



Water Resources
Management
Division

Department of
Environment &
Conservation

Chlorination and pH Adjustment in Drinking Water Systems in NL

Drinking Water Safety Workshop, Gander
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Chlorine Based Disinfection in Newfoundland and Labrador

- 433 chlorination systems
 - 283 liquid hypo-chlorination
 - 133 gas chlorination
 - 10 powder chlorination
 - 6 mixed oxidants systems
 - 1 on-site generator
- Gas Chlorination
 - Typically for large systems (over 200 gpm or 13 L/s)
 - Unlimited shelf life
 - Requires special handling and operator training
- Liquid Hypo-chlorination
 - Typically for smaller systems
 - Easier to handle and store
- Mixed Oxidants (MIOX) Systems
 - Safer than gas chlorination and liquid hypo-chlorination
 - Doesn't involve transporting large amounts of chlorine
 - Produced on-site
- On-Site Generators
 - Increased safety
 - Reduces operational costs
 - On demand production of chlorine

pH Adjustment in Newfoundland and Labrador

- 43 pH adjustment systems
 - 33 soda ash
 - 8 lime
 - 2 caustic soda
- Tap water pH lower than raw water pH in 9 out of 43 systems
- Soda Ash
 - Safe to handle
 - More expensive than lime and caustic soda
 - Dissolves more easily than lime
 - Increases pH and alkalinity
 - Good for small systems
- Lime
 - Increases pH and alkalinity
 - Difficult to handle
 - Inexpensive
 - Adds turbidity to water
- Caustic Soda
 - Hazardous to handle
 - Not recommended for small systems
 - pH control difficult in low alkalinity waters

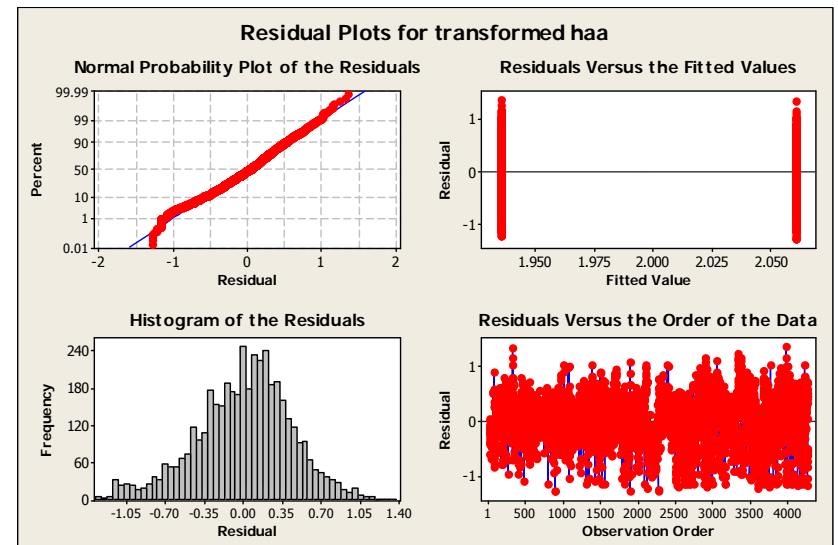
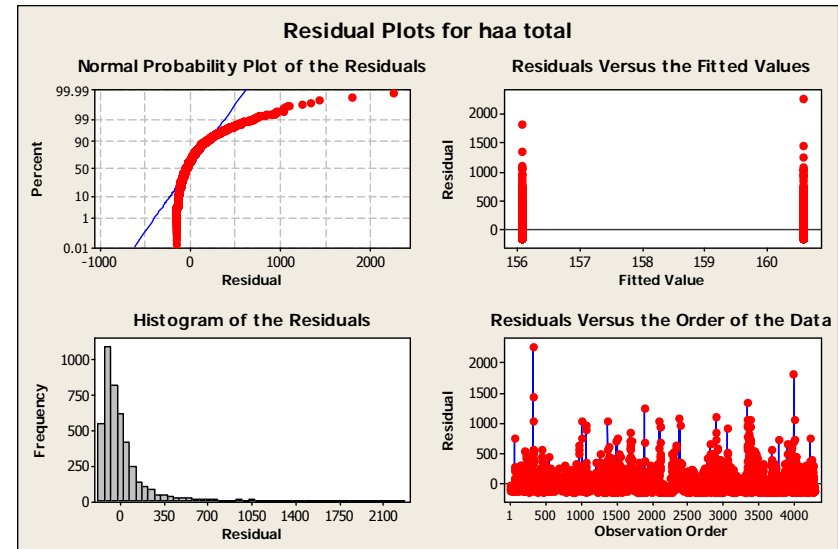
Objectives of Study

1. Comparison of the effects of gas chlorination and liquid hypochlorination on drinking water quality:
 - pH
 - Alkalinity
 - Langelier Index
 - HAAs
 - THMs
 - Free Chlorine
2. Examine effectiveness of pH adjustment systems
 - Why tap water with lower pH than raw water?
 - How are they affecting DBPs?
 - What corrective actions can be recommended?

