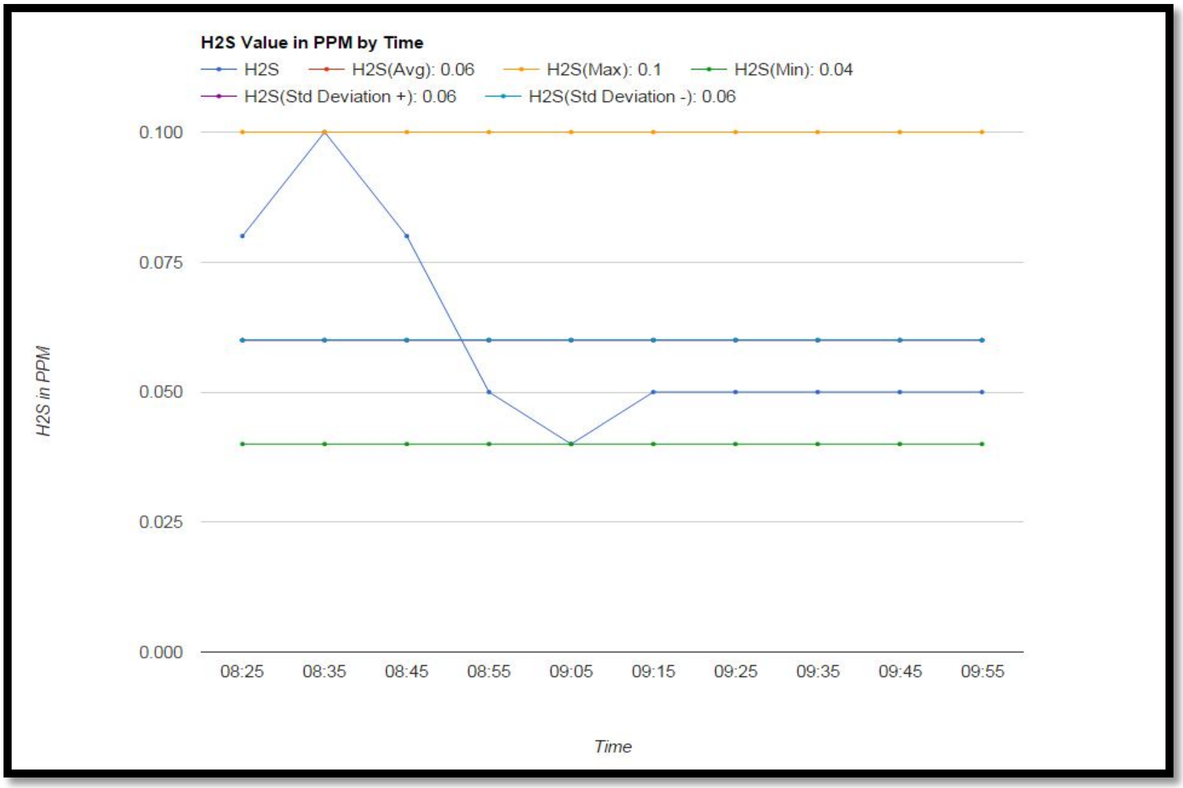

Figure A-57: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 3

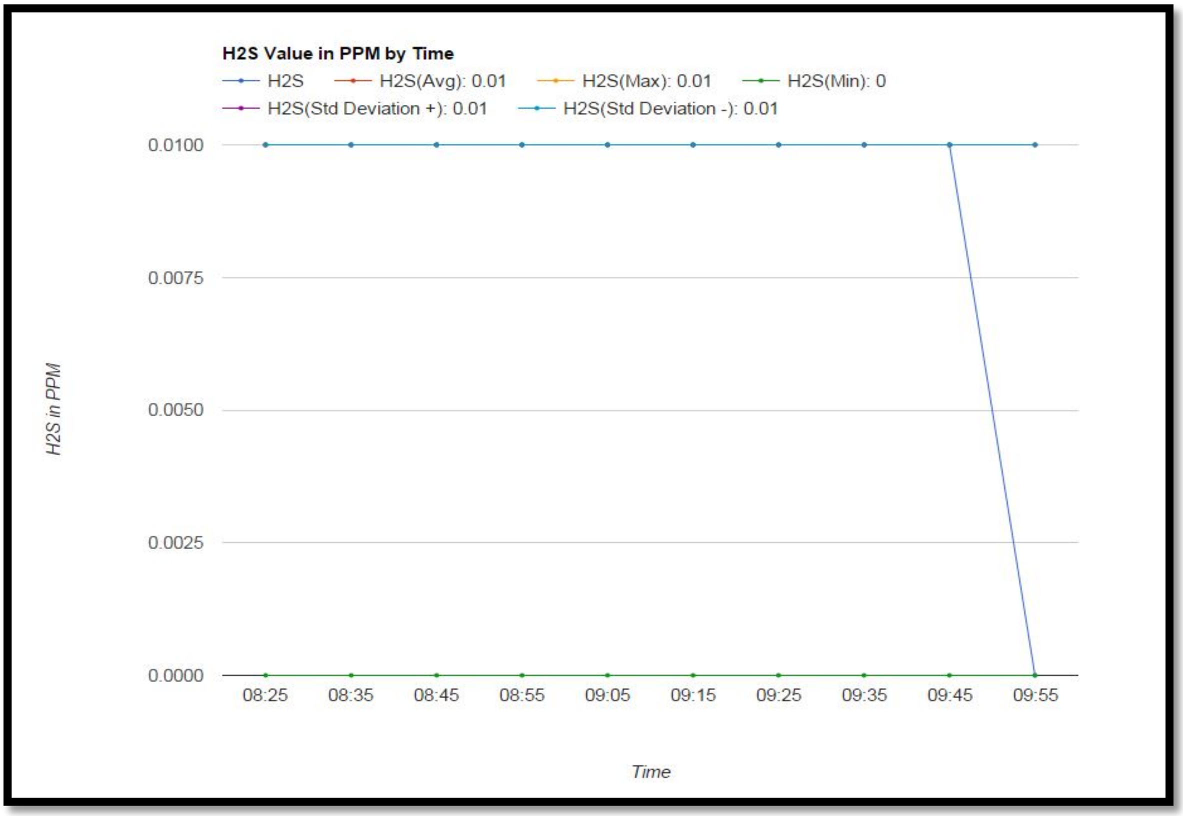

Figure A-58: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 4

Figure A-59: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 5

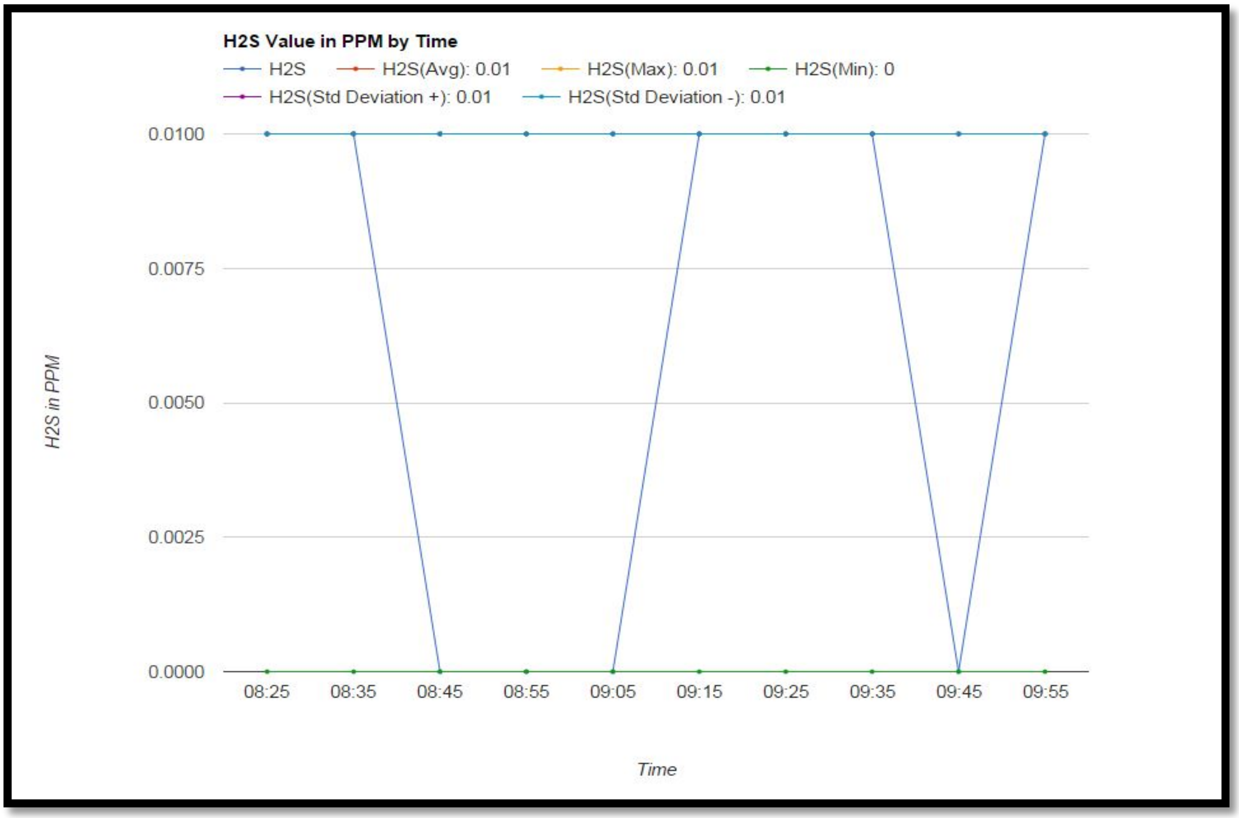

Figure A-60: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 6

Figure A-61: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 7

Figure A-62: Average Hourly Analysis for 10-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 8

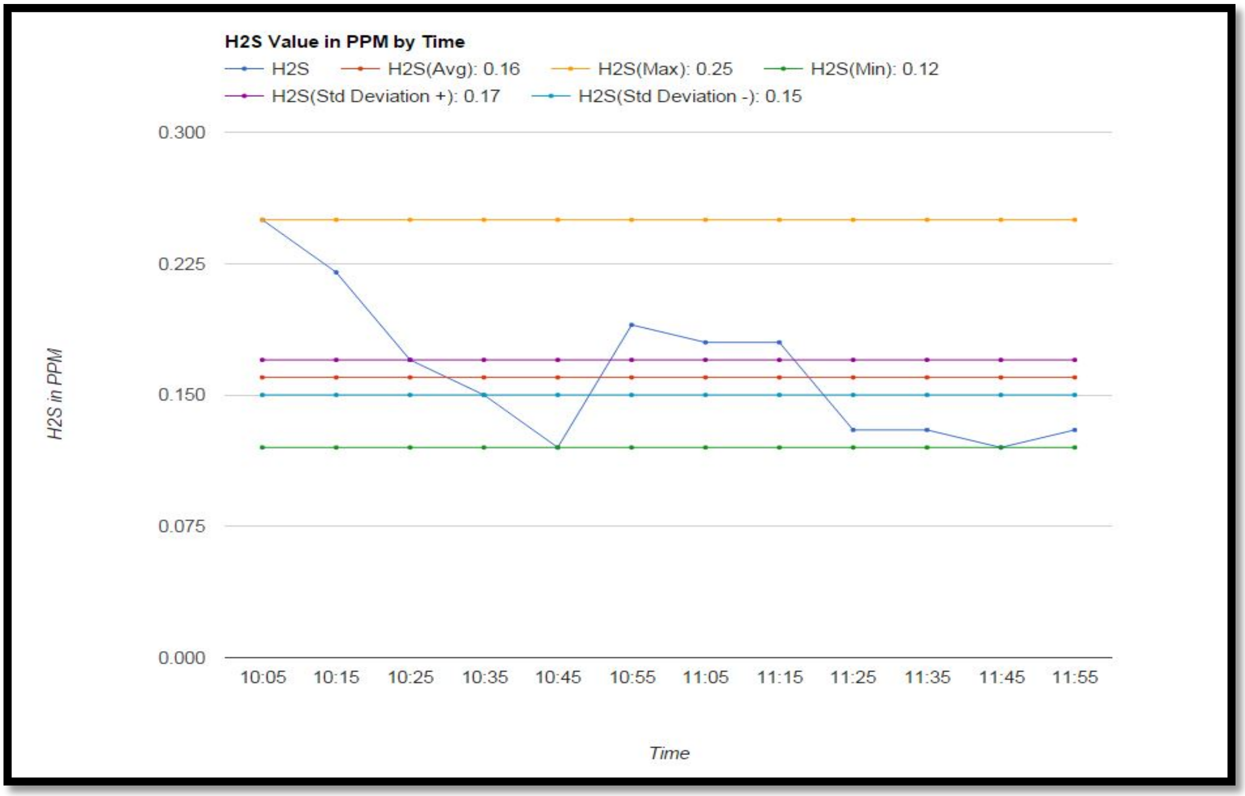

Figure A-63: Average Hourly Analysis for 10-Minute Intervals (10:00 a.m.– 12:00p.m.) – Site 1

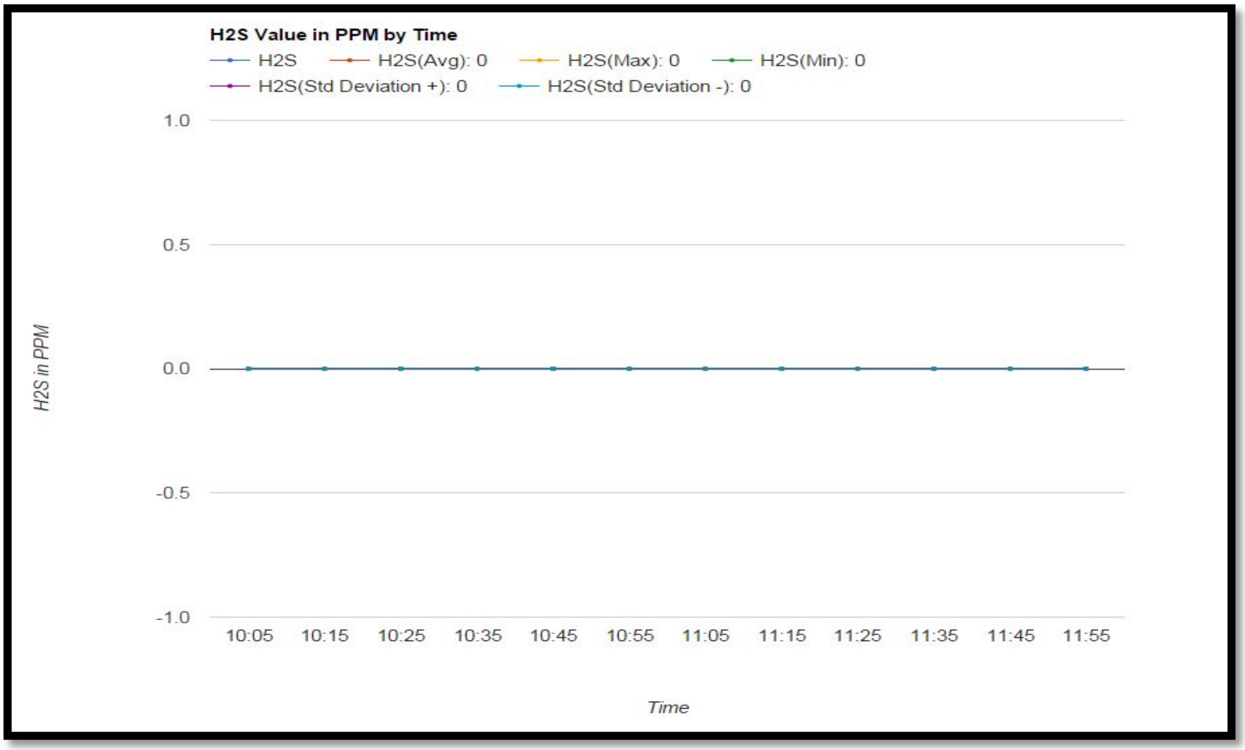

Figure A-64: Average Hourly Analysis for 10-Minute Intervals (10:00a.m. – 12:00 p.m.)– Site 2

Figure A-65: Average Hourly Analysis for 10-Minute Intervals (10:00 a.m. – 12:00p.m.)– Site 3

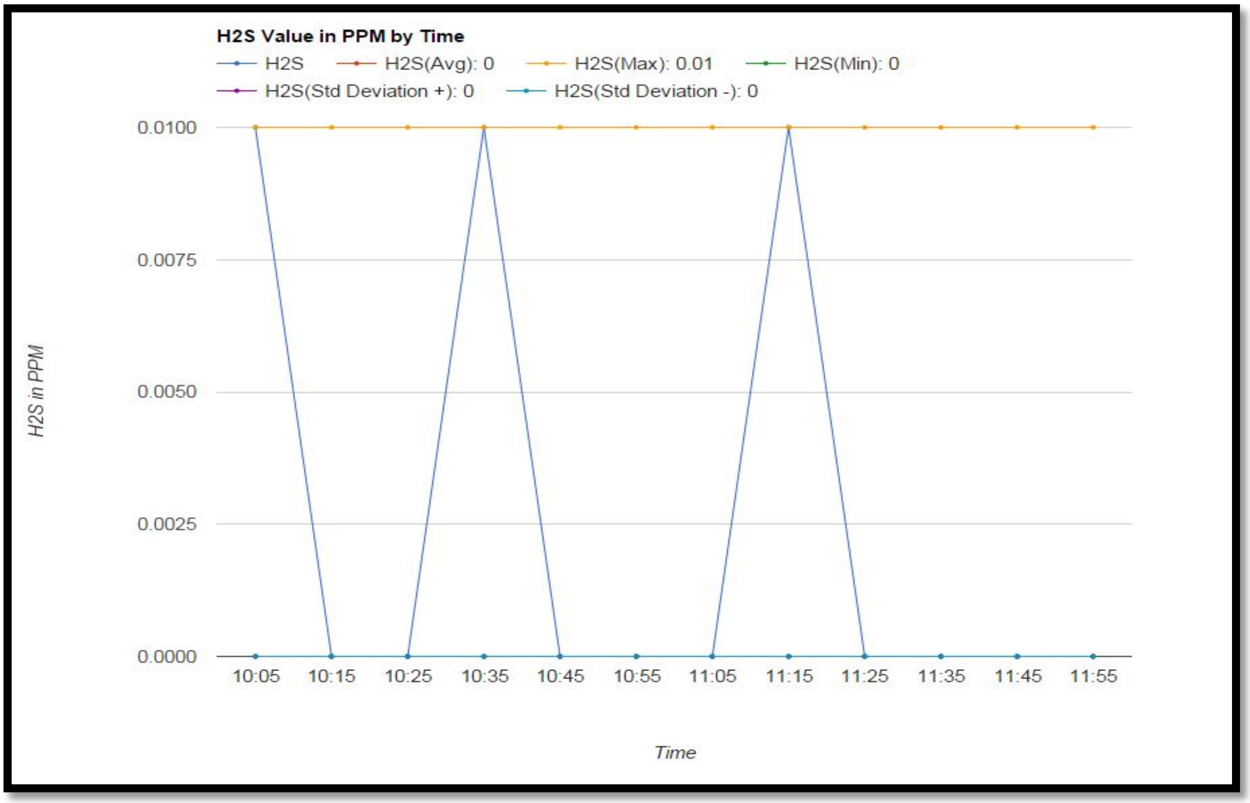

Figure A-66: Average Hourly Analysis for 10-Minute Intervals (10:00 a.m. – 12:00p.m.)– Site 4

Figure A-67: Average Hourly Analysis for 10-Minute Intervals (10:00 a.m.– 12:00 p.m.)– Site 5

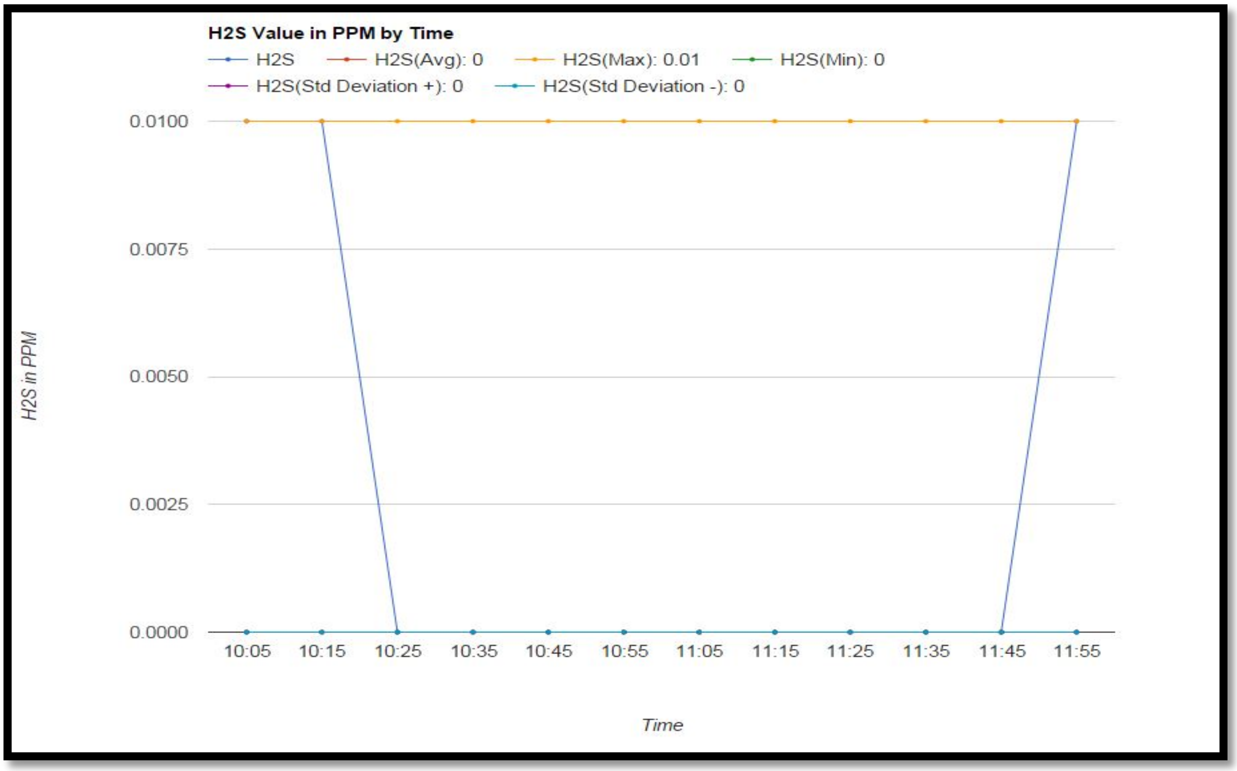

Figure A-68: Average Hourly Analysis for 10-Minute Intervals (10:00 a.m. – 12:00p.m.)– Site 6

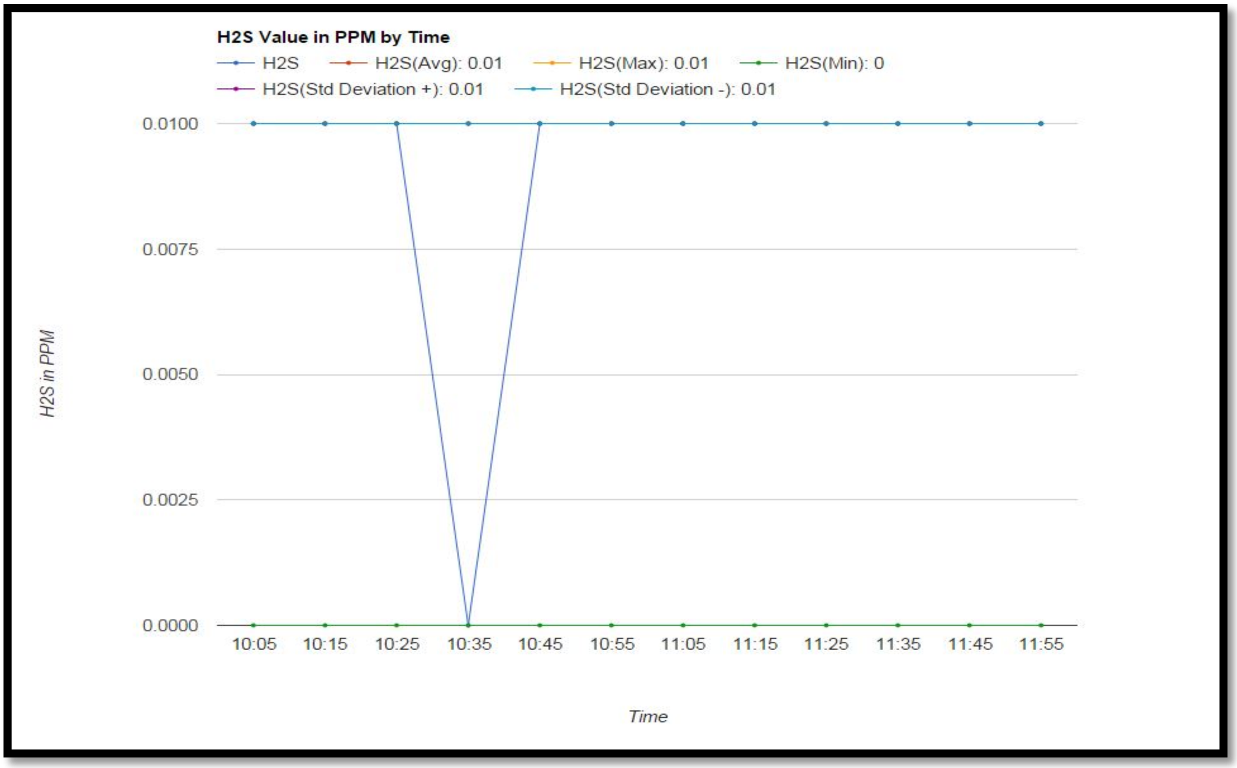

Figure A-69: Average Hourly Analysis for 10-Minute Intervals (10:00 a.m. – 12:00p.m.)– Site 7

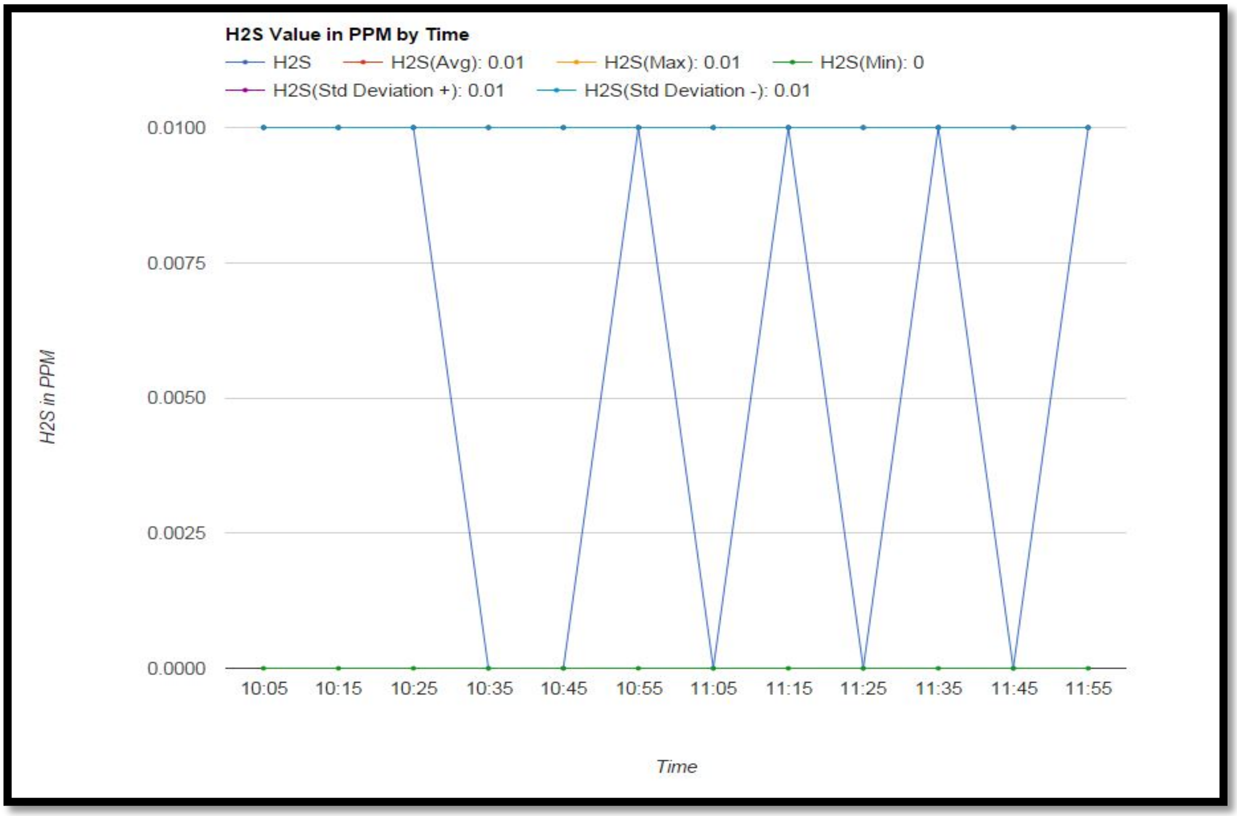

Figure A-70: Average Hourly Analysis for 10-Minute Intervals (10:00 a.m. – 12:00p.m.)– Site 8

