Analysis of Lead in Tap Water Data for the City of Ottawa

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DWRG
NSERC CHAIR IN DRINKING WATER RESEARCH

Objectives

1) Compare different lead sampling protocols for lead in tap water

2) Evaluate effects of temperature and pH changes
   - Apply statistical methods to evaluate data

3) Predict lead concentrations using a regression model

Ottawa Background

- Field data gathered from homes in Ottawa from 1997 to 2008
- Elevated lead levels (>10 µg/L) reported in water samples from some homes

Sampling Protocols

- 5-minute flowing sample (1997 to 2008)
  - Former Ontario sampling protocol

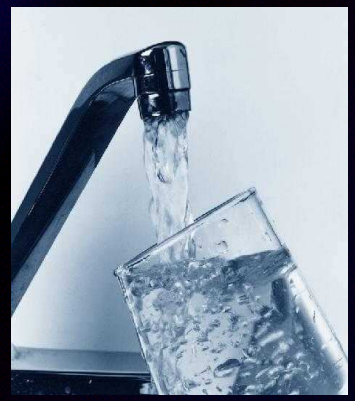
Flush Tap For 5 Minutes

Collect Samples

Sampling Protocols

- 30-minute stagnation (2006 to 2008)
  - Current Ontario sampling protocol (MOE, 2007)
- 6-hour stagnation (2006 to 2008)



Flush Tap For 5 minutes | **Collect Sample** | ~~**Wait 30 minutes**~~ **Wait 6 hours** | **Collect 1-litre Samples**

Sampling Protocols

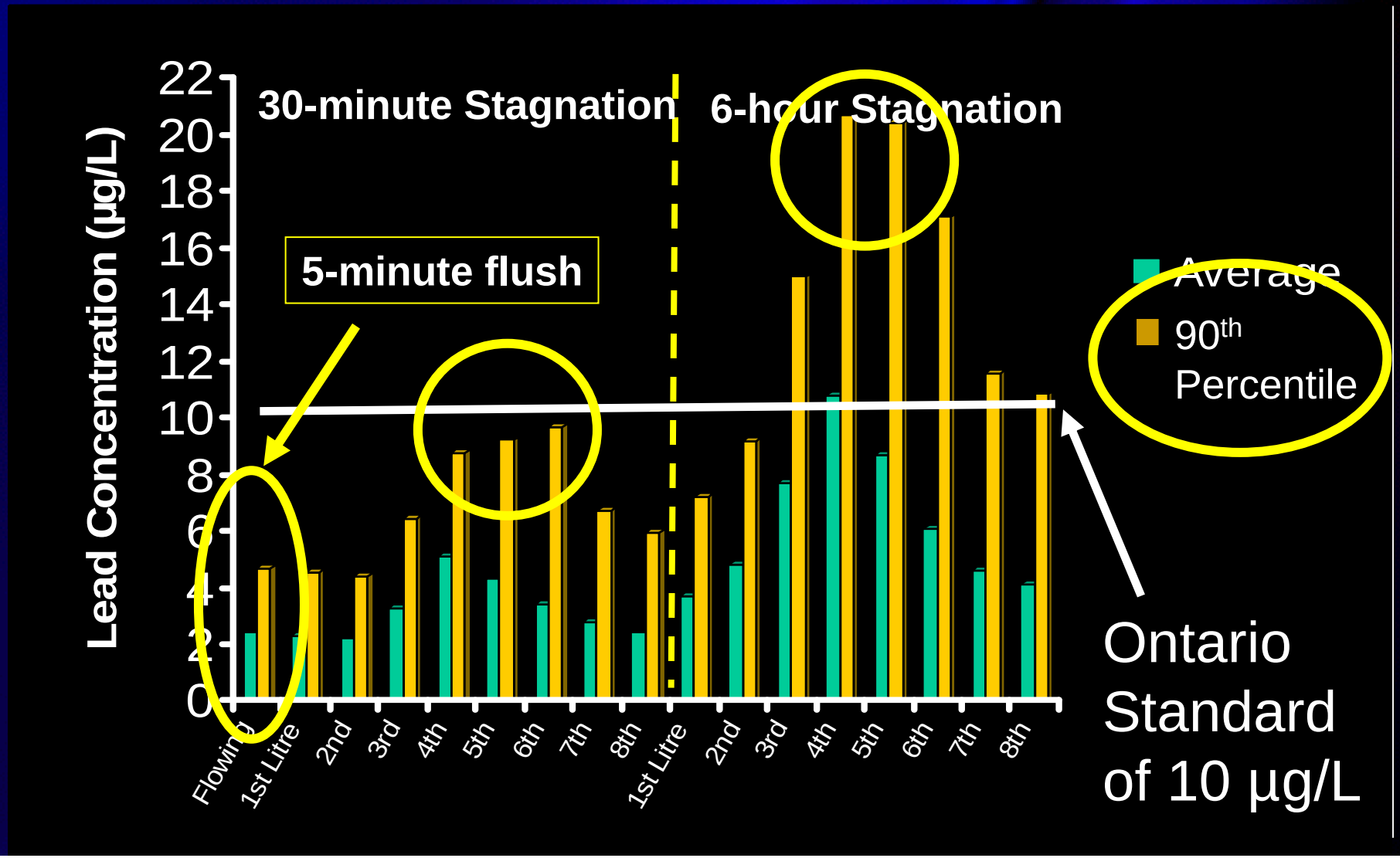
- Ottawa collected 8 litres following 30-minute and 6-hour stagnation protocols
- Conservative sample collection represents lead from different sources