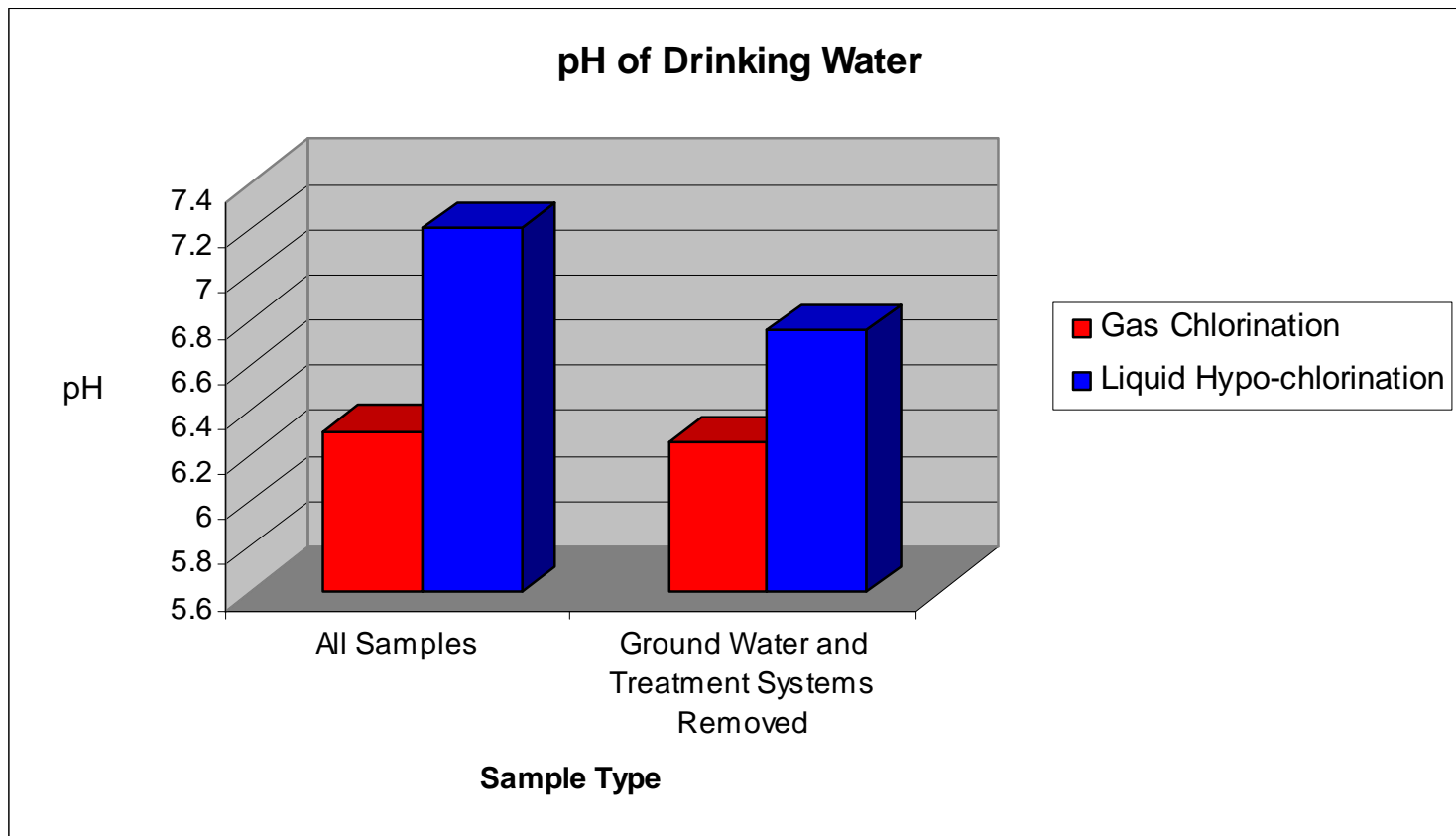


Statistical Evaluation of Water Quality Data

- Data from approximately 8500 samples collected from 1995-2011 used in study
- Difficult data
 - Censored
 - Outliers
 - Parameters with different data distributions
- MINITAB statistical software used to perform
 - Parametric tests
 - Non-parametric tests
- Statistical significance at $\alpha < 0.05$