Figure A-71: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 1

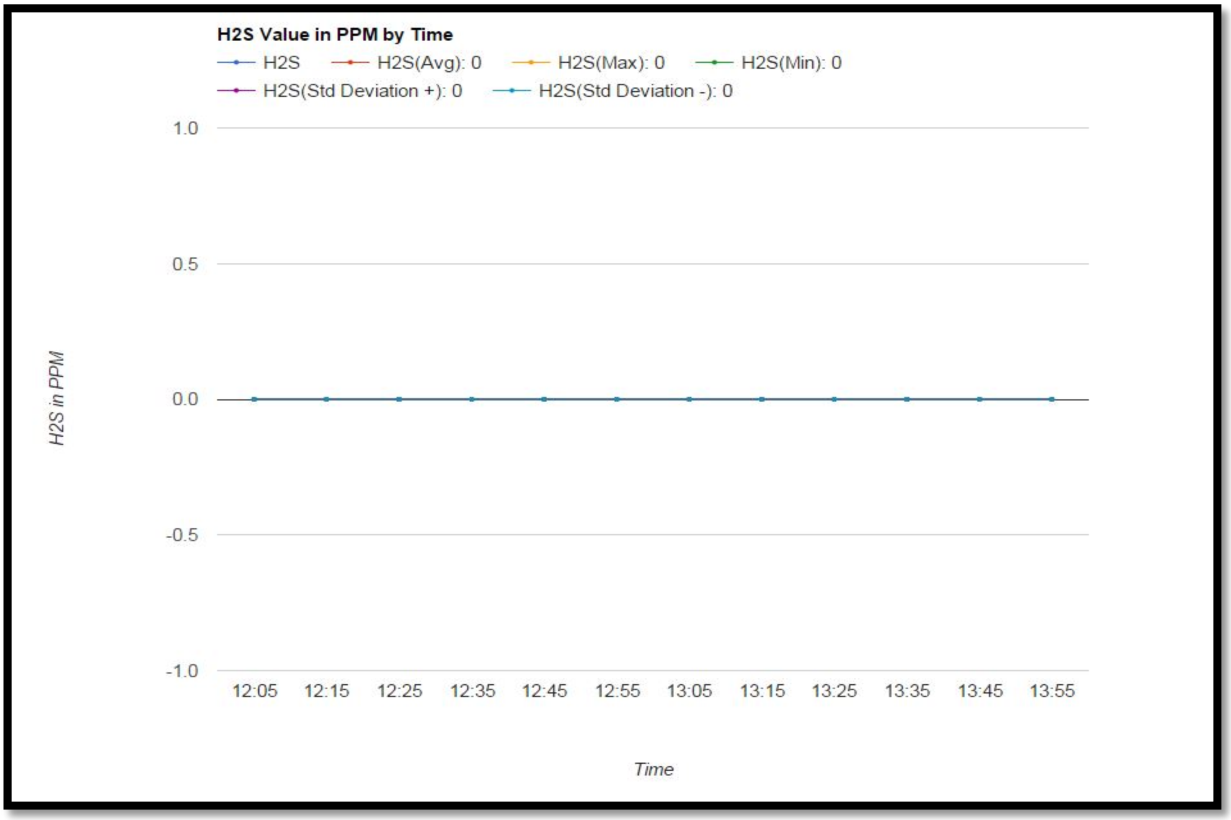

Figure A-72: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 2

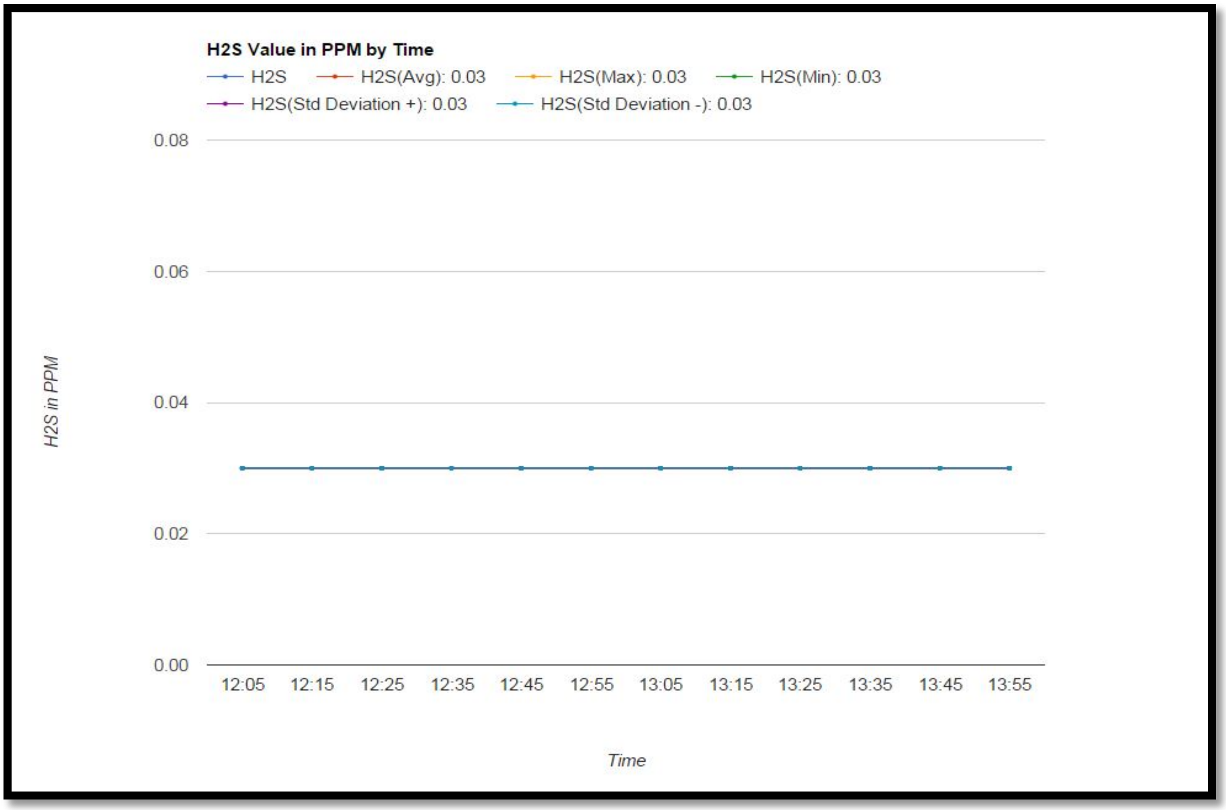

Figure A-73: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 3

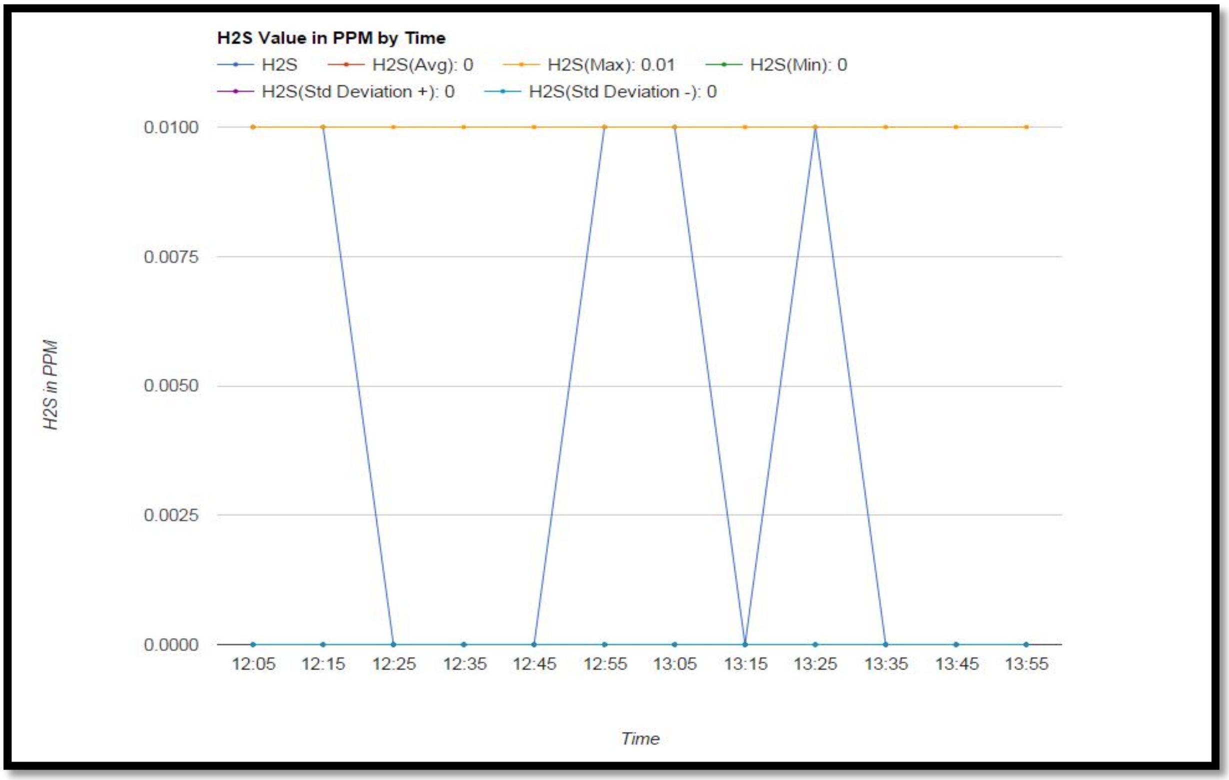

Figure A-74: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 4

Figure A-75: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 5

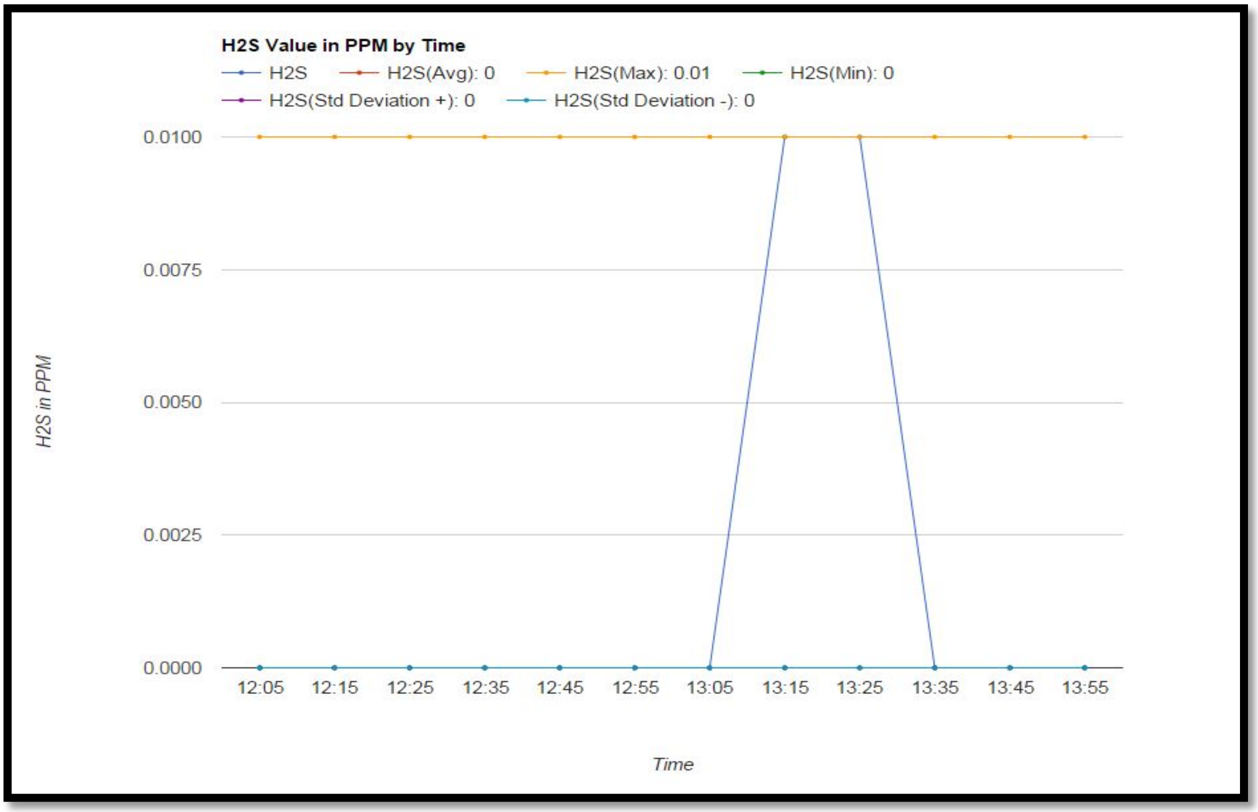

Figure A-76: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 6

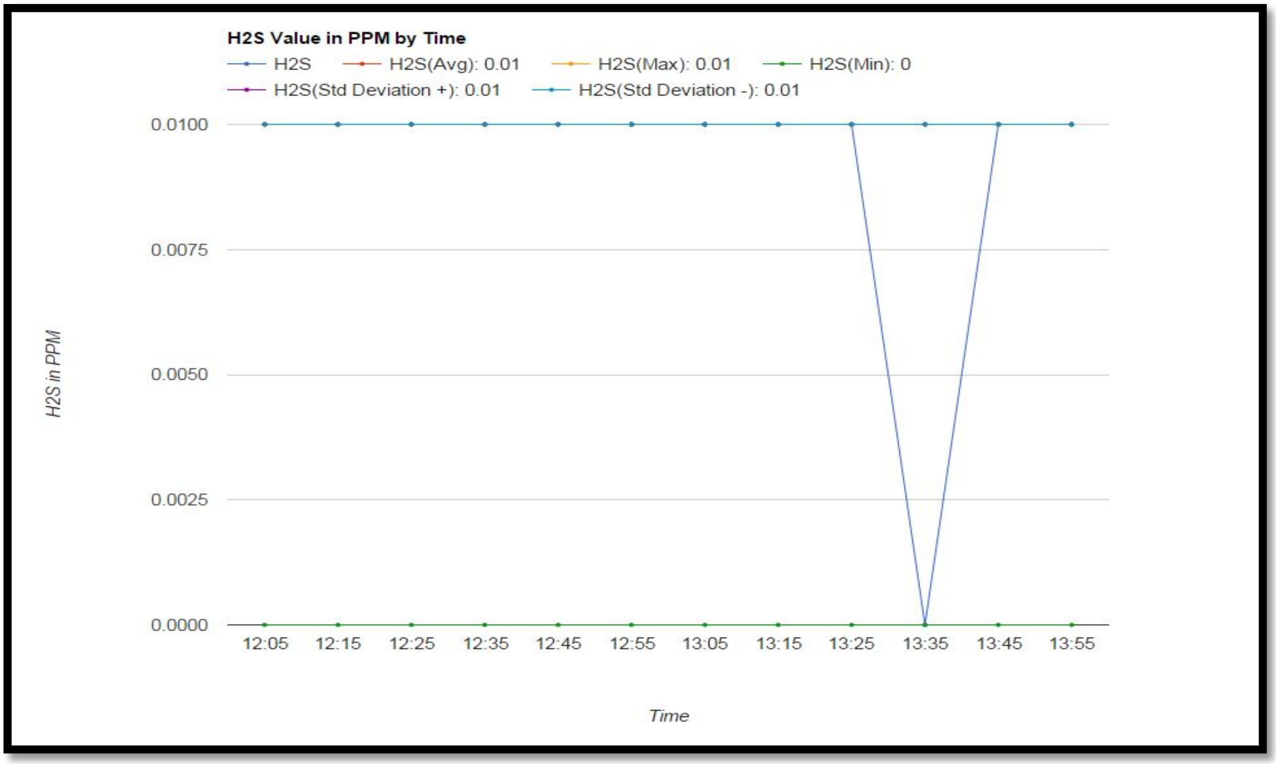

Figure A-77: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 7

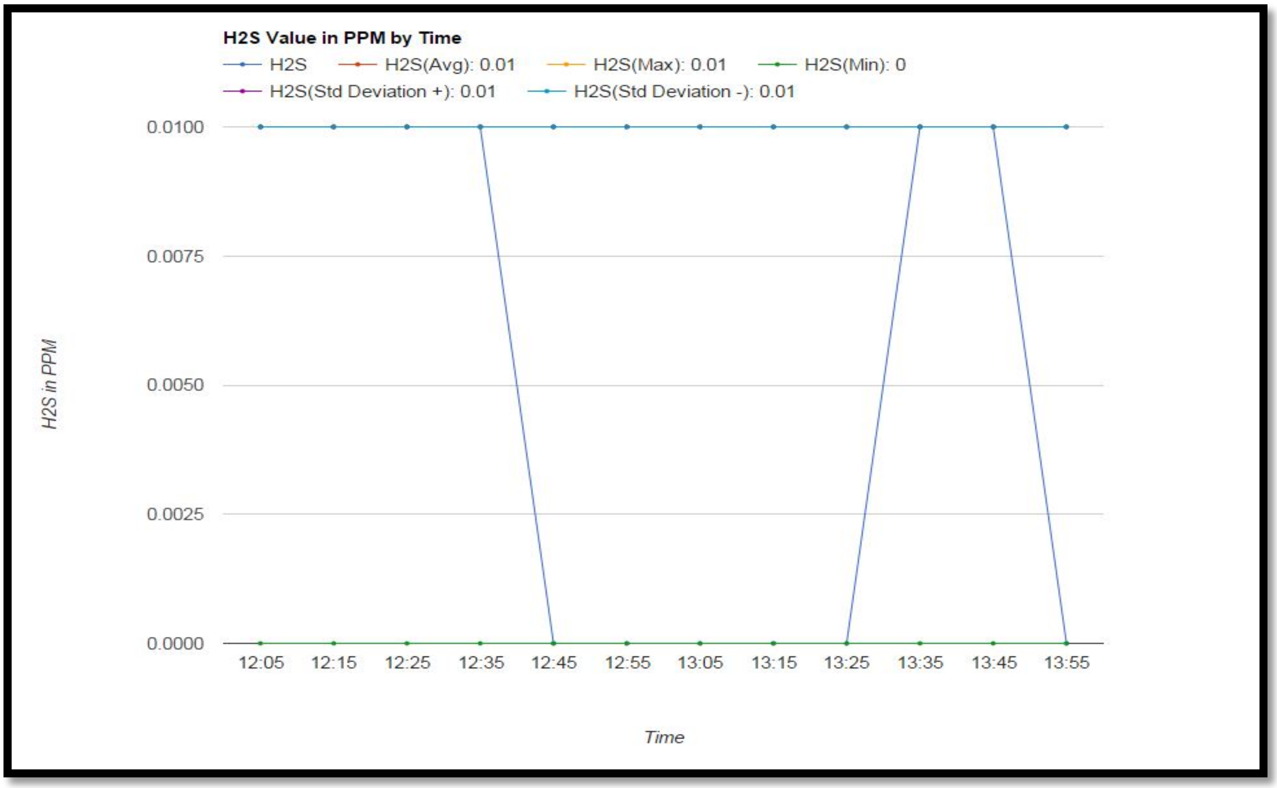

Figure A-78: Average Hourly Analysis for 10-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 8

Figure A-79: Average Hourly Analysis for 10-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 1

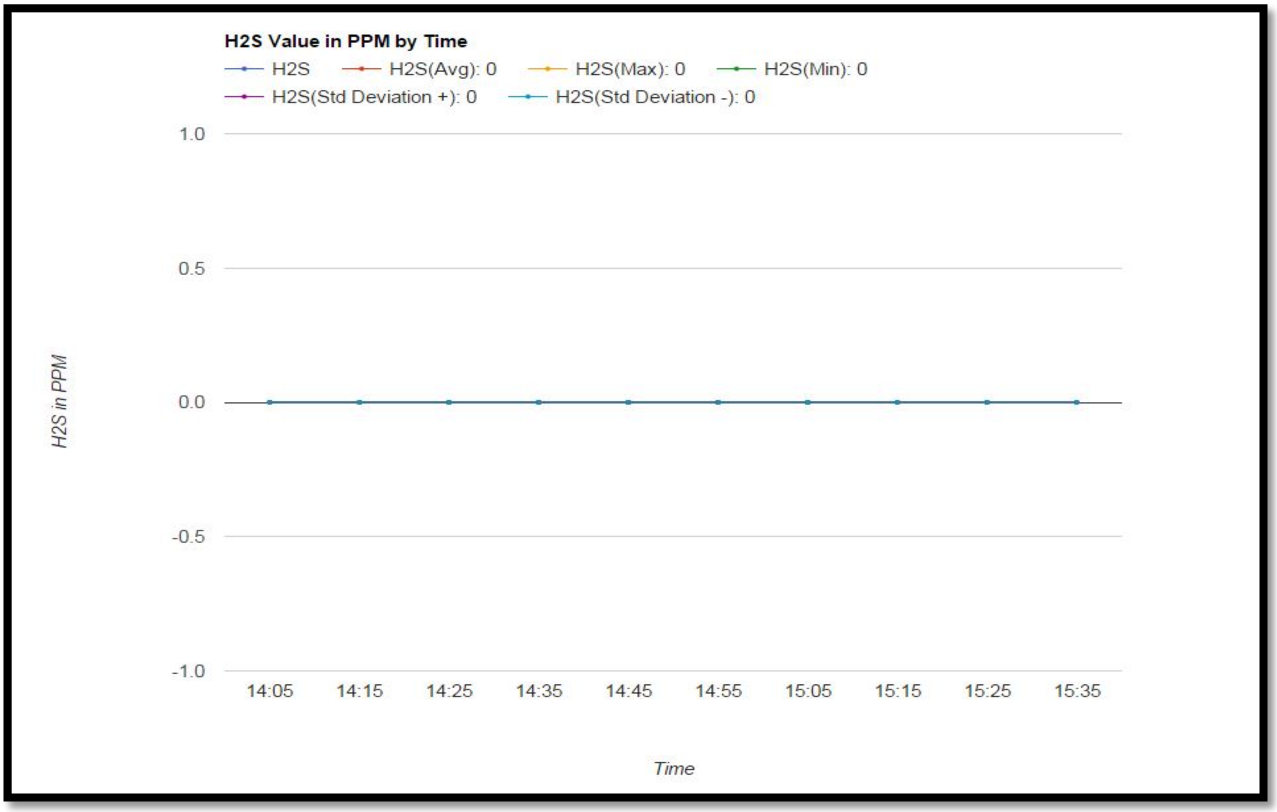

Figure A-80: Average Hourly Analysis for 10-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 2

Figure A-81: Average Hourly Analysis for 10-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 3

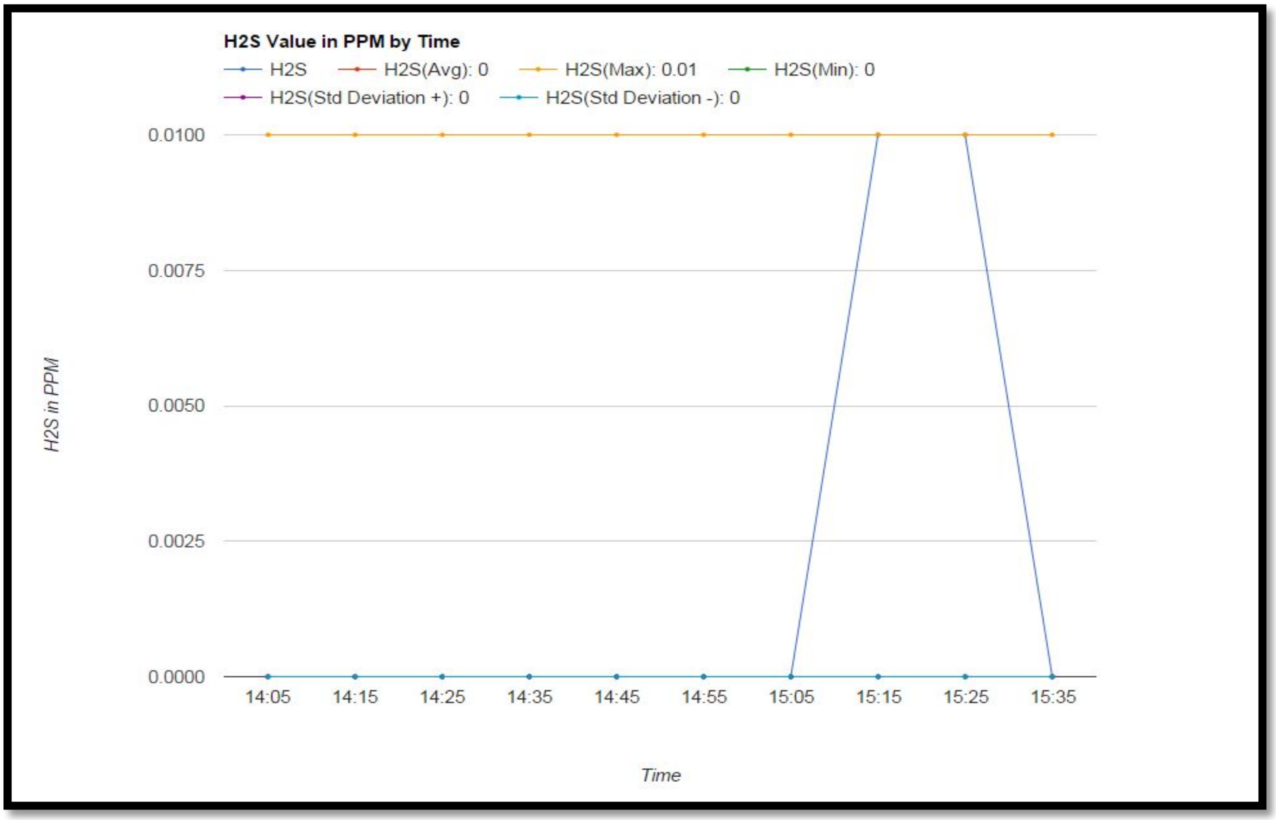

Figure A-82: Average Hourly Analysis for 10-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 4

Figure A-83: Average Hourly Analysis for 10=Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 5

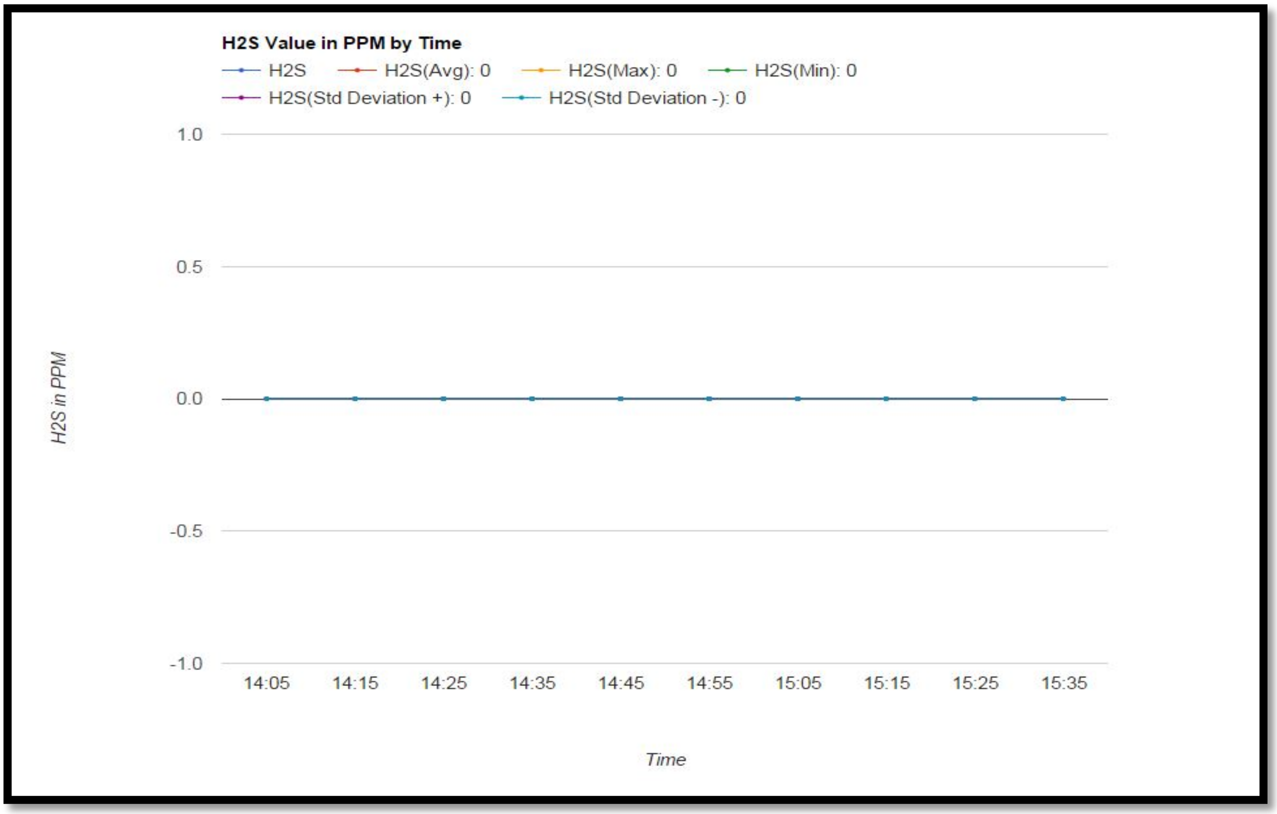

Figure A-84: Average Hourly Analysis for 10-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 6

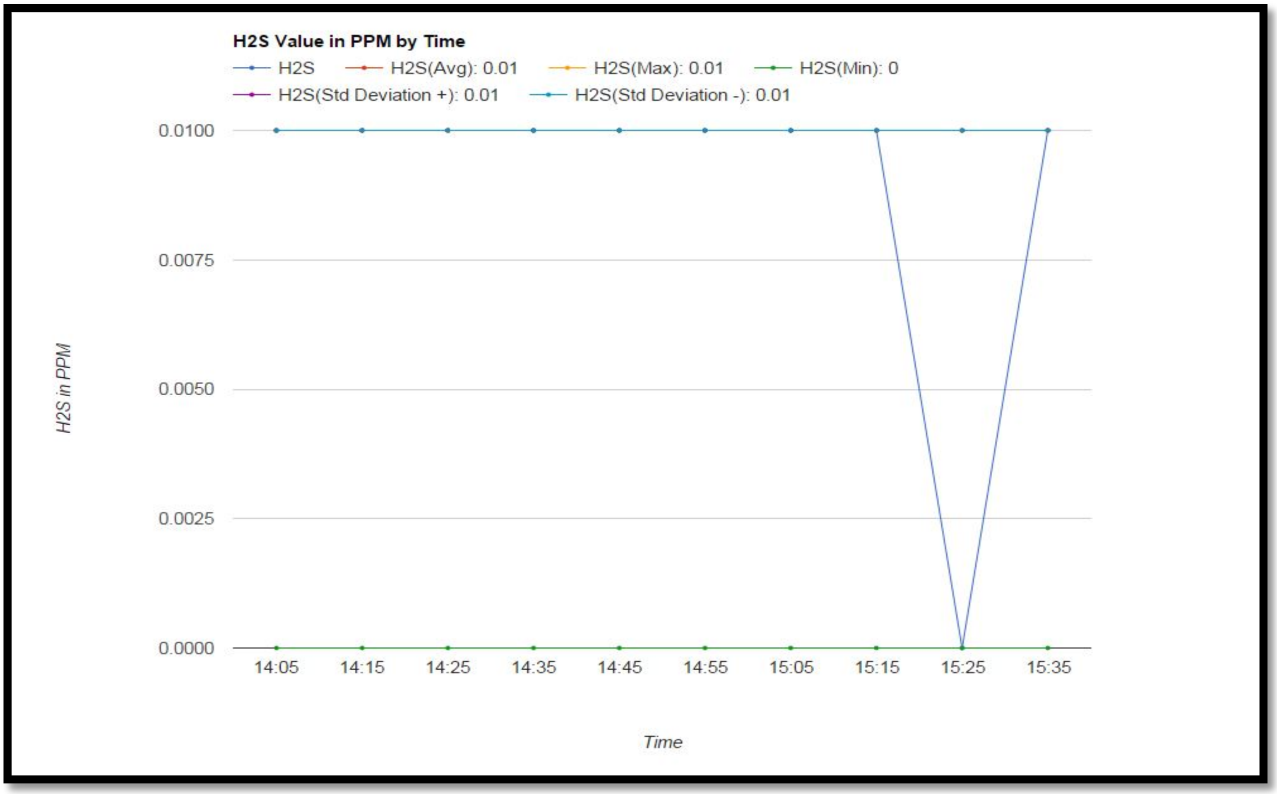

Figure A-85: Average Hourly Analysis for 10-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 7

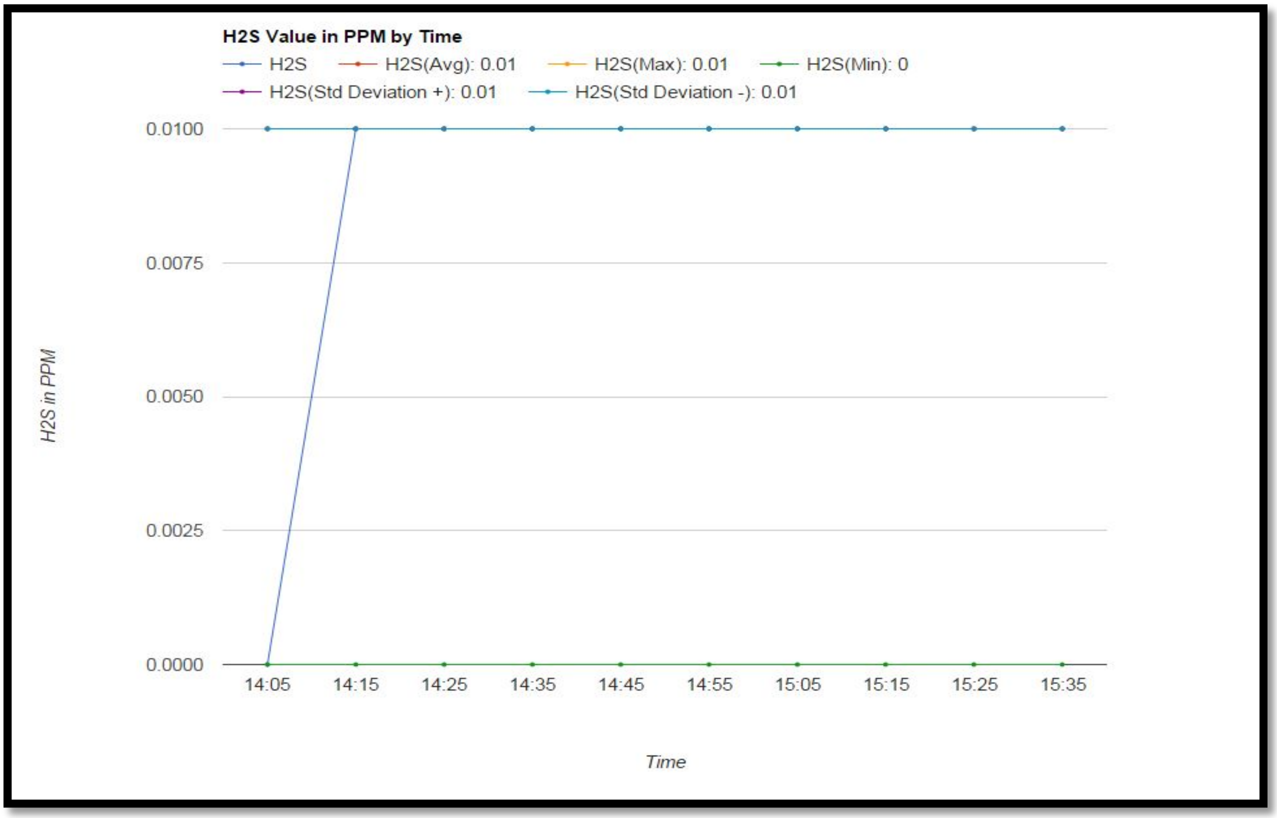

Figure A-86: Average Hourly Analysis for 10-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 8

