# Road Salt in Groundwater: Consequences for Drinking Water

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**2019 Connecticut Private Well Conference**

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Cary Institute of Ecosystem Studies

# Talk Outline

- History of road salt use
- Discovery of road salt in groundwater
- How road salt gets into groundwater
- Legacy of road salt use – how long it would take to flush out of groundwater
- Where salt is in groundwater
- Seasonal patterns
- What else is associated with road salt
- Recommendations

# History of Road Salt

Bubeck et al. 1971. Science 172: 1128-1131

# Runoff of Deicing Salt: Effect on Irondequoit Bay, Rochester, New York

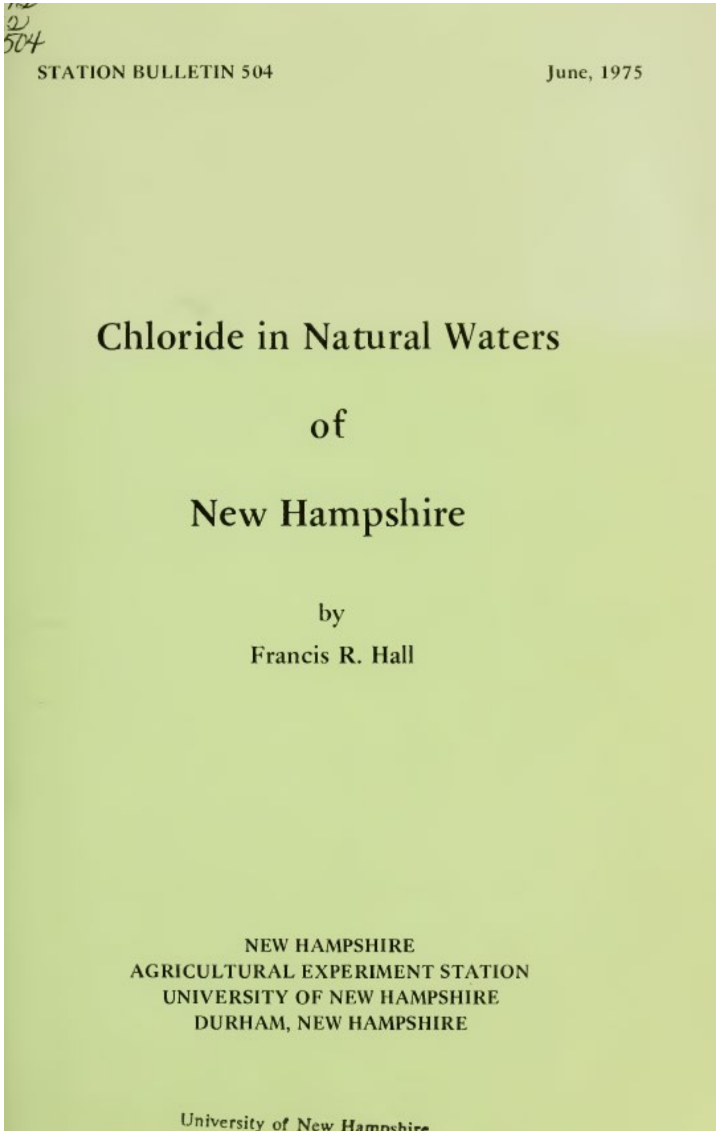
Abstract. *Salt used for deicing the streets near Rochester, New York, has increased the chloride concentration in Irondequoit Bay at least fivefold during the past two decades. During the winter of 1969–70 the quantity and salinity of the dense runoff that accumulated on the bottom of the bay was sufficient to prevent complete vertical mixing of the bay during the spring. Comparison with 1939 conditions indicates that the period of summer stratification has been prolonged a month by the density gradient imposed by the salt runoff.*

Huling & Hollocher. 1972. Science 176: 288-289

## Groundwater Contamination by Road Salt: Steady-State Concentrations in East Central Massachusetts

Abstract. *The average steady-state contamination of groundwater by road salt in the suburban area around Boston, on the assumption that current rates of application of salt will continue, is about 160 milligrams of sodium chloride per liter of water (100 milligrams of chloride per liter). This value is compared with values of 50 to 100 milligrams of chloride per liter found rather commonly now in town wells in eastern Massachusetts. These salt concentrations may be of concern to persons on low-sodium diets and to persons who obtain water from wells in the vicinity of major highways where salt concentrations could be several times higher than average.*