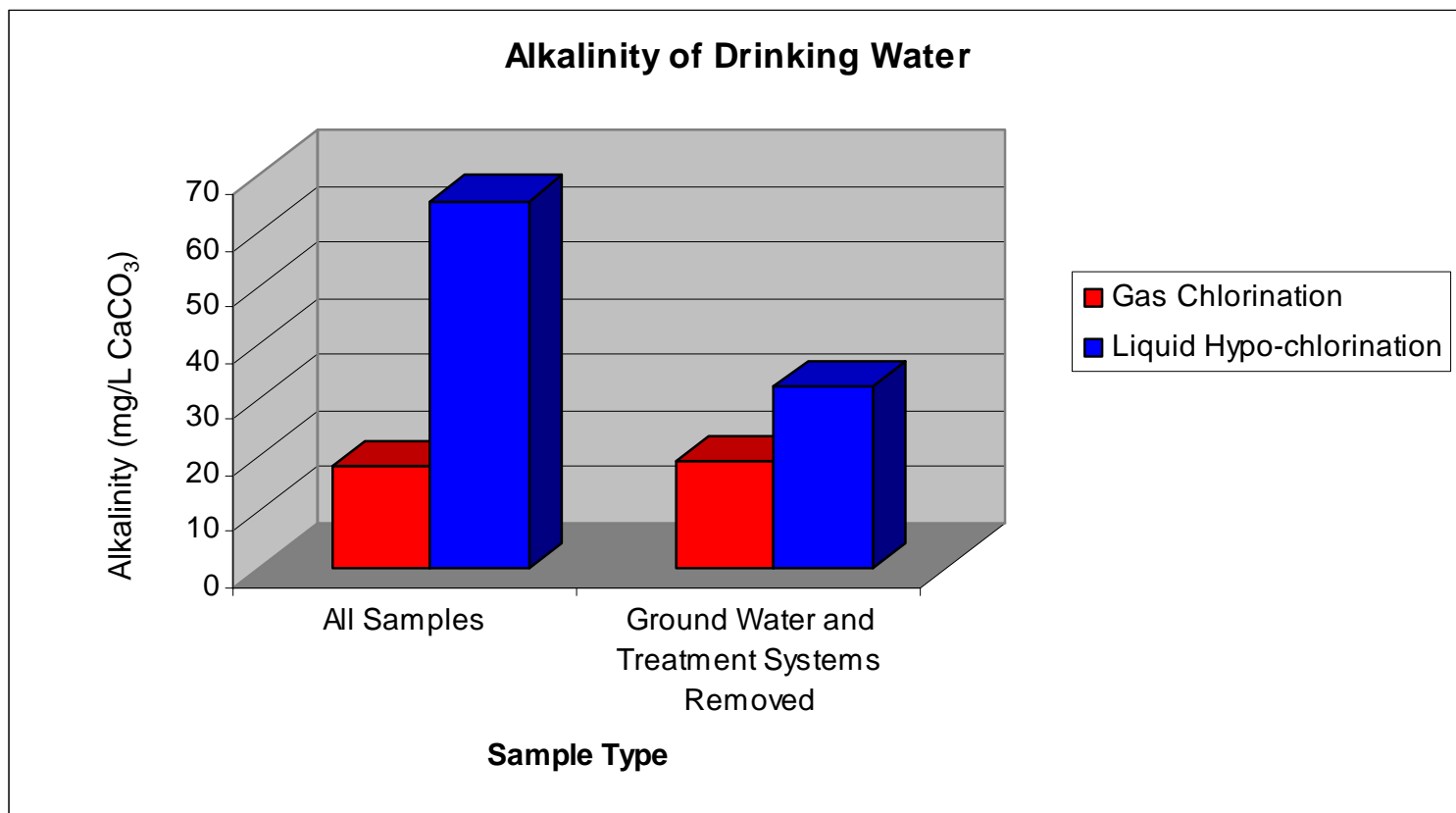


pH



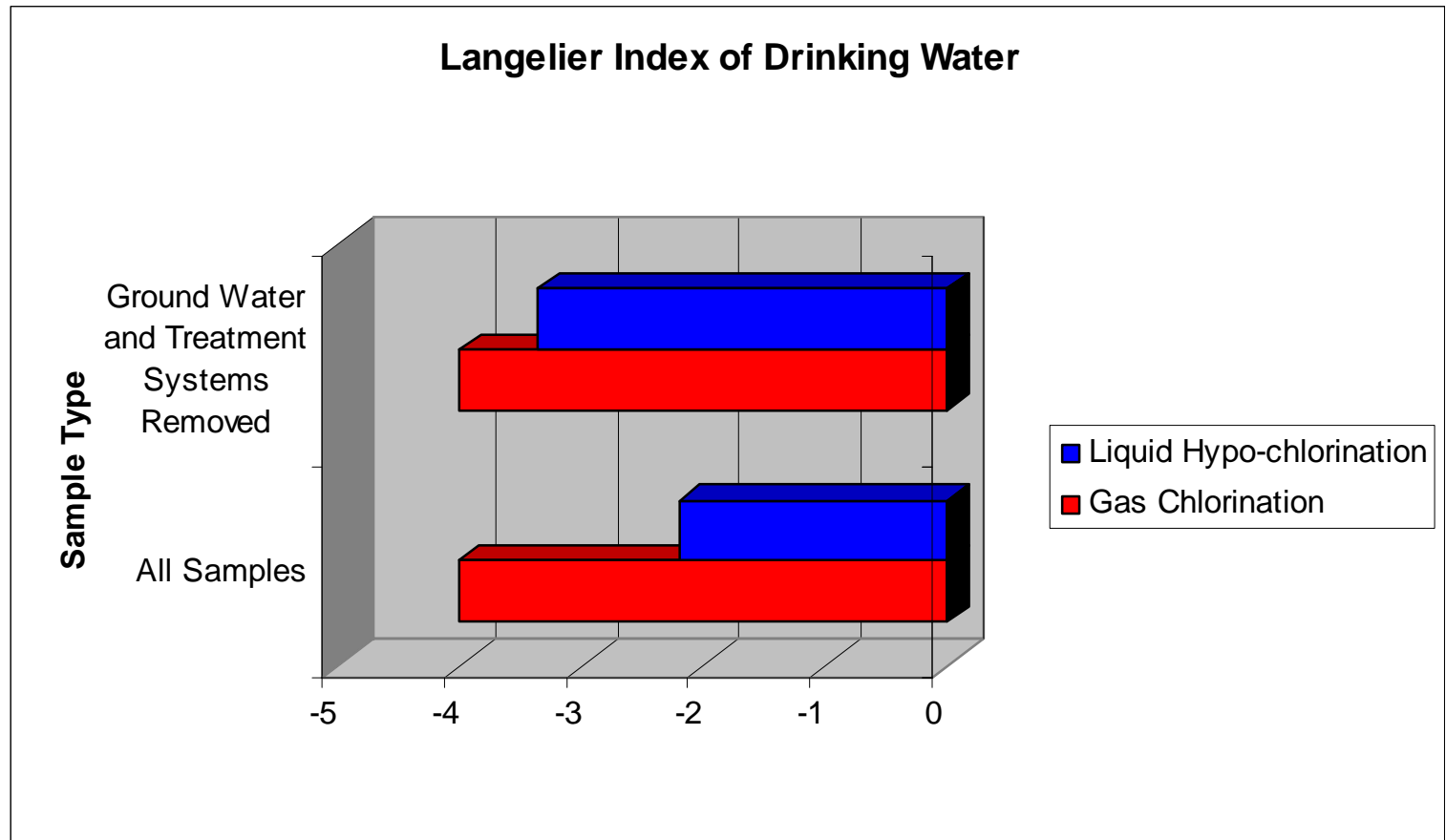
- Comparison of means
- pH of tap water from gas chlorination systems was significantly lower than that of liquid chlorination systems