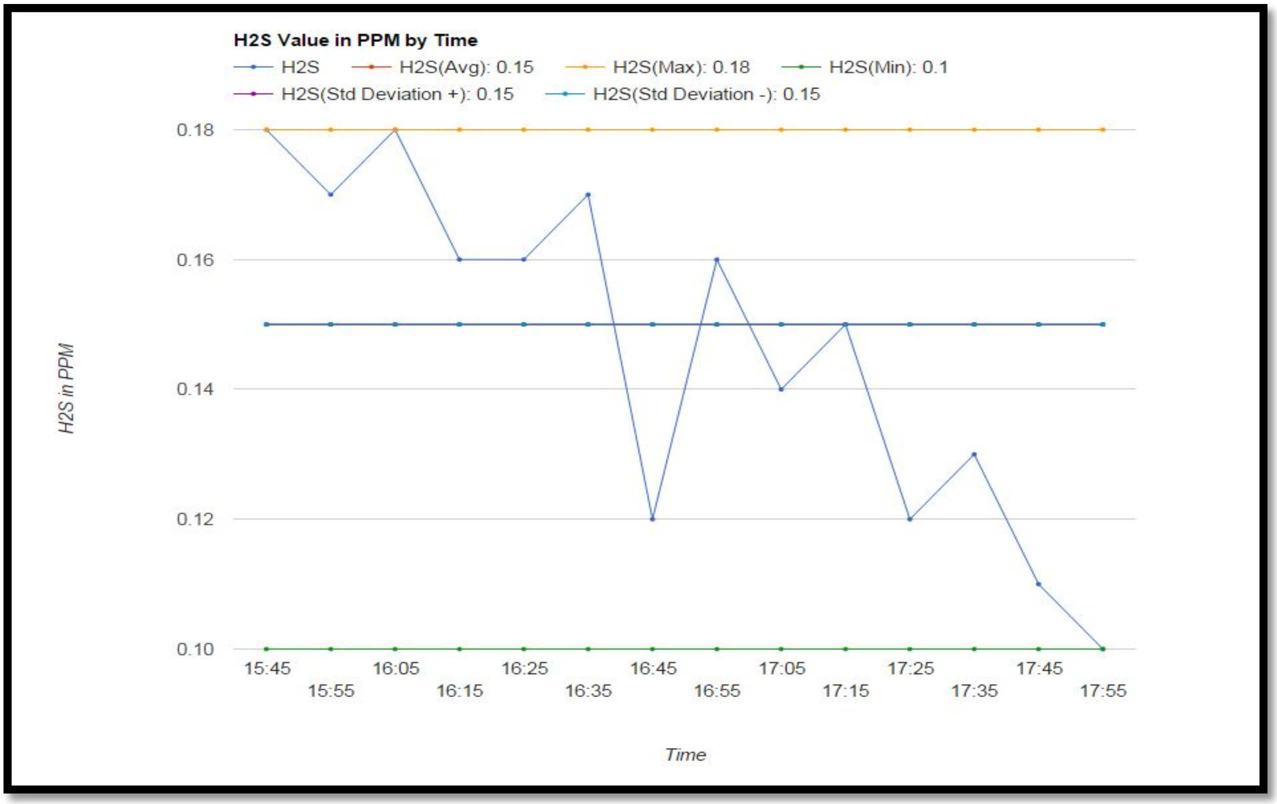

Figure A-87: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 1

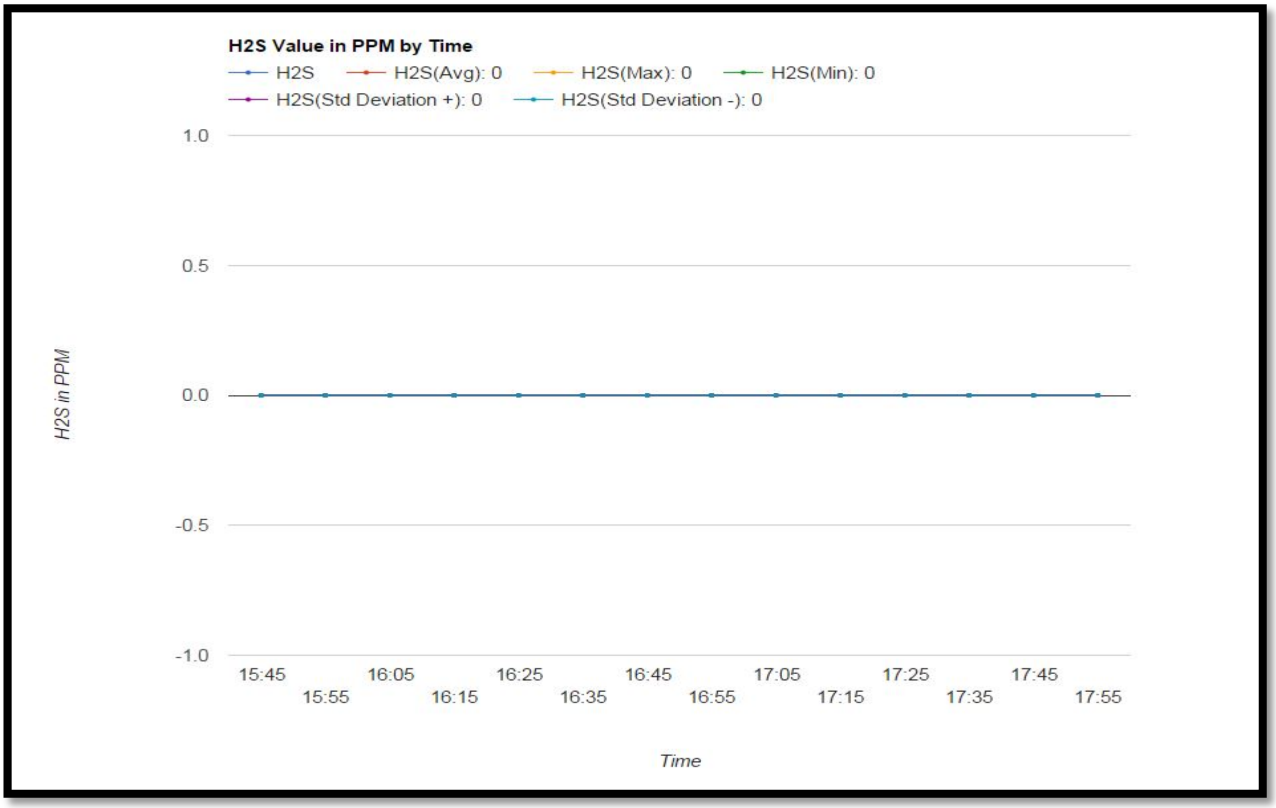

Figure A-88: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 2

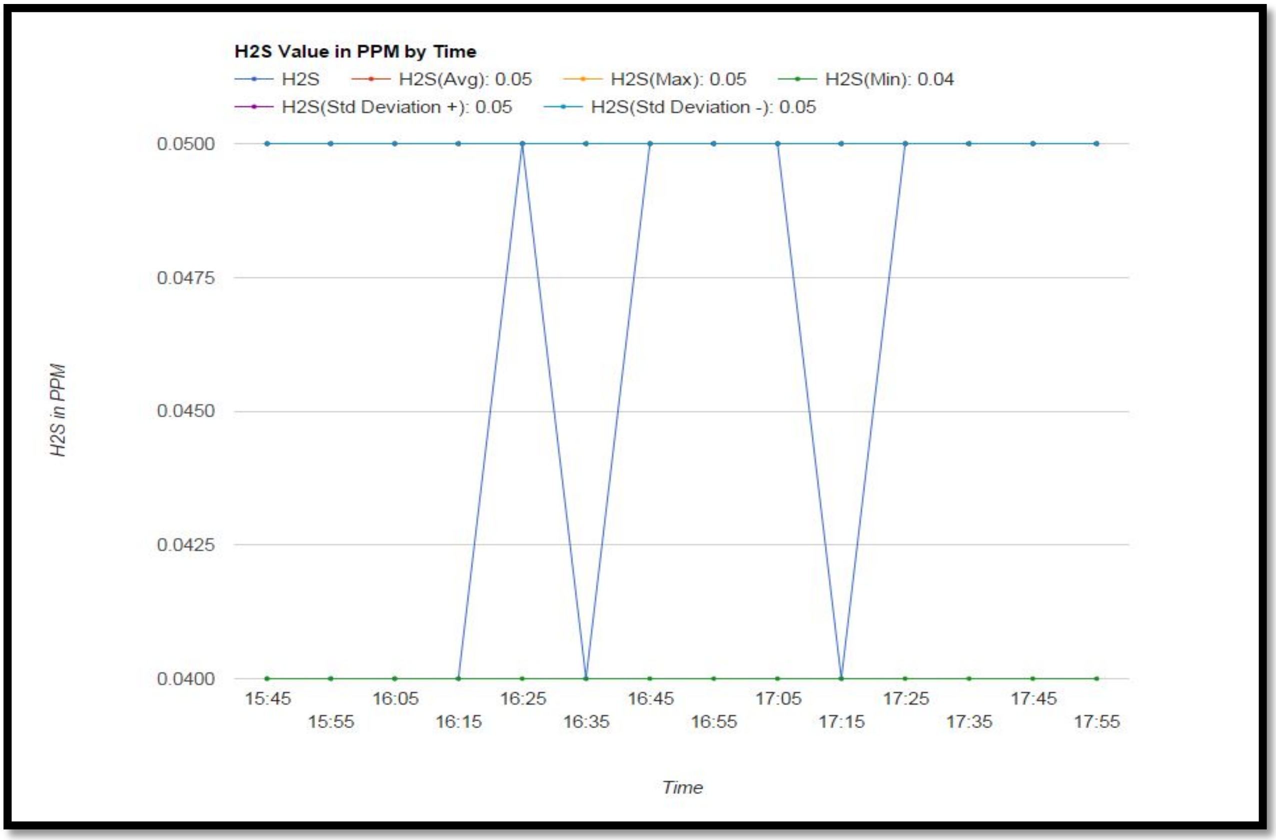

Figure A-89: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 3

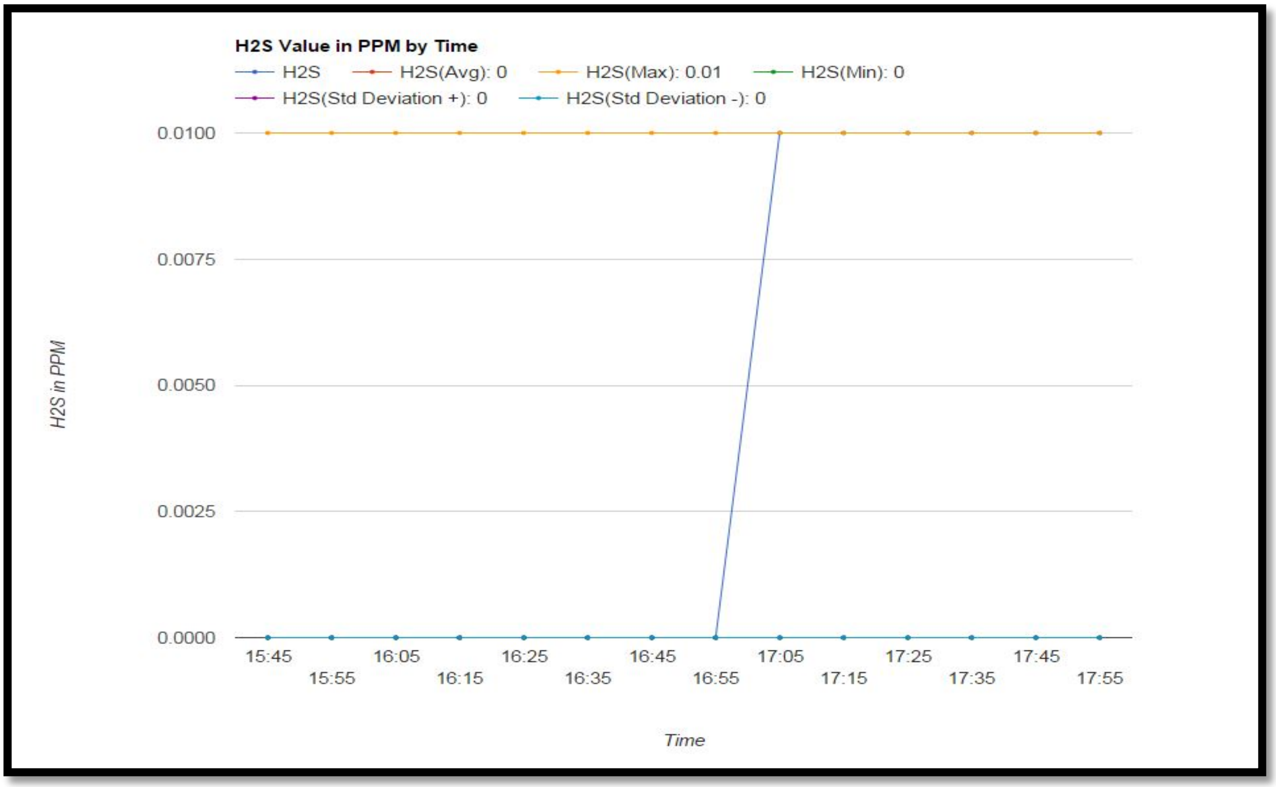

Figure A-90: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 4

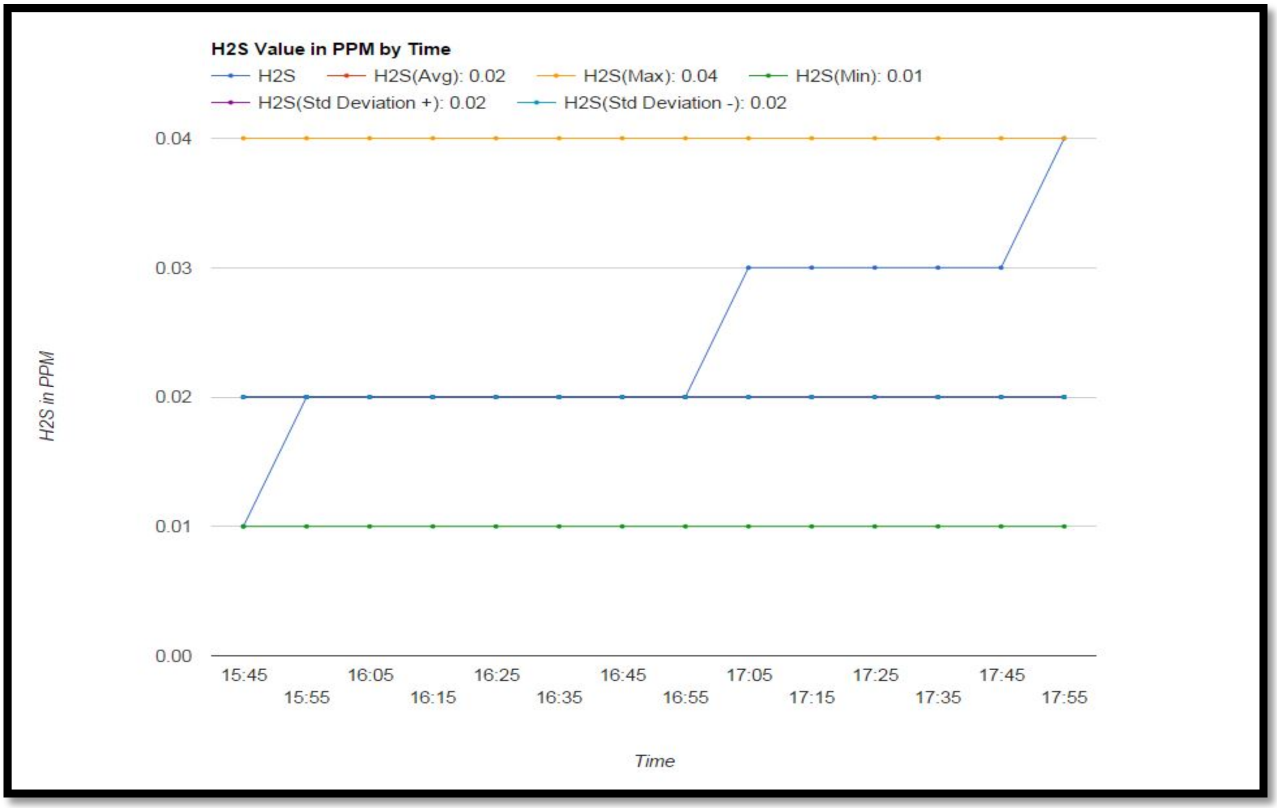

Figure A-91: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 5

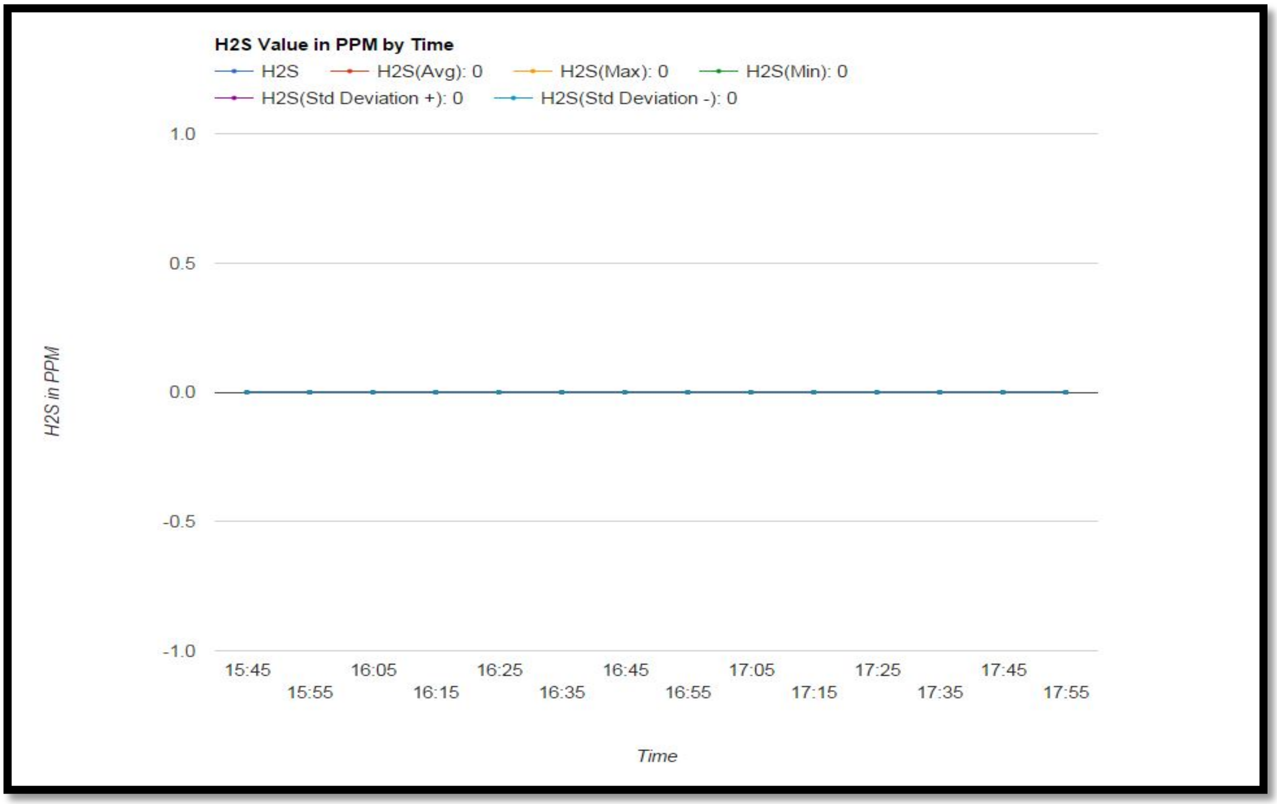

Figure A-92: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 6

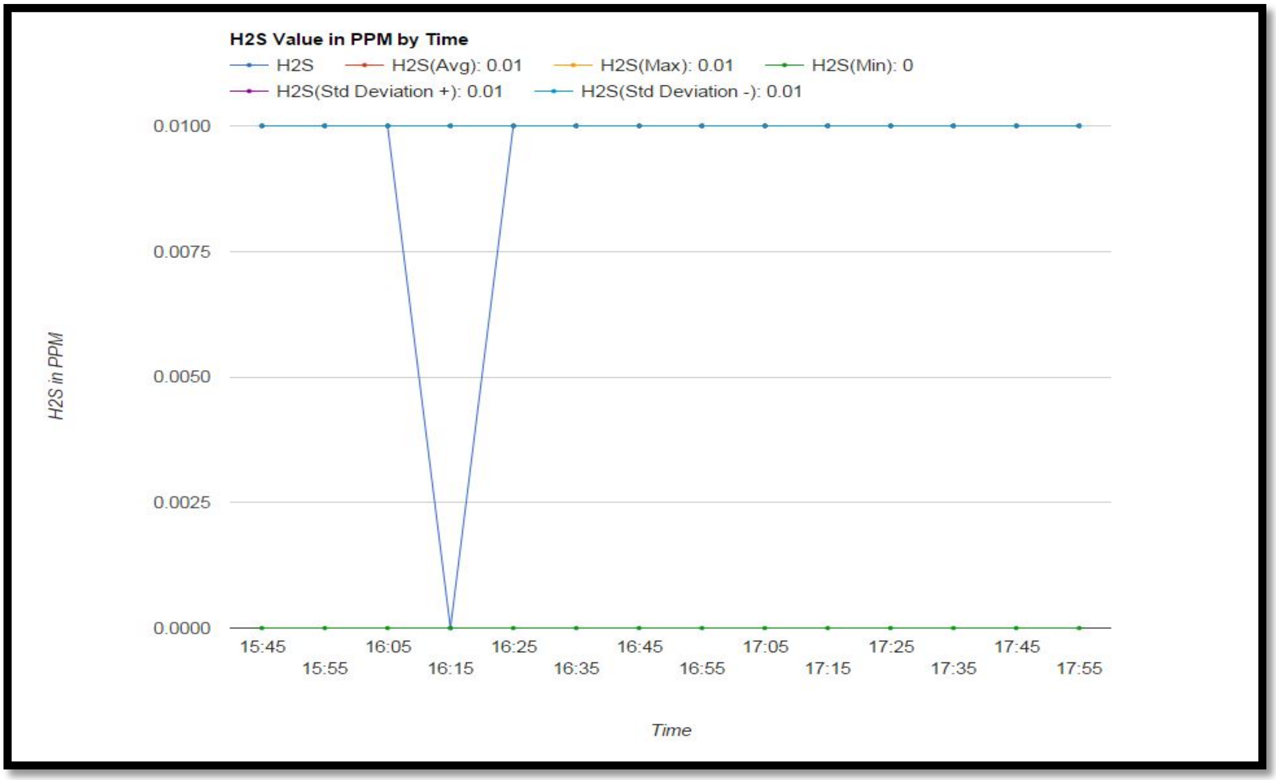

Figure A-93: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 7

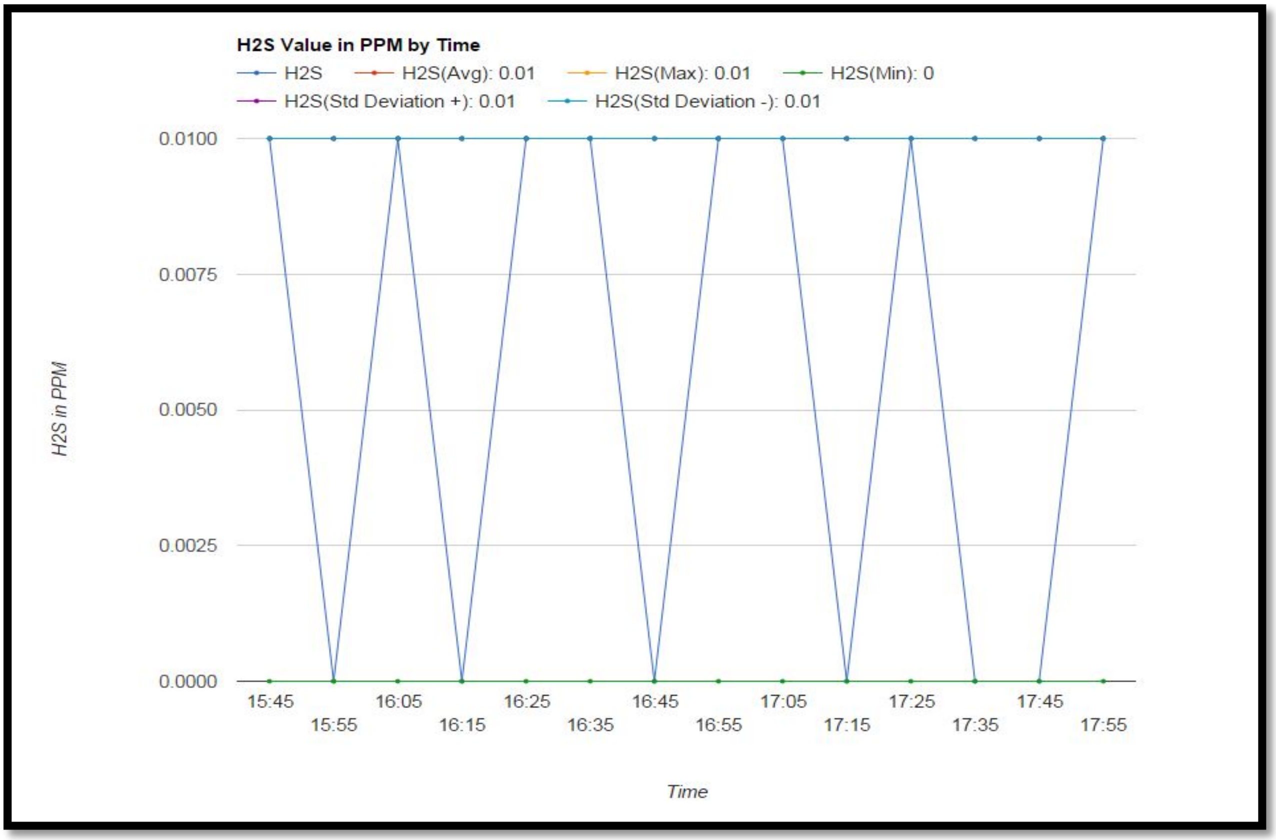

Figure A-94: Average Hourly Analysis for 10-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 8

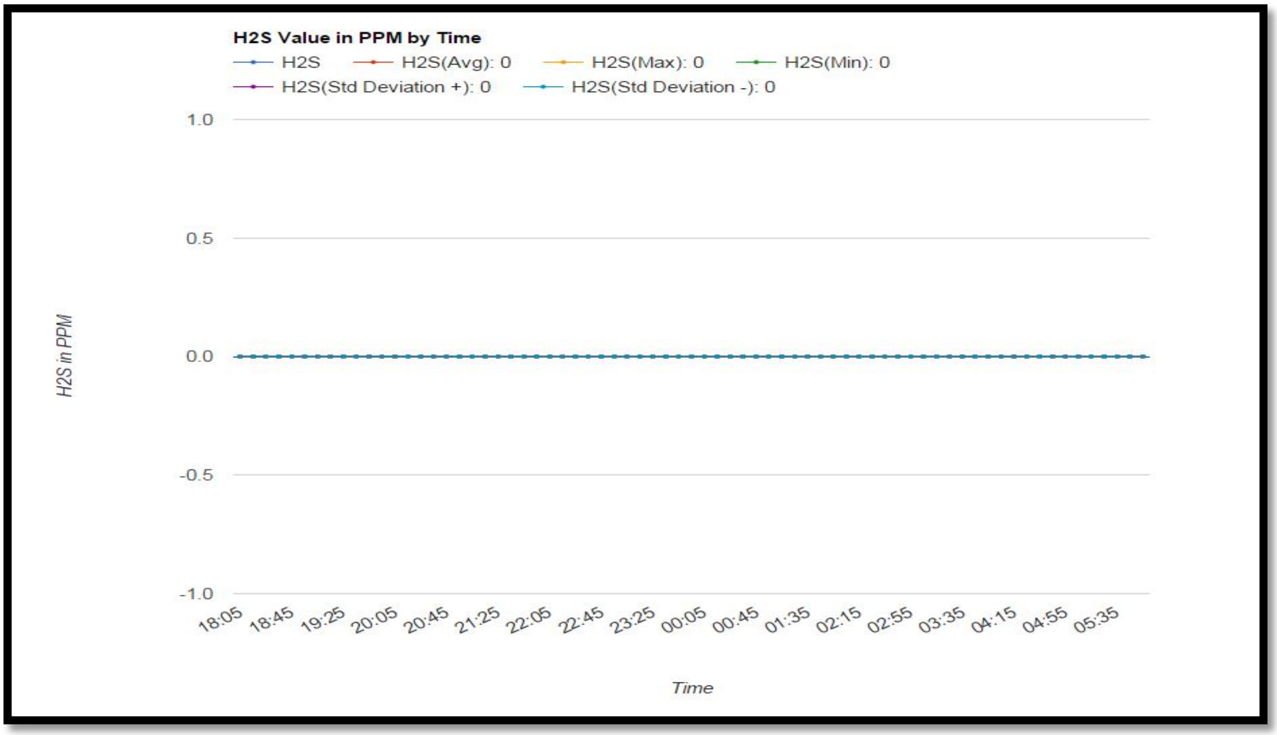

Figure A-95: Average Hourly Analysis for 10-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 2

