Control of Microbiologically Induced Corrosion of Collection System Infrastructure

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Outline

- Hydrogen sulfide generation in collection systems
- Health and infrastructure effects
- Hydrogen sulfide control
- Field studies and results
- Conclusions

Hydrogen Sulfide Generation in Collection Systems

- Sulfate reducing bacteria (SRB)
  - Genus *Desulfovibrio*, *Desulfobulbus*
  - Use sulfate or oxidized sulfur compounds to oxidize organic matter
- Anaerobic conditions
  - Absence of oxygen, nitrate

Favorable Conditions for H2S Generation

- Accelerated at higher temperatures

  T > ~ 15 C

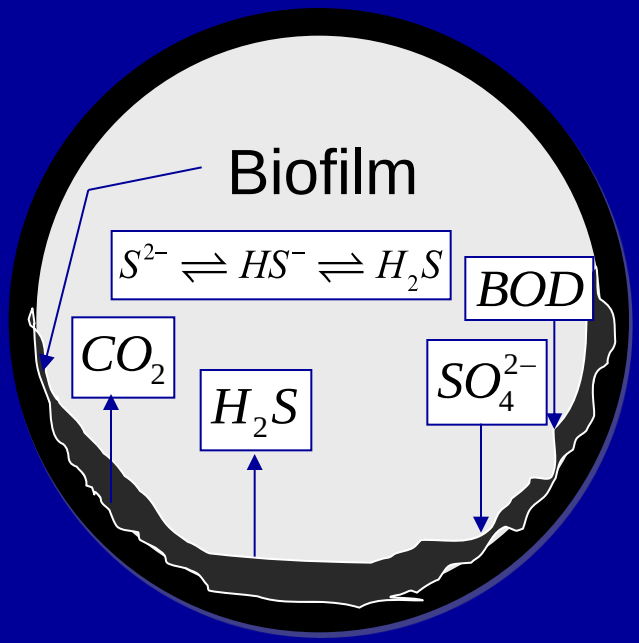
- Low flow velocities

  < ~ 1ft/s

- High residence time

  > ~ 0.5 – 2 h

H2S generation in Biofilms



Forcemain under anaerobic conditions

$$SO_4^{2-} \xrightarrow{SRB} S^{2-}$$

$$S^{2-} + H_2O \rightleftharpoons HS^{-} + OH^{-}$$

$$HS^{-} + H_2O \rightleftharpoons H_2S(aq) + OH^{-}$$

$$H_2S(aq) \rightleftharpoons H_2S(g)$$

Favorable Conditions for H2S Emission

- Low pH

  pH < ~ 9

- High turbulence

- Higher temperatures

Safety and Health effects

	Concentration (ppm)
Detectable odor	~ 4.6
Strong and unpleasant	~ 27
Olfactory paralysis	~ 100 - 150
Fatal	> ~ 500

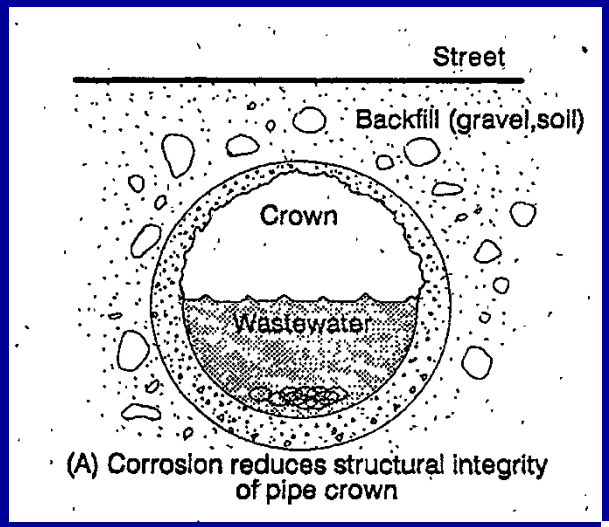
Physiological Responses

- 10 ppm – eye irritation
- 50 to 100 ppm – Conjunctivitis, respiratory irritation
- 100 ppm – Coughing, eye irritation, loss of sense of smell in 2 to 15 minutes
- 500 to 700 ppm – Loss of consciousness and death in 30 to 60 minutes
- 700 to 1000 ppm – Rapid unconsciousness and cessation of respiration and death

Infrastructure corrosion

- Corrosion of concrete sewers

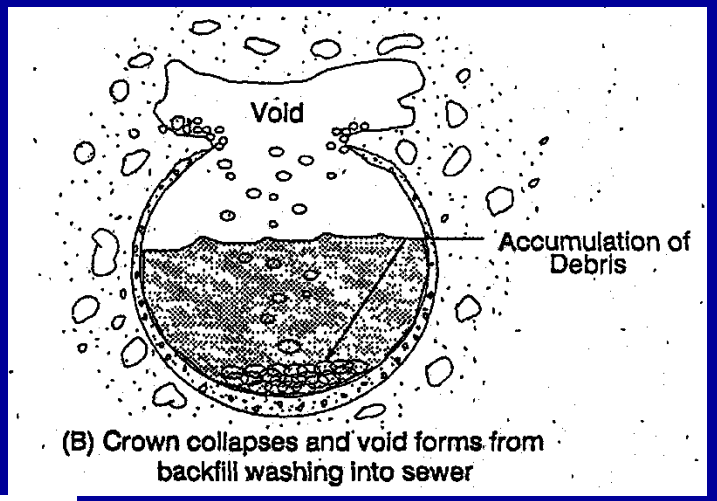
Corrosion of concrete sewers



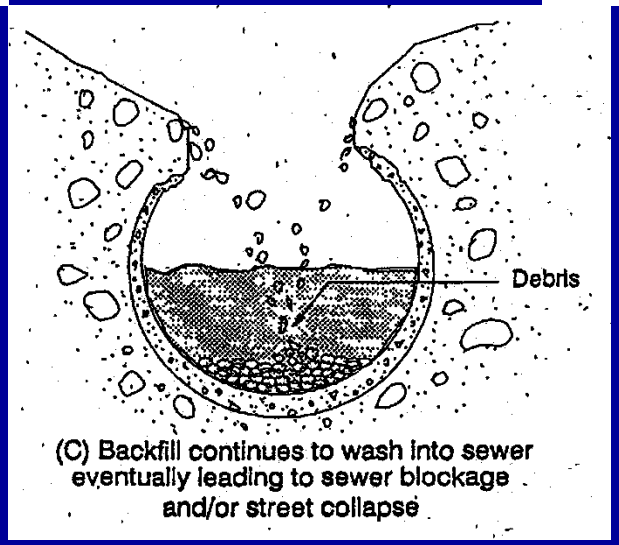
(A) Corrosion reduces structural integrity of pipe crown

Crown corrosion

Collapse of pipe



(B) Crown collapses and void forms from backfill washing into sewer



(C) Backfill continues to wash into sewer eventually leading to sewer blockage and/or street collapse

Reactions at Pipe Crown

- Sulfide oxidizing bacteria

  Thiobacillus neapolitanus
  Acidothiobacillus thiooxidans
  Thiobacillus intermedius