Alkalinity



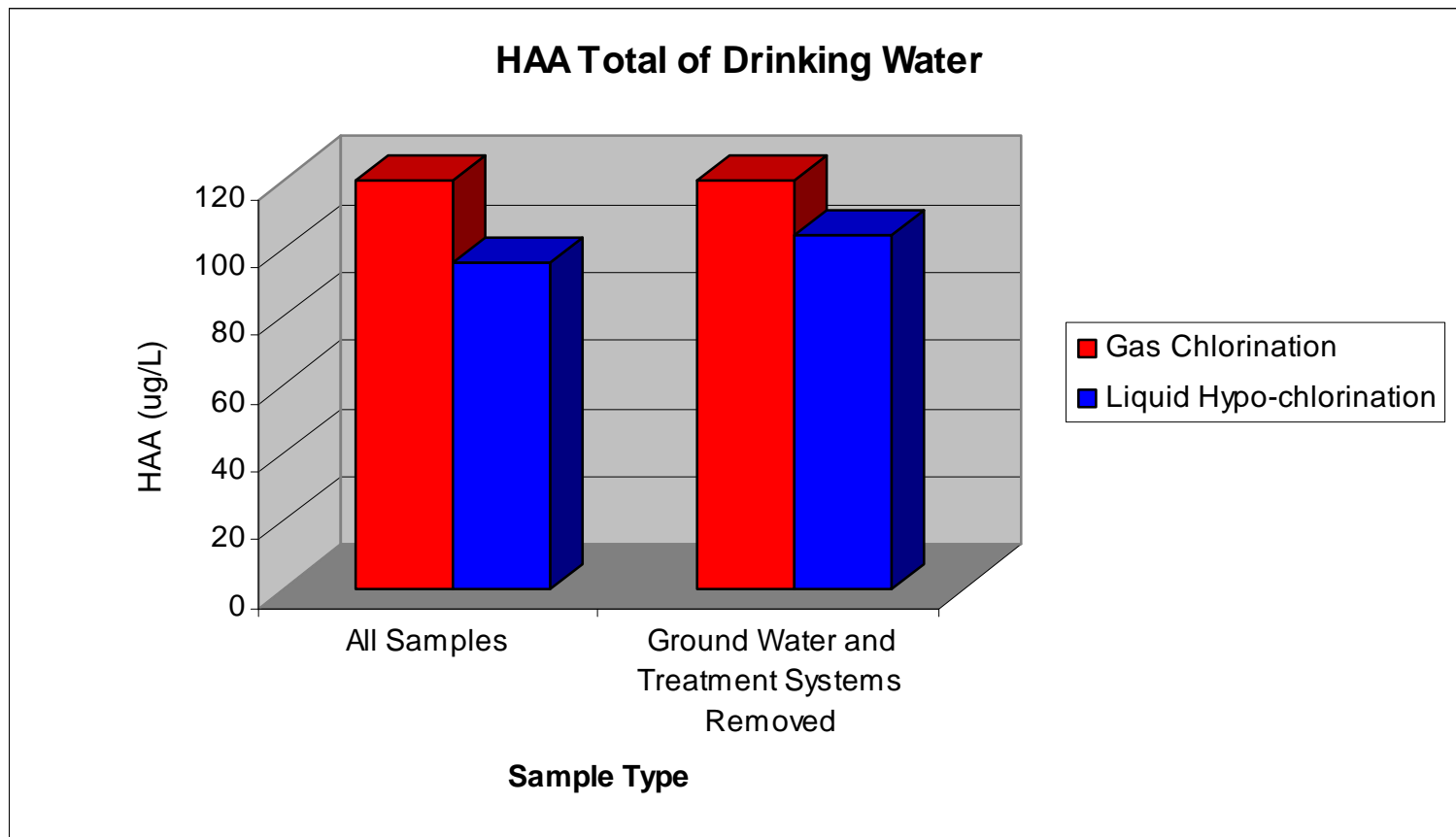
- Comparison of means
- Alkalinity of water from gas chlorination systems was significantly lower than that of liquid chlorination systems

Langelier Index



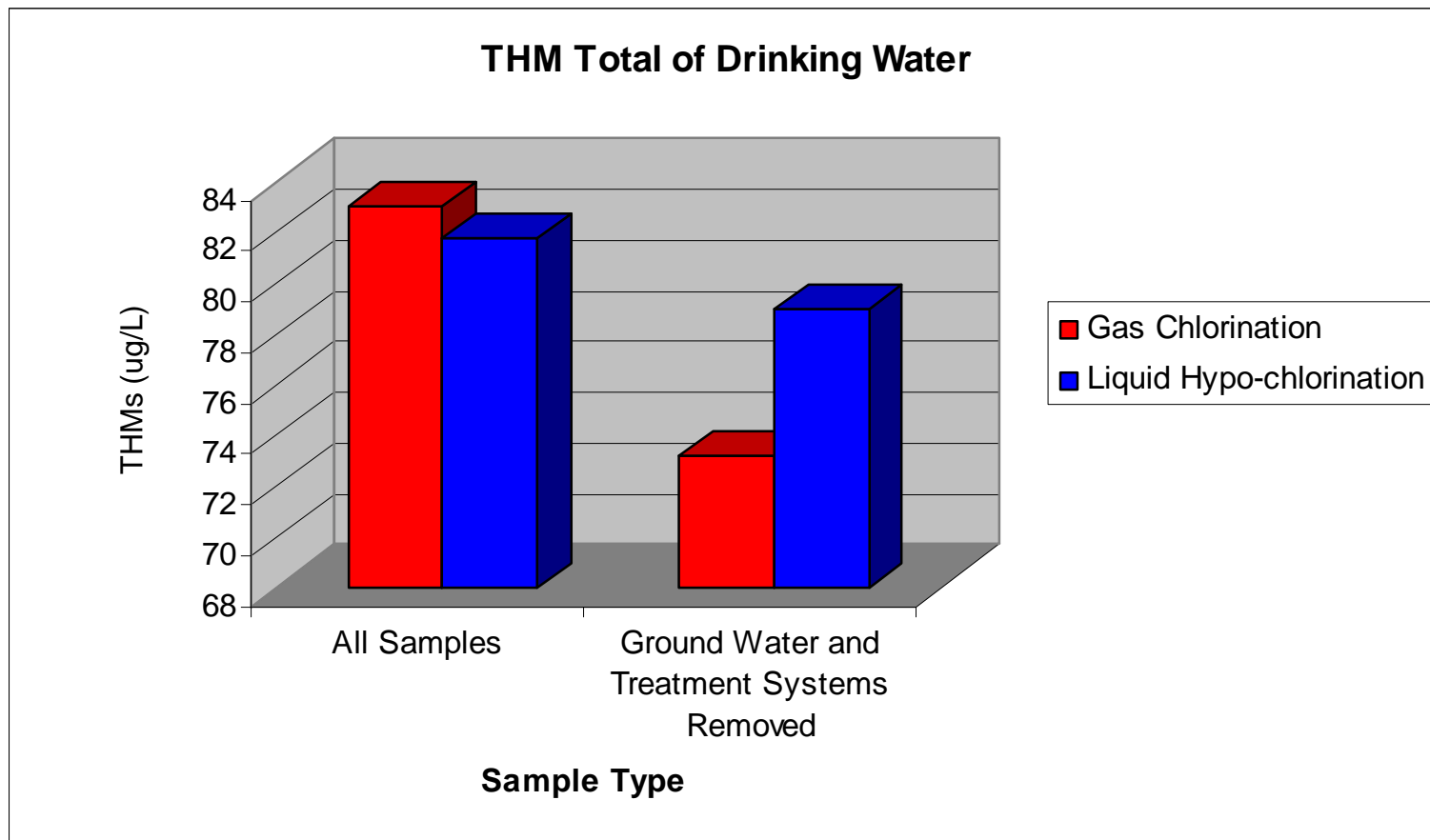
- Comparison of means
- Langelier index of water from gas chlorination systems was significantly lower than that of liquid chlorination systems