# Hall 1975


STATION BULLETIN 504 June, 1975

Chloride in Natural Waters

of

New Hampshire

by

Francis R. Hall

NEW HAMPSHIRE
AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE

University of New Hampshire

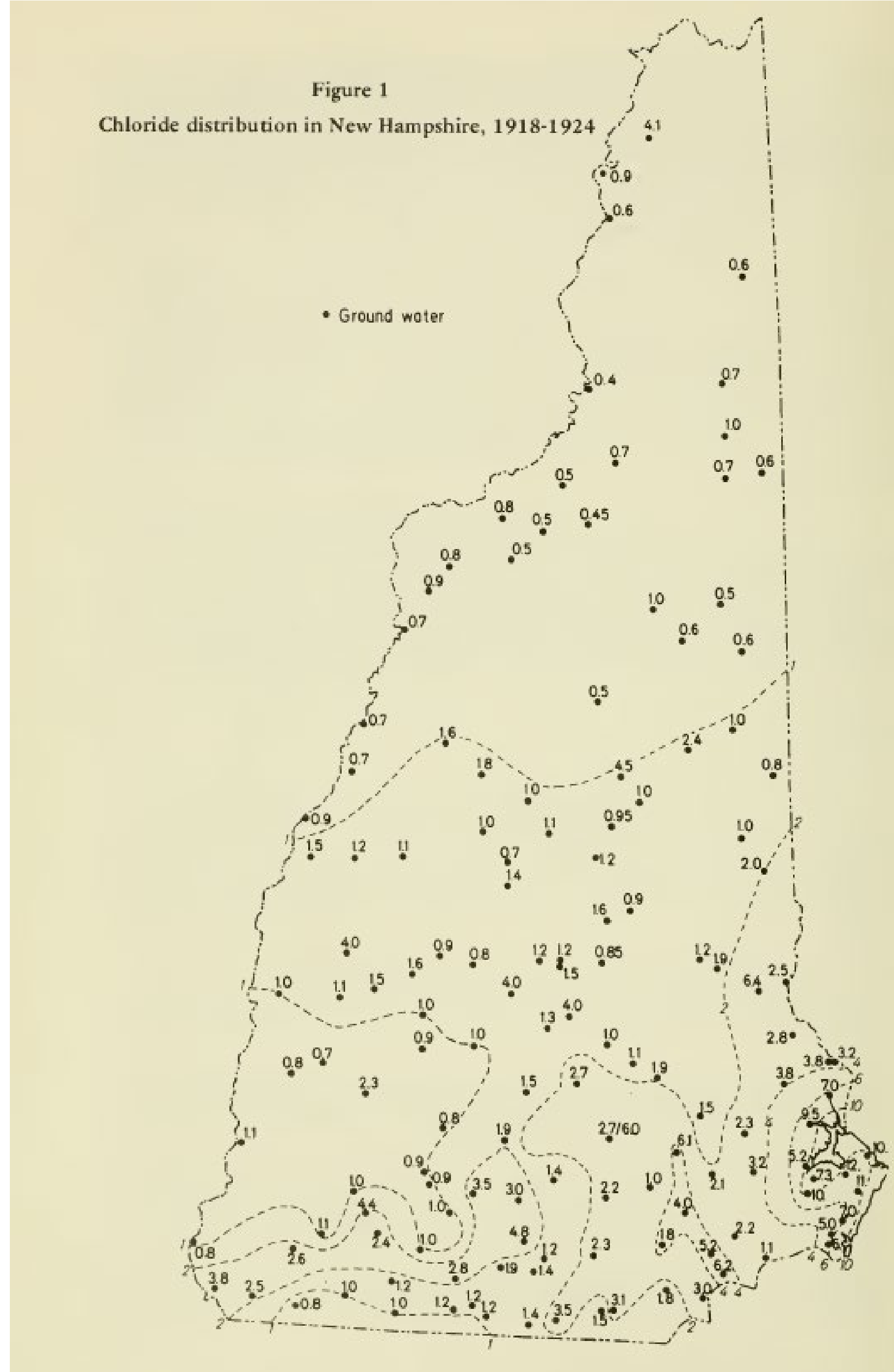



Figure 1
Chloride distribution in New Hampshire, 1918-1924

# Hall 1975

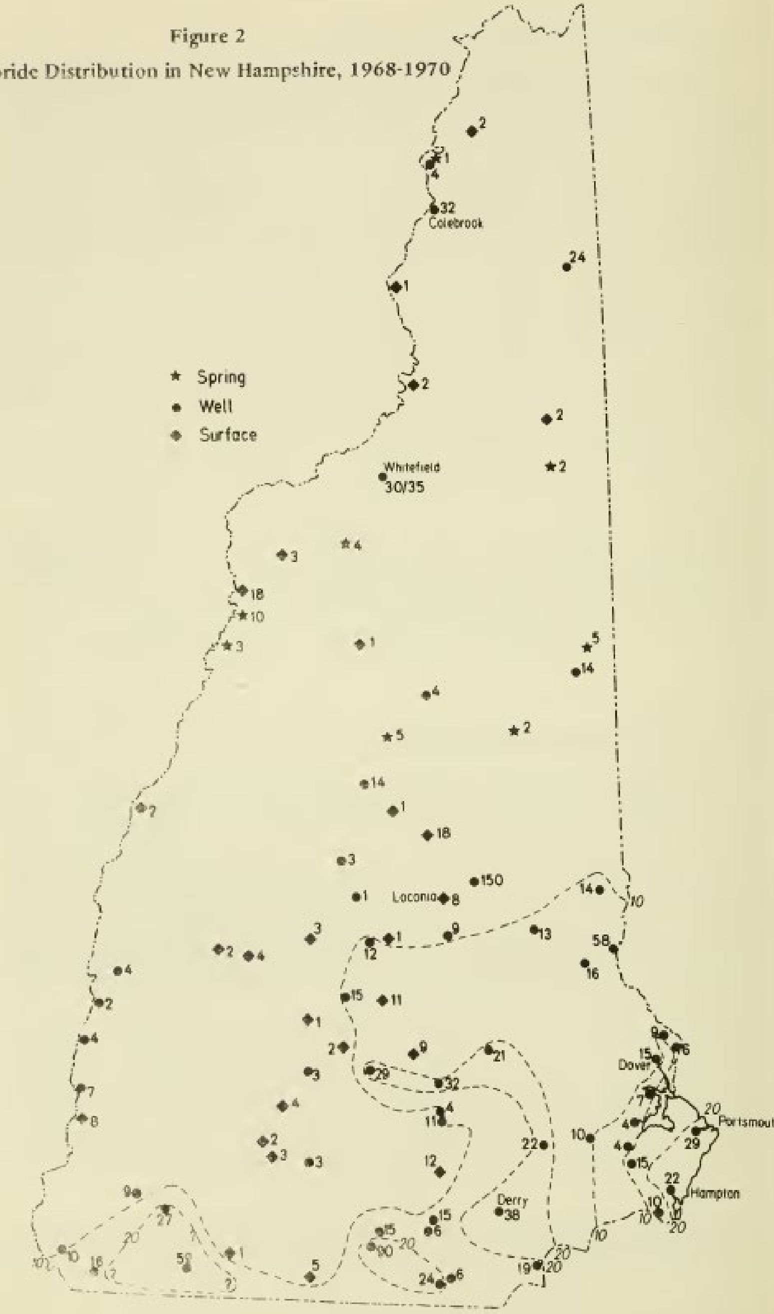
Table 3.