$$H_2S + O_2 \xrightarrow{SOB} H_2SO_4$$

$$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4(gypsum)$$

- Corrosion products: gypsum, ettringite

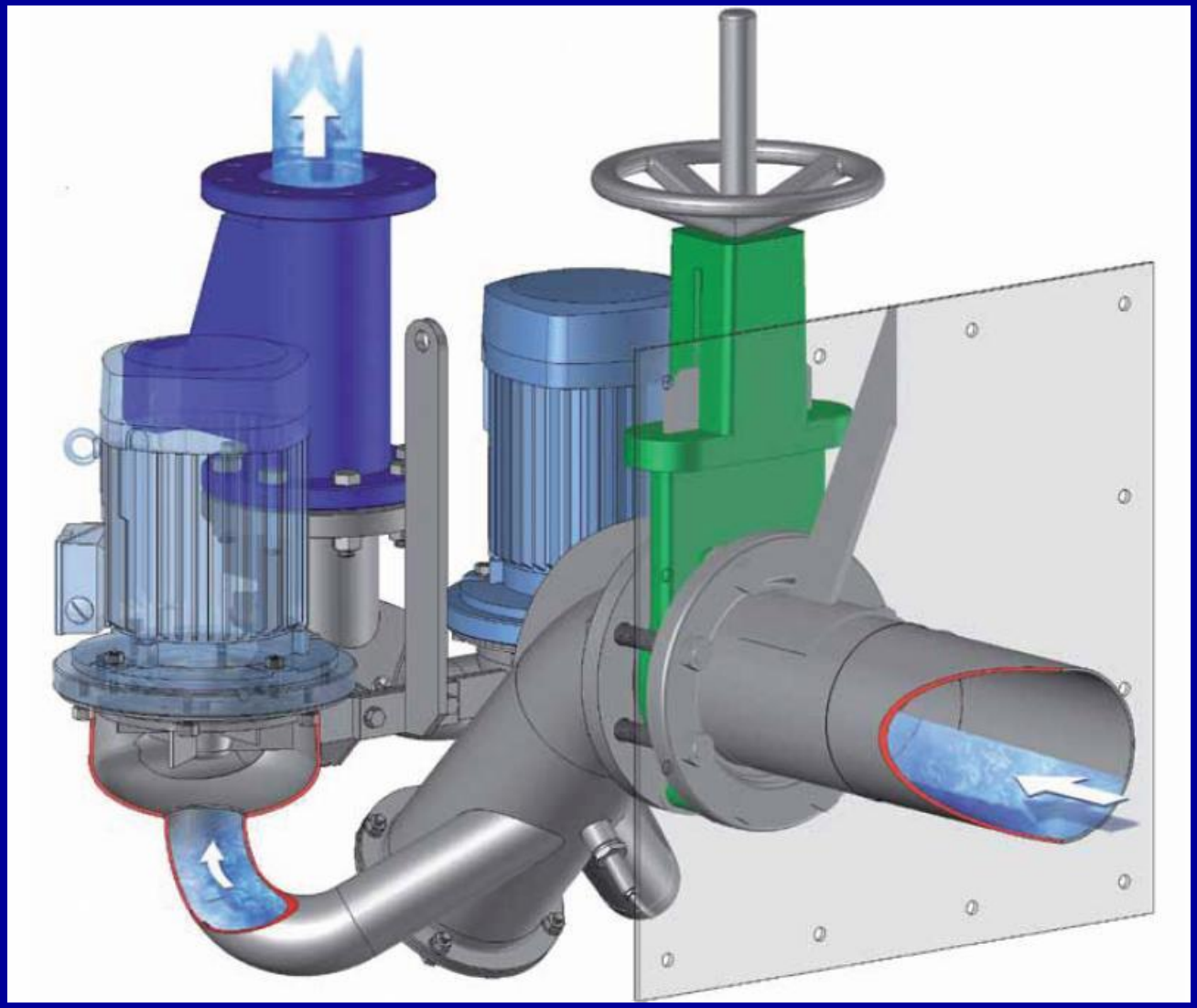
Infrastructure corrosion

- Manholes and pump stations
  - Electrical and mechanical equipment
- Wastewater treatment facilities
  - Grit chambers

H_2S Control Methods

Non-chemical method

- Eliminate wet well and potential for anaerobic conditions
- Variable speed pumping
- Air aspirating pump



Minimizes H2S odor problems and corrosion

Direct in-line pump system (no wet well) SIDE INDUSTRIE

H_2S Control Methods

- Nitrate addition
  - Nitrate is used by SRB instead of sulfate
  - High chemical costs
- Maintaining aerobic conditions
  - Inject air or oxygen
  - Inject hydrogen peroxide
- Addition of iron salts
  - Sulfide formed is precipitated as FeS

H_2S Control Methods

- Addition of biocides

  Add sodium hydroxide to raise pH ~ 9

  Injection of ozone and oxygen
  Ozone can act as a biocide

Envirozone Process

- Injection of ozone at high pressure during pump operation
- Effective dissolution of ozone using diffuser
- Injection of ozone followed by oxygen

Field Studies

Forcemain and Pump Station Data

- Location: Job Corps LS, Manhattan, KS
- PS Type: Suction lift station
- Forcemain: 2.4 miles, 8” dia
- Pump capacity: 430 gpm
- Pump run time during study: ~ 2.2 min
- Pump cycle time: ~ 20 min

Parameters monitored

- H_2S in gas phase: Odalog H_2S monitor
- Sulfate
- Sulfide
- Dissolved oxygen
- COD
- Suspended solids
- Temperature