HAA Total



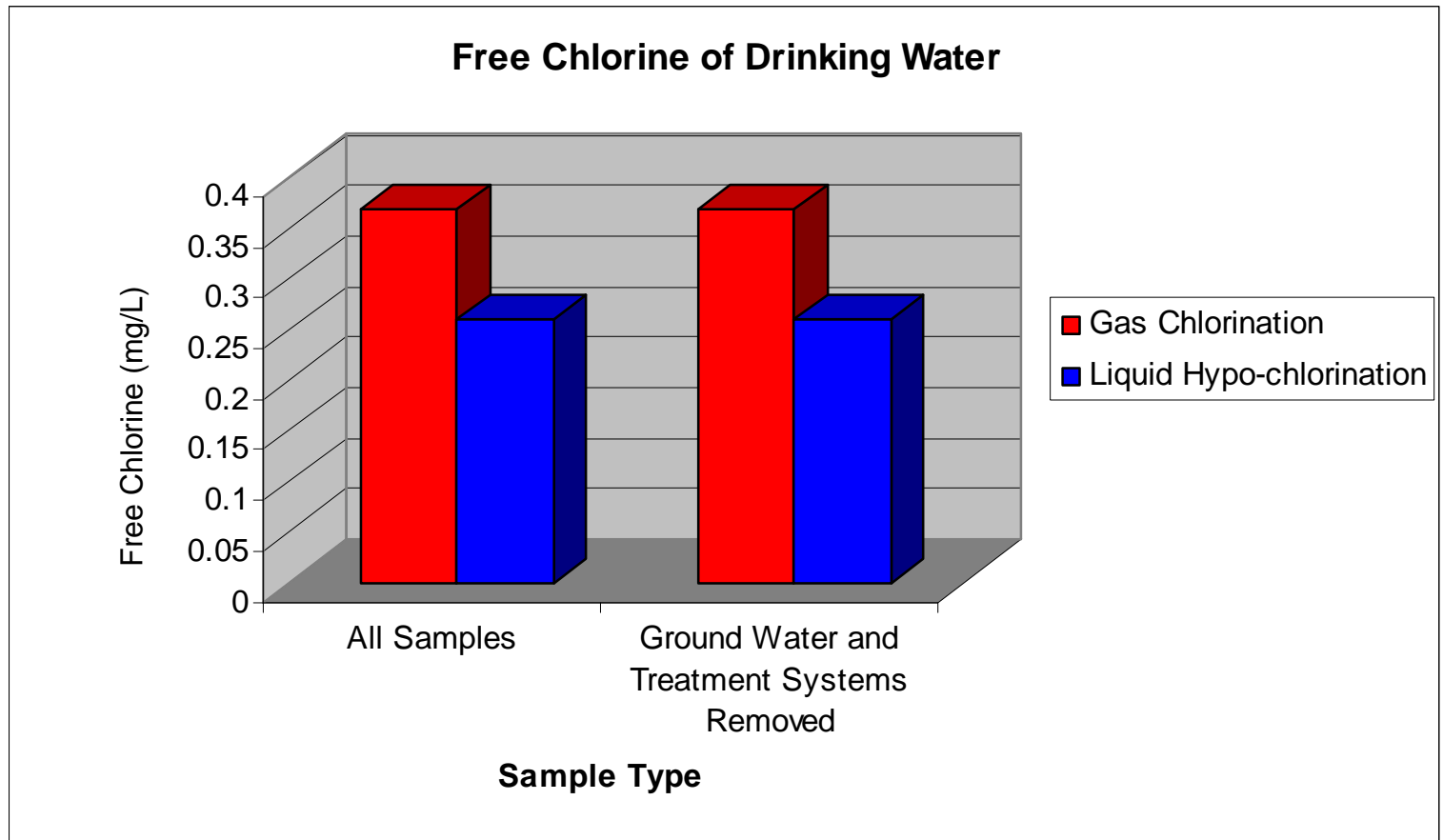
- Comparison of medians
- HAAs from gas chlorination systems were significantly higher than that of liquid hypo-chlorination systems

THM Total



- Comparison of medians
- No statistically significant result

Free Chlorine



- Comparison of medians
- Free chlorine of water from gas chlorination systems was significantly higher than that of liquid chlorination systems

Summary of Chlorine Gas vs. Hypo-chlorination Findings

- **pH**
 - higher in liquid hypo-chlorination systems
- **Alkalinity**
 - higher in liquid hypo-chlorination systems
- **Langelier Index**
 - higher in liquid hypo-chlorination systems
- **HAAs**
 - higher in gas chlorination systems
 - more sensitive to changes in pH than THMs
- **THMs**
 - no statistically significant result
- **Free Chlorine**
 - higher in gas chlorination systems