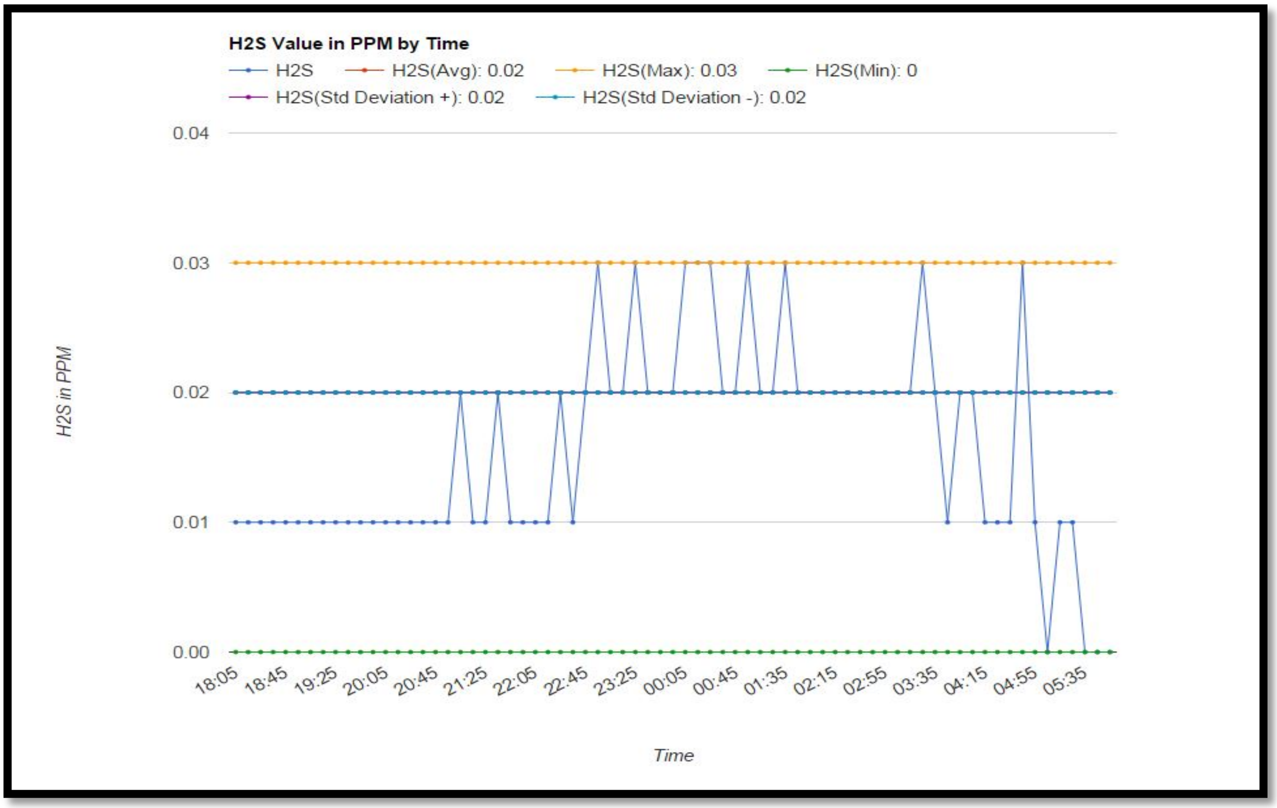

Figure A-96: Average Hourly Analysis for 10-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 4

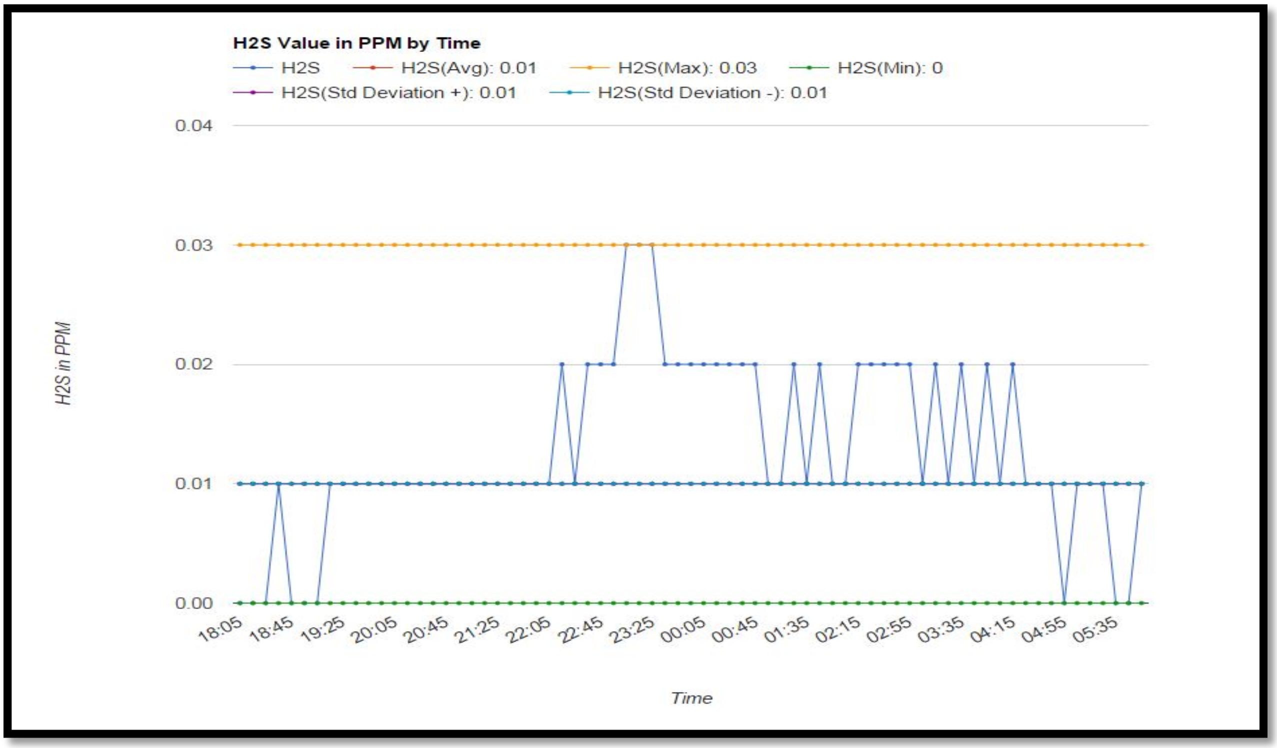

Figure A-97: Average Hourly Analysis for 10-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 6

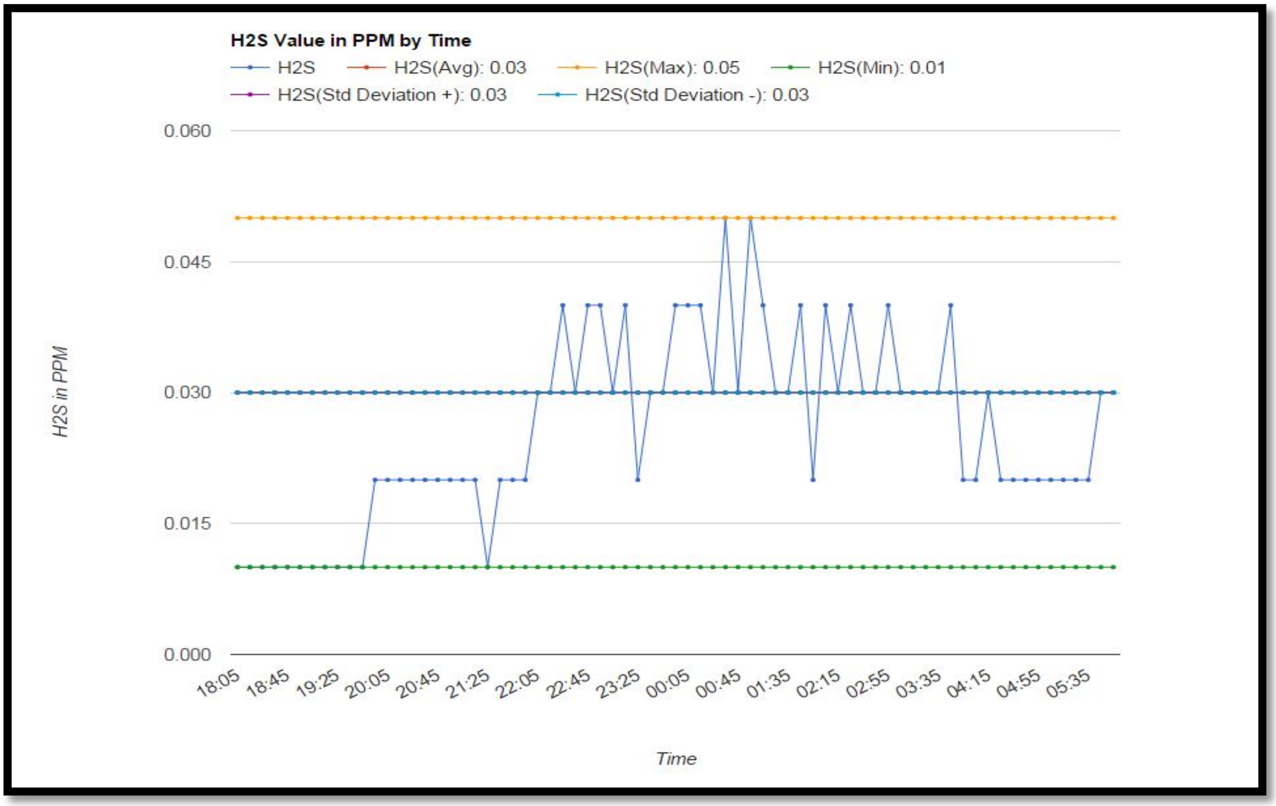

Figure A-98: Average Hourly Analysis for 10-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 7

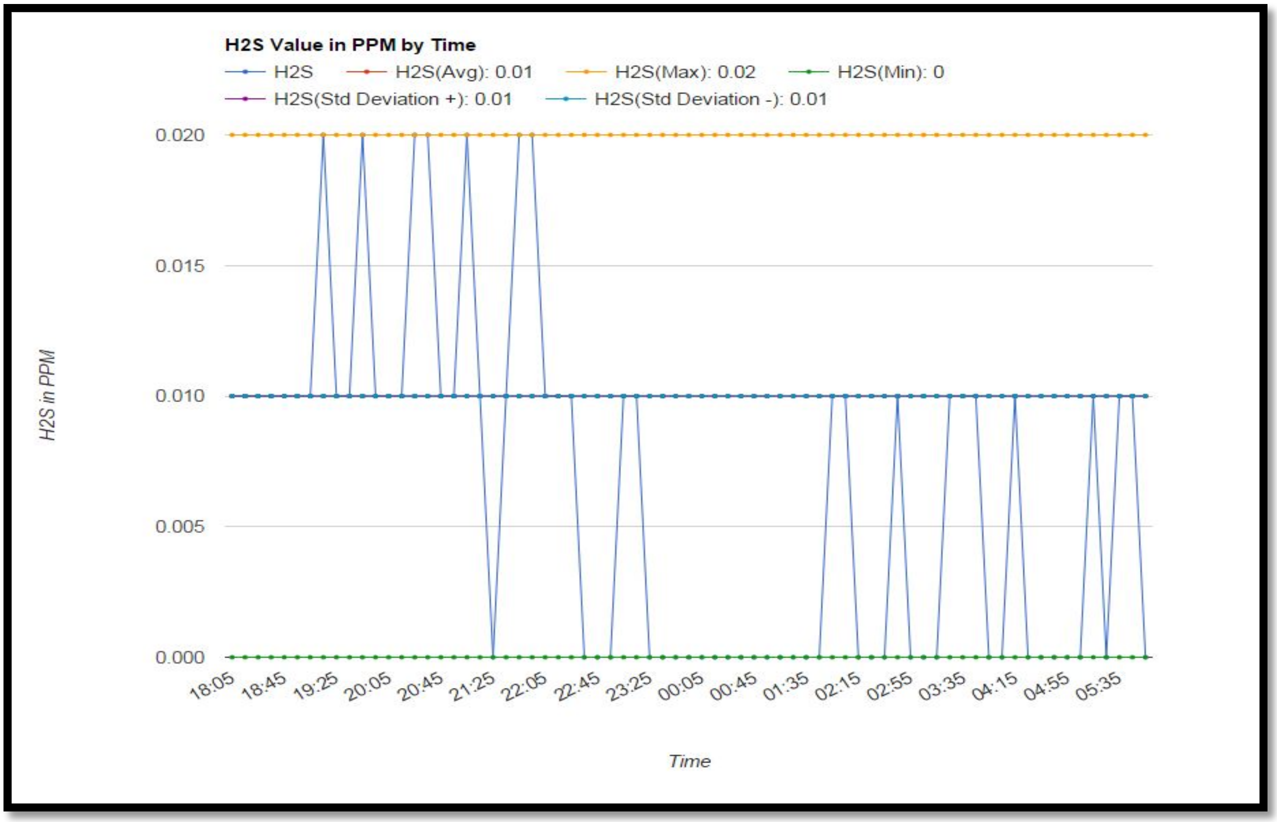

Figure A-99: Average Hourly Analysis for 10-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 8

Figure A-100: Average Hourly Analysis for 30-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 1

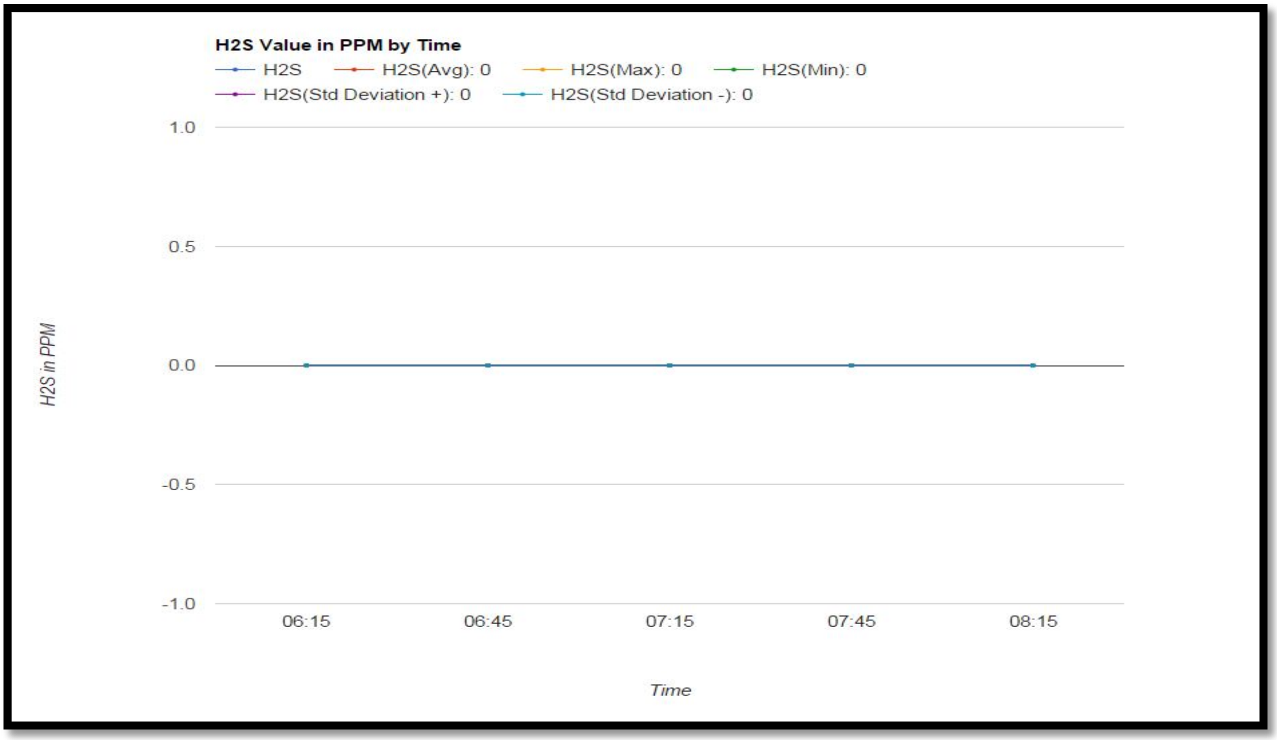

Figure A-101: Average Hourly Analysis for 30-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 2

Figure A-102: Average Hourly Analysis for 30-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 4

Figure A-103: Average Hourly Analysis for 30-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 6

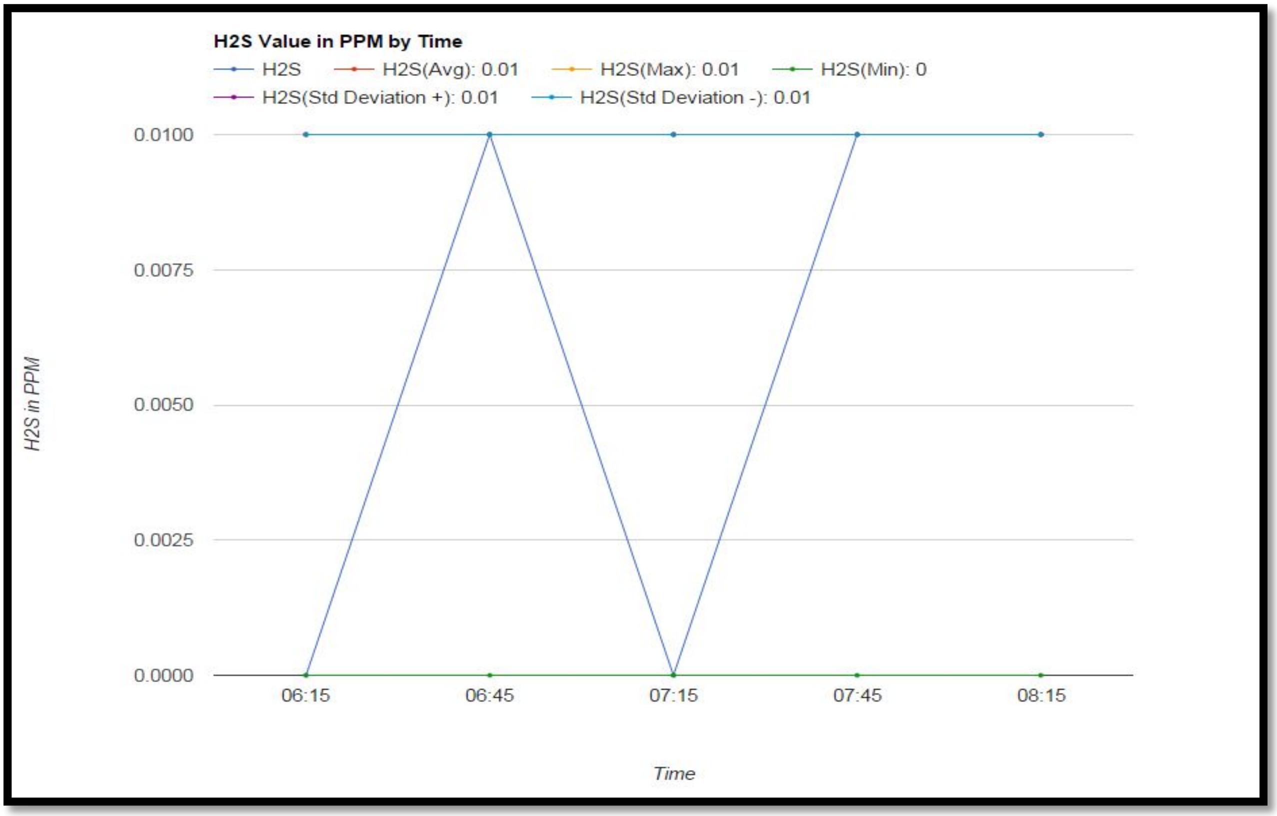

Figure A-104: Average Hourly Analysis for 30-Minute Intervals (6:00 a.m. – 8:20 a.m.) – Site 8

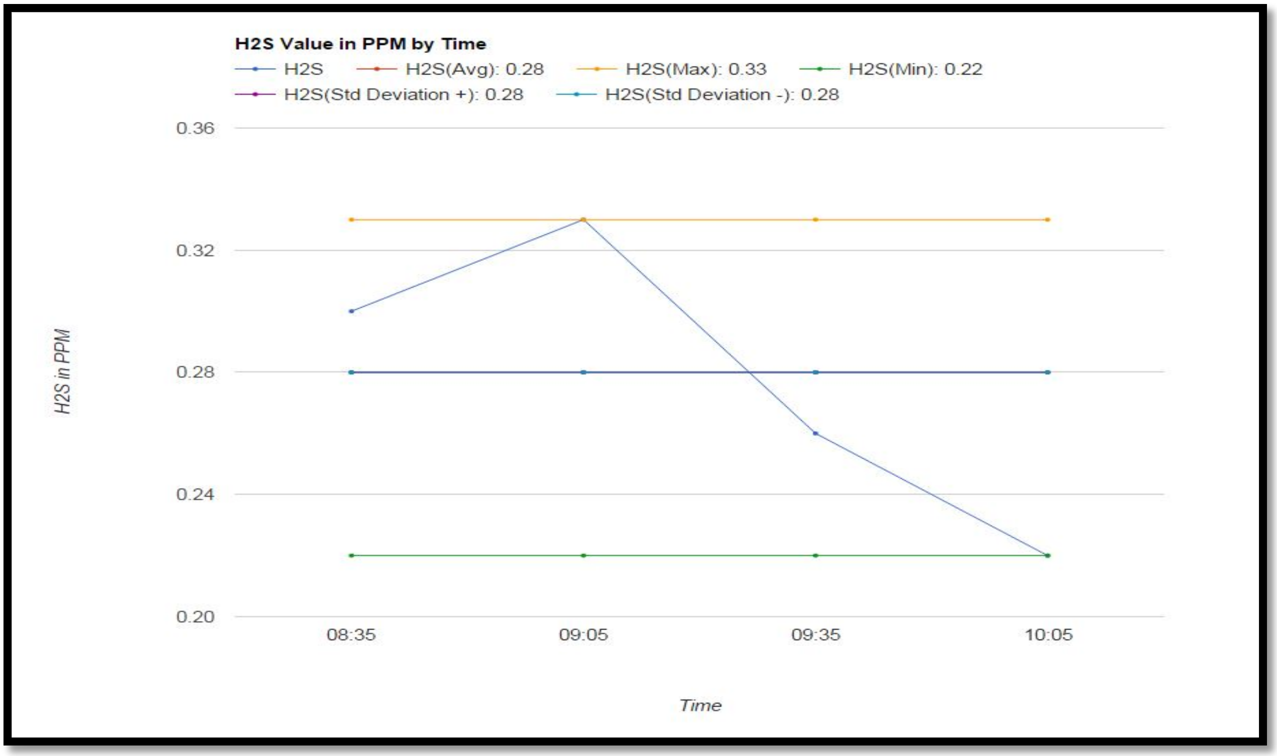

Figure A-105: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.)– Site 1

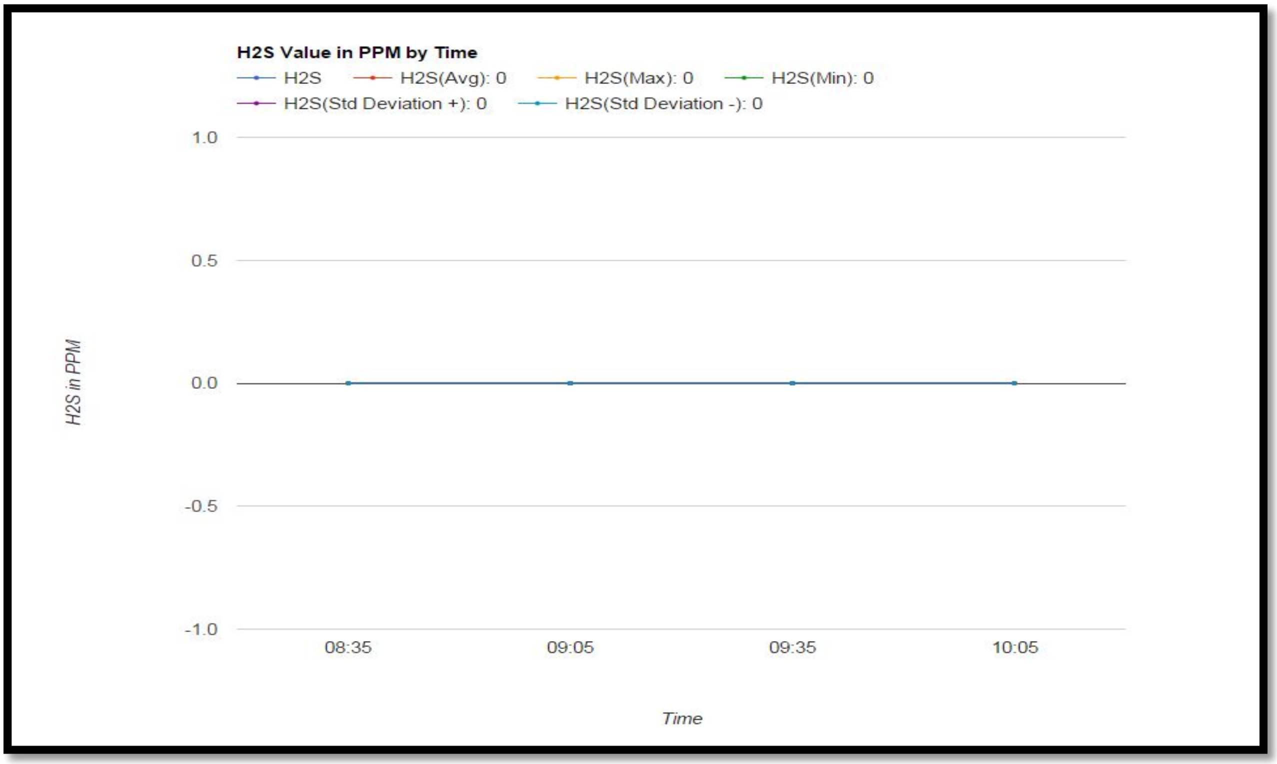

Figure A-106: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.) – Site 2

Figure A-107: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.)– Site 3

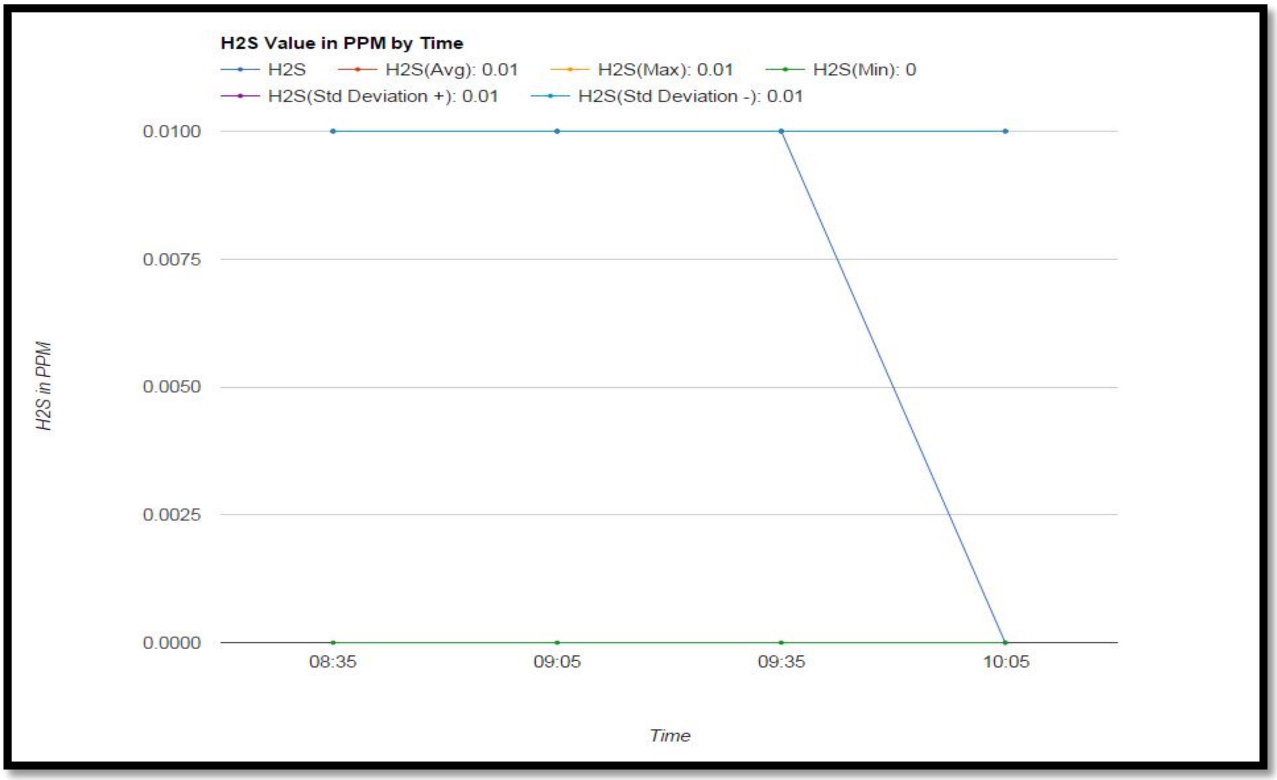

Figure A-108: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.)– Site 4

Figure A-109: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.)– Site 5

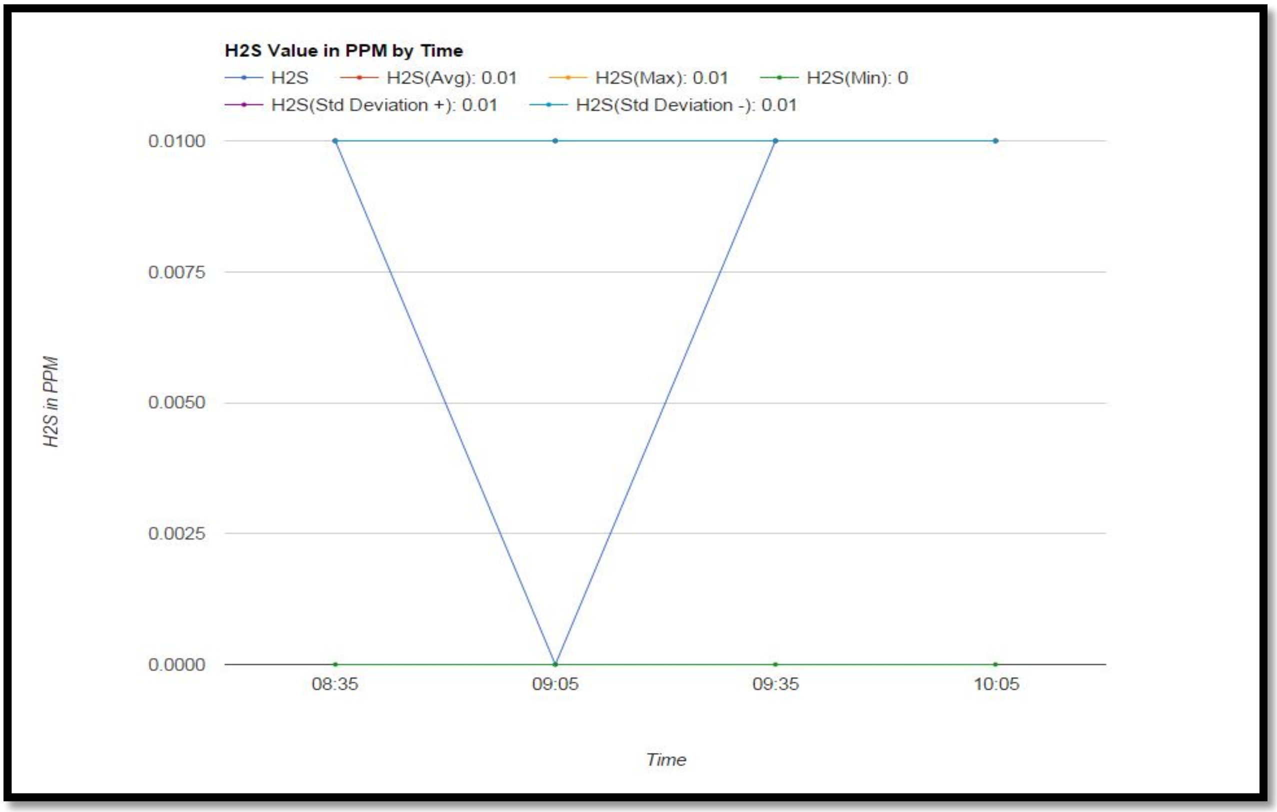

Figure A-110: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.)– Site 6

Figure A-111: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.)– Site 7

Figure A-112: Average Hourly Analysis for 30-Minute Intervals (8:20 a.m. – 10:00 a.m.)– Site 8