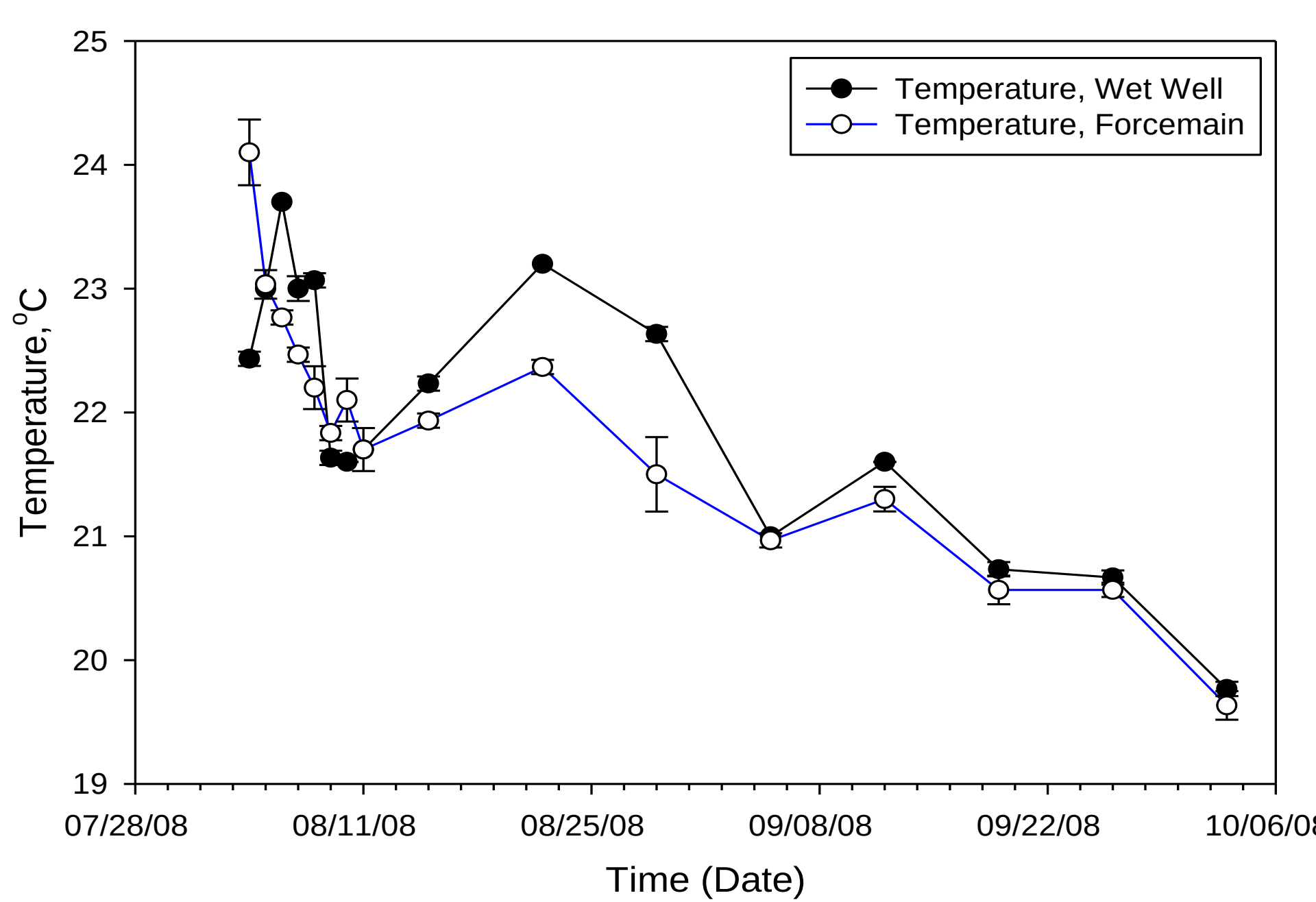


Fig 1. Wet well and forcemain temperatures

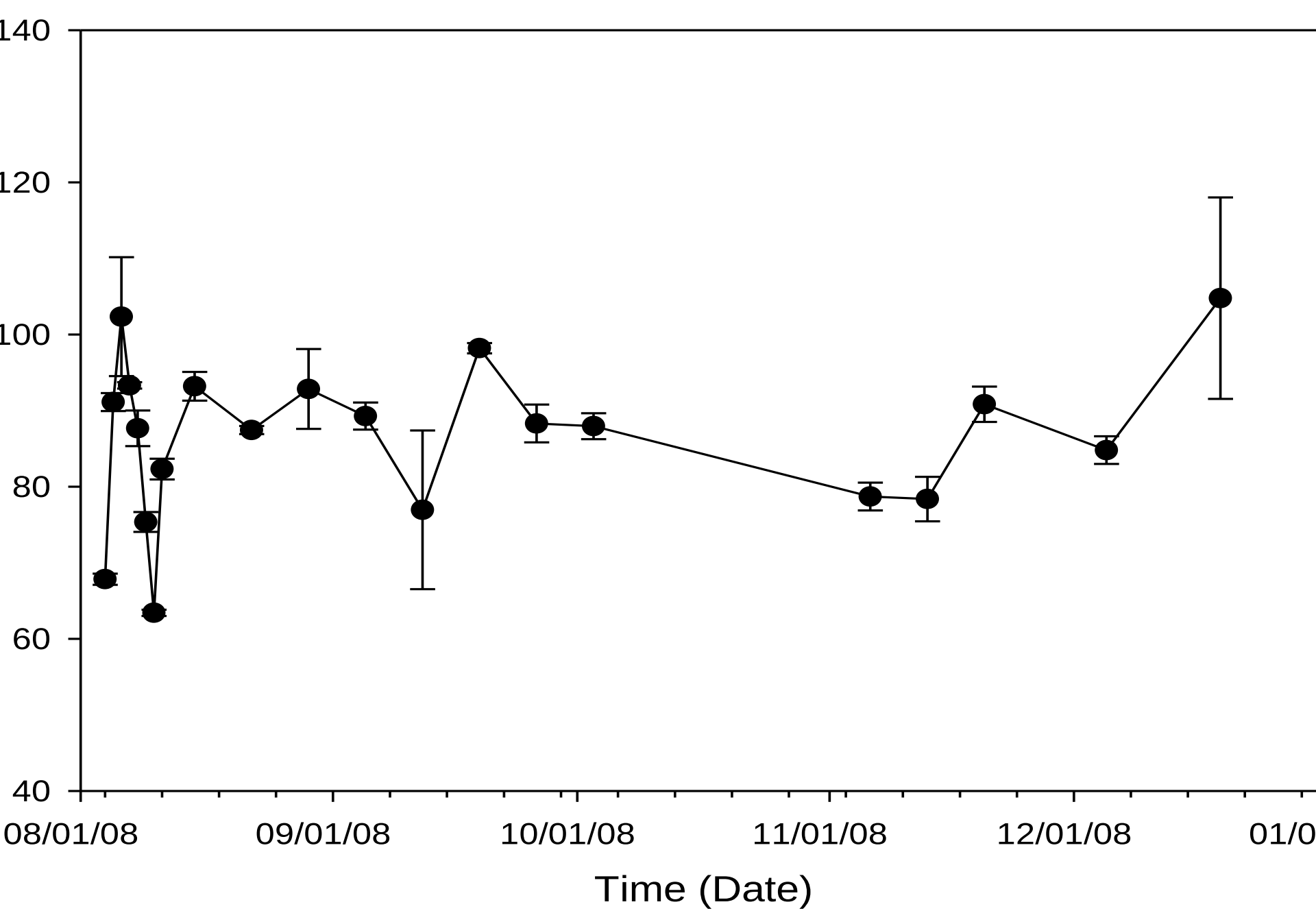
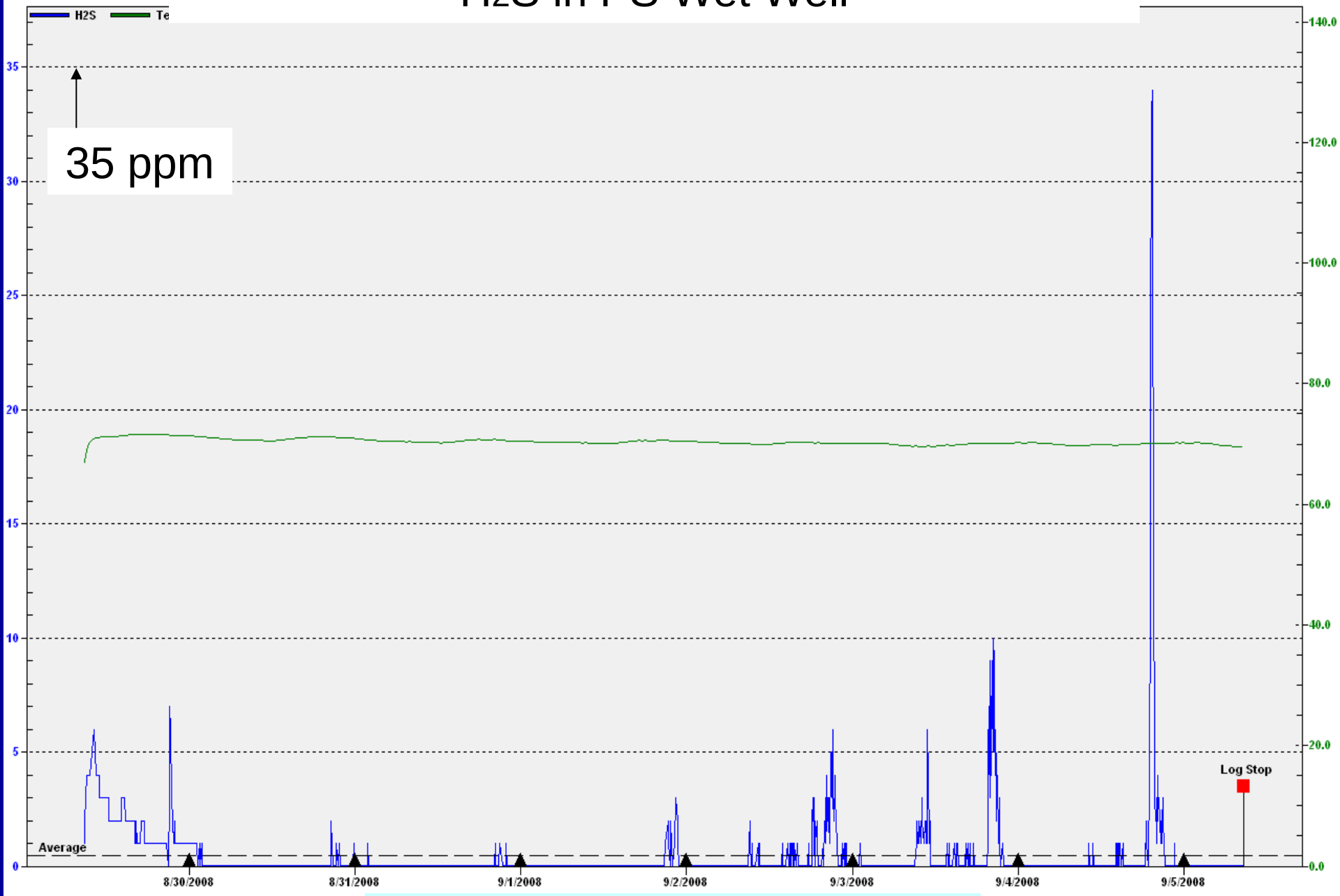