Chloride Balance for New Hampshire, 1970

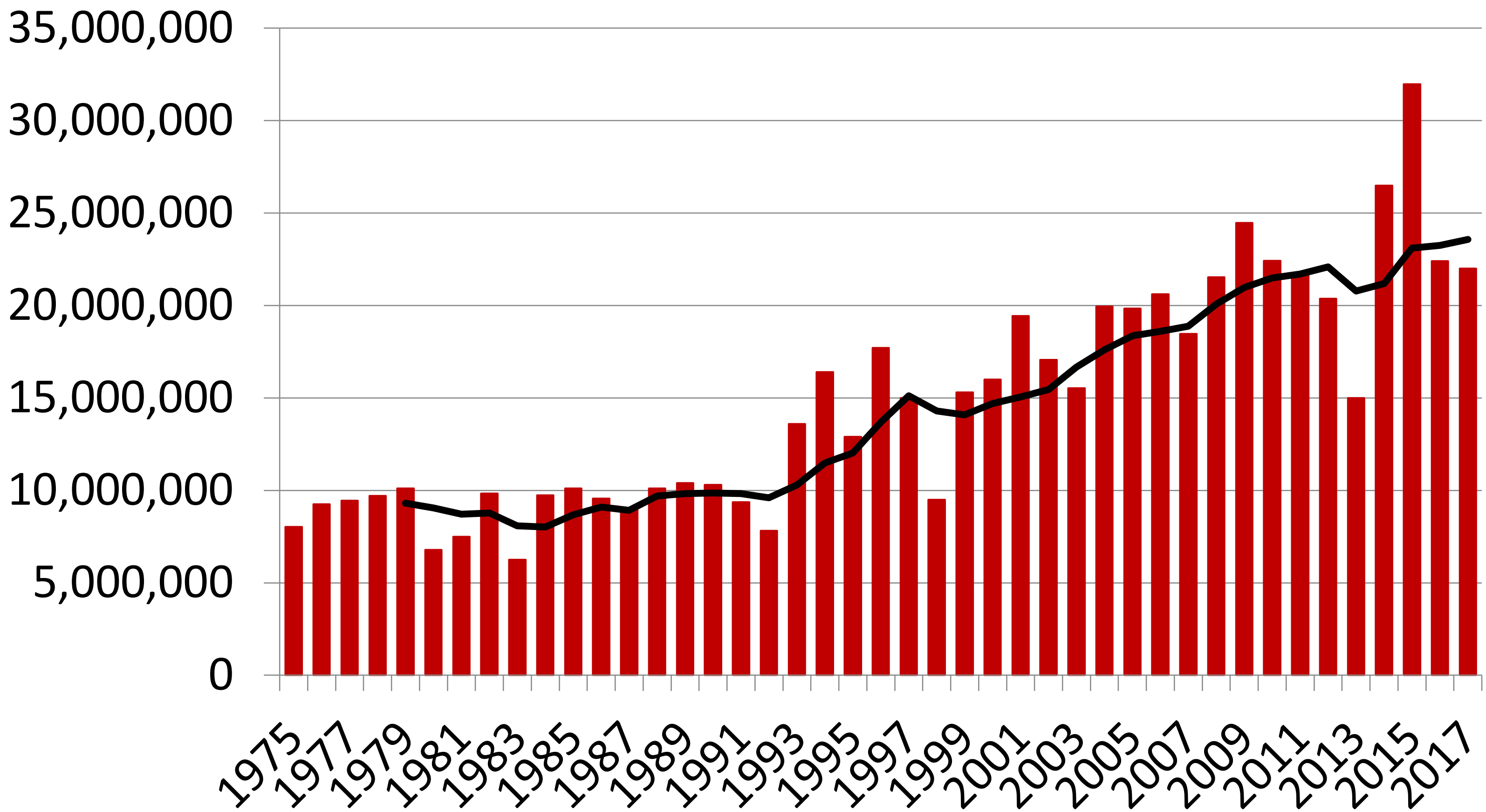
| Inflow | Chloride, Tons |
|---|---|
| Atmospheric Precipitation and Dry Fallout[1/] | 14,500 |
| Human Activity[2/] | 7,400 |
| Highway Deicing Salt[3/] | 91,000 |
| Town Road Deicing Salt[4/] | 20,000 |
| | 132,900 |
| **Outflow** | |
| Surface and Groundwater[5/] | 135,900 |
| Change in Storage[6/] | −3,000 |

Figure 2

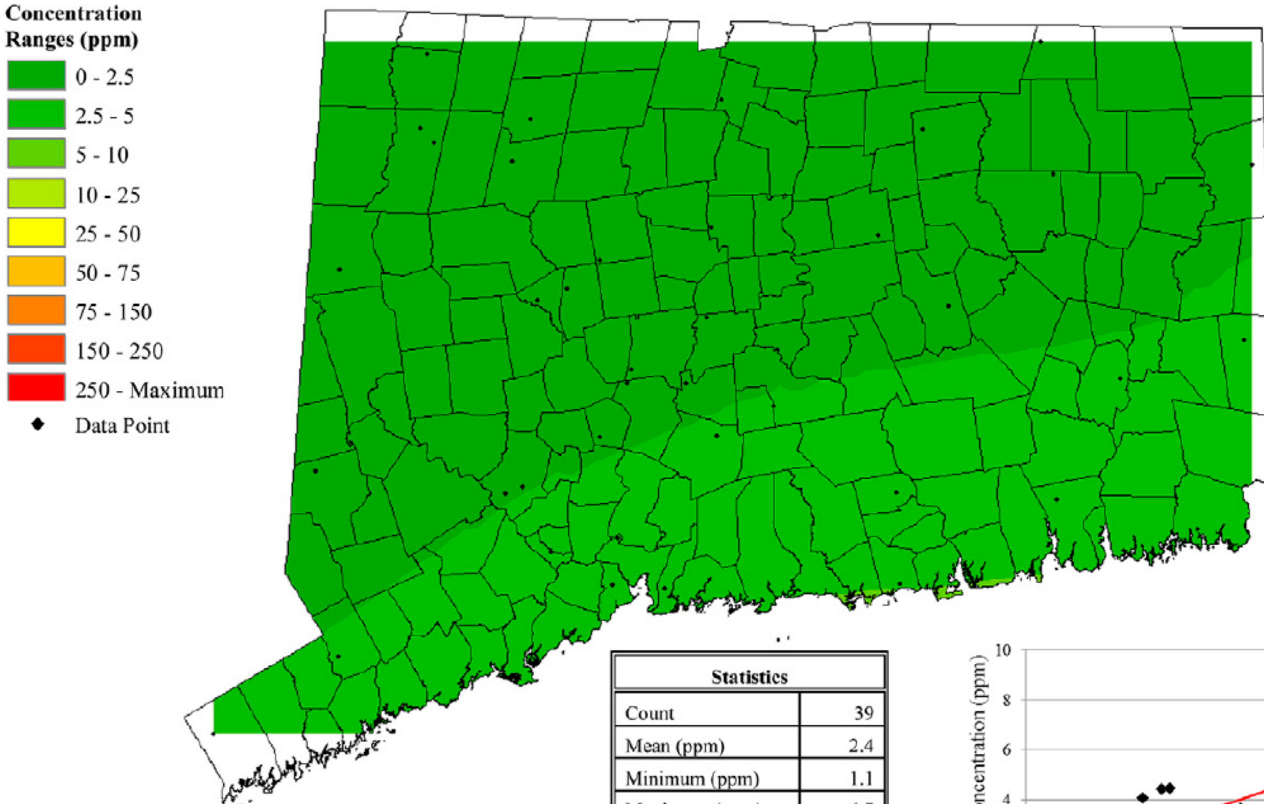
Chloride Distribution in New Hampshire, 1968-1970