Faucets and fittings (1st and 2nd Litres)

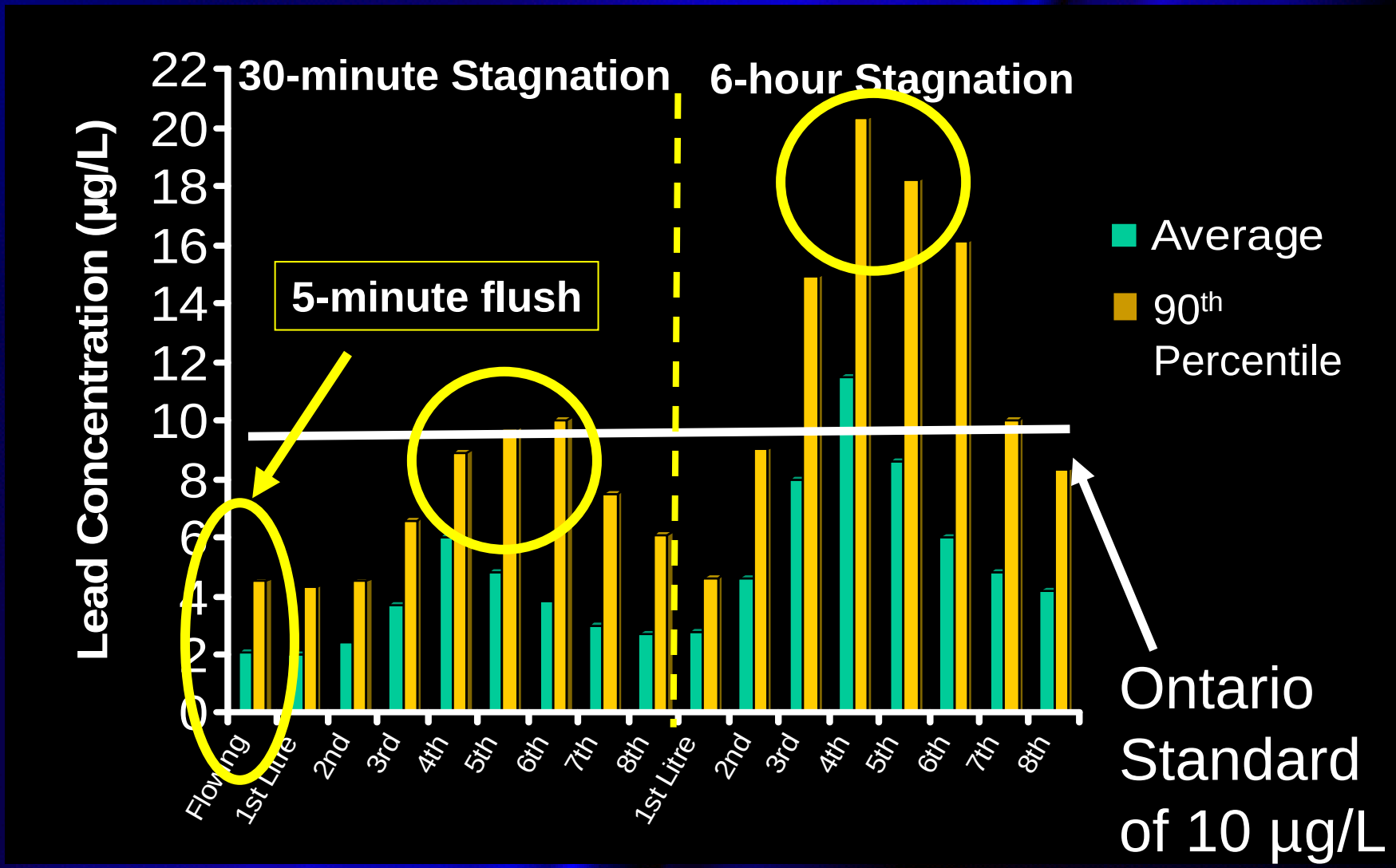
Home Owner Piping (3rd , 4th , 5th Litres)