Fig 2. Wet well sulfate concentration

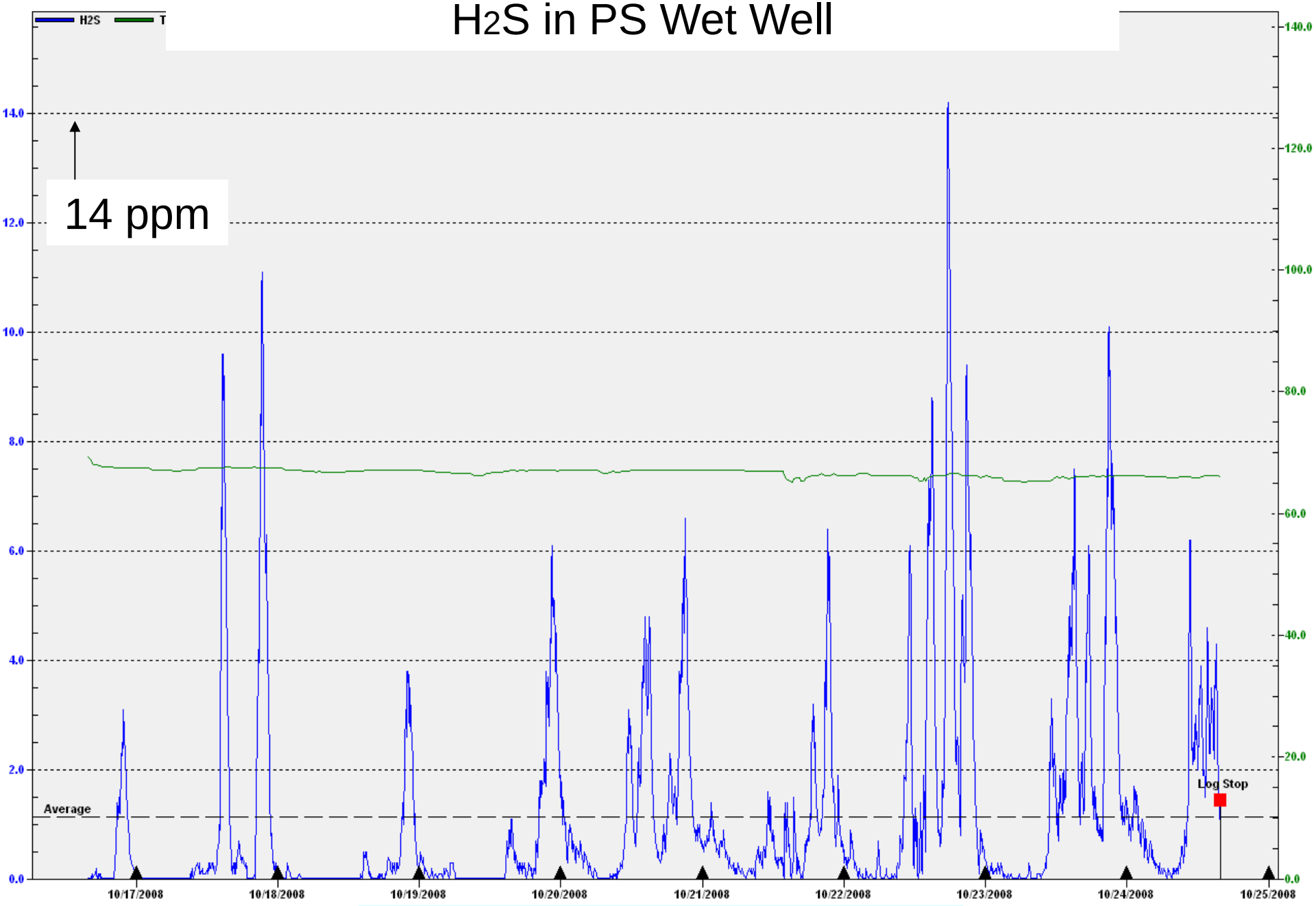
H_2S in PS Wet Well



Period Displayed: 8/29/2008 - 9/5/2008 (Oda File: Wetwell20080908_

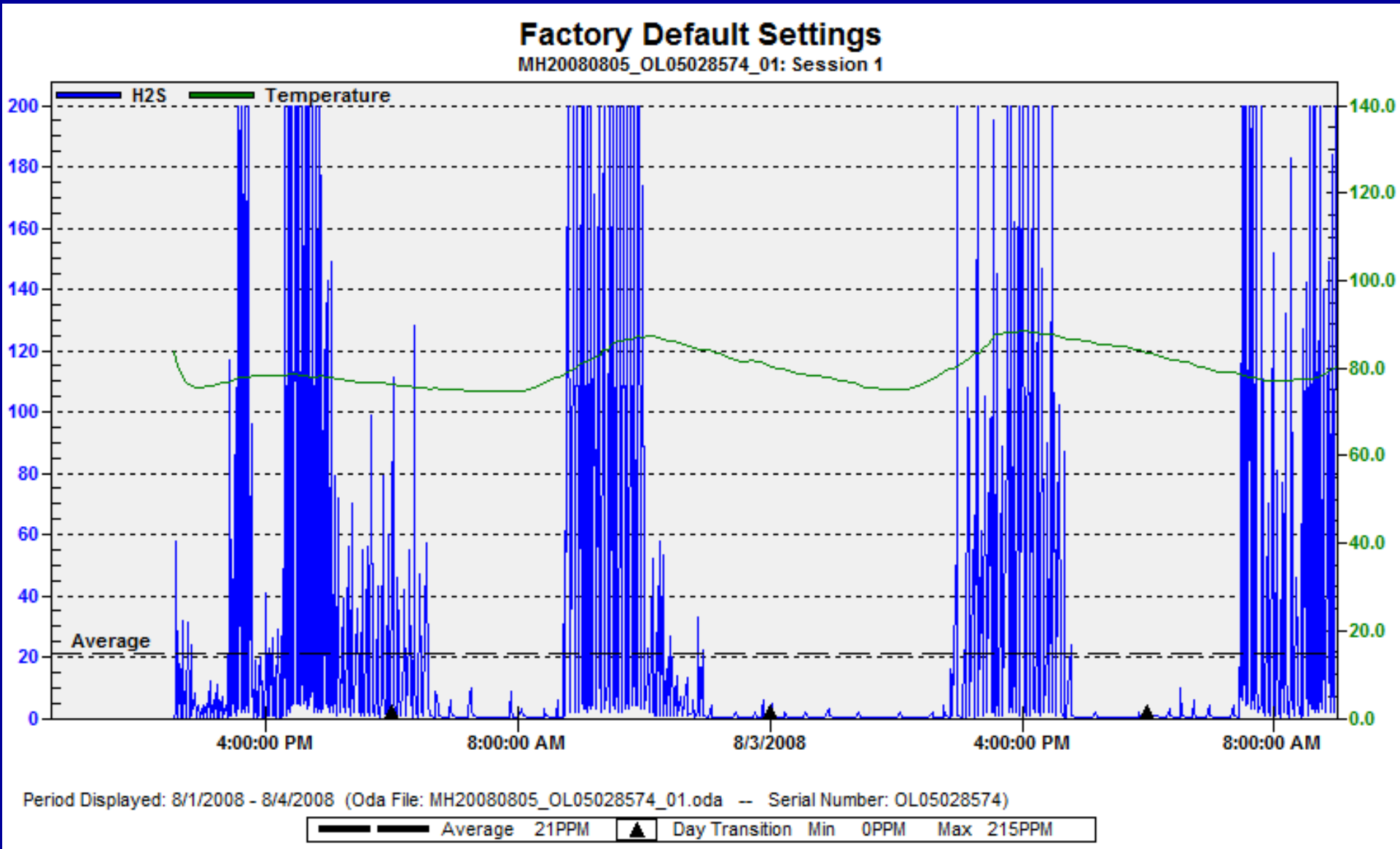
Data for 8/29/08 – 9/5/08

H_2S in PS Wet Well



Period Displayed: 10/16/2008 - 10/25/2008 (Oda File: Wet well 20081