# NaCl Salt Used for Deicing in the United States (metric tons)




USGS 2017




| Statistics | |
|---|---|
| Count | 39 |
| Mean (ppm) | 2.4 |
| Minimum (ppm) | 1.1 |
| Maximum (ppm) | 6.7 |
| Standard Deviation | 1.2 |
| Mean Error (ppm) | -0.008 |
| Trendline Slope | 0.52 |

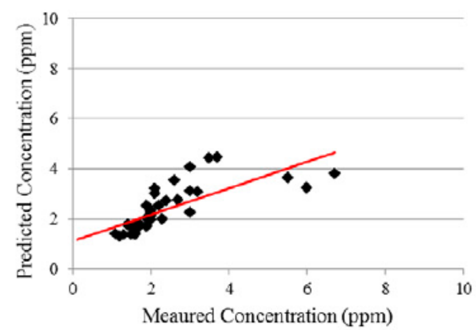
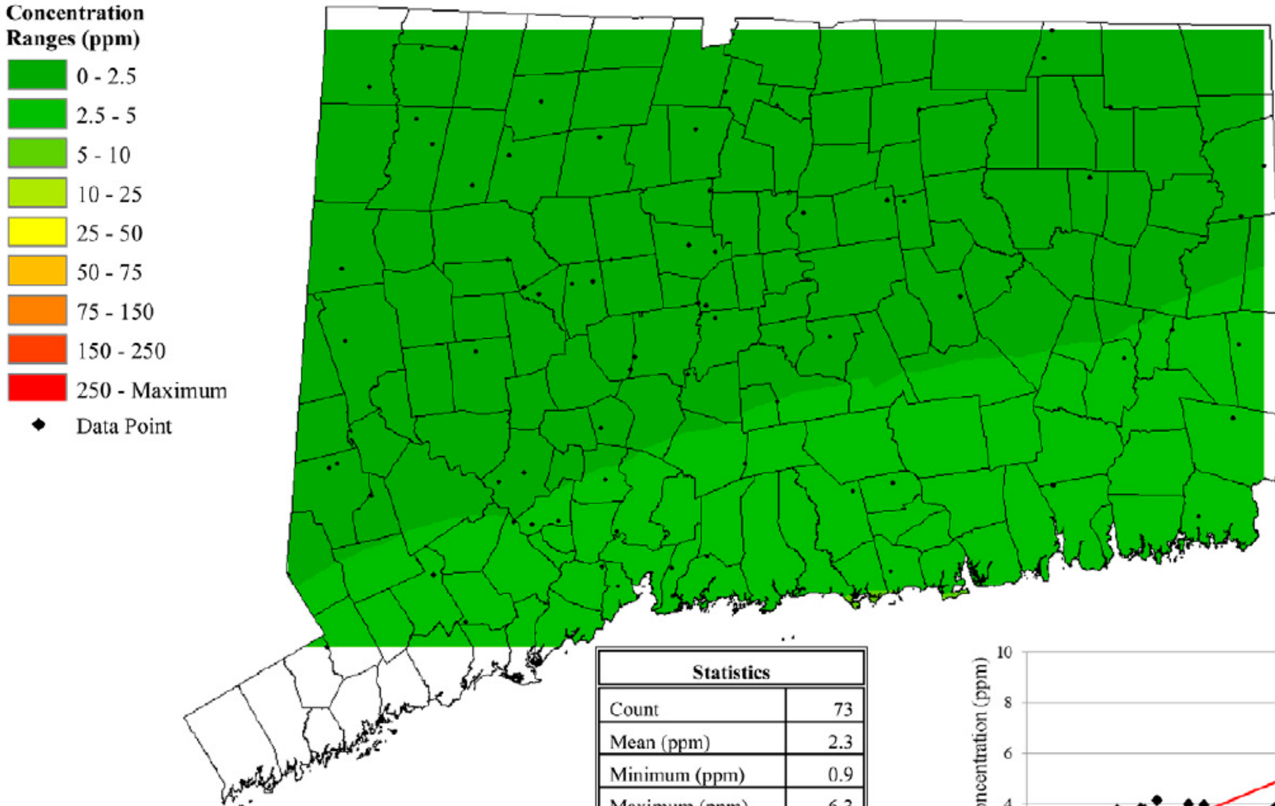



**Fig. 1. Chloride concentration map based on Kriging concentrations measured in groundwater samples collected as part of the Connecticut State Board of Health report during 1894.**

# 1894

Cassanelli & Robbins 2013 J. Environ. Qual.




| Statistics | |
|---|---|
| Count | 73 |
| Mean (ppm) | 2.3 |
| Minimum (ppm) | 0.9 |
| Maximum (ppm) | 6.3 |
| Standard Deviation | 1.0 |
| Mean Error (ppm) | 0.007 |
| Trendline Slope | 0.64 |