City Piping (6th, 7th, 8th Litres)

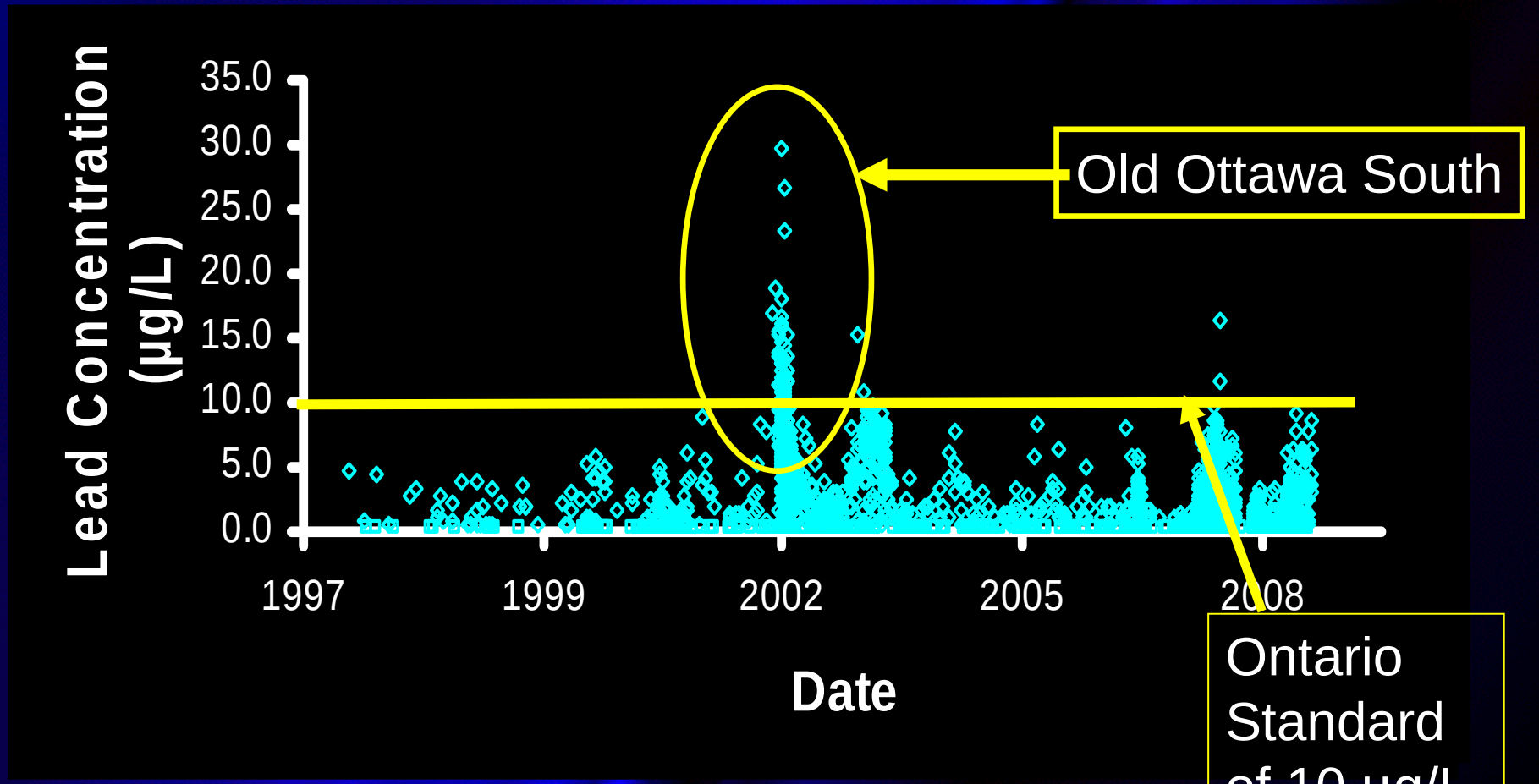
Effects of Sampling Protocol (Less Than 5°C)