Data for 10/17/08 – 10/24/08



Hydrogen sulfide concentration in forcemain discharge prior to treatment

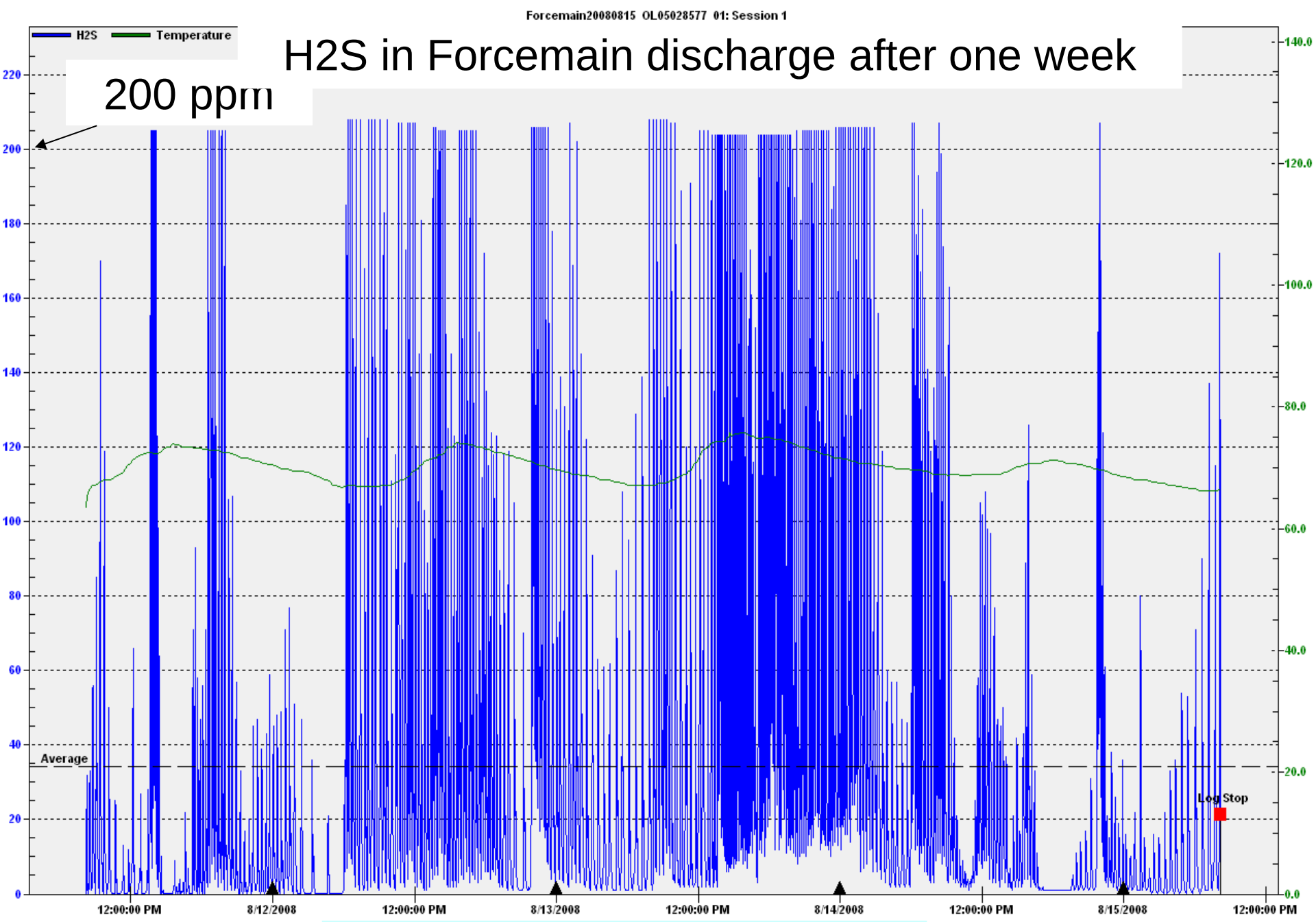
Goals

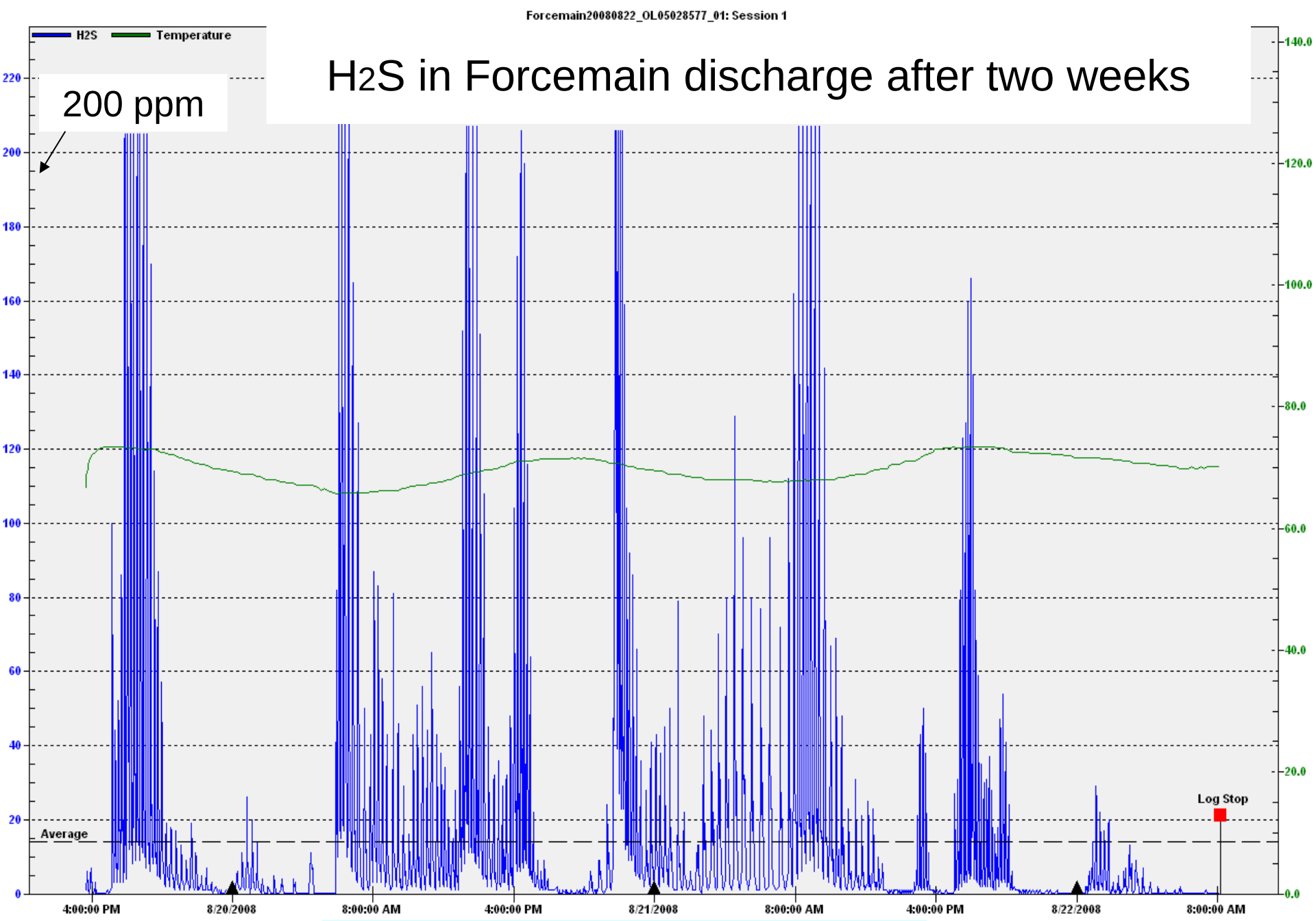
- Reduce H_2S concentration to < 5 ppm
- Reduce sulfide to < 0.3 mg/L
- Increase DO > 2 mg/L