Microsoft Excel - Chemical Dosing Calculator v1.xls

File Edit View Insert Format Tools Data Window Help

E46 21

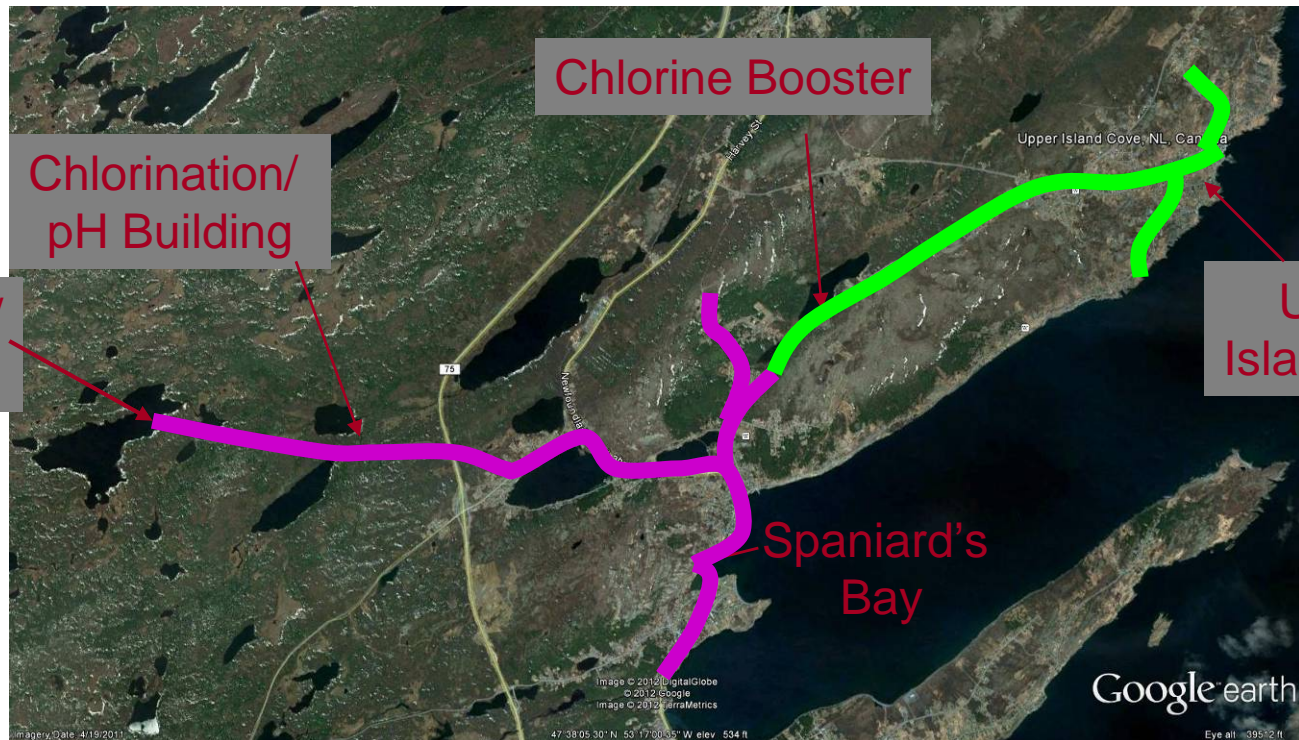
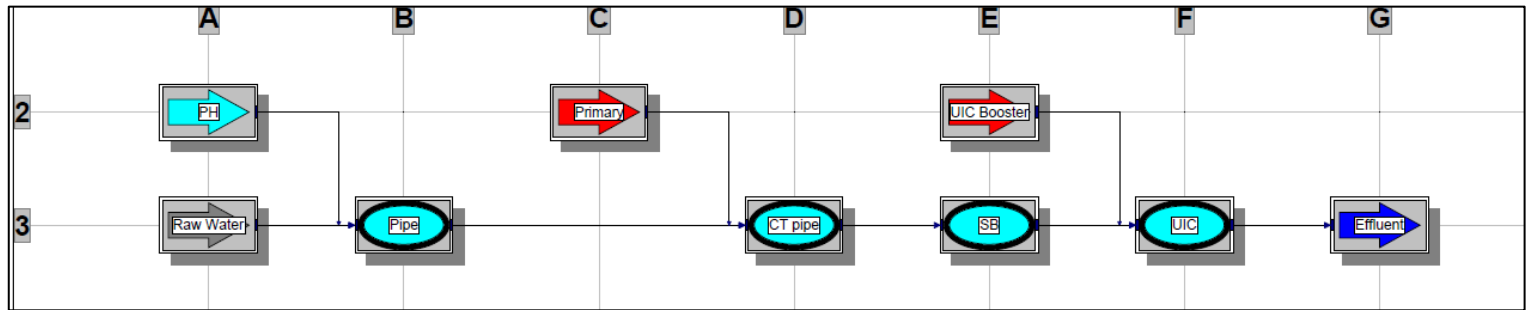
	A	B	C	D	E
1					
2	Soda Ash Dosage Calculator				
3	Available CaCO₃				
4				Soda Ash Available CaCO₃	
5	Estimated Available CaCO ₃ (%)	99.4		Commercial grade soda ash	99.4%
6					
7	System Defaults				
8					
9	Target pH	7			
10	Target Langelier Index	0			
11					
12	System Characteristics			Optimized Langelier Index	
13					
14	Actual pH	5.55		SW or GW	SW
15	Actual Langelier Index	-5.88		Soda Ash Dosage	21 mg/L
16					
17	Inputs- Based on Solution Tank Filling Frequency				
18					
19	Volume of Soda Ash Solution Tank	995 L		Total Alkalinity	19.75 mg/L
20	Mass of Soda Ash	73.5 kg		Emperically Calculated pH	7.02
21	Frequency Tank Refilled	13.9 days		Decrease Soda Ash Dosage for pH= 7	
22	Flow	3818880 L/d		Langelier Index	-3.86
23				Increase Soda Ash Dosage for LI= 0	
24	Daily Soda Ash Solution Used	71.6 L/d		Mass of Soda Ash Needed	325 kg
25	Daily Soda Ash Mass Used	5.29 kg/d		Frequency Tank Refilled	3 days
26	% Dilution of Soda Ash	6.84 %			
27					
28	Actual Soda Ash (CaCO₃) Dosage- Metric			% Dilution of Soda Ash	
29				Dosage	
30	Dosage	1.28 mg/L		24.5 %	
31				21.3 mg/L	