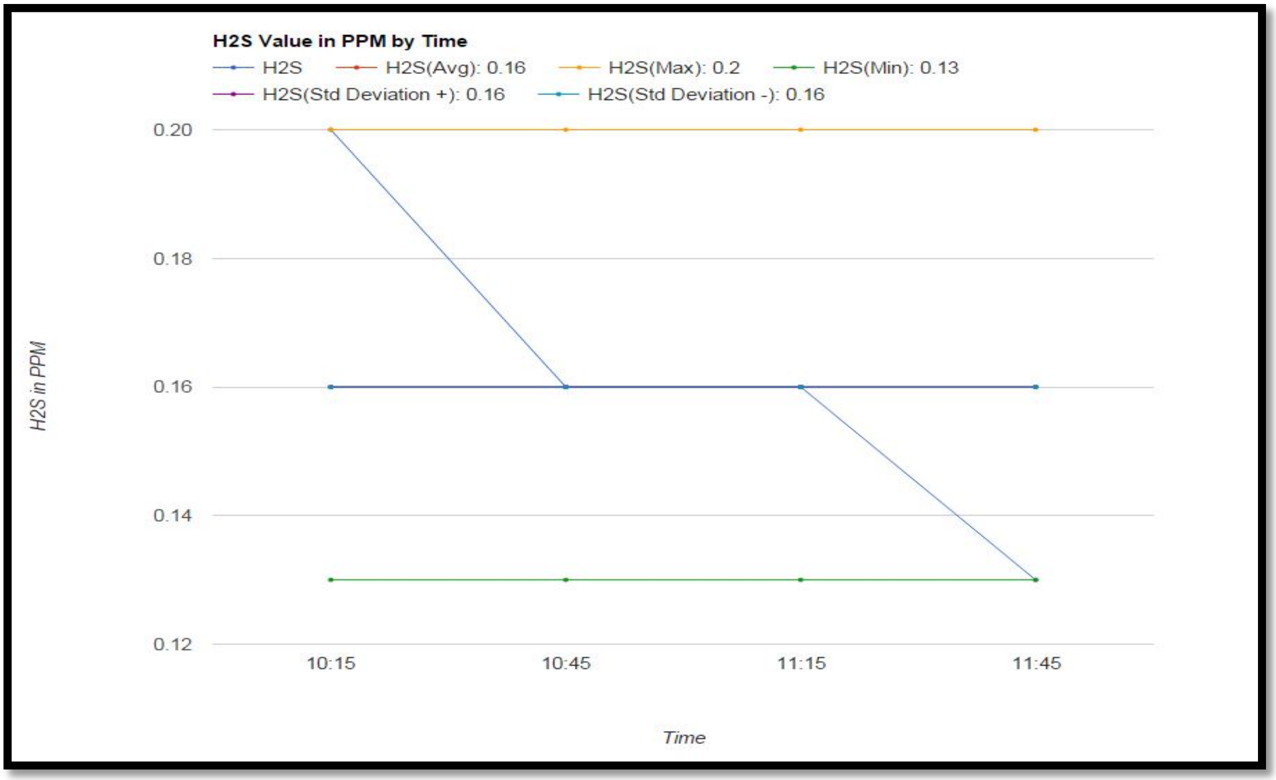

Figure A-113: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 1

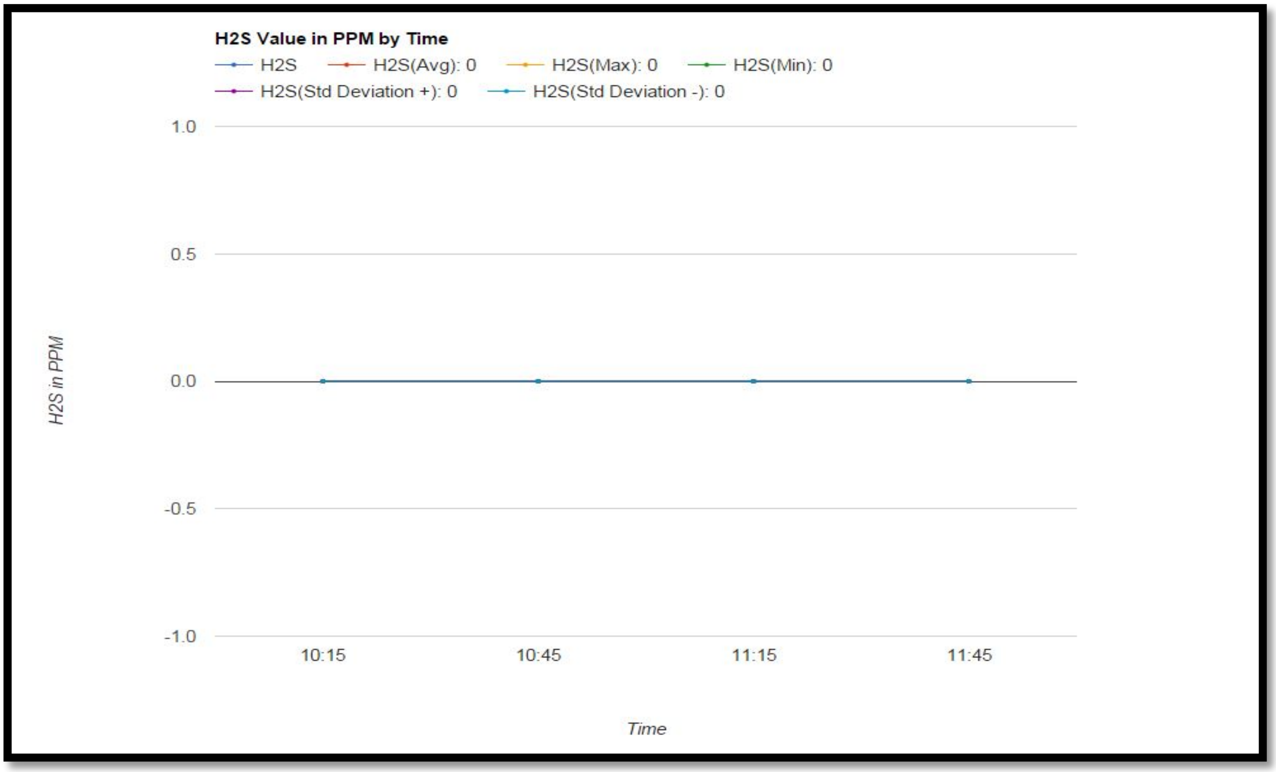

Figure A-114: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 2

Figure A-115: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 3

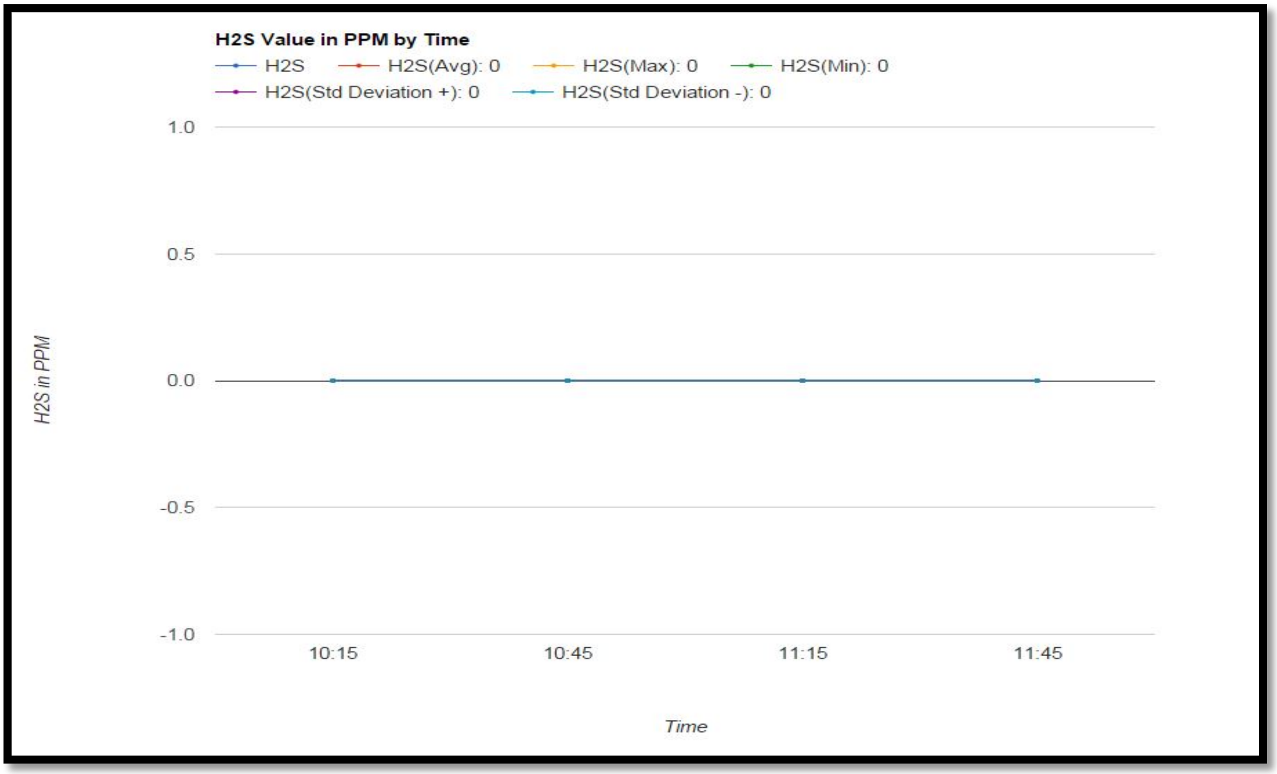

Figure A-116: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 4

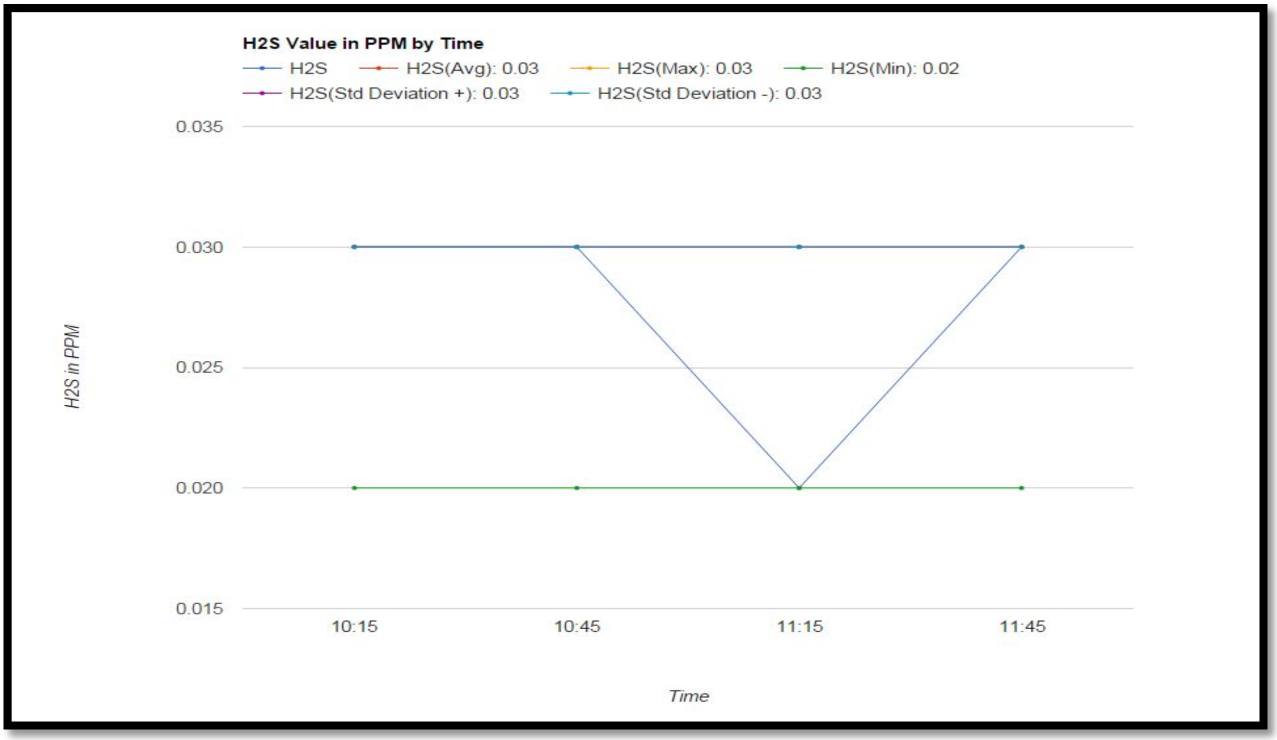

Figure A-117: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 5

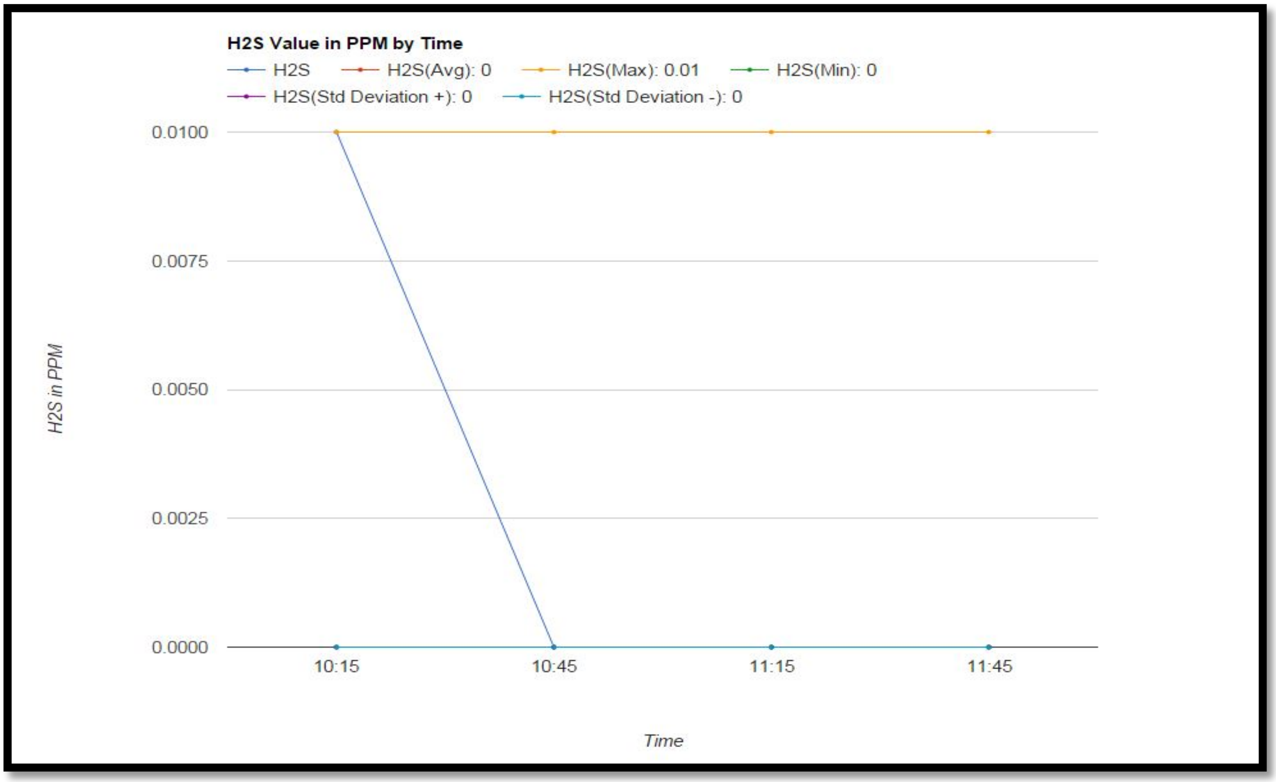

Figure A-118: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 6

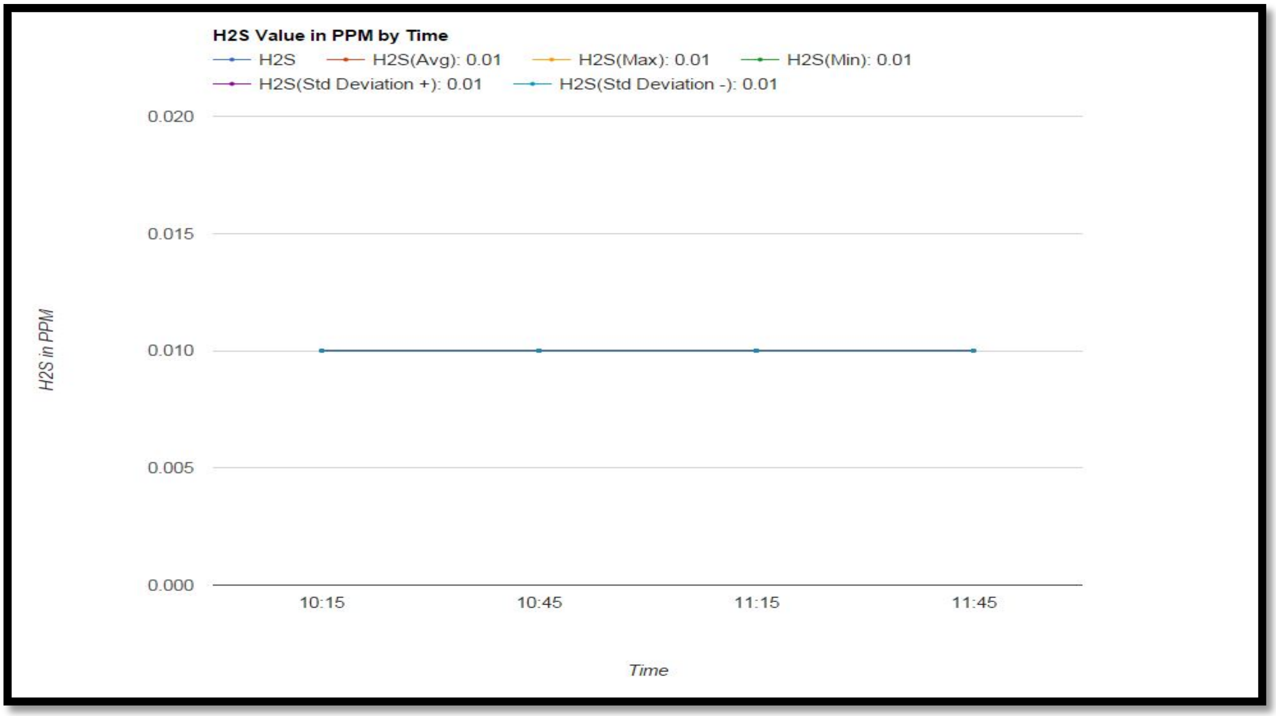

Figure A-119: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 7

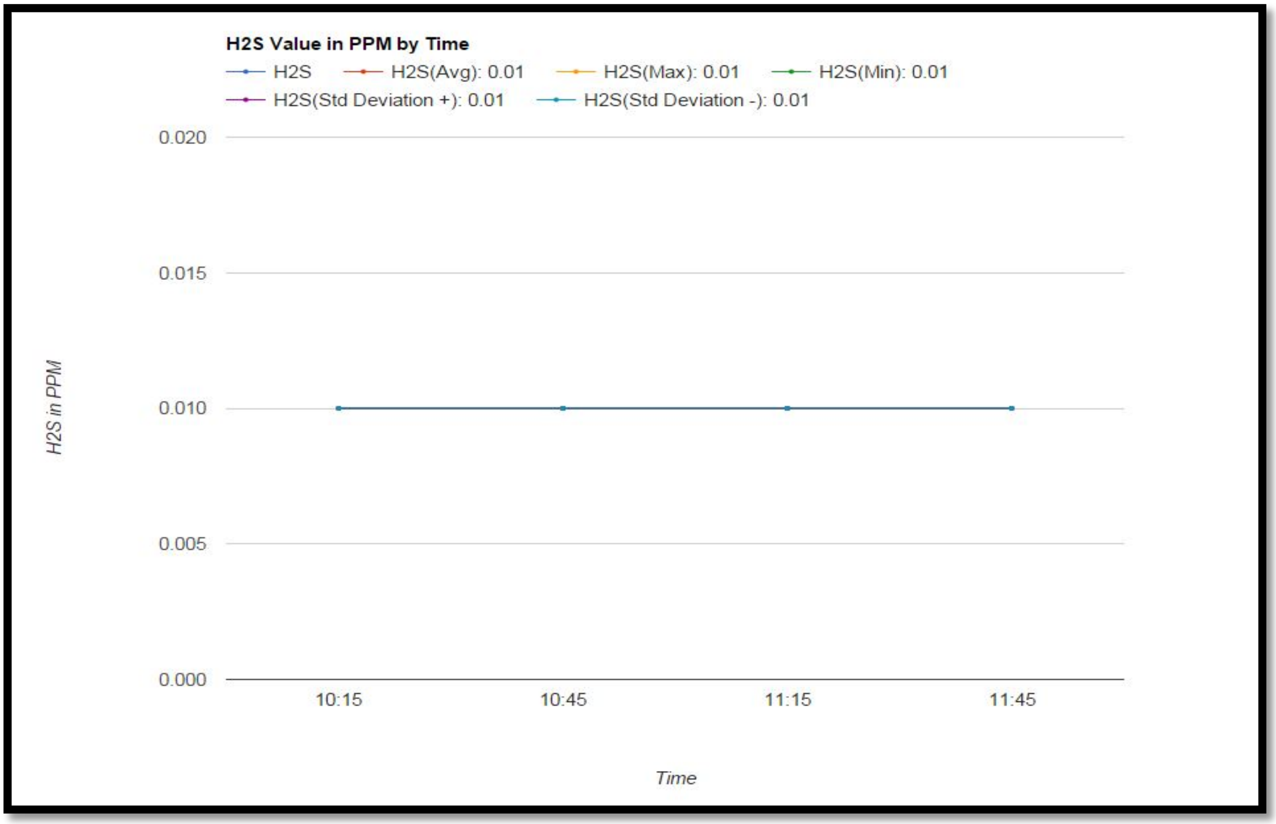

Figure A-120: Average Hourly Analysis for 30-Minute Intervals (10:00 a.m. – 12:00 p.m.) – Site 8

Figure A-121: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 1

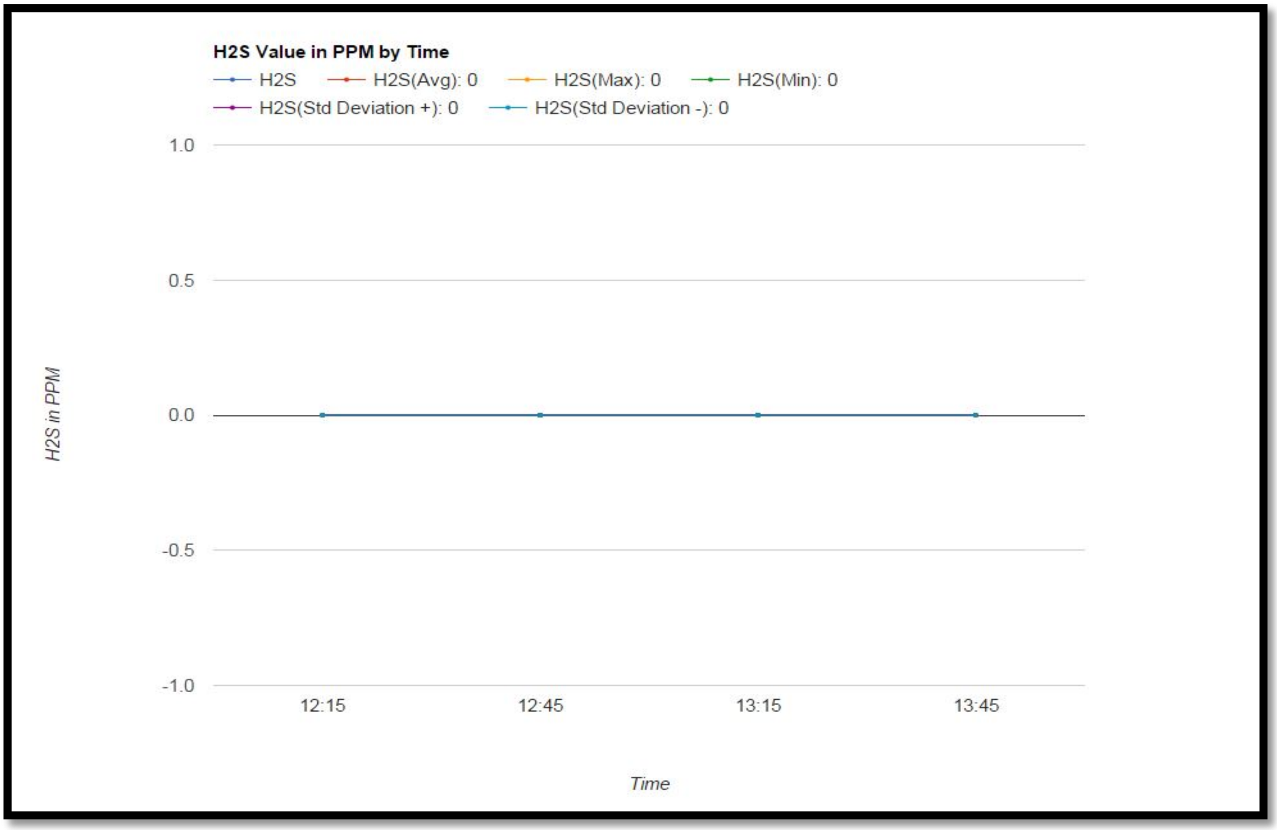

Figure A-122: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 2

Figure A-123: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 3

Figure A-124: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00 p.m.) – Site 4

Figure A-125: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00p.m.)– Site 5

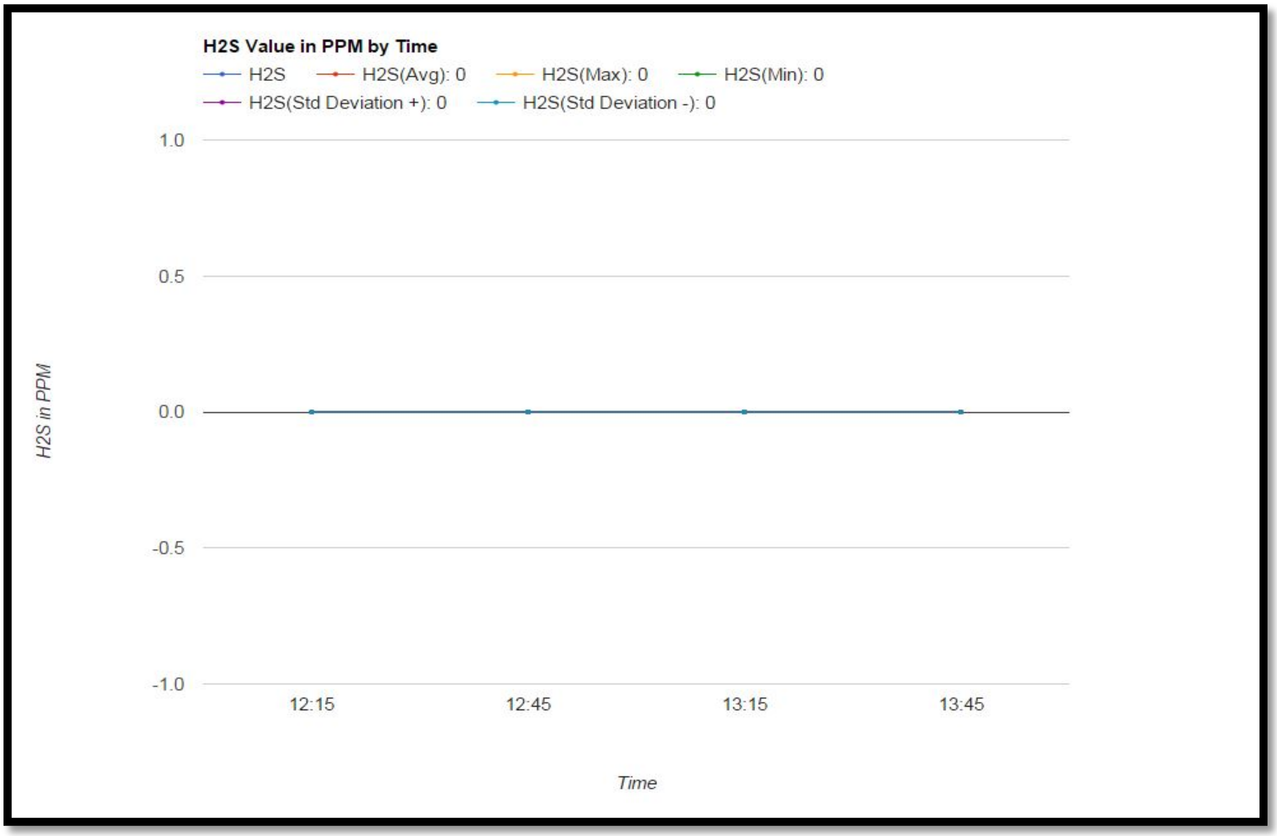

Figure A-126: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00p.m.)– Site 6

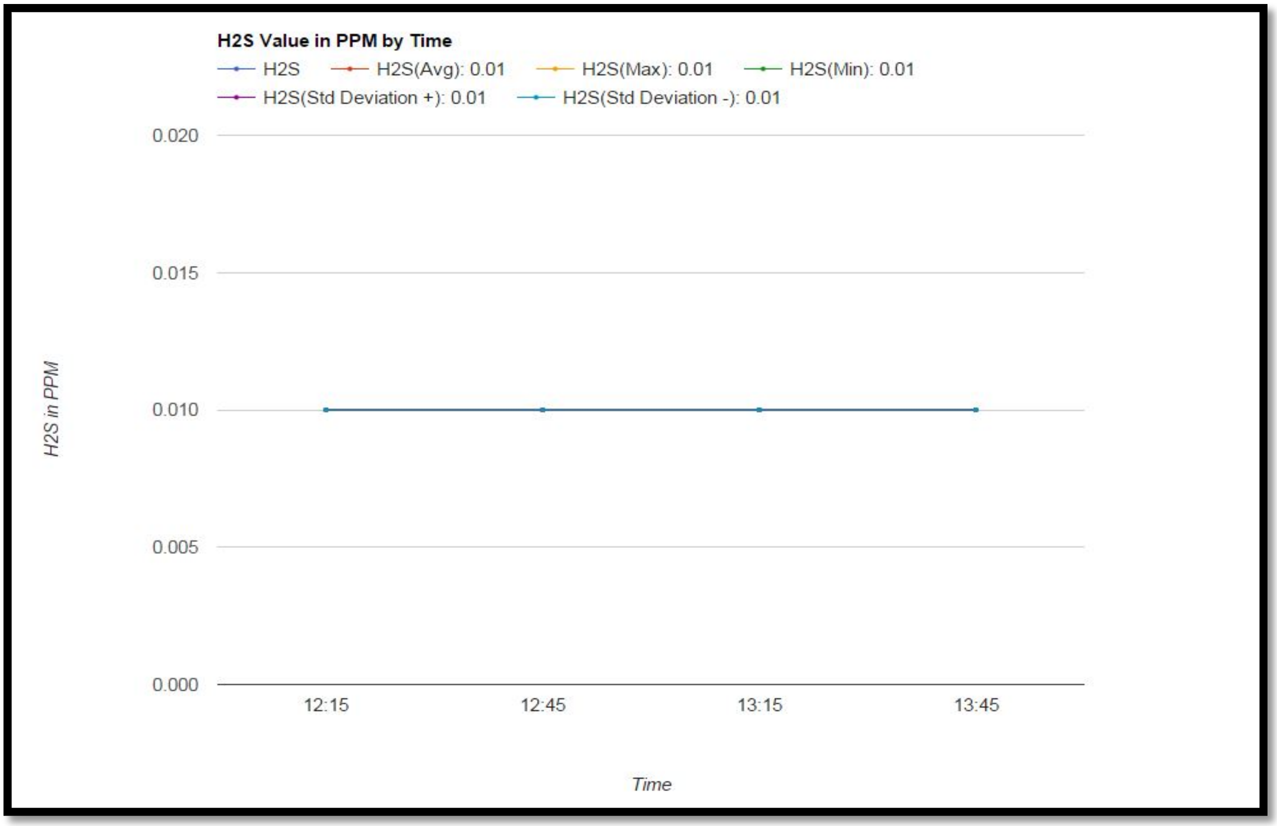

Figure A-127: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00p.m.)– Site 7