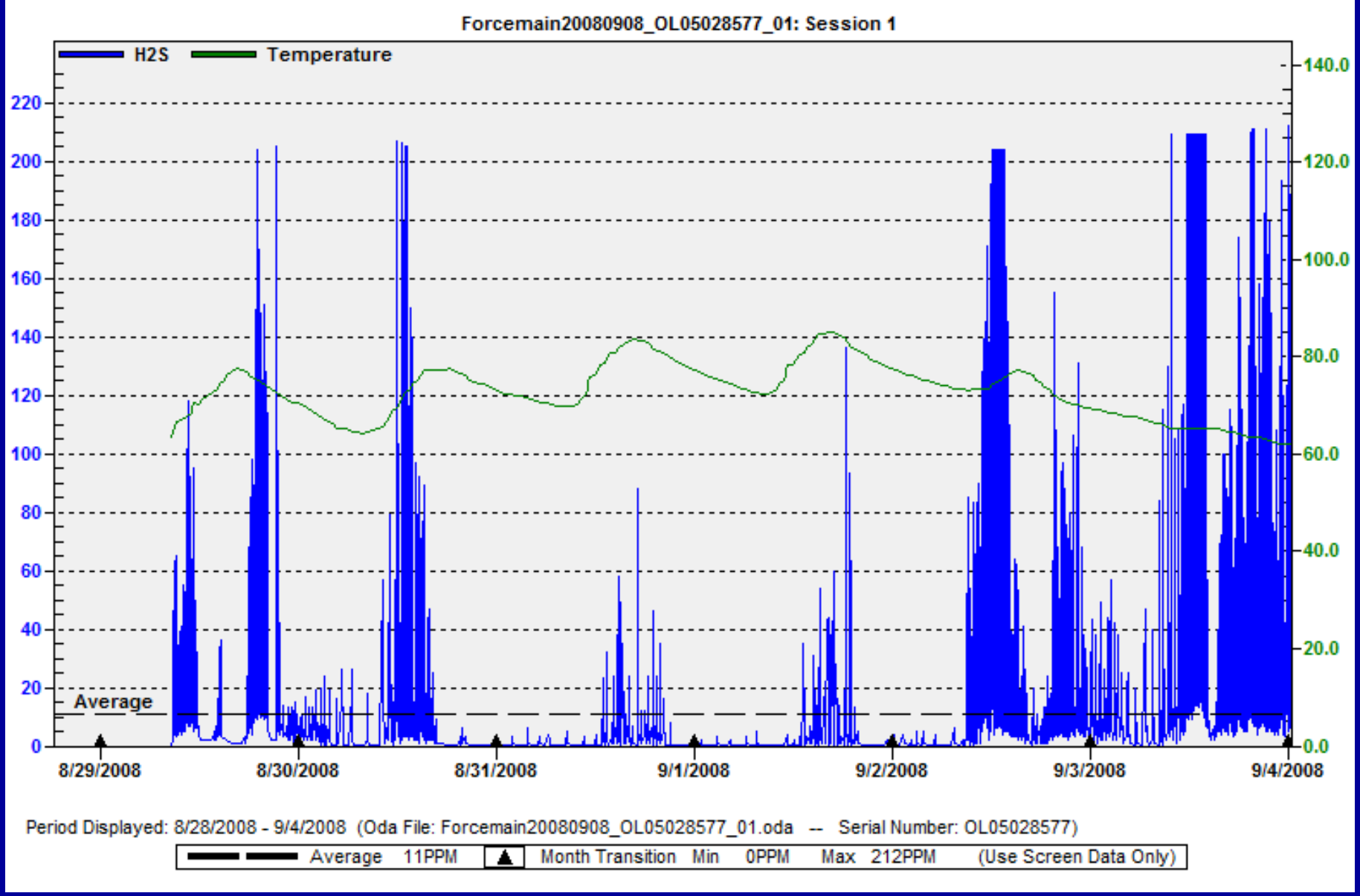
Field studies

- Stage I: Ozone injection only during pump operation
- Stage II: O3 injection into pump suction and timed ozone injection into wet well (10 min O3 in 20 min cycle)
- Stage III: O3 injection into pump suction and 4 min O3 in 20 min cycle in wet well
- Stage IV: Ozone and oxygen injection into forcemain

Results


Forcemain20080815 OL05028577 01: Session 1
H2S
Temperature
H2S in Forcemain discharge after one week
200 ppm
220
200
180
160
140
120
100
80
60
40
20
0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Average
Log Stop
12:00:00 PM
8/12/2008
12:00:00 PM
8/13/2008
12:00:00 PM
8/14/2008
12:00:00 PM
8/15/2008
12:00:00 PM
Period Displayed: 8/11/2008 - 8/15/2008 (Oda File: Forcemain2
Data for 8/11/08 – 8/16/08


Forcemain20080822_OL05028577_01: Session 1
H2S
Temperature
H2S in Forcemain discharge after two weeks
200 ppm
Average
Log Stop
4:00:00 PM
8/20/2008
8:00:00 AM
4:00:00 PM
8/21/2008
8:00:00 AM
4:00:00 PM
8/22/2008
8:00:00 AM
Period Displayed: 8/19/2008 - 8/22/2008 (Oda File: Forcemain1
Data for 8/19/08 – 8/22/08



H_2S levels in forcemain discharge after 1 month of O_3 injection

Phase I results

- Number of adverse peak event days were reduced
- Peak H_2S concentration ~ 200 ppm