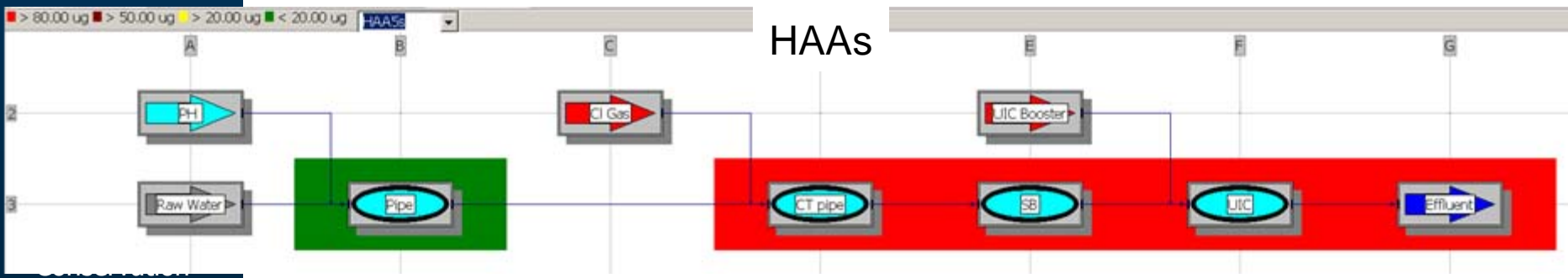
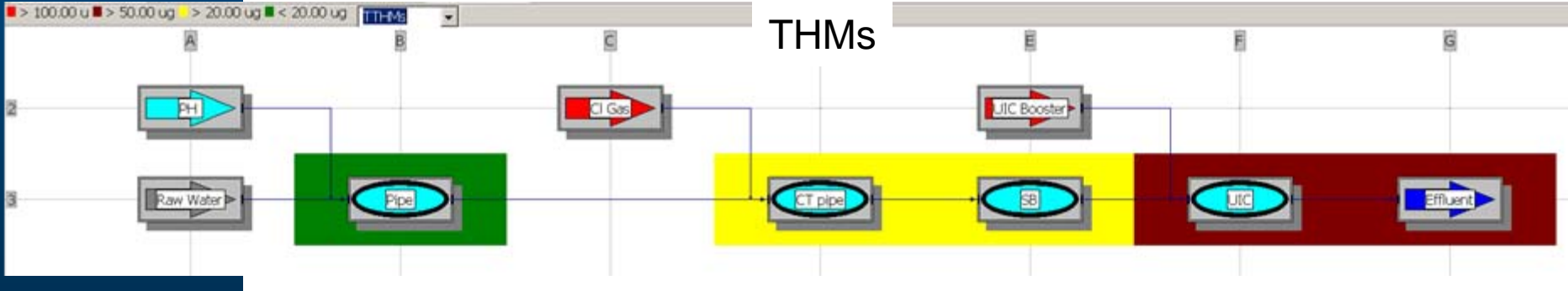
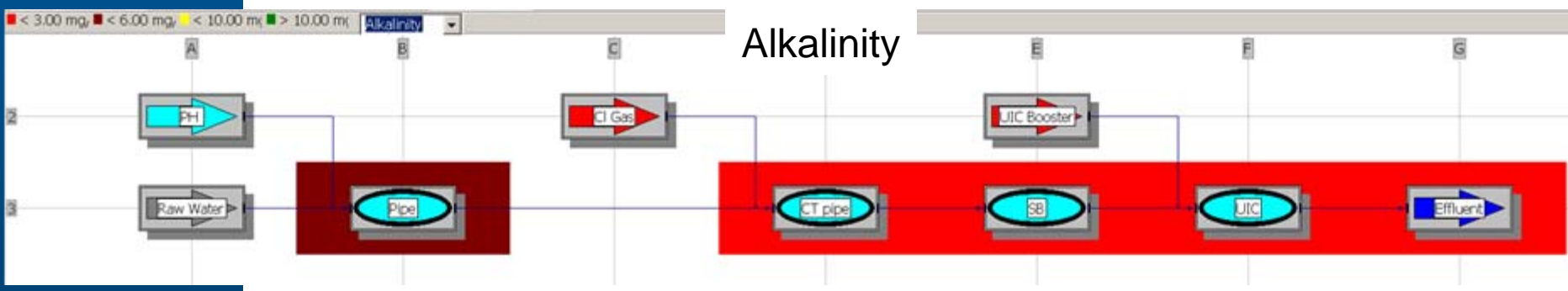
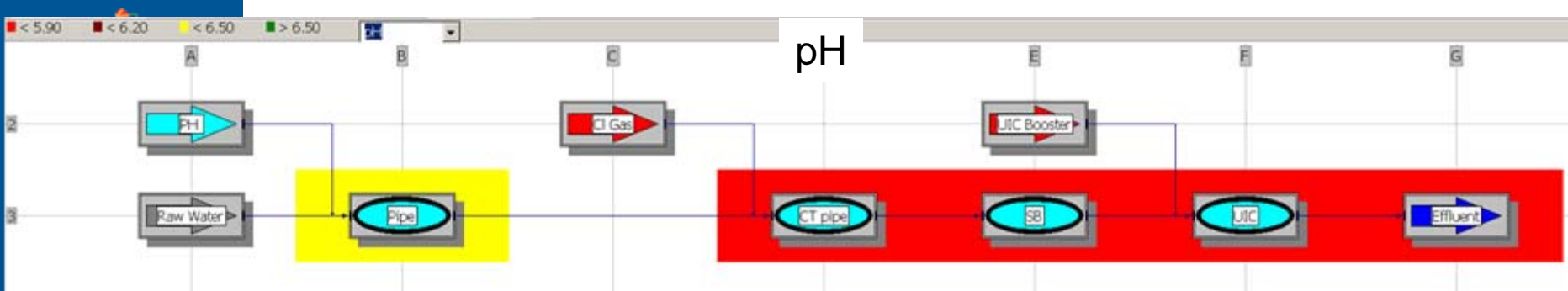
Cl Gas / Liquid Cl / Powder Cl / **Soda Ash**