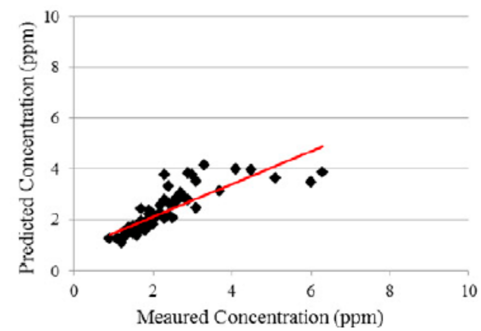
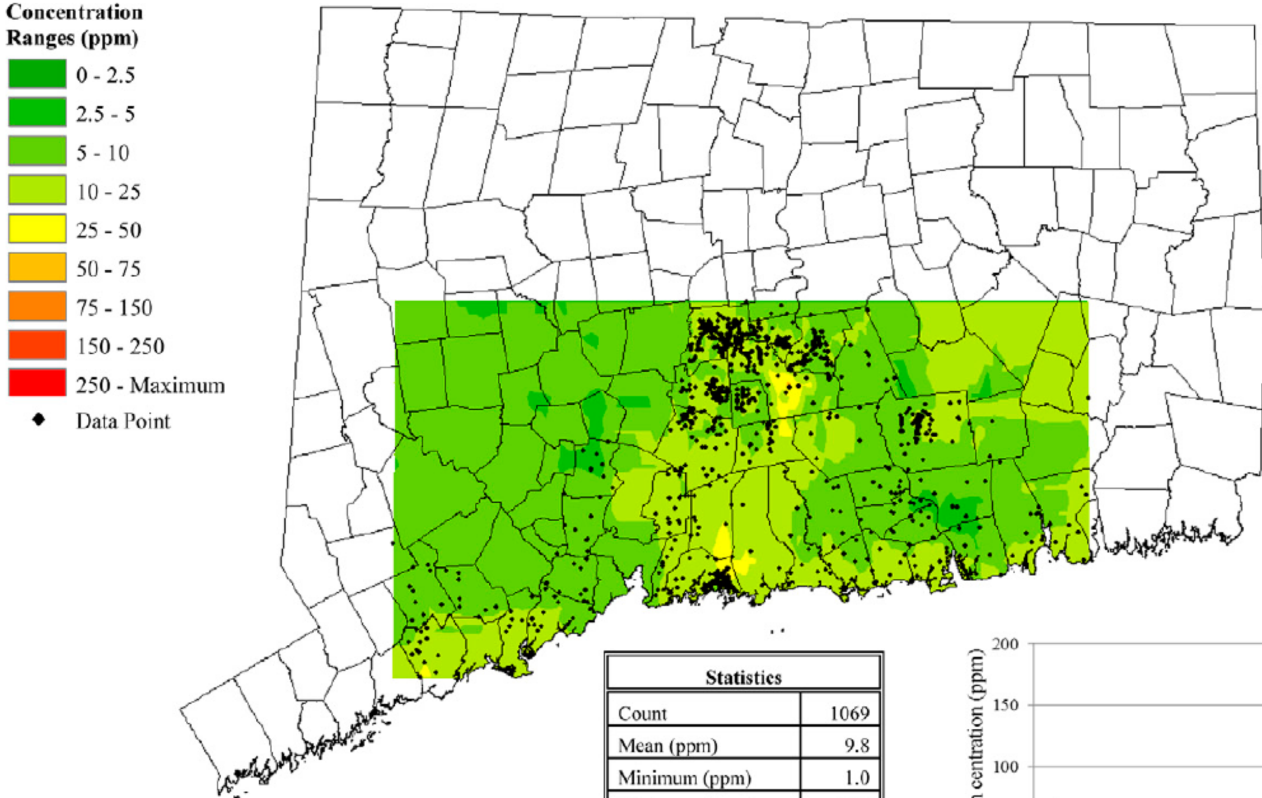



Fig. 2. Chloride concentration map based on Kriging concentrations measured in groundwater samples collected as part of the Connecticut State Board of Health report during 1902.

# 1902

Cassanelli & Robbins 2013 J. Environ. Qual.




| Statistics | |
|---|---|
| Count | 1069 |
| Mean (ppm) | 9.8 |
| Minimum (ppm) | 1.0 |
| Maximum (ppm) | 175 |
| Standard Deviation | 14.4 |
| Mean Error (ppm) | -0.005 |
| Trendline Slope | 0.10 |

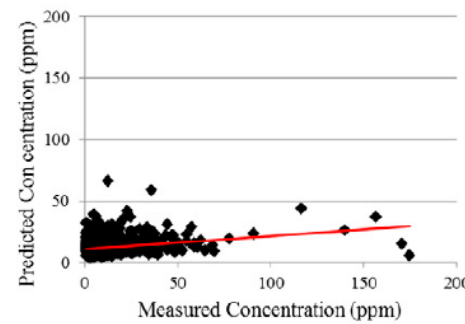
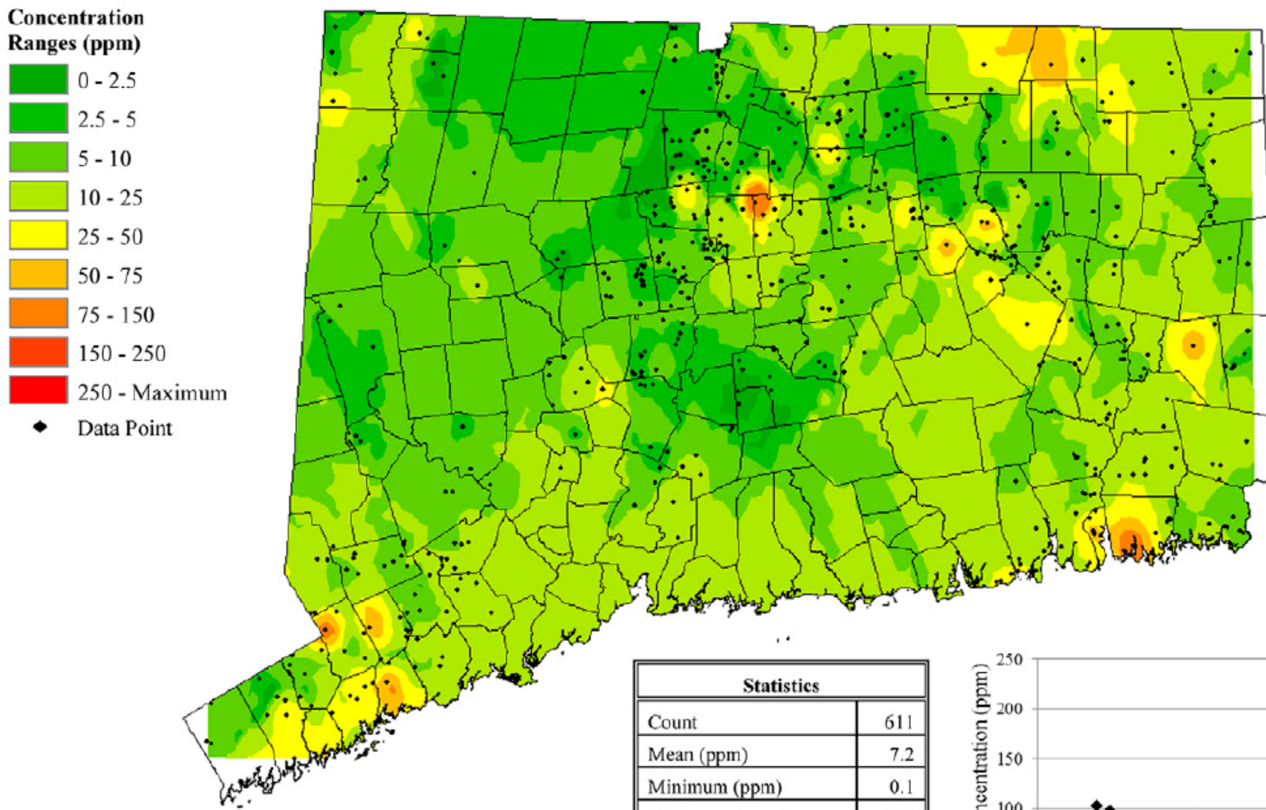



Fig. 3. Chloride concentration map based on Kriging concentrations measured in groundwater samples collected as part of the Connecticut Work Progress Administration report from 1920 to 1938.