Stages II and III: Effect of supplemental ozone injection into wet well

Stage II

- Cycle time 20 minutes

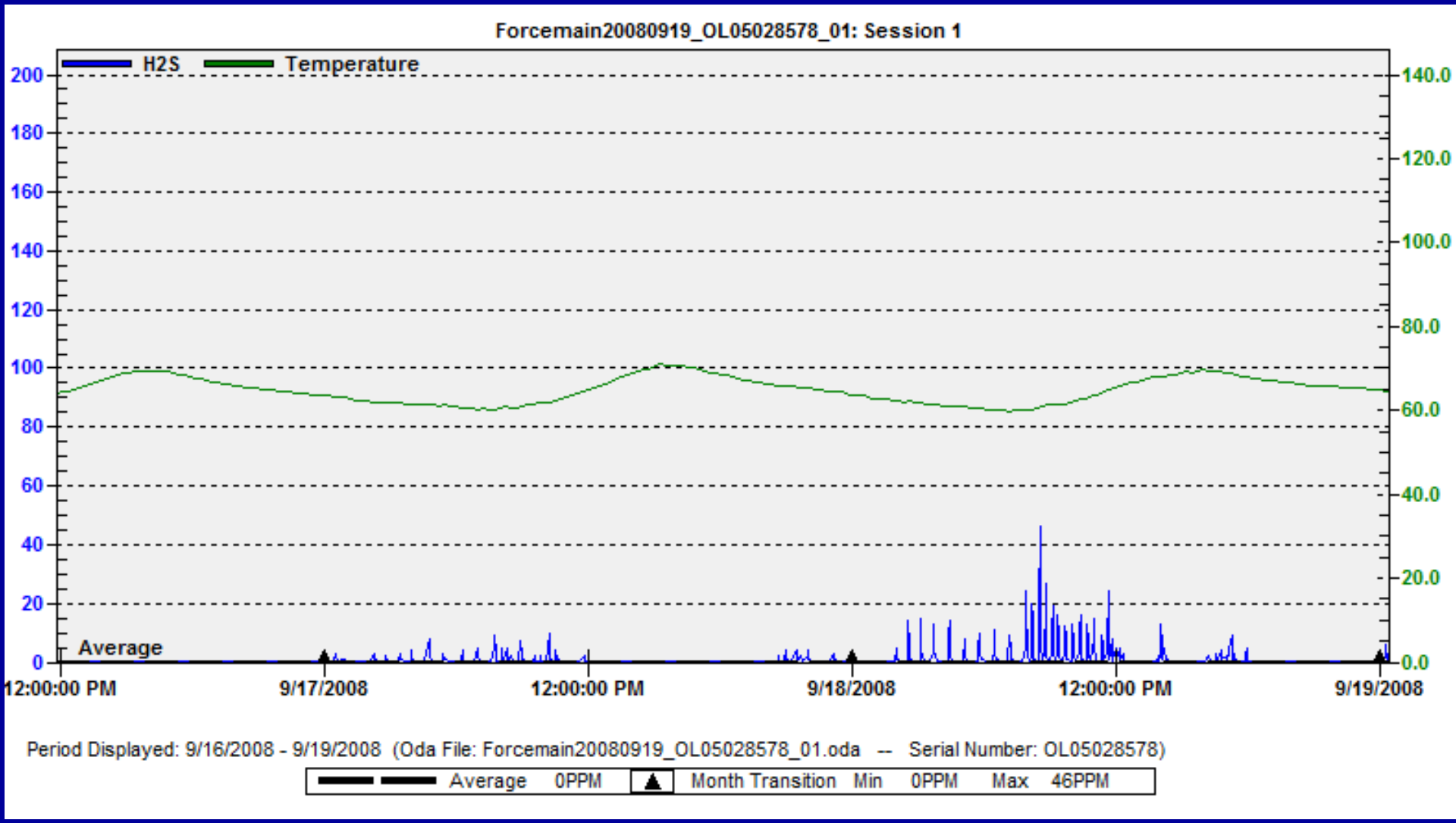
  Ozone injection: 10 min

  Oxygen injection : 10 min

Stage III

  Ozone injection: 4 min

  Oxygen injection : 16 min



H_2S levels in forcemain discharge after O_3/O_2 injection into wet well

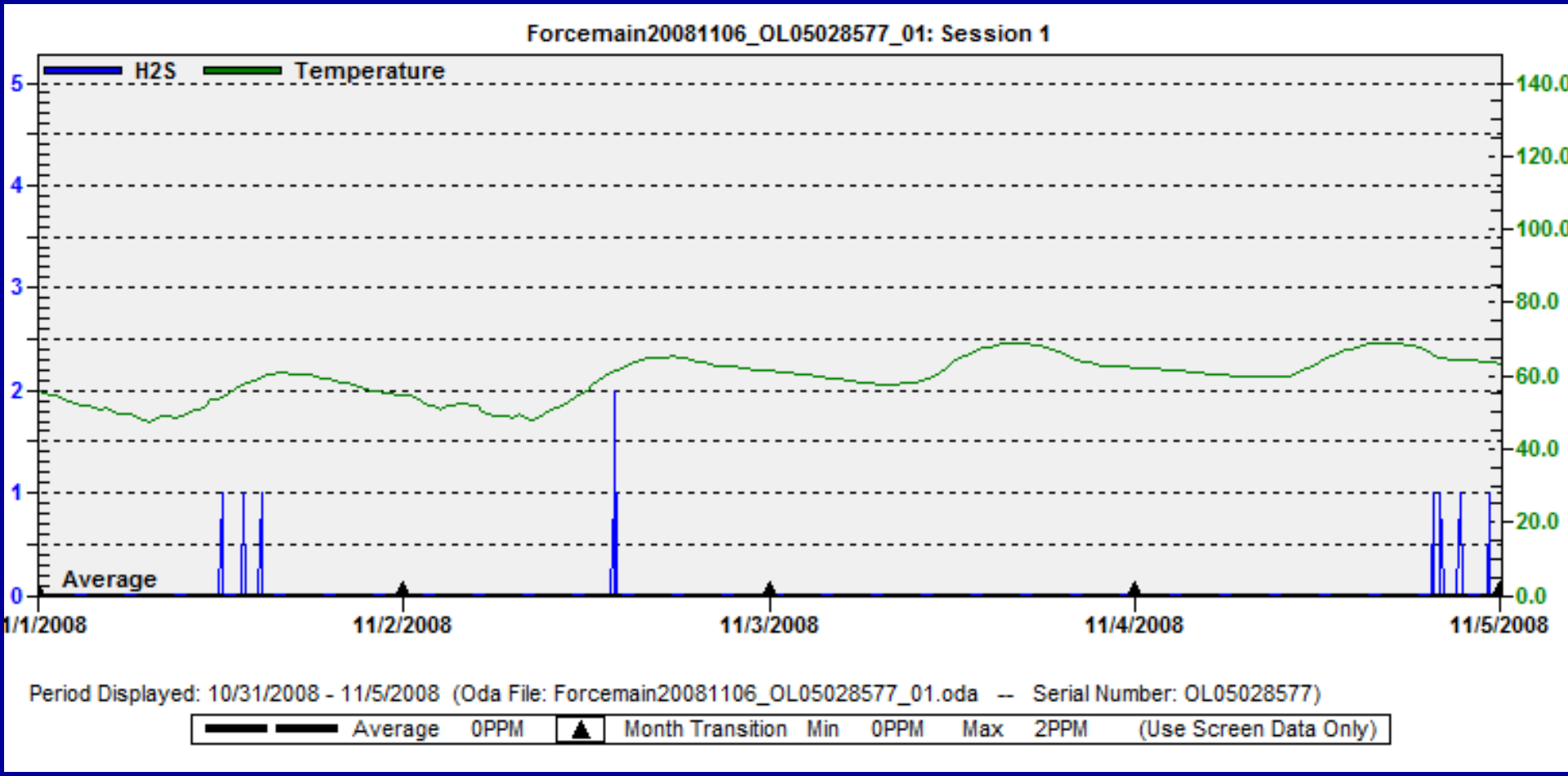
Phase II results

- Number of adverse peak event days were reduced markedly

- Peak H_2S concentration ~ 45 ppm

Effect of ozone and oxygen injection

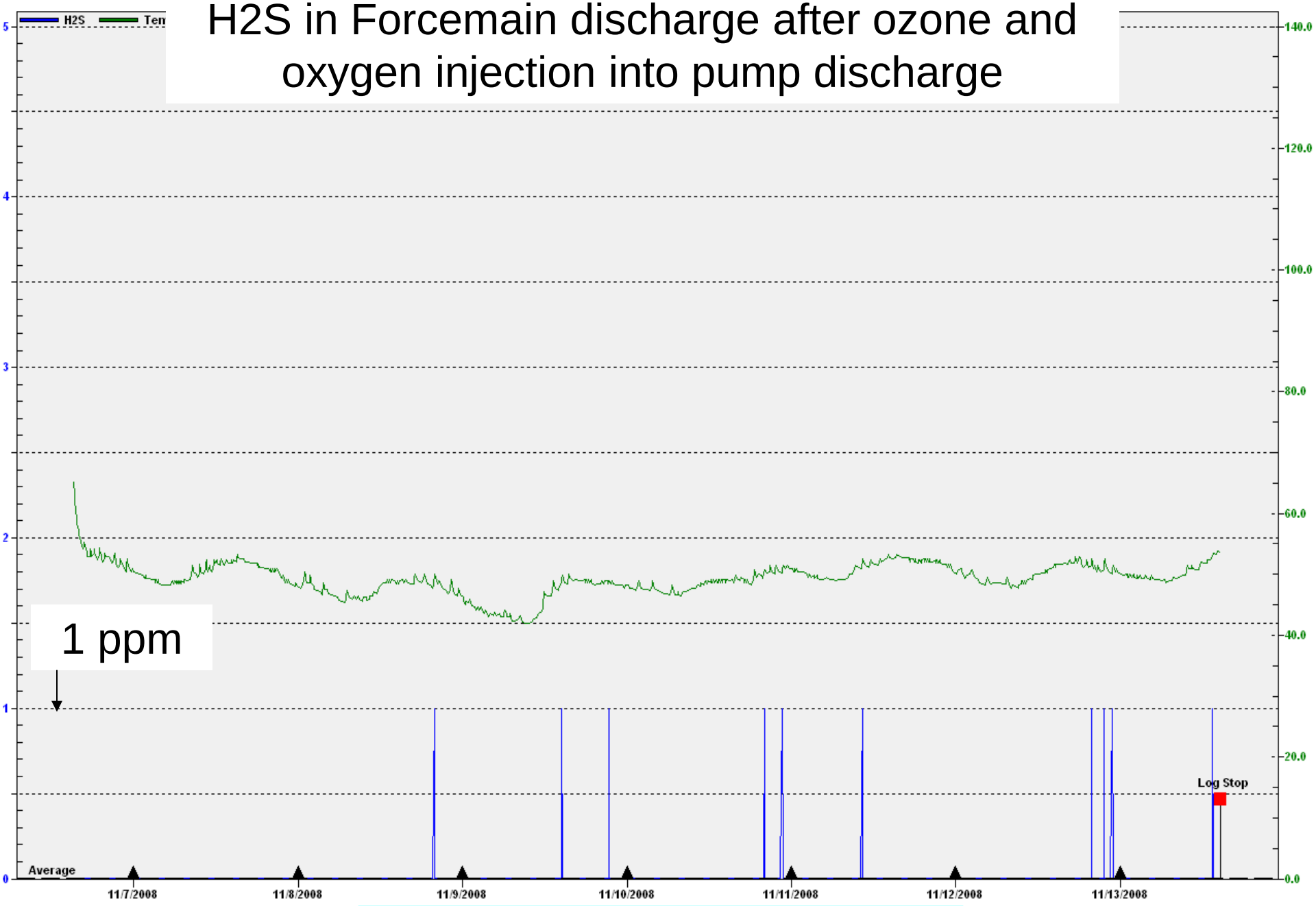
- Ozone injection during pump discharge during pump operation only
- Oxygen injection into pump discharge when pump is not in operation