Effectiveness of pH Adjustment Systems

- Developed dosing calculator to evaluate current and optimized soda ash dosage

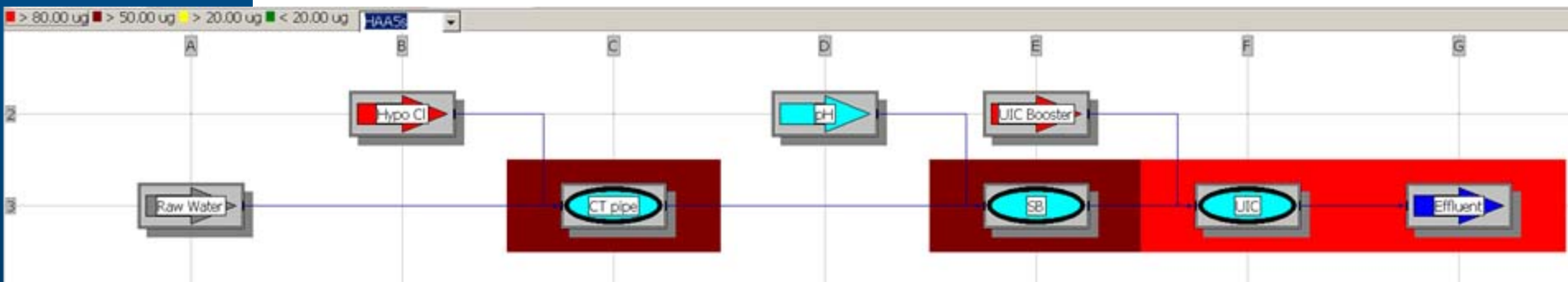
Case Study: Spaniard's Bay- Upper Island Cove



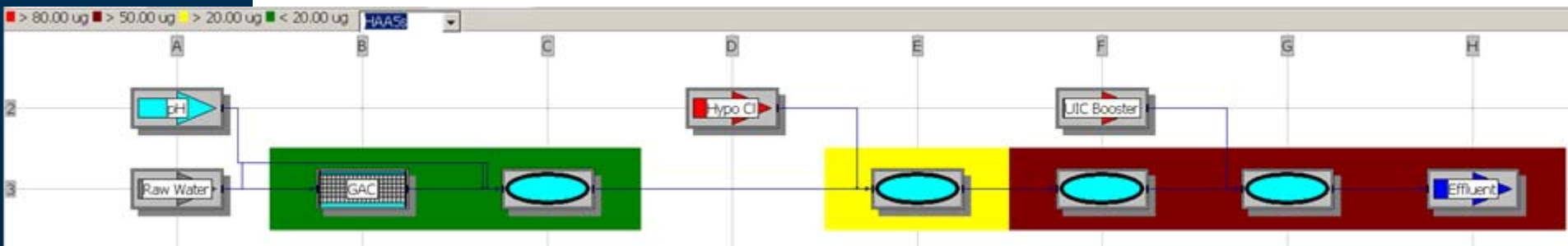


Best Options for HAA Reduction

- moved intake to deeper, colder water
- switched from chlorine gas to hypochlorination
- moved pH adjustment downpipe of chlorination
- increased soda ash dosage to 20 mg/L of alkalinity



- added GAC filtration for removal of TOC
- switched from chlorine gas to hypochlorination
- increased soda ash dosage to 5 mg/L of alkalinity



Summary of pH Adjustment Systems Findings

- pH adjustment systems are not dosing enough
- Some systems may not be able to dose enough due to:
 - Extremely low source water pH and alkalinity
 - Configuration of system (type of chlorination, location of pH adjustment)
 - Maximum recommended dilution of chemical- 30% for soda ash
- In most cases, more than just tweaks to pH adjustment are required to address DBP issues
 - Removal of TOC required
- pH adjustment systems are not optimally located
 - pH adjustment located immediately after chlorination adds to chlorine demand and increases the chlorine dosage required
- Many systems with pH adjustment have lower pH in tap water than in source water
- Gas chlorination is not a good fit for smaller systems with low pH, low alkalinity source water

Recommendations- Corrosion

- Small drinking water systems prone to corrosion or that have a lot of leaks should use liquid hypochlorination
 - CI or DI pipe
- Gas chlorination systems should not be used in conjunction with pH adjustment systems outside of a full scale water treatment plants



Recommendations-

Gas chlorination

- Gas chlorination should not be used on small drinking water systems unless there are known issues with pathogens
- The Chlorine Equipment Selection Guidelines should be used to determine whether to install gas or liquid hypo-chlorination

**CHLORINATION EQUIPMENT SELECTION
GUIDELINES**

PROVINCE OF NEWFOUNDLAND & LABRADOR



**A GUIDE FOR THE SELECTION OF APPROPRIATE
DISINFECTION EQUIPMENT FOR MUNICIPAL
APPLICATIONS**

**DEPARTMENT OF ENVIRONMENT & CONSERVATION
DEPARTMENT OF MUNICIPAL AFFAIRS**

Recommendations- HAAs

- Systems with high HAA levels should consider:
 - Switching to liquid hypo-chlorination
 - Increasing chemical dosage of pH adjustment system
 - Optimizing location of pH adjustment system



Other Factors- Cost

Gas Chlorination	Liquid Hypo-chlorination
Capital Cost: \$216,000	Capital Cost: \$104,000
Maintenance (1 st year): \$1,740	Maintenance (1 st year): \$2,340
Cost of Chlorine per lb: \$1.00	Cost of Chlorine per lb: \$1.24
Equivalent Annual Cost over 10 years: \$37, 928	Equivalent Annual Cost over 10 Years: \$23,857

- Using Chlorination Equipment Selection spreadsheet tool
- Costs from 2005
- Gas chlorination has higher capital cost, liquid hypo-chlorination has higher chemical and maintenance costs
- Gas chlorination is more cost-effective for large distribution systems

Other Factors- Safety

- Chlorine gas leaks:
 - Baie Verte: January 2011
 - Baie Verte: June 2011
 - Main Brook: June 2011
 - Ming's Bight: August 2010 (false alarm due to faulty sensor)
 - Trinity Bay North: fall 2008 (equipment failure)
 - Seal Cove (FB): Prior to 2005
- Gas chlorination systems require large amounts of operator training



Questions?