# 1920-1938

Cassanelli & Robbins 2013 J. Environ. Qual.




| Statistics | |
|---|---|
| Count | 611 |
| Mean (ppm) | 7.2 |
| Minimum (ppm) | 0.1 |
| Maximum (ppm) | 220 |
| Standard Deviation | 20.1 |
| Mean Error (ppm) | 0.004 |
| Trendline Slope | 0.27 |

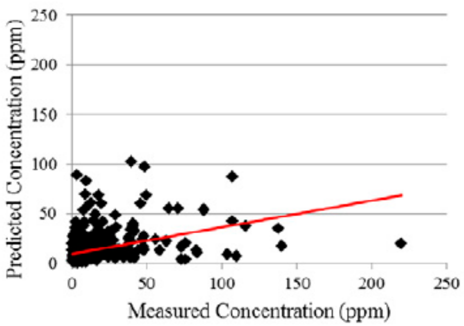
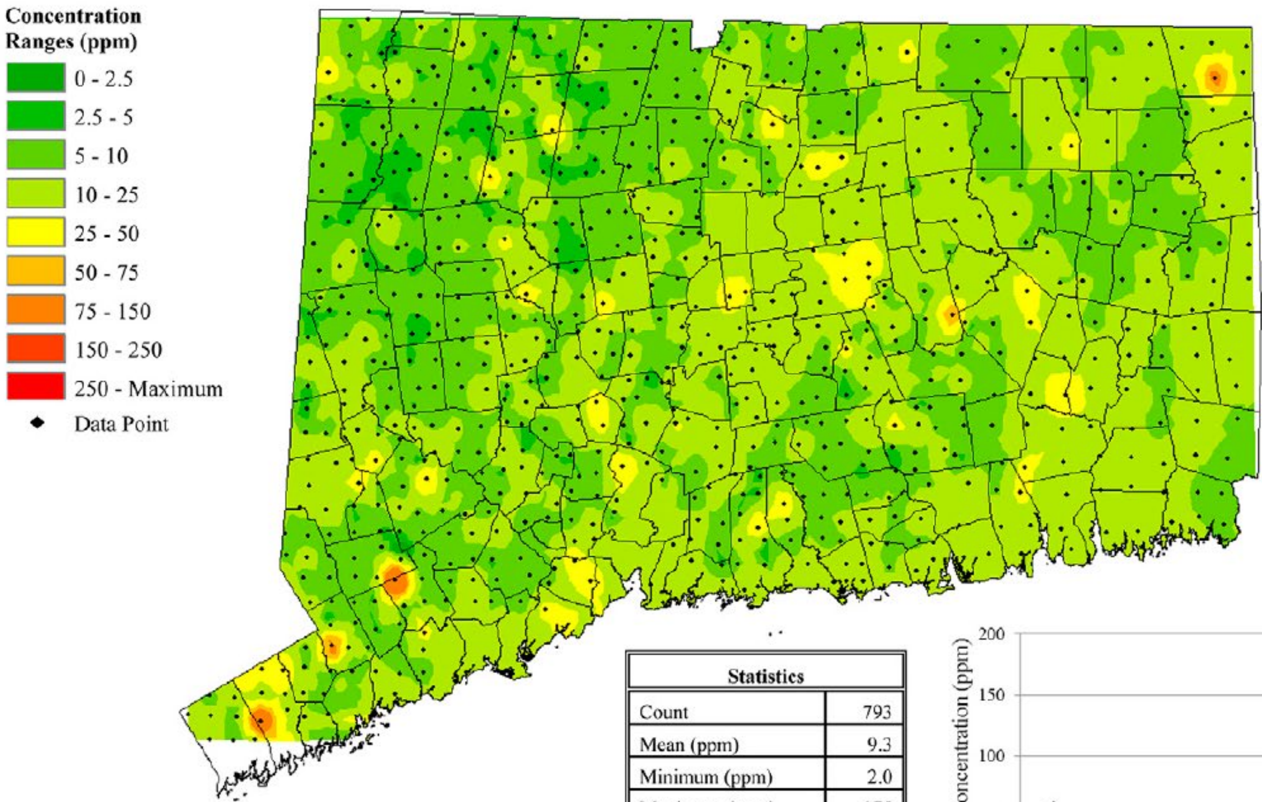



Fig. 4. Chloride concentration map based on Kriging concentrations measured in groundwater samples collected as part of the Connecticut Water Resource Bulletin reports from 1950 to 1969.

# 1950-1969

Cassanelli & Robbins 2013 J. Environ. Qual.




| Statistics | |
|---|---|
| Count | 793 |
| Mean (ppm) | 9.3 |
| Minimum (ppm) | 2.0 |
| Maximum (ppm) | 175 |
| Standard Deviation | 13.4 |
| Mean Error (ppm) | 0.0002 |
| Trendline Slope | 0.01 |