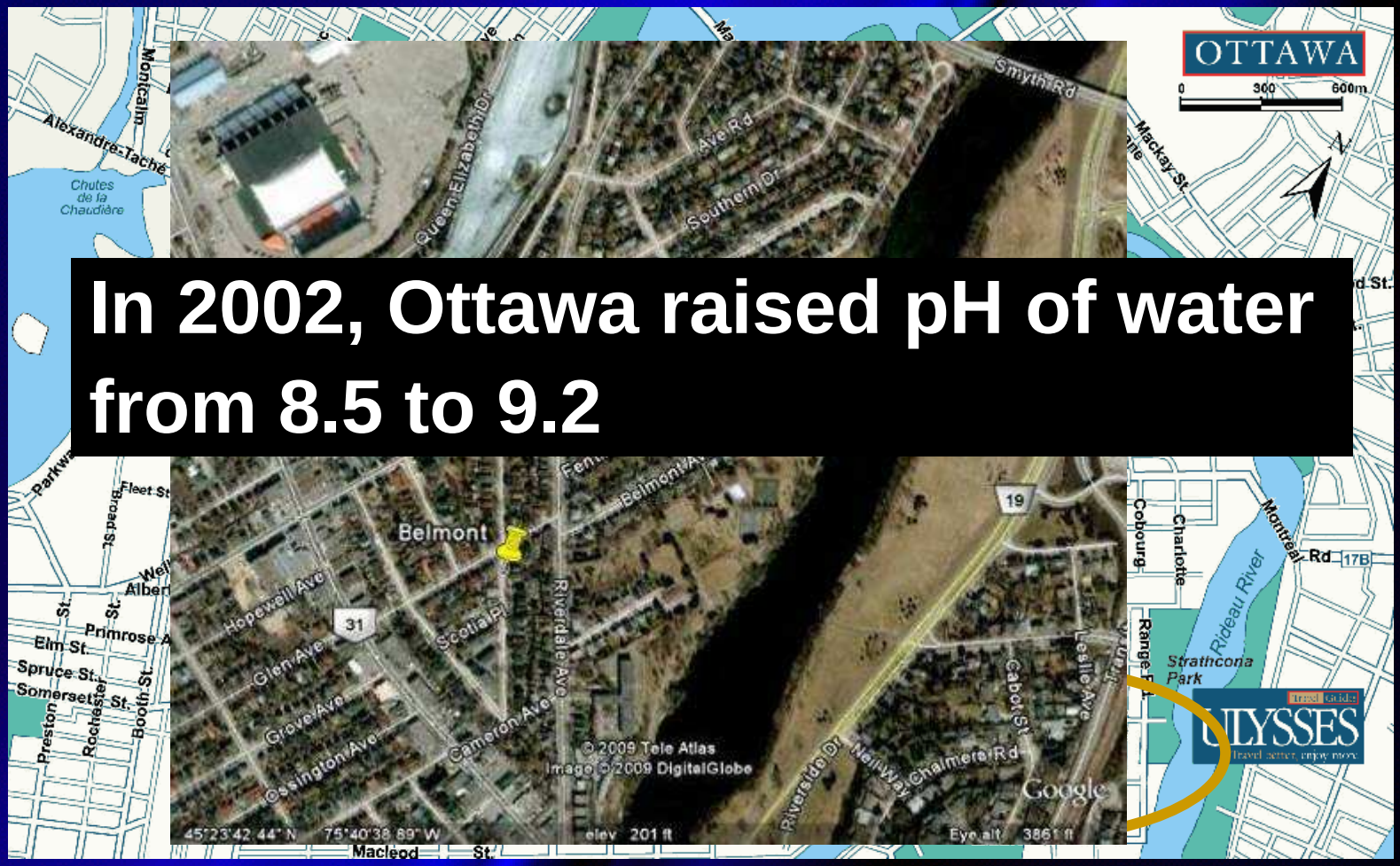
Effects of Sampling Protocol (Greater Than 15°C)