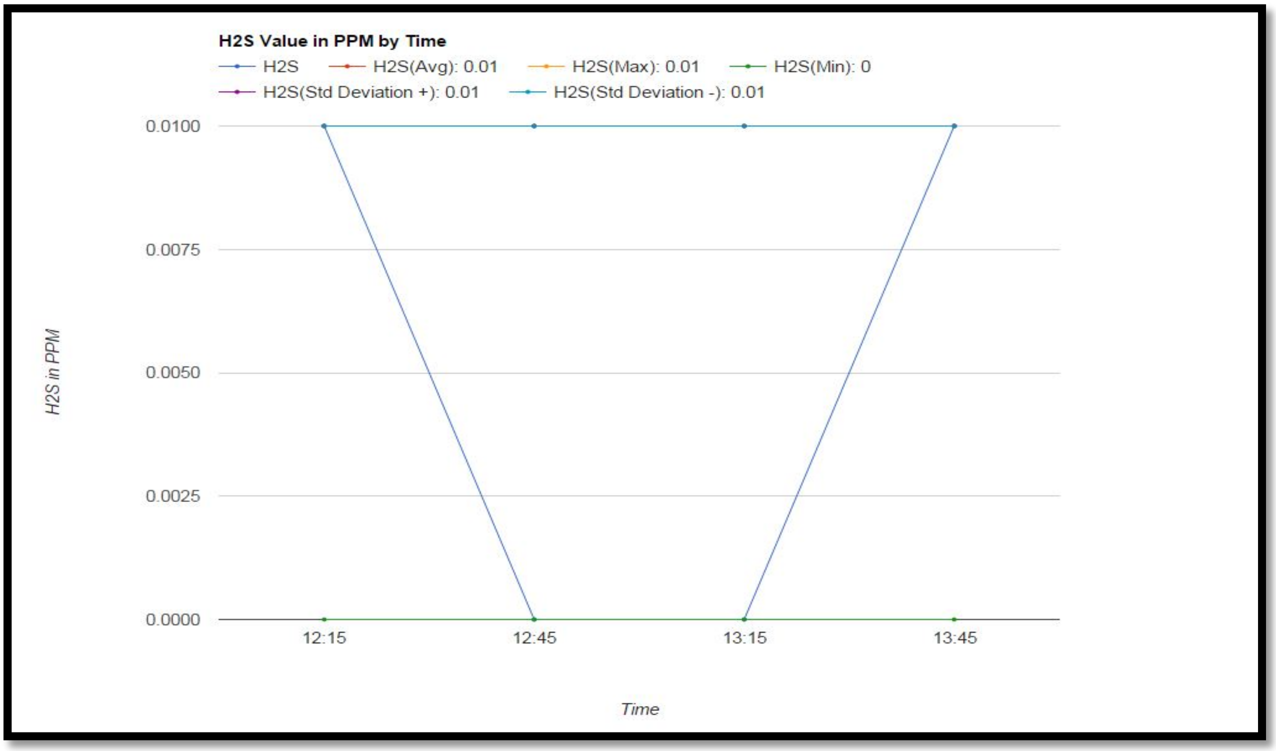

Figure A-128: Average Hourly Analysis for 30-Minute Intervals (12:00 p.m. – 2:00p.m.)– Site 8

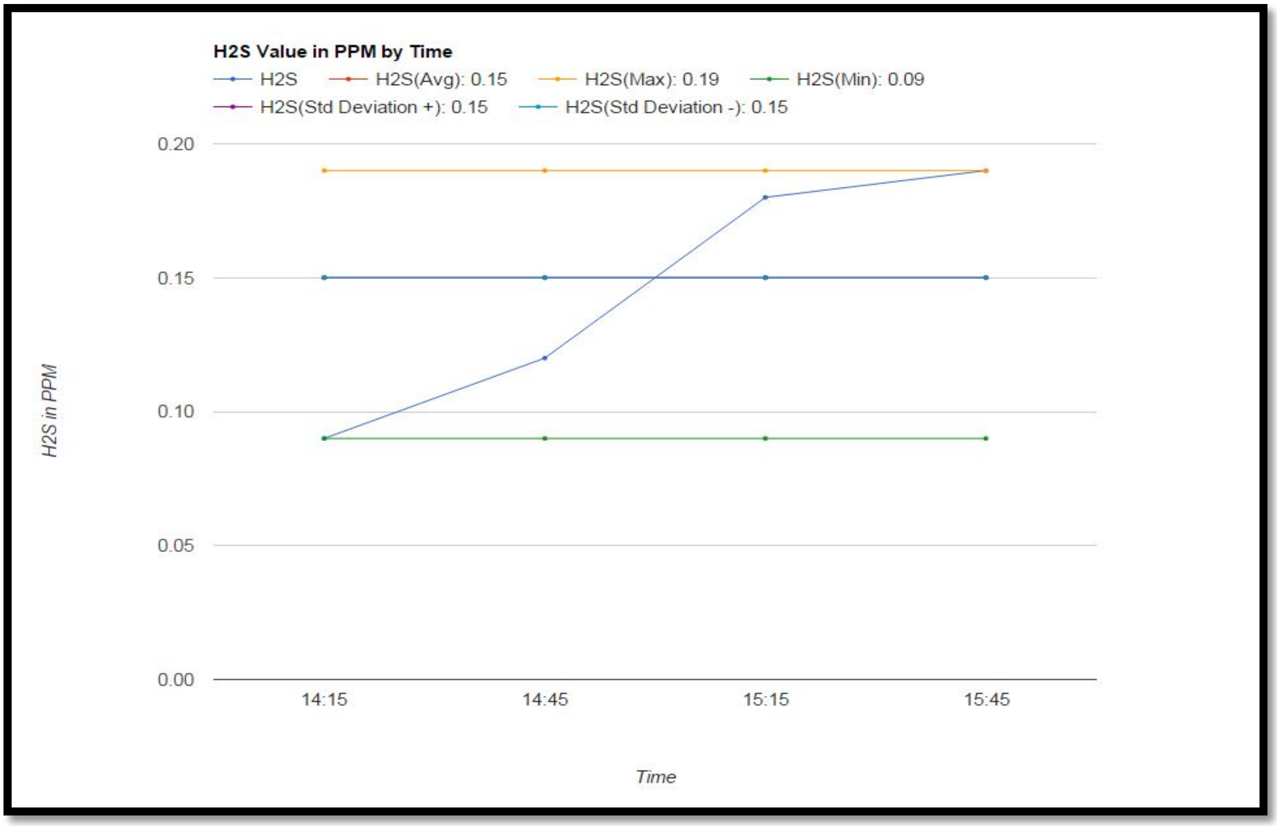

Figure A-129: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 1

Figure A-130: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 2

Figure A-131: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 3

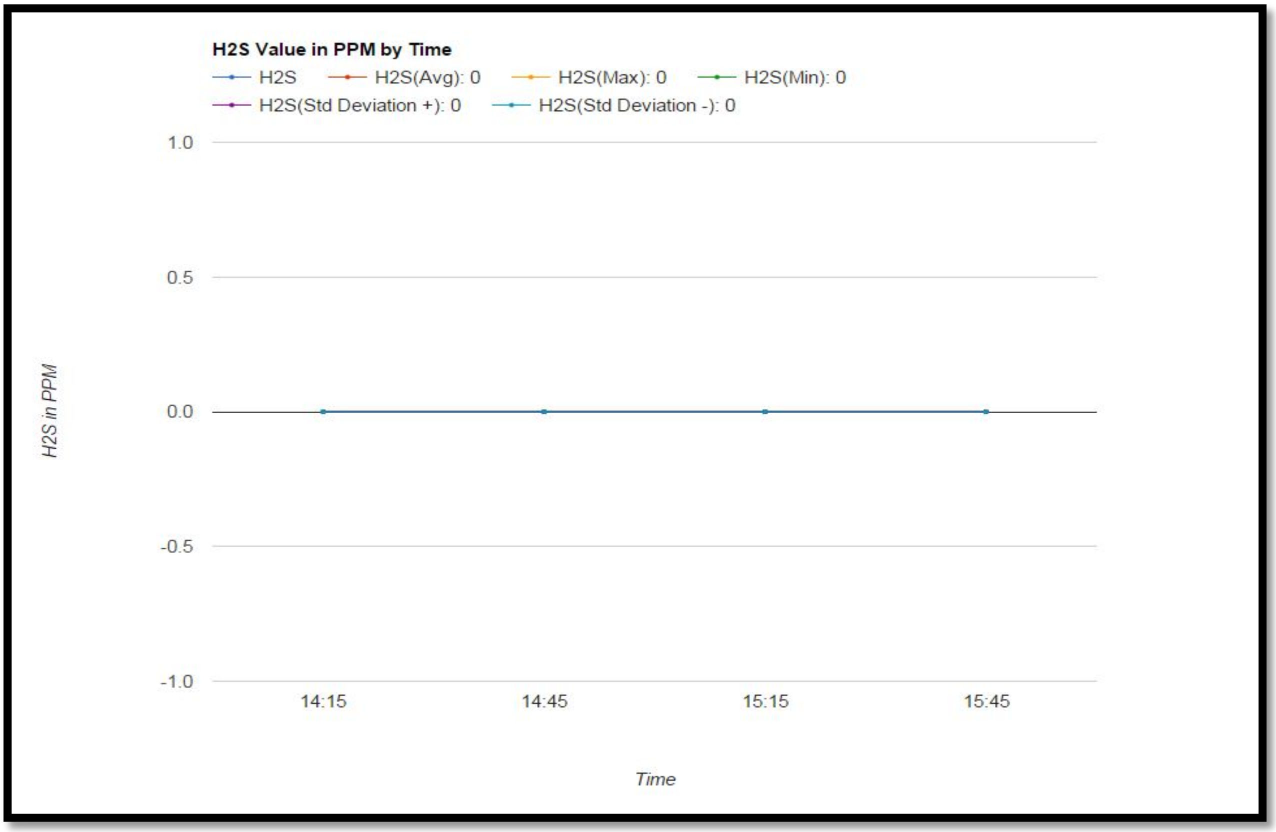

Figure A-132: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 4

Figure A-133: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 5

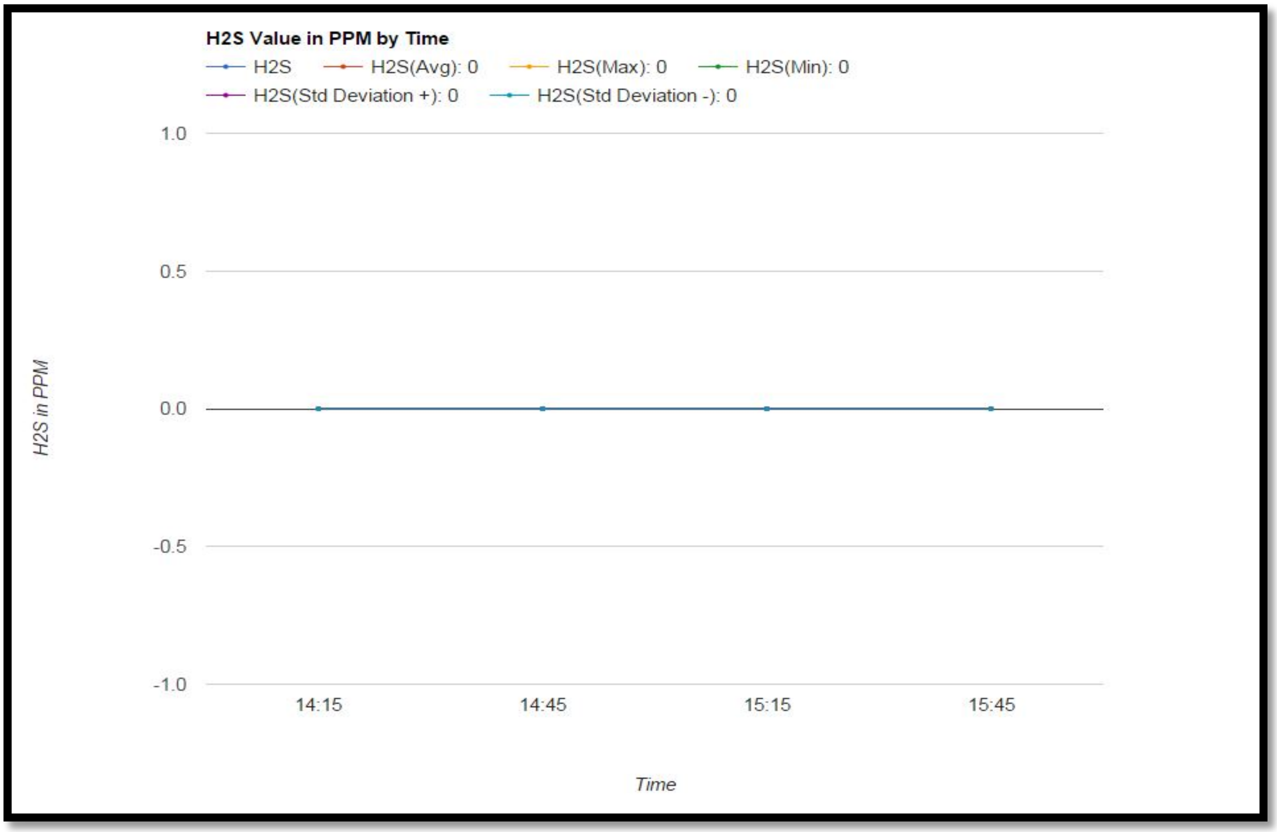

Figure A-134: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 6

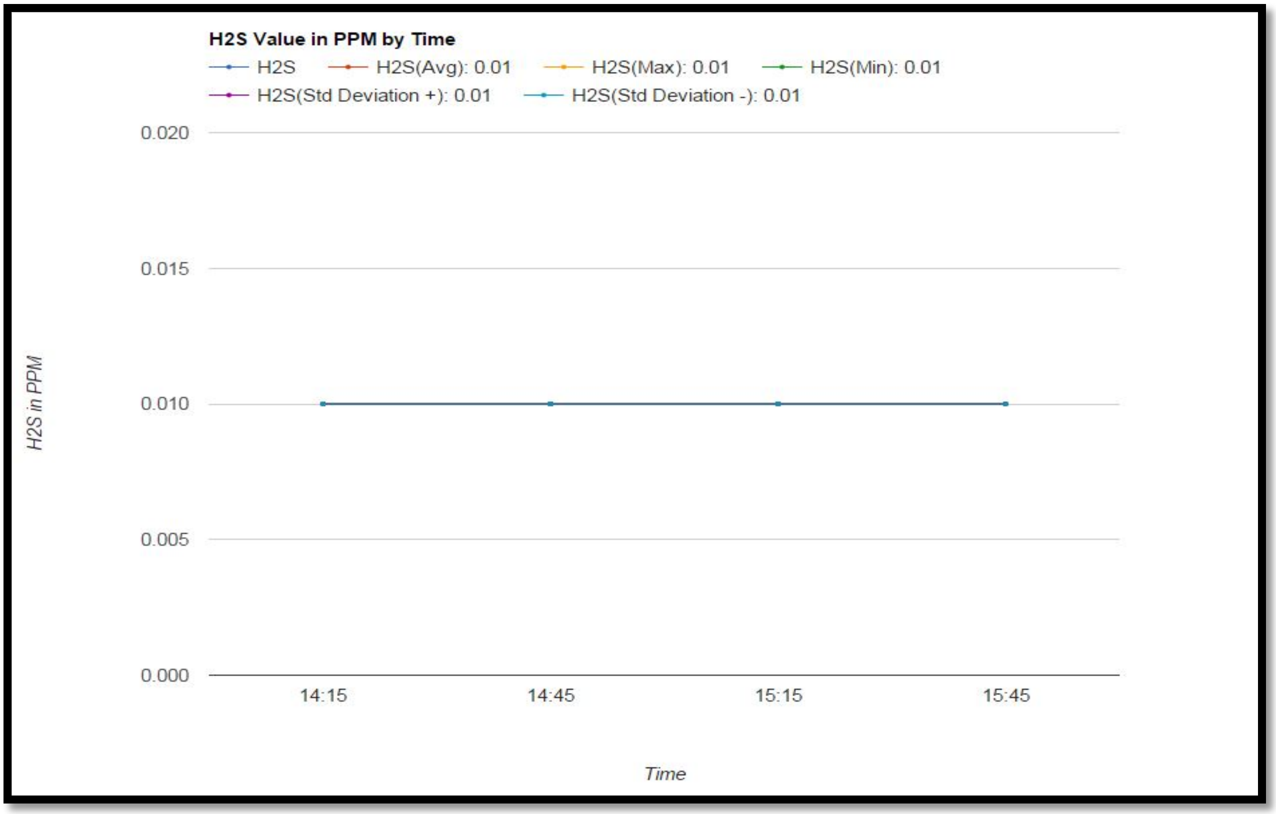

Figure A-135: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 7

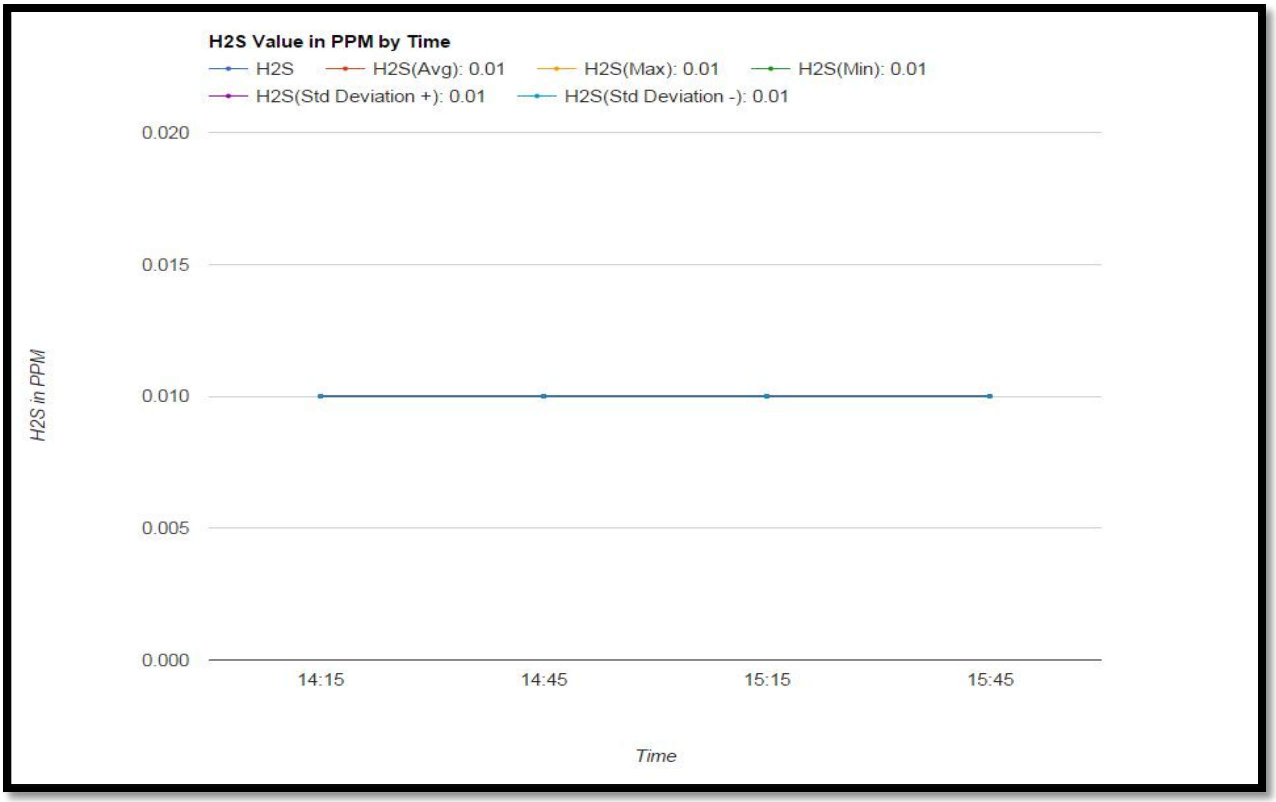

Figure A-136: Average Hourly Analysis for 30-Minute Intervals (2:00 p.m. – 3:40 p.m.) – Site 8