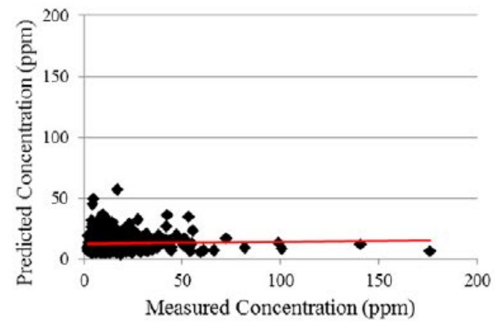
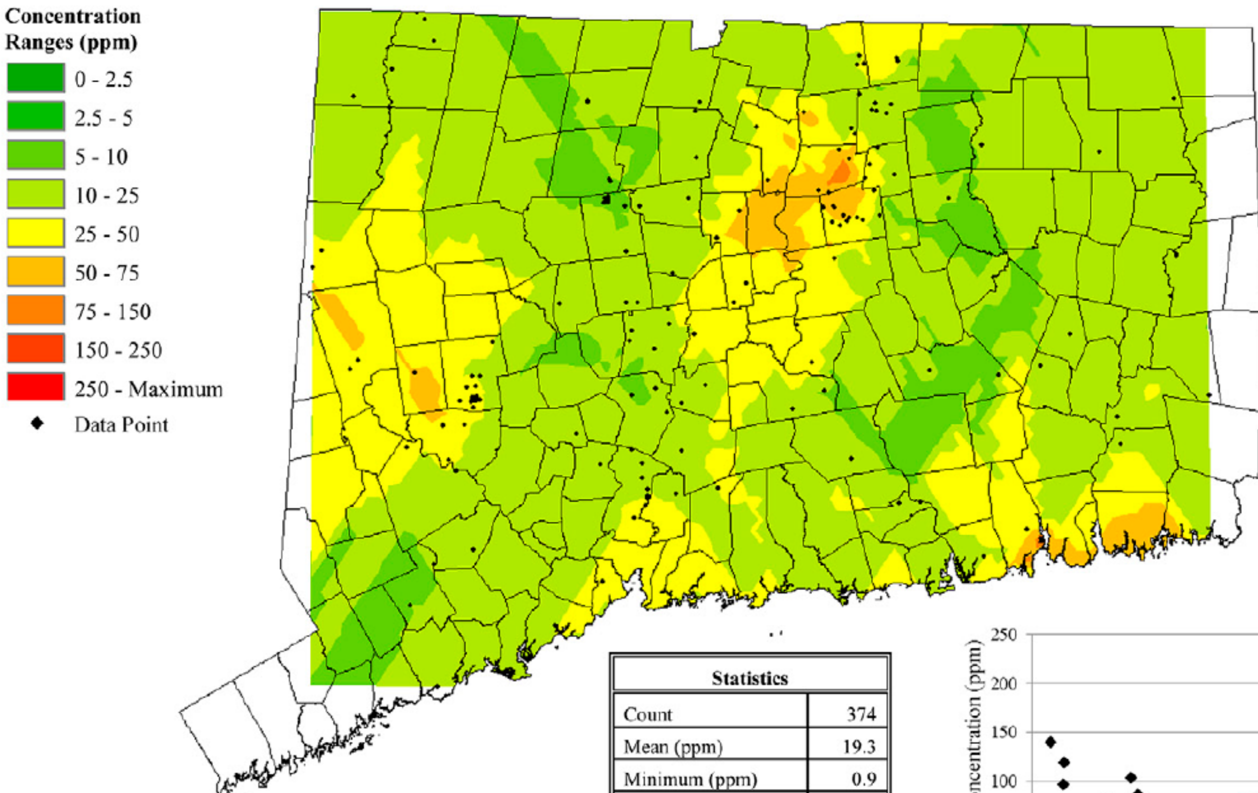



Fig. 5. Chloride concentration map based on Kriging concentrations measured in groundwater samples collected as part of the National Uranium Resource Evaluation report from 1977 to 1978.

# 1977-1978

Cassanelli & Robbins 2013 J. Environ. Qual.




| Statistics | |
|---|---|
| Count | 374 |
| Mean (ppm) | 19.3 |
| Minimum (ppm) | 0.9 |
| Maximum (ppm) | 214 |
| Standard Deviation | 32.6 |
| Mean Error (ppm) | -0.235 |
| Trendline Slope | 0.44 |

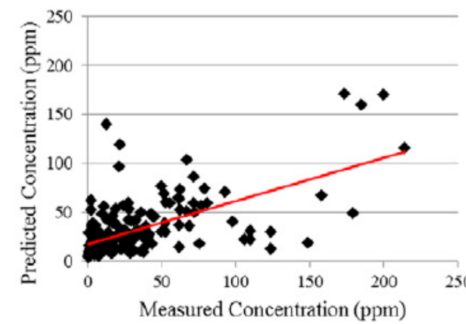
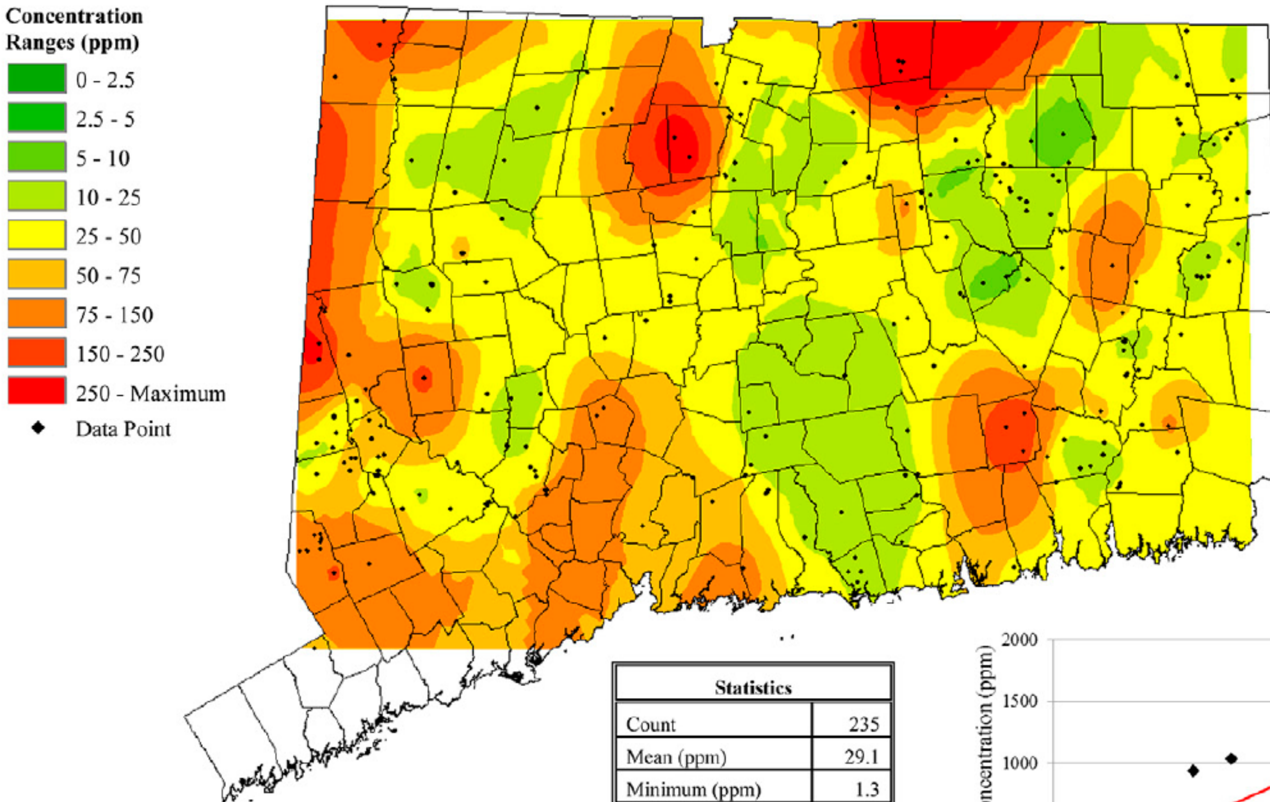