Historical Lead Sampling Data

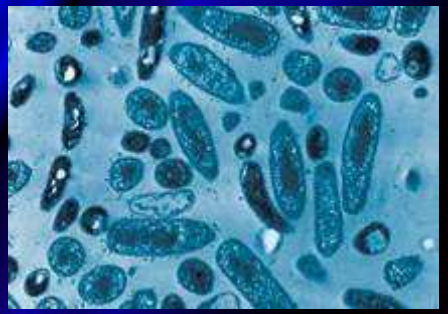


Old Ottawa South



Why Raise pH?

- Lower pH values tends to increase lead solubility in tap water (Singley, 1994; Schock, 1989)



- Nitrification (> 15°C)
  - Natural process on internal pipe surfaces
  - $NH_3+O_2 \rightarrow NO_2^- + H^+$
  - Results in pH decrease (8.5 ->7.8)

Nitrifying Bacteria

- Raised pH in August 2002 from 8.5 to 9.2 in the distribution system

Effect of Temperature Changes on Lead (Pb)

Water Temperature (°C)	Average Lead Concentration (µg/L)
Greater than 15	2.60
5 to15	1.70
0 to 5	1.04

Based on data from 1997 to 2008

Effect of Temperature Grouping on Lead (Pb)

Water Temperature (°C)	Pb (µg/L) (pH 8.5)	Pb (µg/L) (pH 9.2)	Statistically Significant (p<0.05)
0 to 5	1.2	1.01	No
5 to 15	1.58	1.7	No
>15	5.1	2.4	Yes

Based on data from 1997 to 2008

Predicting Lead Concentrations

- Enable Ottawa and other municipalities to predict impact of corrosion control strategies in the future
- Apply linear and logistic regression
- Assess accuracy of models through R^2 (correlation coefficient)
  - 0 = No correlation
  - 1 = Perfect correlation