H_2S levels in forcemain discharge after O_3/O_2 injection into forcemain

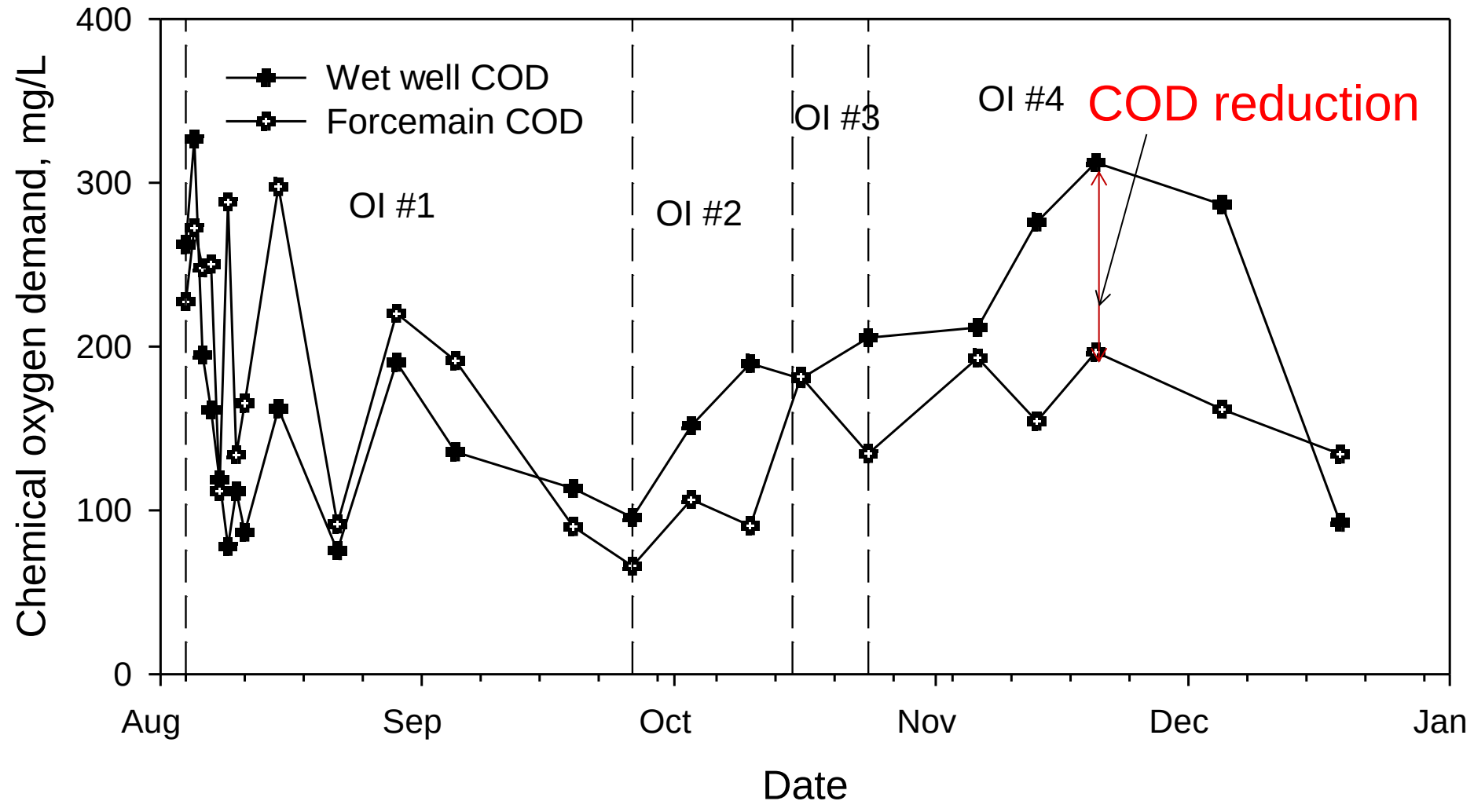
Data for 11/1/08 – 11/5/08

H2S in Forcemain discharge after ozone and oxygen injection into pump discharge

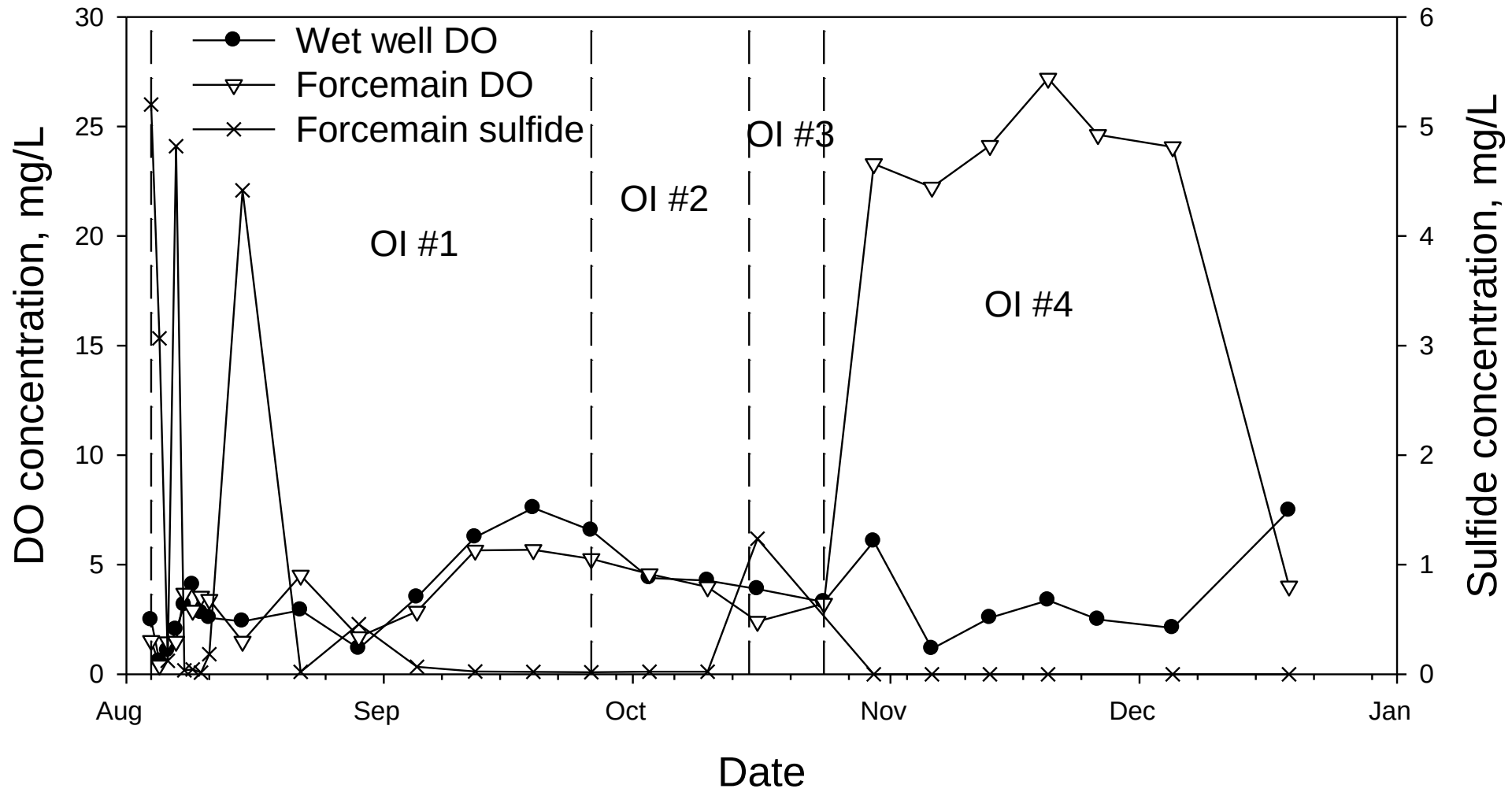


Period Displayed: 11/6/2008 - 11/13/2008 (Oda File: Forcemain20081

Data for 11/7/08 – 11/14/08



COD concentrations in the wet well and forcemain discharge



DO and sulfide concentrations in forcemain discharge

Phase IV results

- H_2S concentrations on most days ~ zero
- Peak H_2S concentration ~ 1 ppm
- COD reduction of about 41%
- Increased DO levels in discharge wastewater

Conclusions

- Field studies were conducted for H_2S control at a suction lift station with ~ 2.4 mile long forcemain
- Ozone and oxygen injection is effective in reducing H_2S level to < ~ 1ppm
- Sulfide concentration reduced to ~ 0 mg/L

- No chemicals or chemical storage and feed equipment are required
- Only mechanical equipment to generate oxygen and ozone are required
- Additional benefits include:

  Increased DO in wastewater

  Reduction in wastewater treatment costs due to reduction in COD