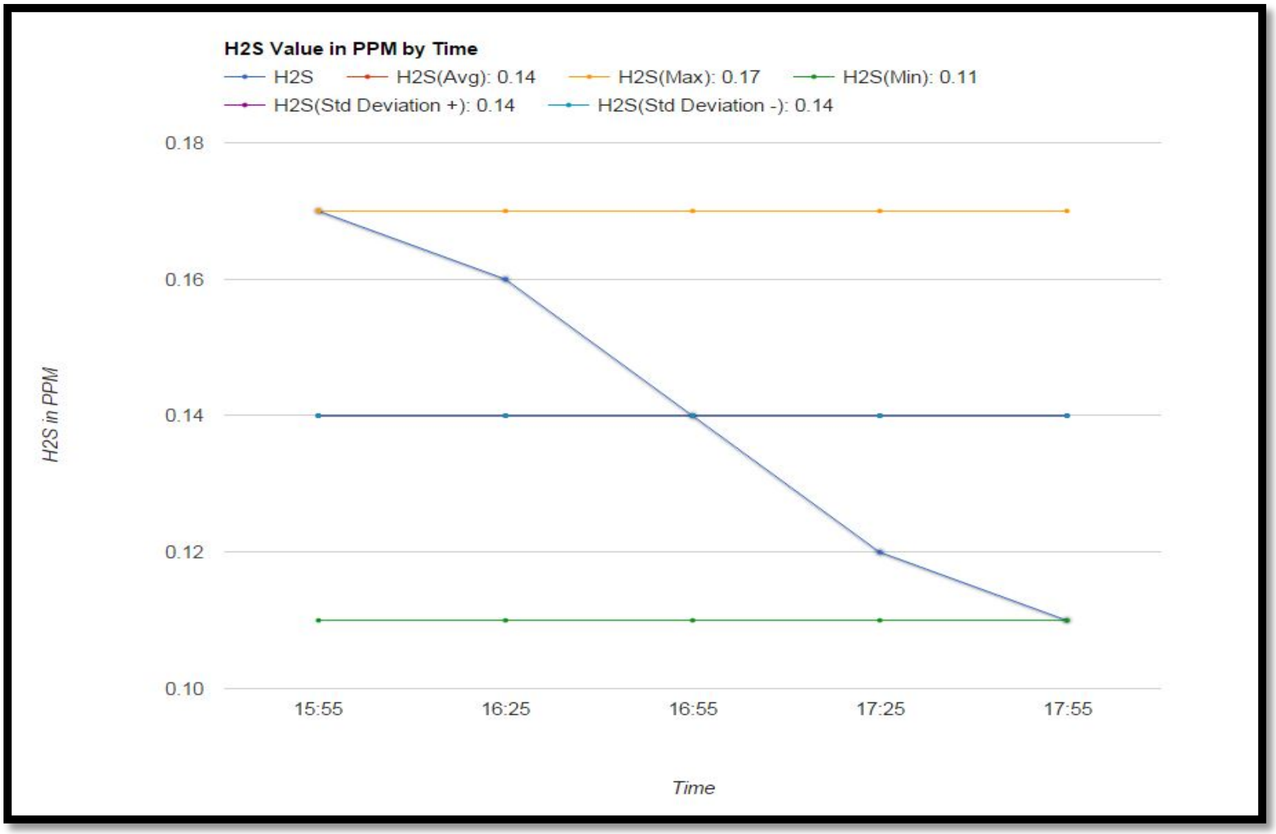

Figure A-137: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 1

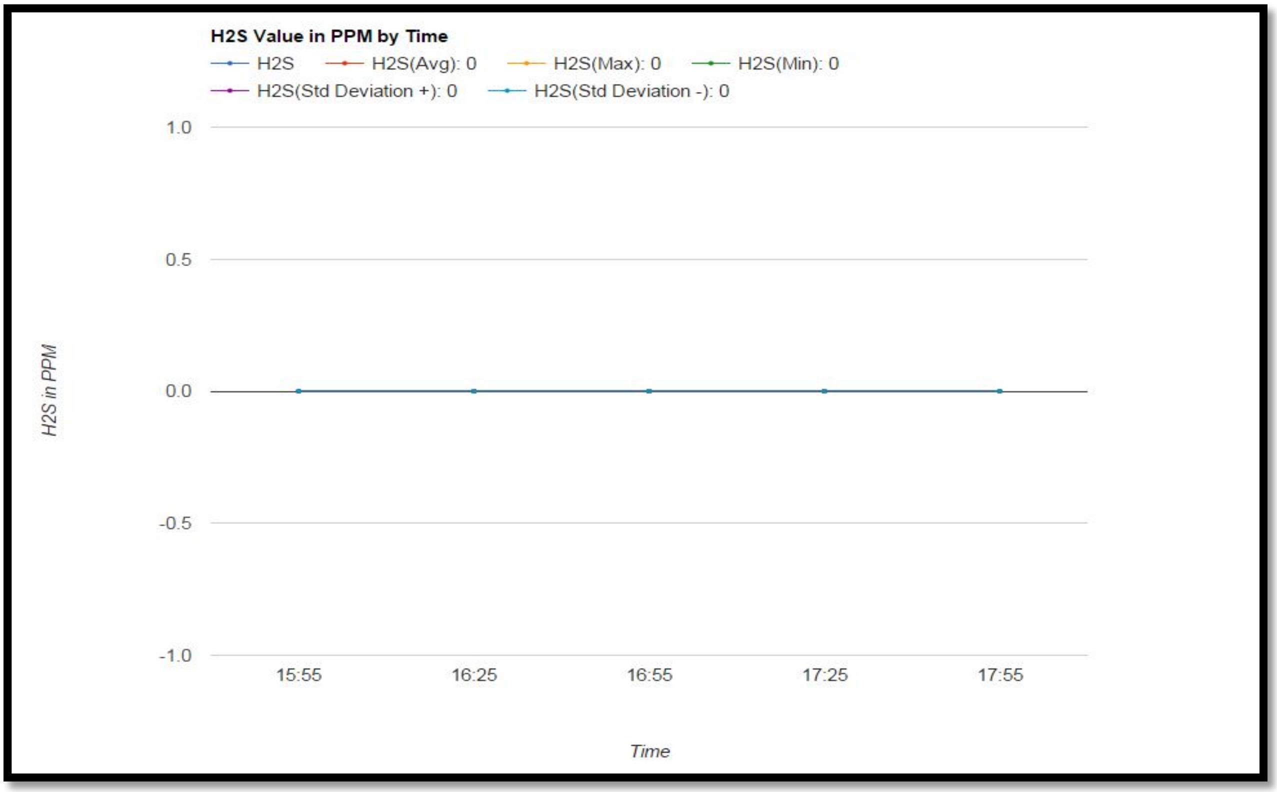

Figure A-138: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 2

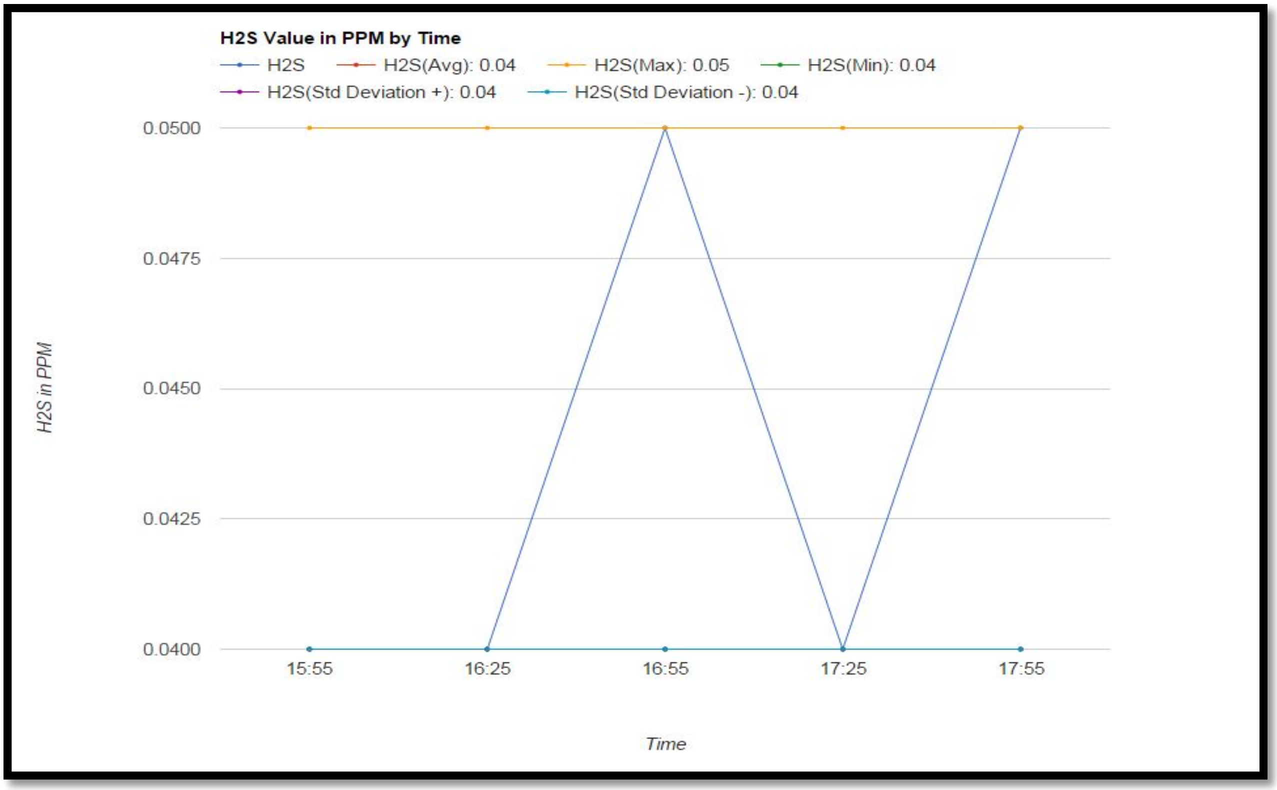

Figure A-139: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 3

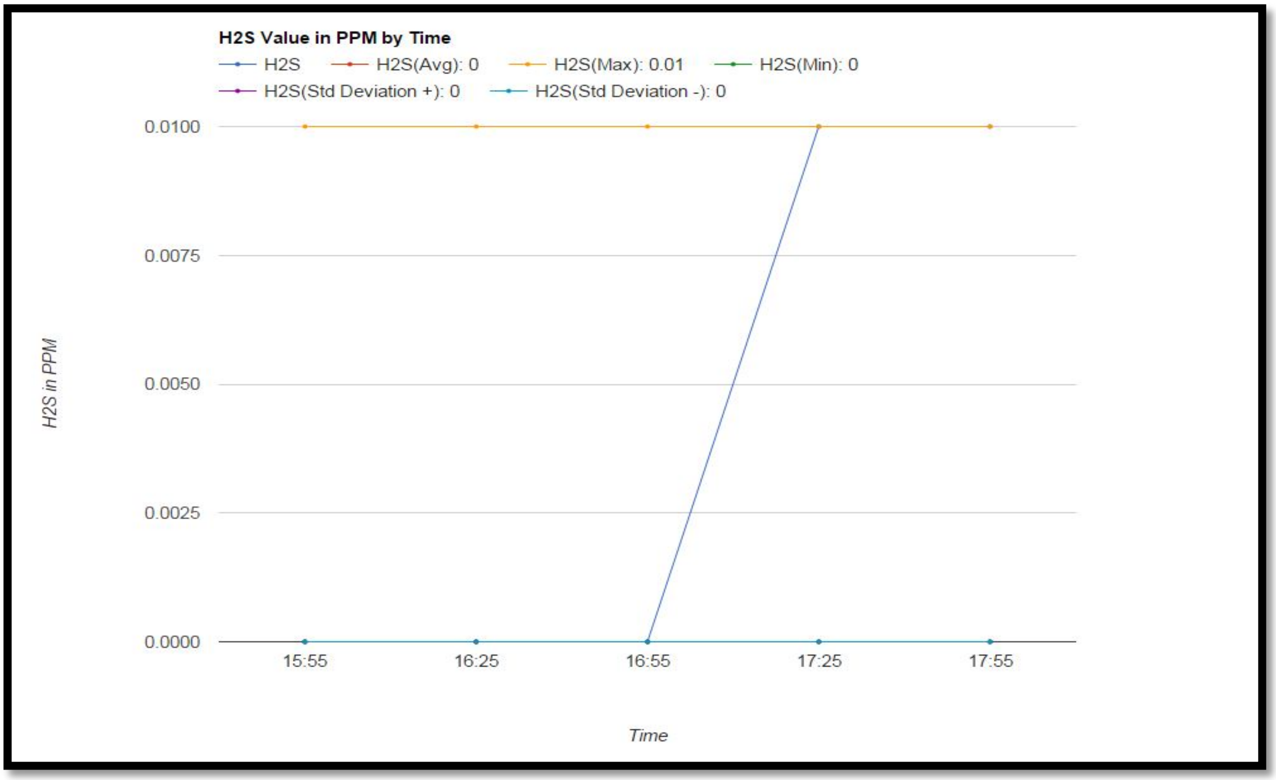

Figure A-140: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 4

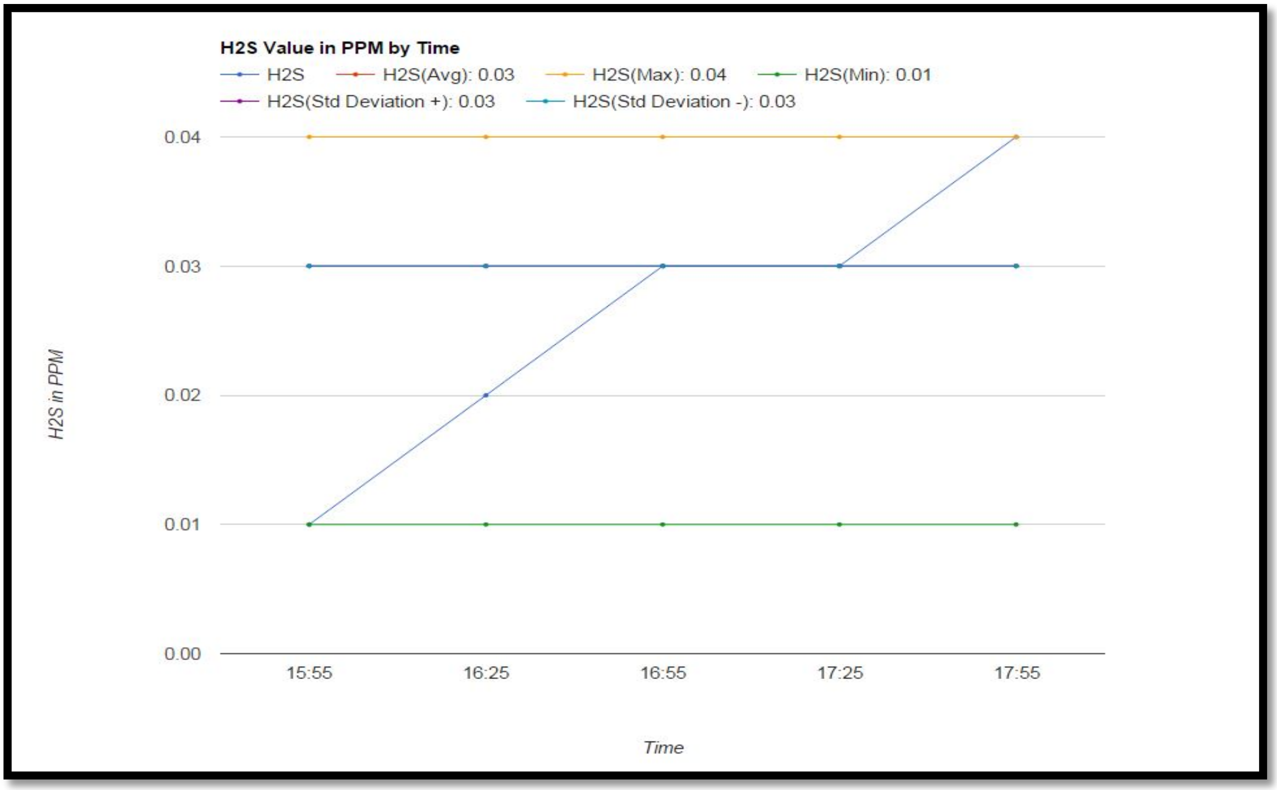

Figure A-141: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 5

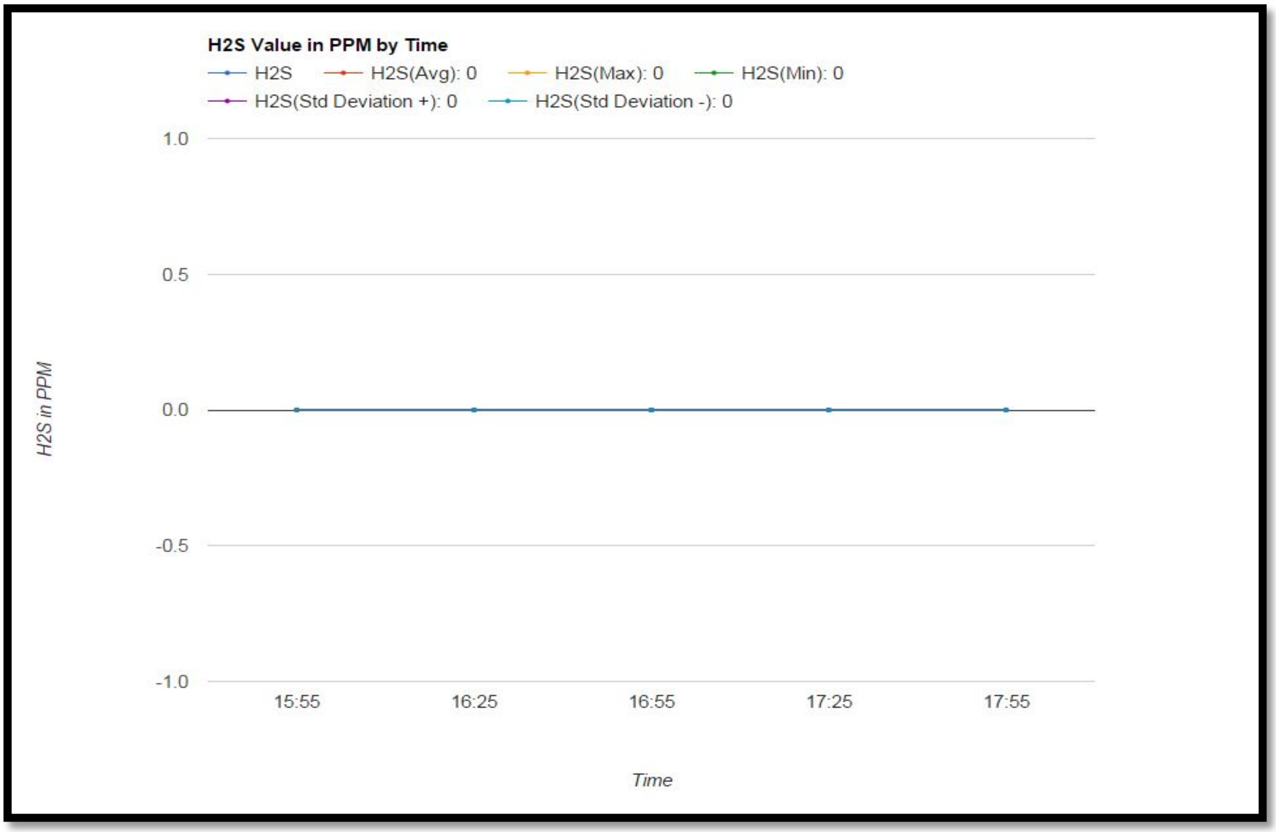

Figure A-142: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 6

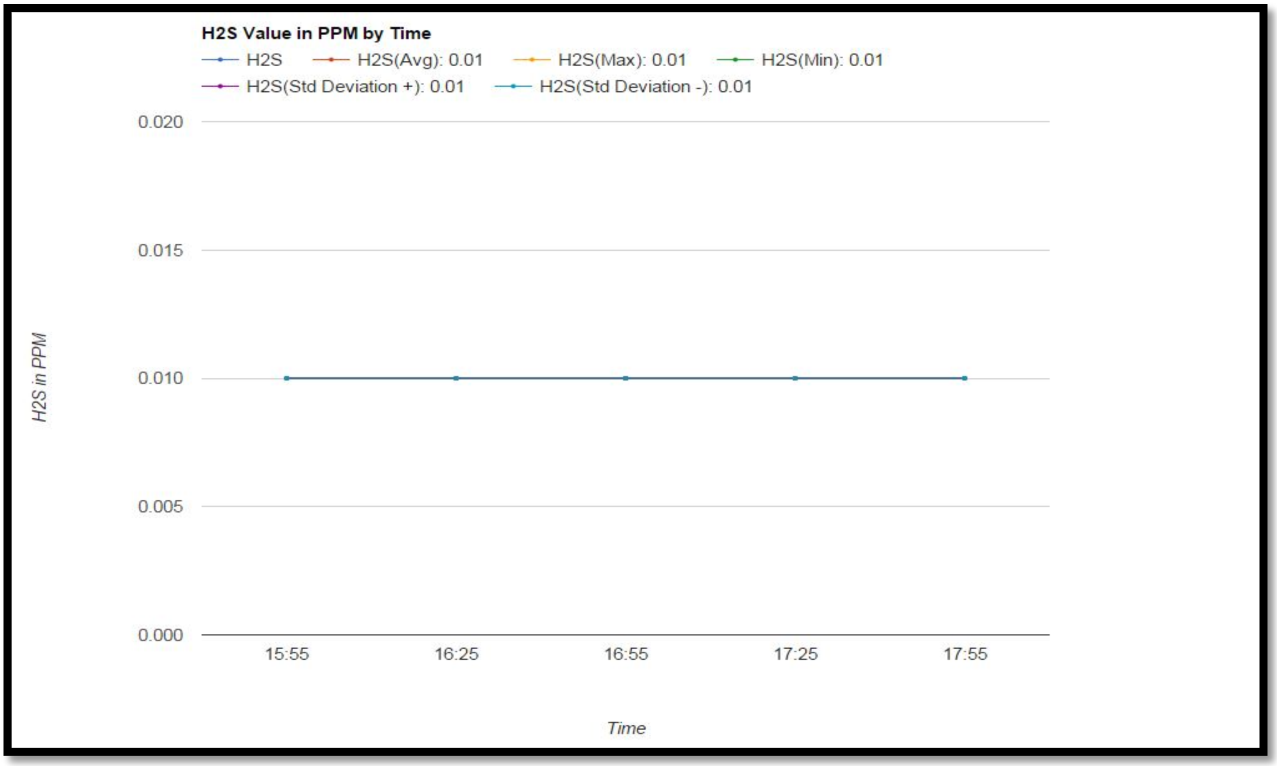

Figure A-143: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 7

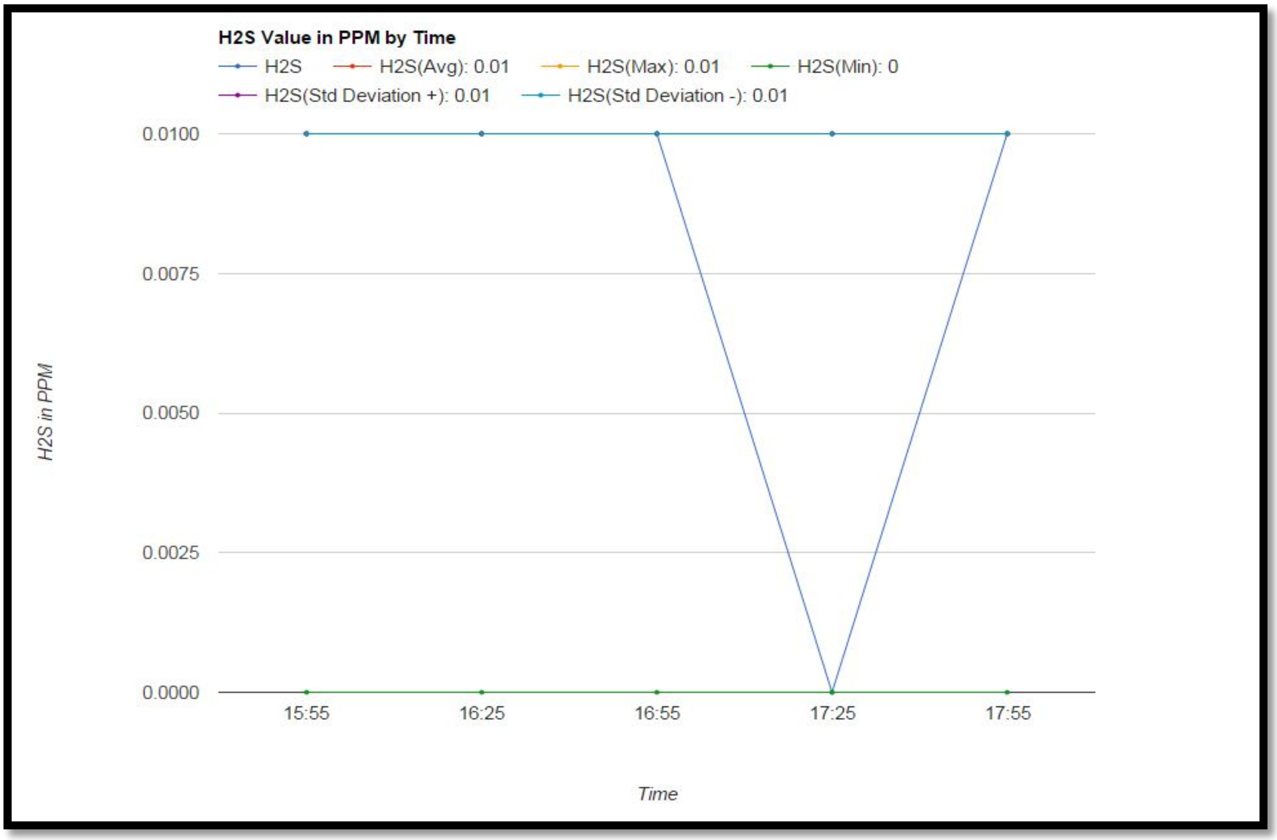

Figure A-144: Average Hourly Analysis for 30-Minute Intervals (3:40 p.m. – 6:00 p.m.) – Site 8

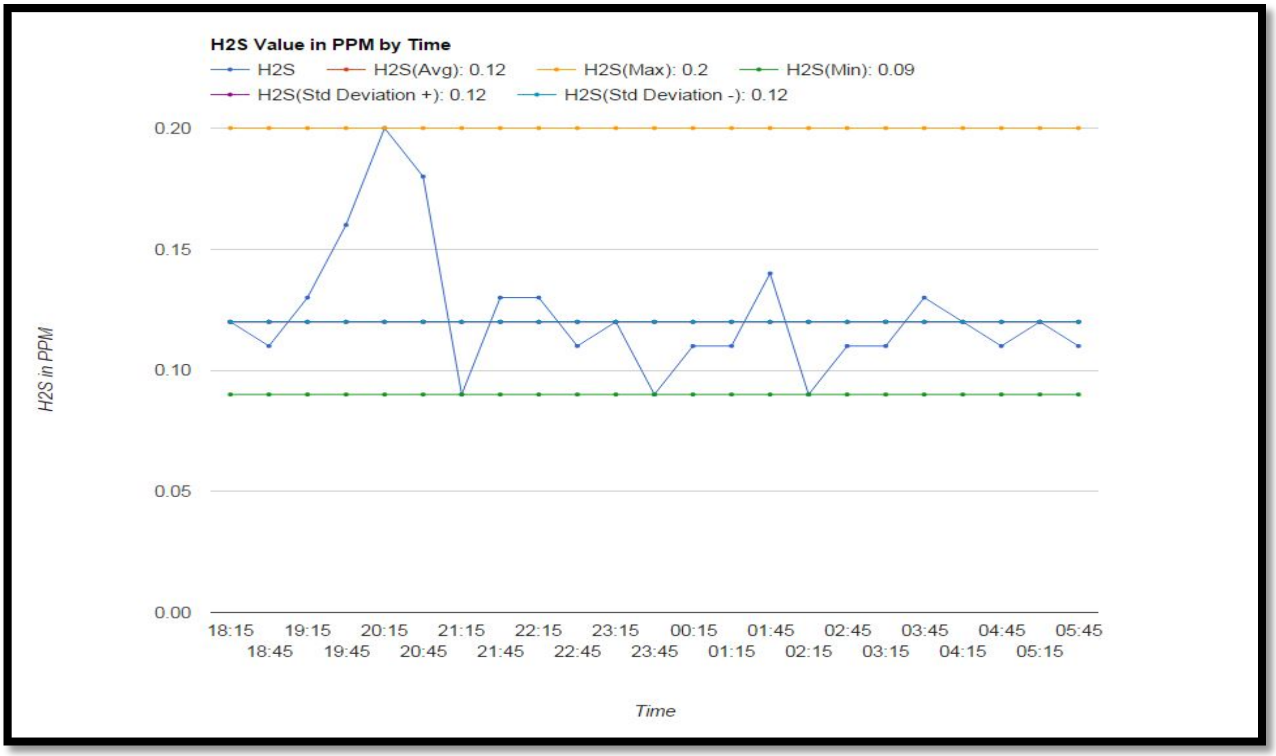

Figure A-145: Average Hourly Analysis for 30-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 1

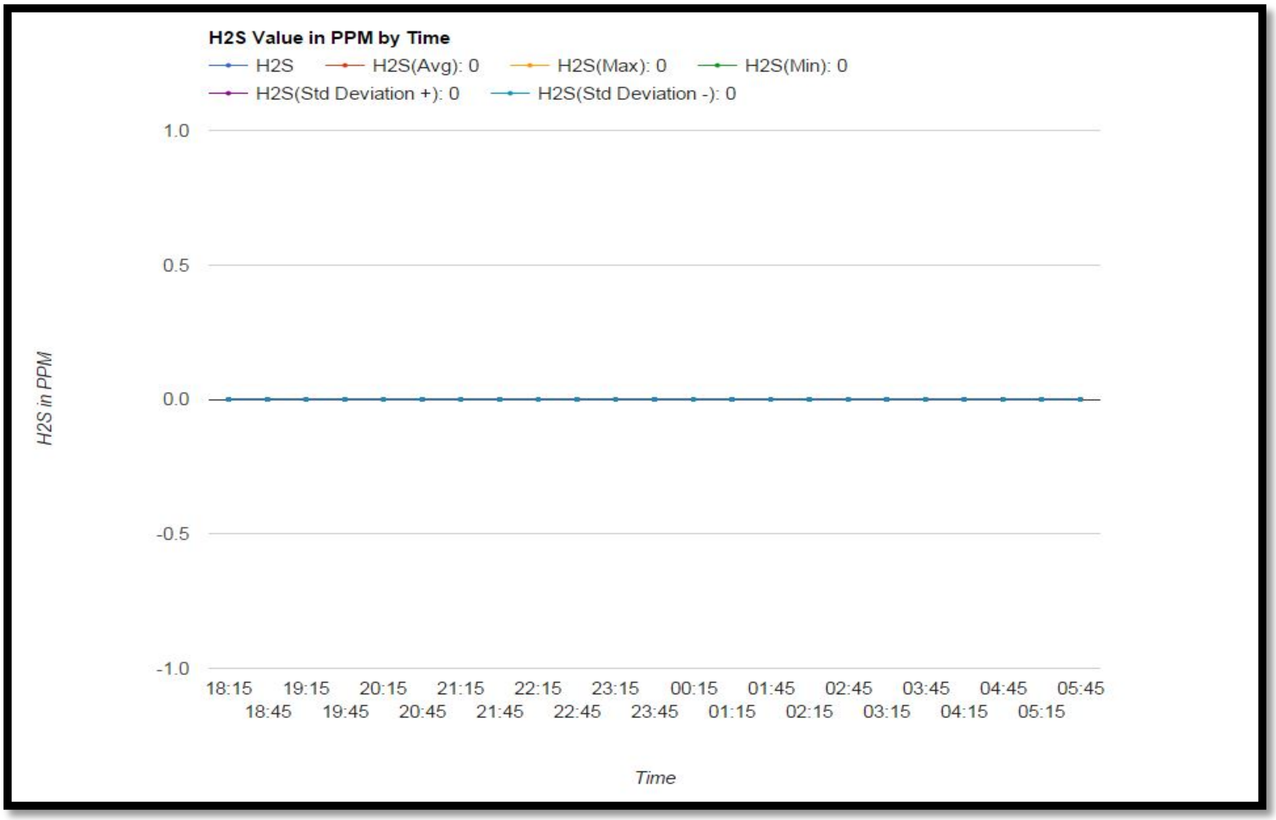

Figure A-146: Average Hourly Analysis for 30-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 2

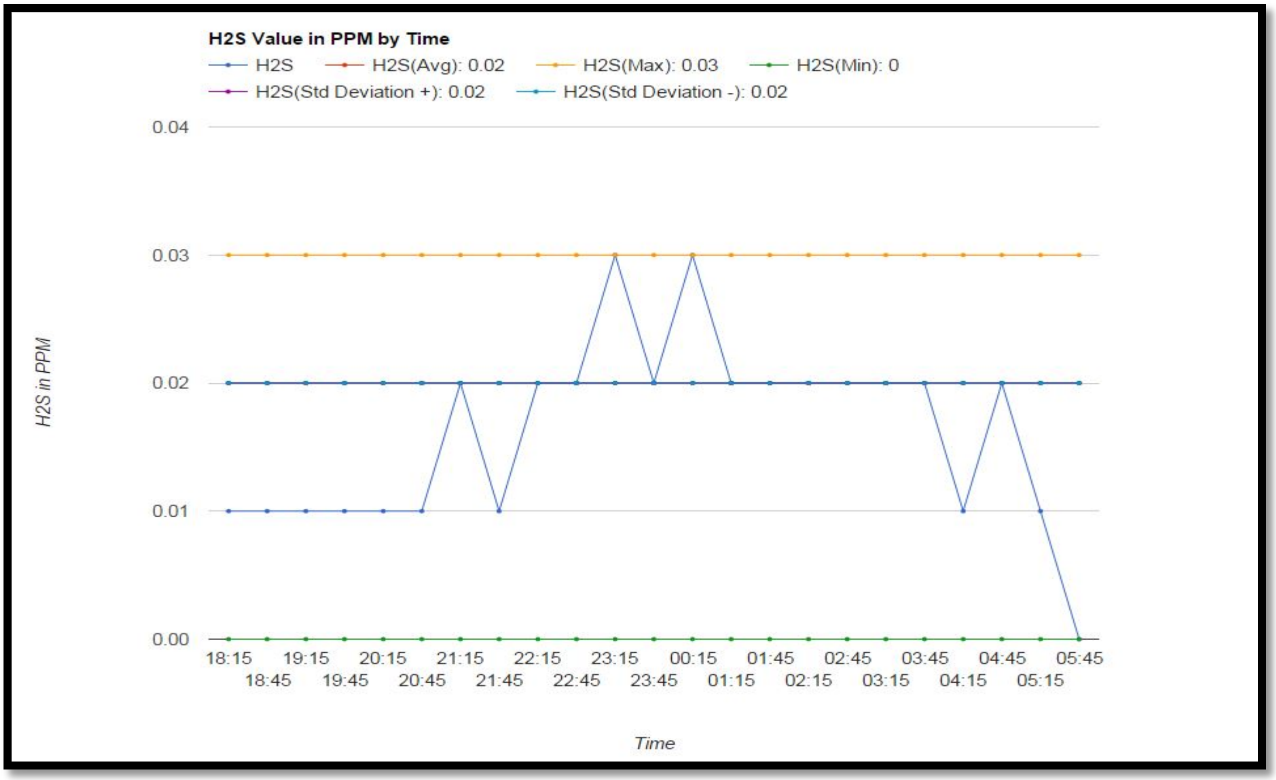

Figure A-147: Average Hourly Analysis for 30-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 4

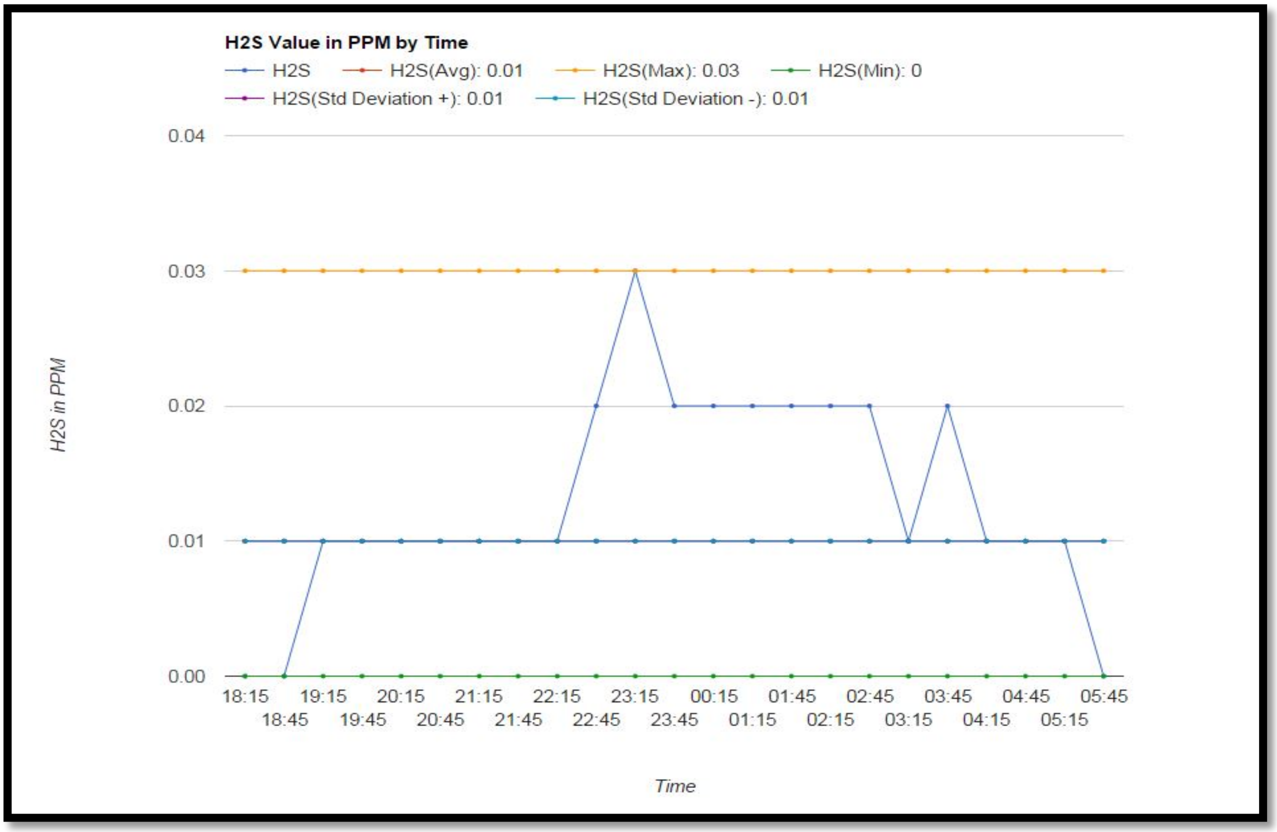

Figure A-148: Average Hourly Analysis for 30-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 6

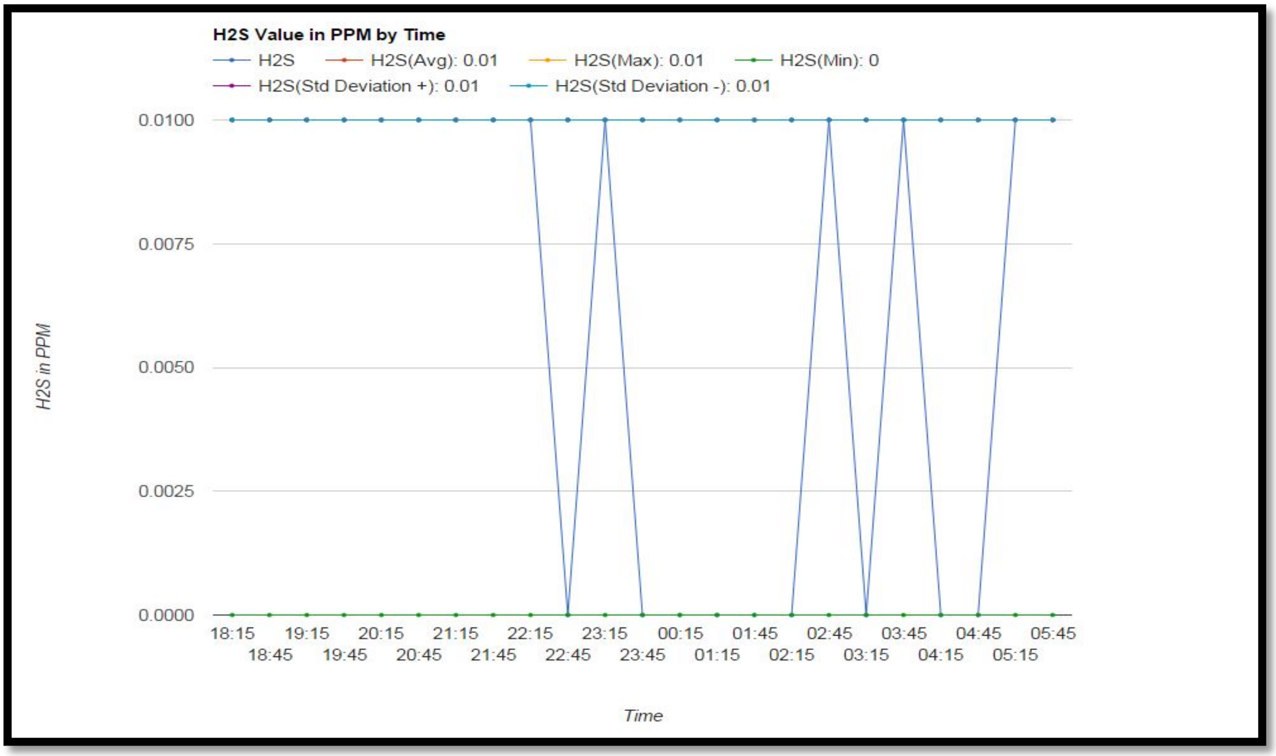

Figure A-149: Average Hourly Analysis for 30-Minute Intervals (6:00 p.m. – 6:00 a.m.) – Site 8