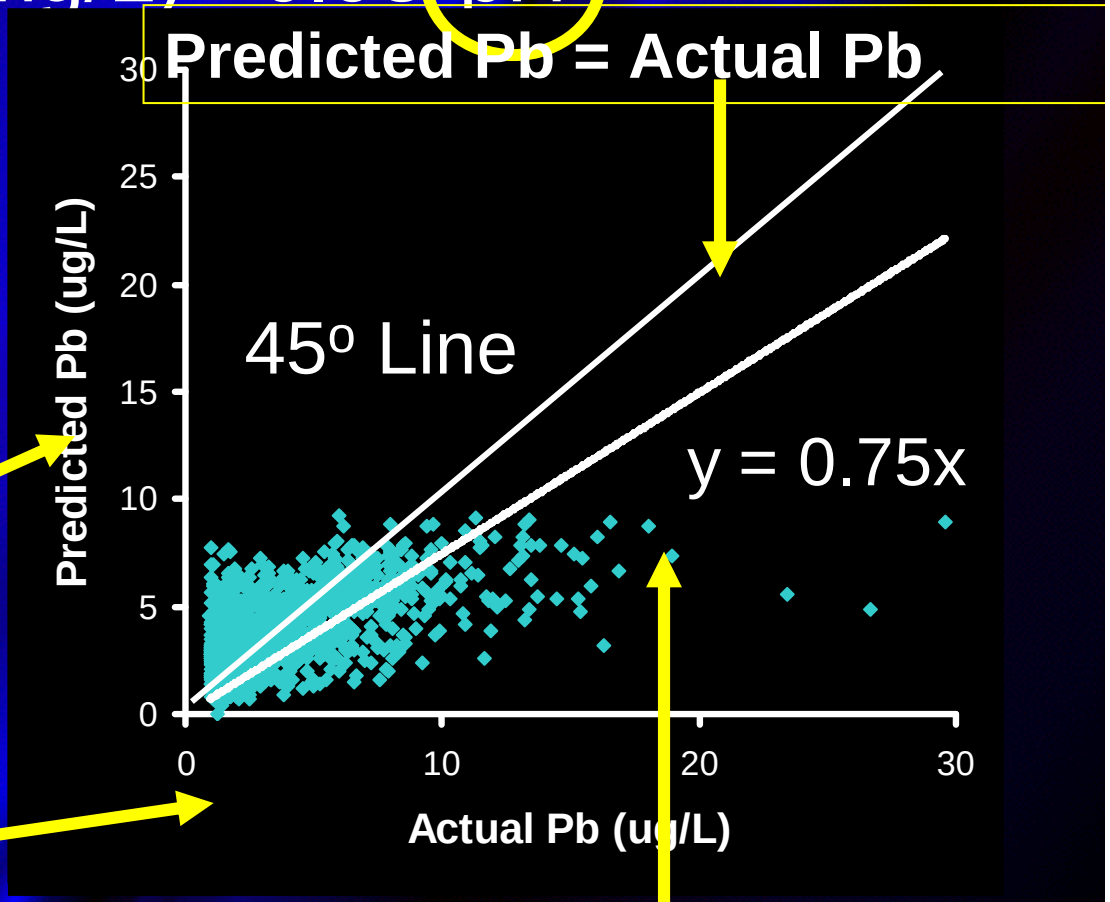
Data Preparation for Regression

- Water Quality Parameters

Chloramine residual
pH
Temperature
Lead Concentration

Multiple Linear Regression

- Lead (µg/L) = 12.3 + 0.2*Temperature (ºC) - 2.3*Cl_2 (mg/L) - 0.98*pH
- R^2 of 0.34

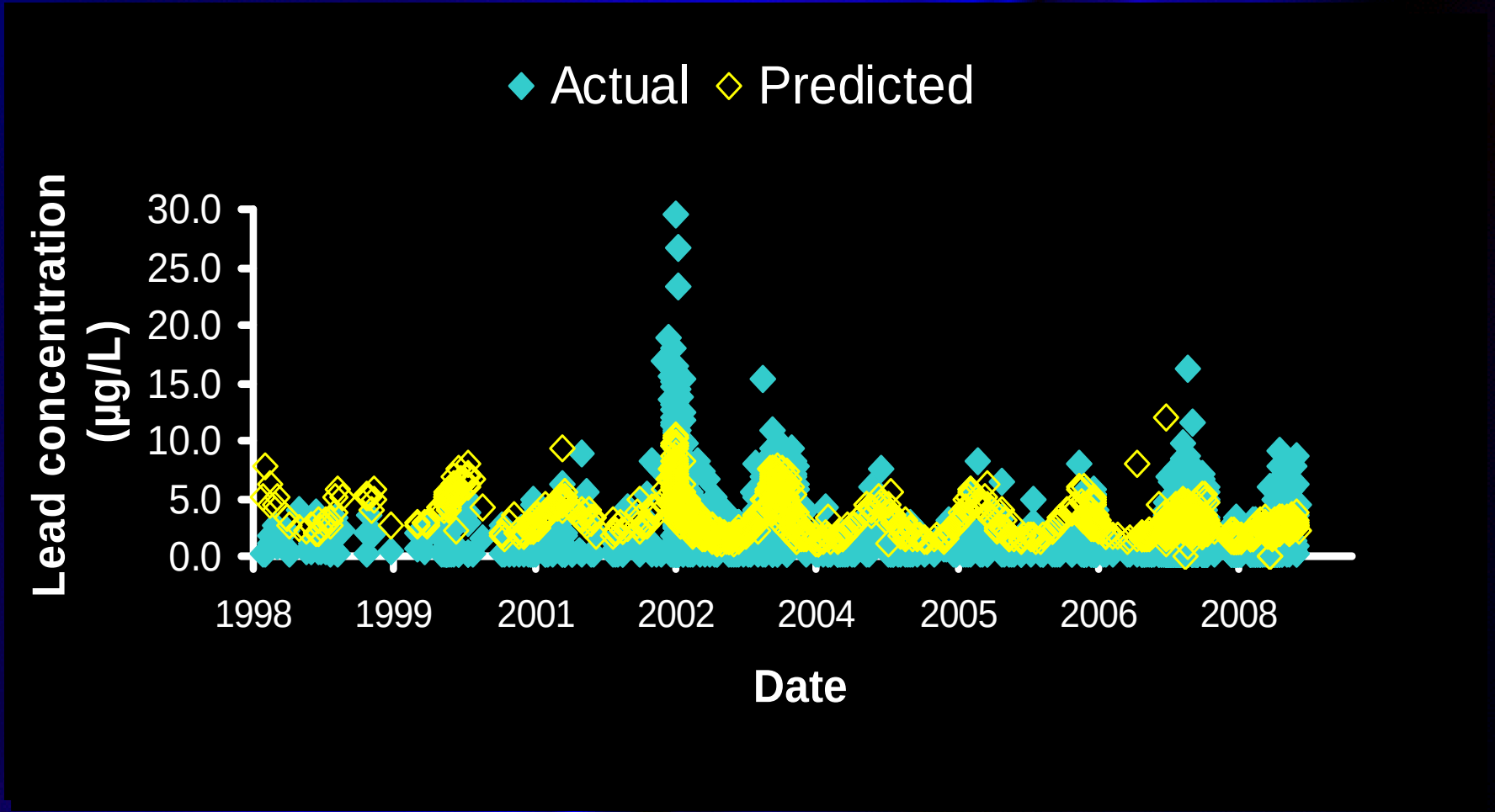


Predicted Pb From Equation

Measured Pb From Historical Data

Model under-predicts Pb

Multiple Linear Regression



Logistic Regression

- Binomial logistic regression
  - Categorical variable response
- Transformed lead variable into 2 categories
  - 0 (less than 10 µg/L)
  - 1 (greater than or equal to 10 µg/L)

Logistic Regression Results

- Overall accuracy = 96.4%

$Z = 3.6 - 1.9 * Cl_2\ (mg/L) - 1.2 * pH + 0.3 * Temperature\ (^oC)$

$$\textbf{Probability of 0 or 1} = \frac{1}{1+e^{-z}}$$

Sample Model Output

Sample Home	Cl_2 (mg/L)	pH	Temperature (^oC)	Probability
1	1.12	8.00	15.6	0.18
2	1.20	8.36	17.2	0.11
3	0.74	8.30	18.5	0.53