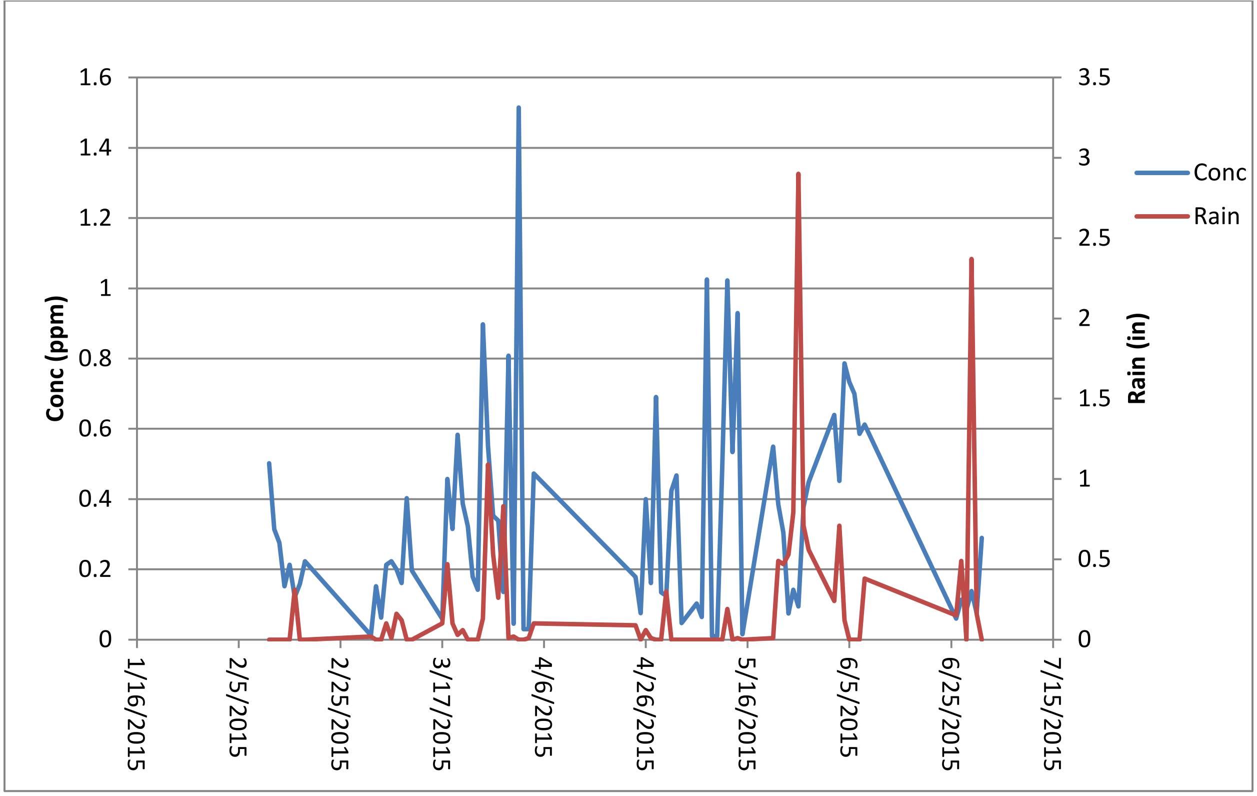

Figure A-150: Historical Analysis and Rainfall – Site 1

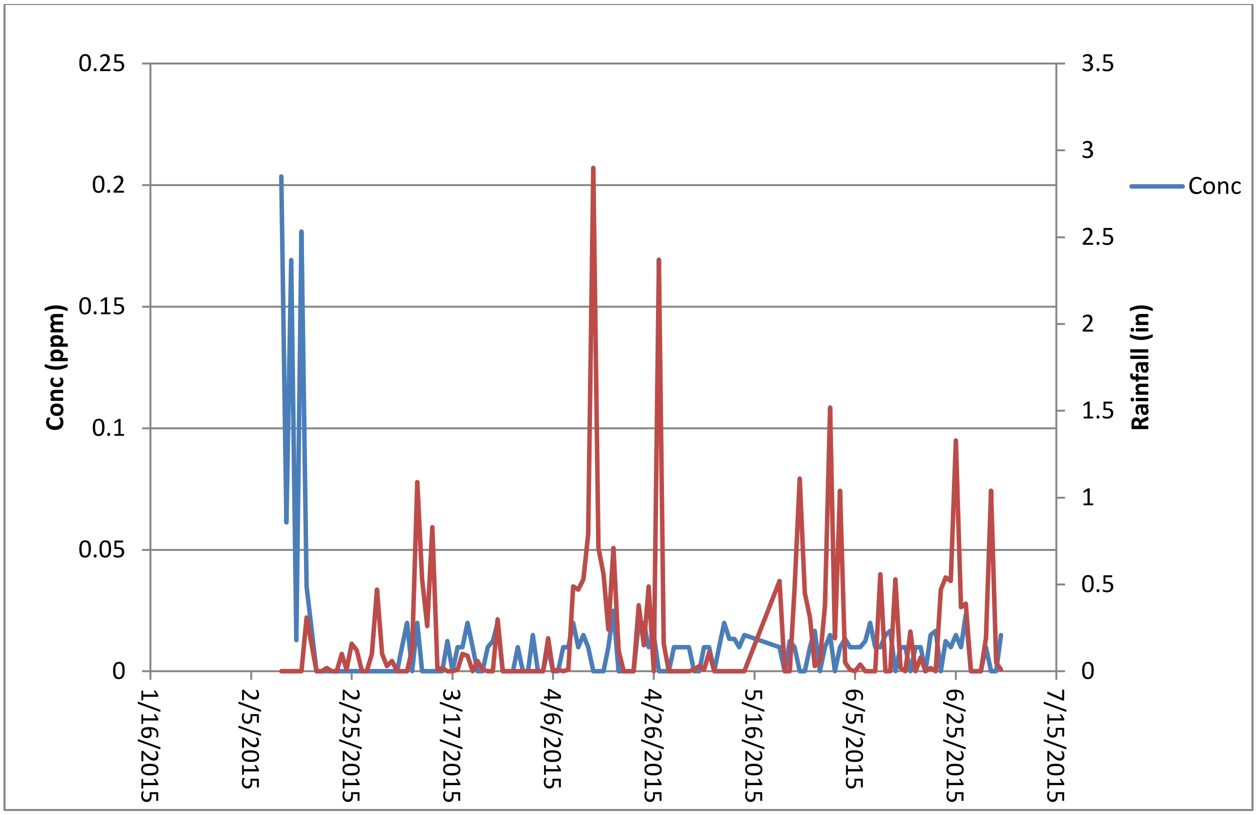

Figure A-151: Historical Analysis and Rainfall – Site 2

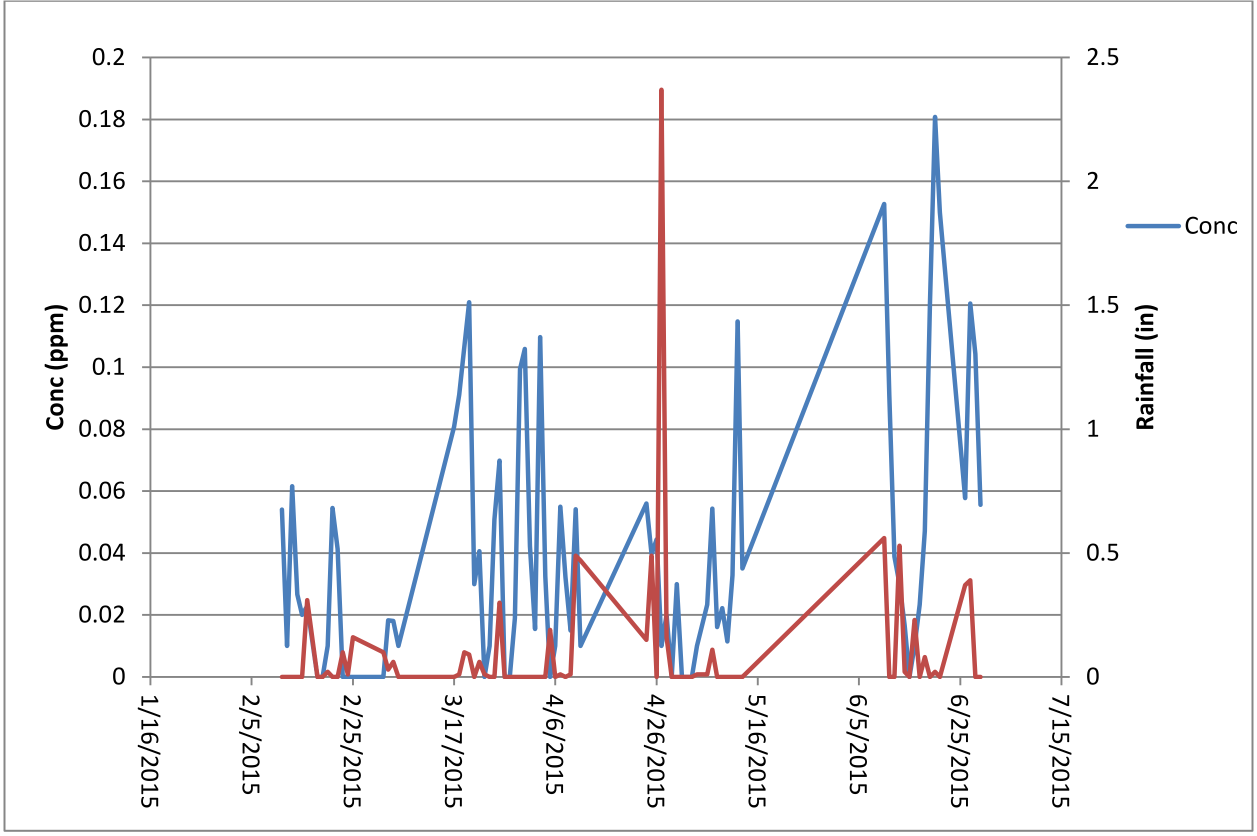

Figure A-152: Historical Analysis and Rainfall – Site 4

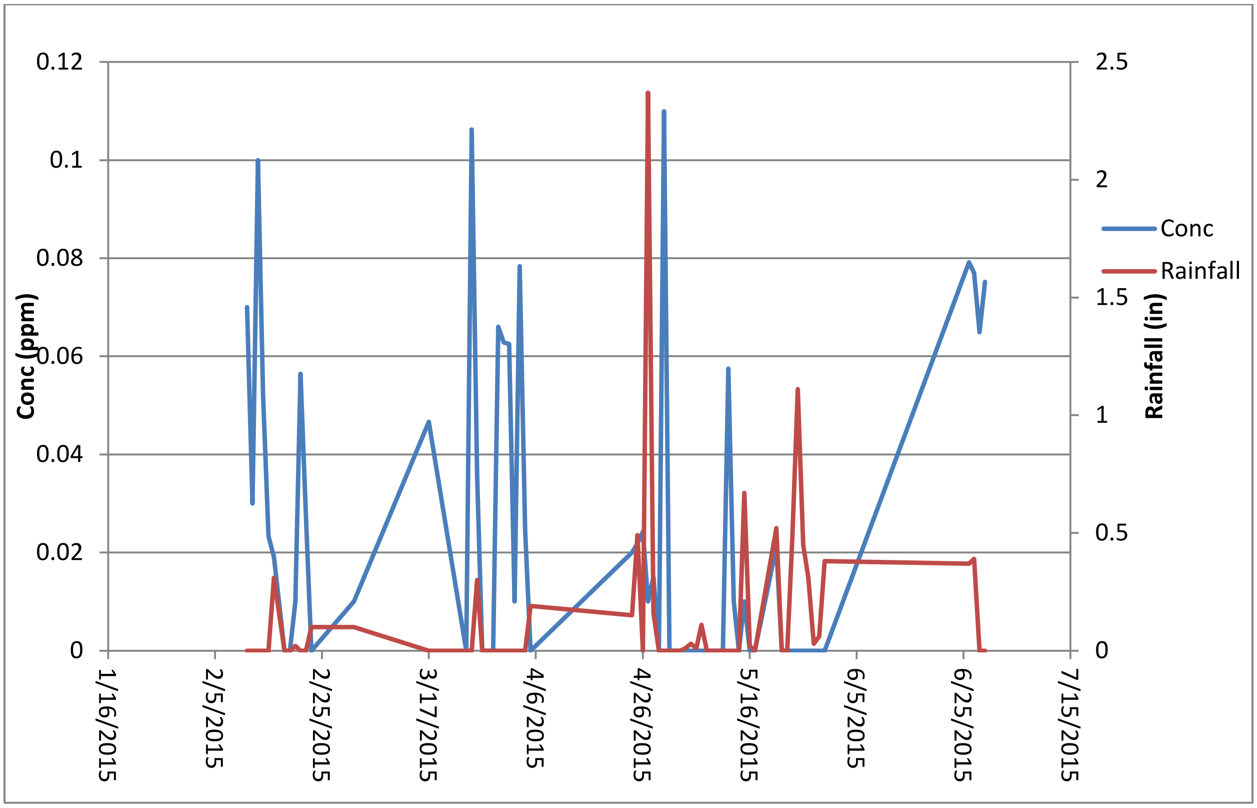

Figure A-153: Historical Analysis and Rainfall – Site 6

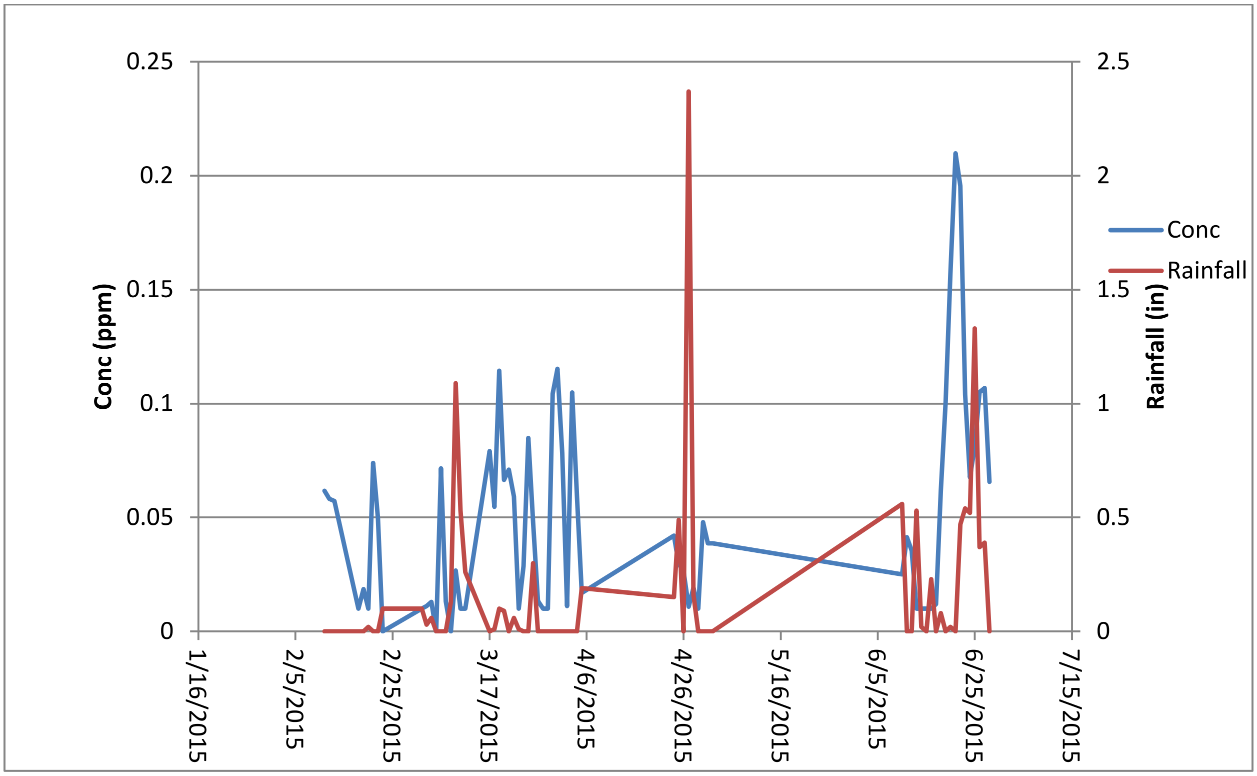

Figure A-154: Historical Analysis and Rainfall – Site 7

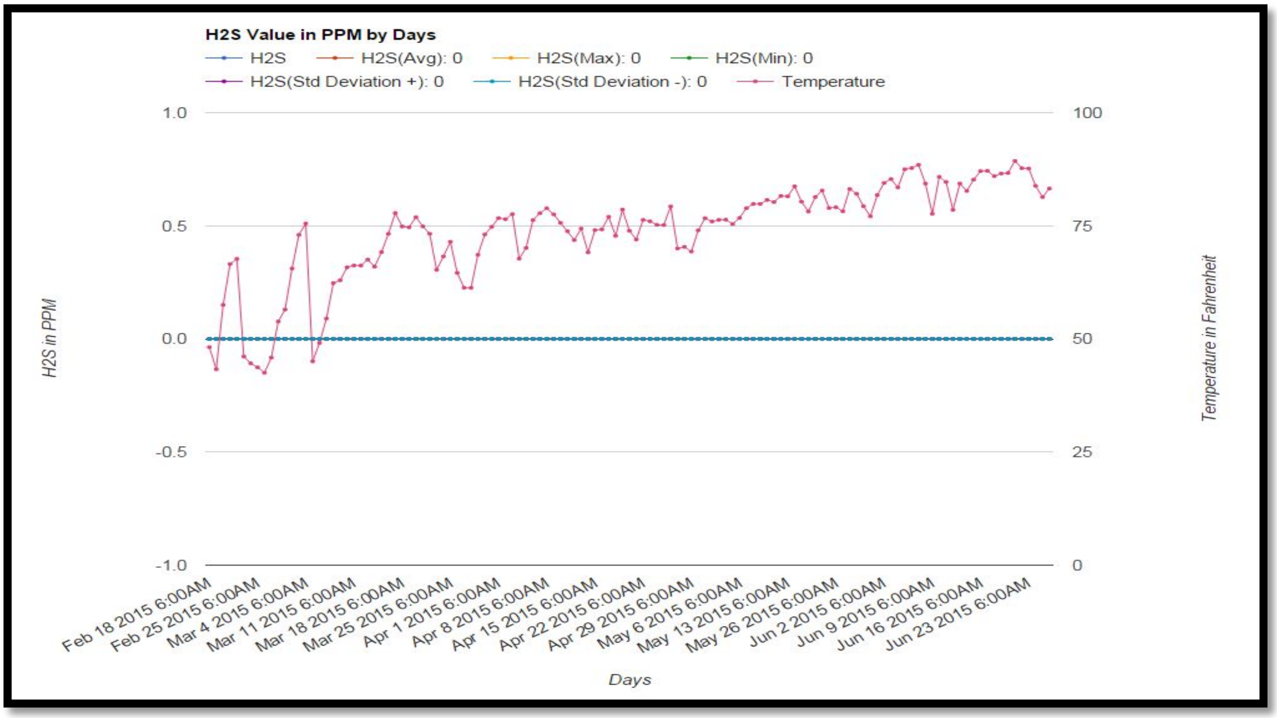

Figure A-155: Historical Analysis and Temperature – Site 2

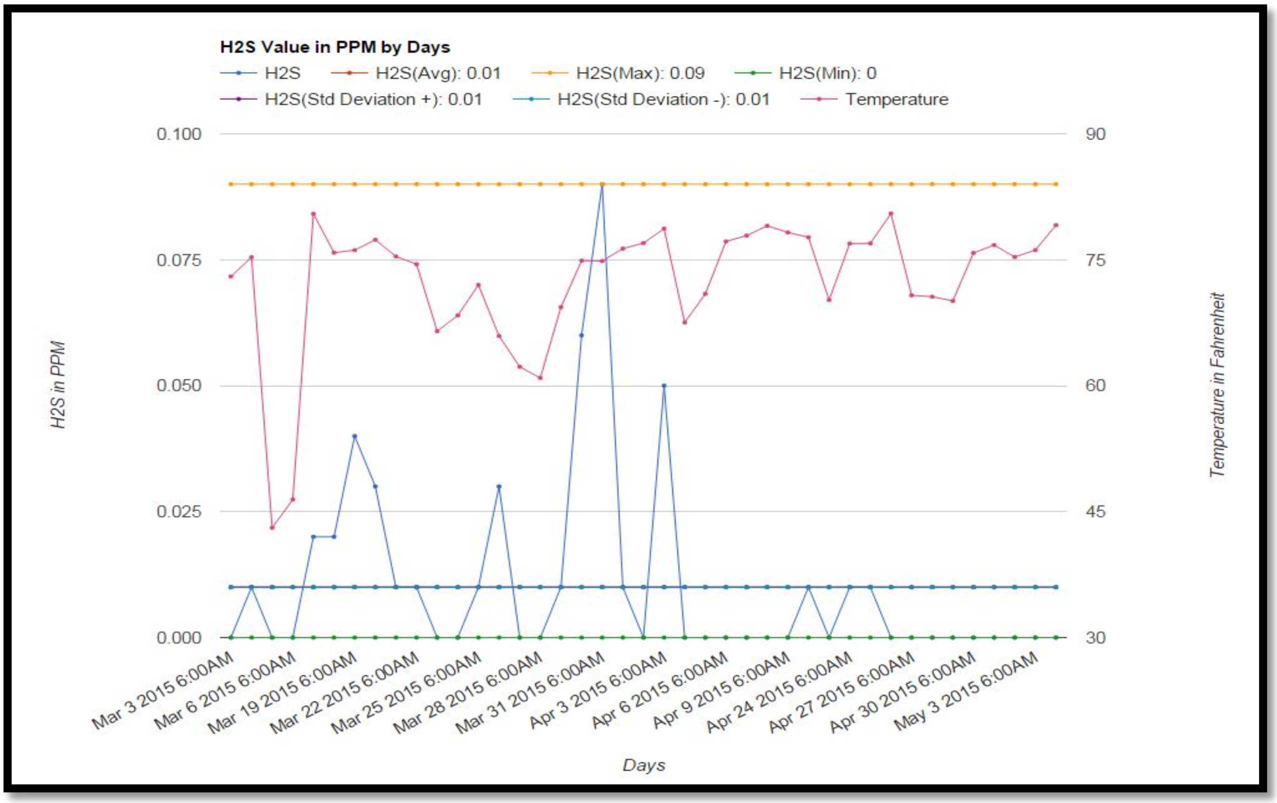

Figure A-156 Historical Analysis and Temperature – Site 4

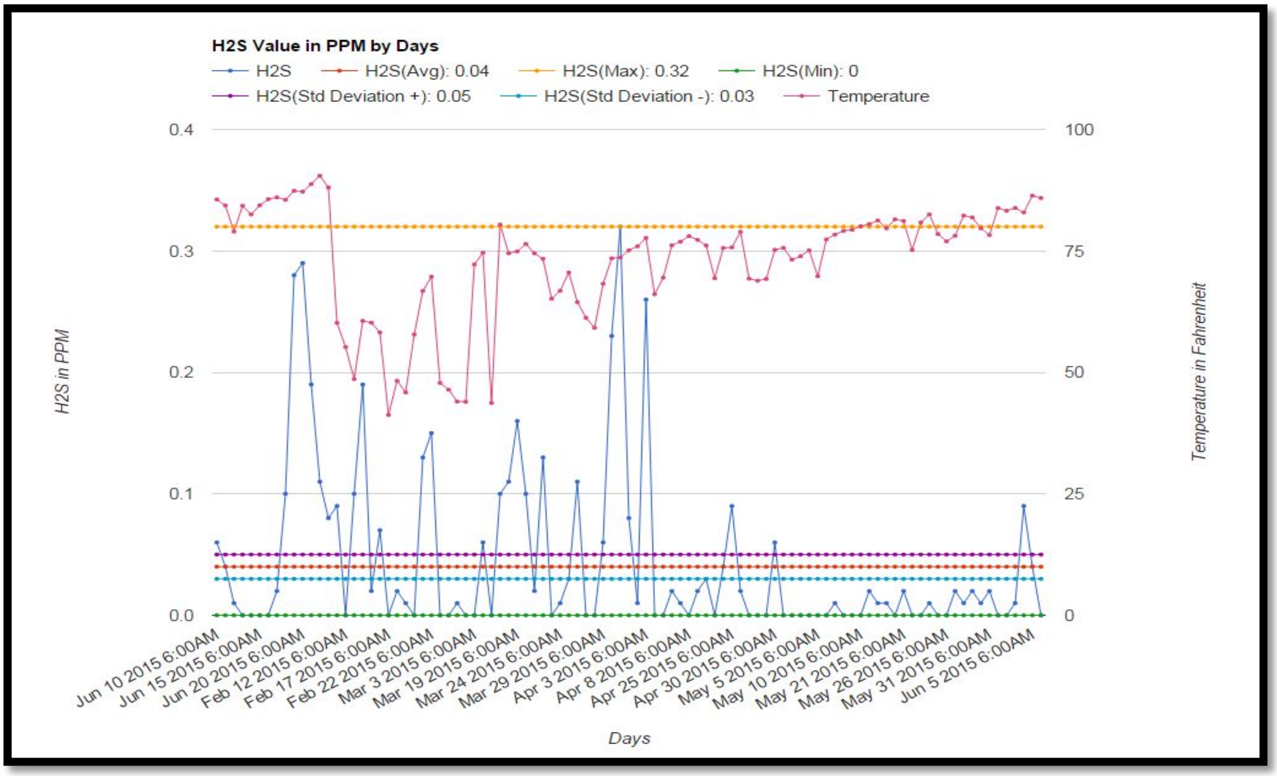

Figure A-157: Historical Analysis and Temperature – Site 5

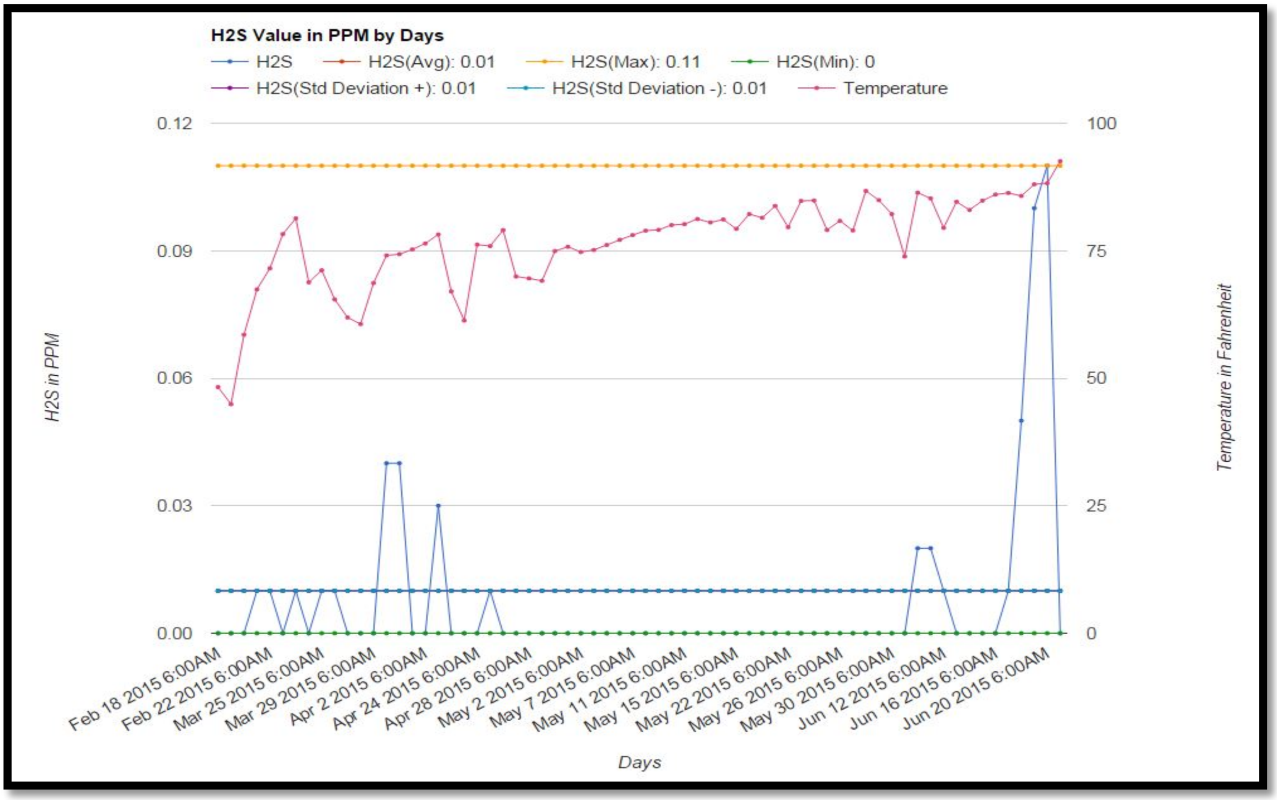

Figure A-158: Historical Analysis and Temperature – Site 6

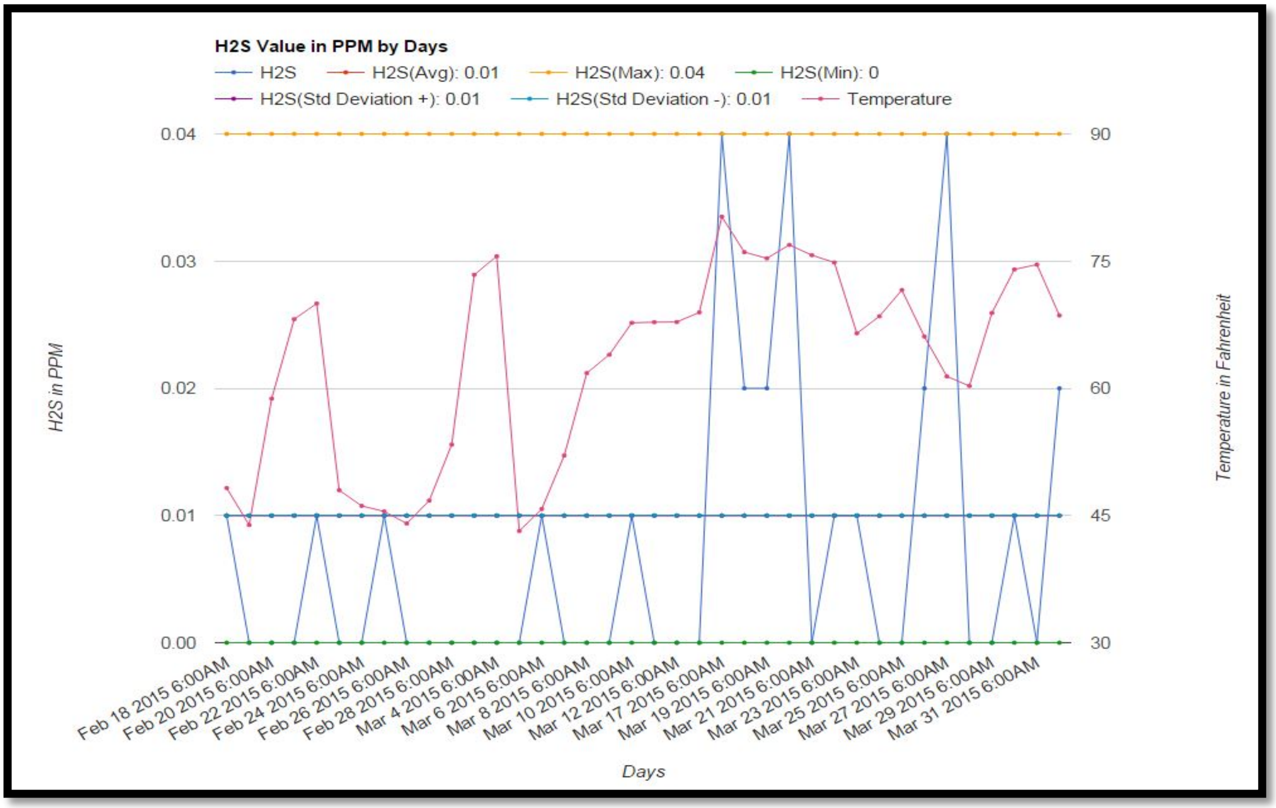

Figure A-159: Historical Analysis and Temperature – Site 8

Vita

The author was born in Katy, Texas. She attended Katy High School, and received her Bachelors of Science in chemical engineering from the University of Texas at Austin in 2009. She currently works for the Sewerage and Water Board of New Orleans (SWBNO) in their Engineering Group. She is the liaison between the SWBNO and Veolia Water, the private company that manages the Board's two wastewater treatment plants. She joined the University of New Orleans graduate program in 2011 to pursue a master's degree in environmental engineering. She also acquired her professional engineering license in environmental engineering in 2015.