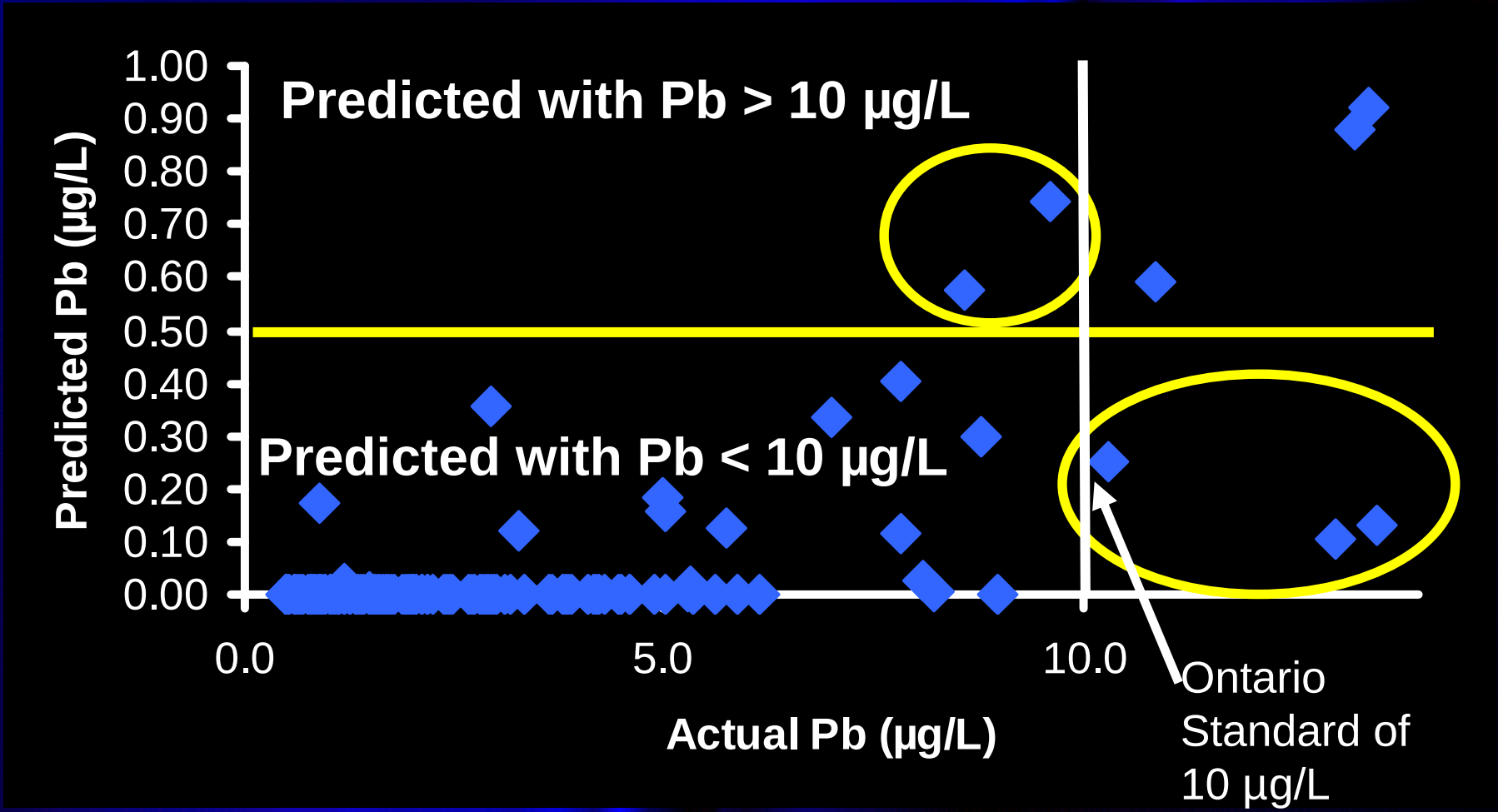
Sample Model Output

Predicted Pb Less Than 10 µg/L

Sample Home	Probability	Model Output	Measured Lead (µg/L)
1	0.18	0	0.9
2	0.11	0	7.8
3	0.53	1	16.8

Predicted Pb Greater Than 10 µg/L

Logistic Regression Results



Summary

- Effect of pH increase (8.5 to 9.2) significantly lowered lead concentrations for temperatures > 15^{o}C
- Stagnation protocols (30-minute and 6-hour) illustrated higher lead when compared to 5-minute flushing protocol
- Linear and logistic regression are valid methods for predicting lead concentrations based on historical water quality data

Acknowledgements

- City of Ottawa for providing lead data from 1997 to 2008

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Acknowledgements

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Region of Durham
Peterborough Utilities Commission
Lake Huron and Elgin Area Primary Water Supply Systems
Town of Parry Sound
Toronto Water