Fig. 6. Chloride concentration map based on Kriging concentrations measured in groundwater samples collected as part of the National Water Quality Assessment report from 1992 to 2005.

# 1992-2005

Cassanelli & Robbins 2013 J. Environ. Qual.




| Statistics | |
|---|---|
| Count | 235 |
| Mean (ppm) | 29.1 |
| Minimum (ppm) | 1.3 |
| Maximum (ppm) | 1500 |
| Standard Deviation | 138.7 |
| Mean Error (ppm) | 3.15 |
| Trendline Slope | 0.64 |

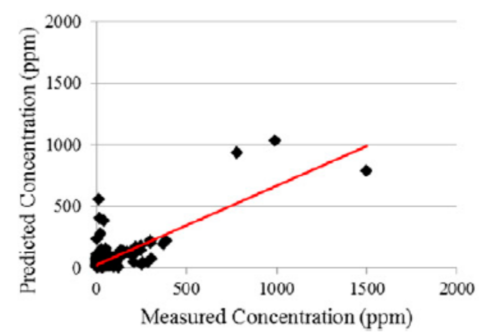
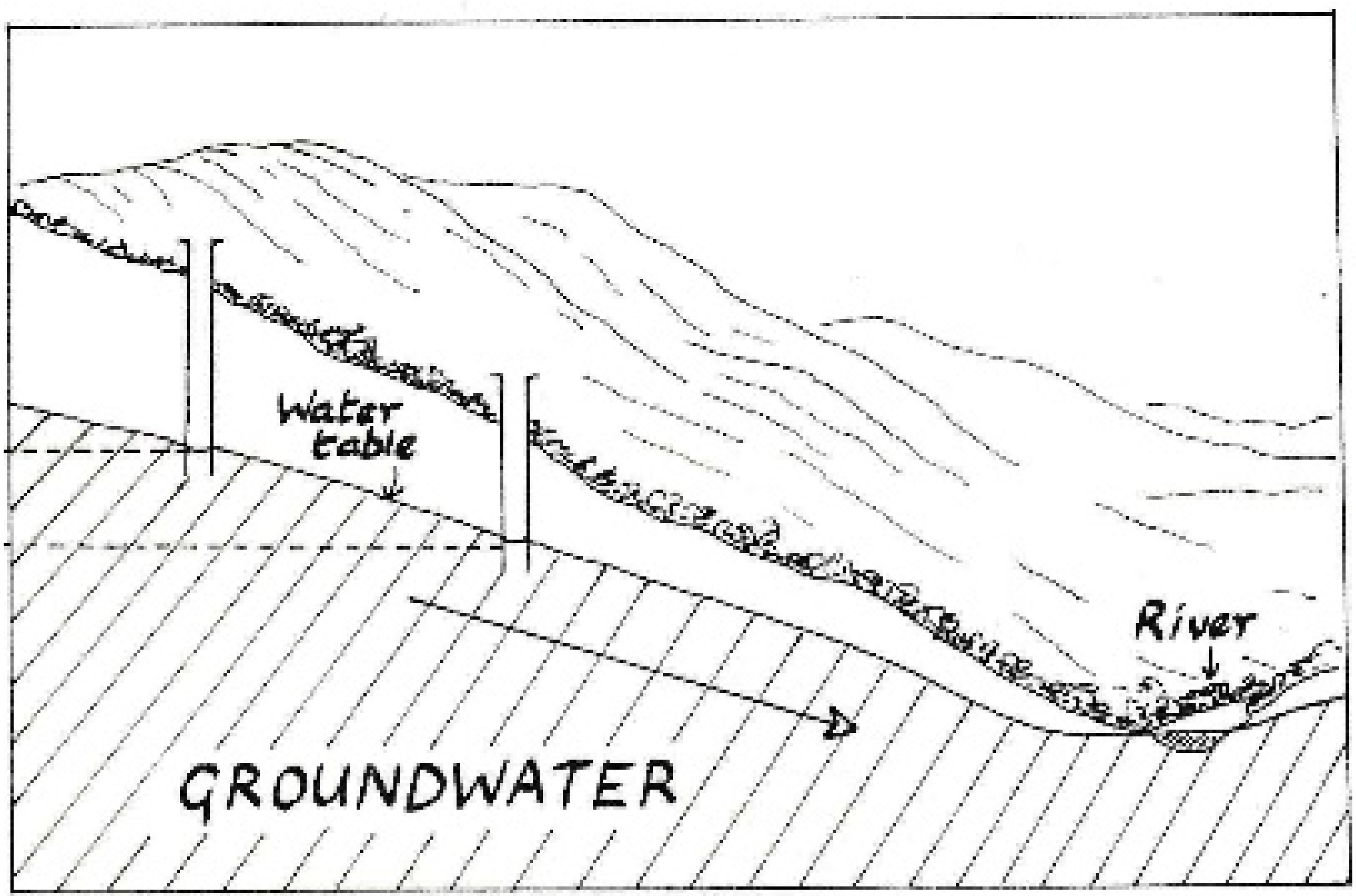



**Fig. 7. Chloride concentration map based on Kriging concentrations measured in groundwater samples collected from Connecticut Public Water Supply systems between 2002 and 2007.**

# 2002-2007

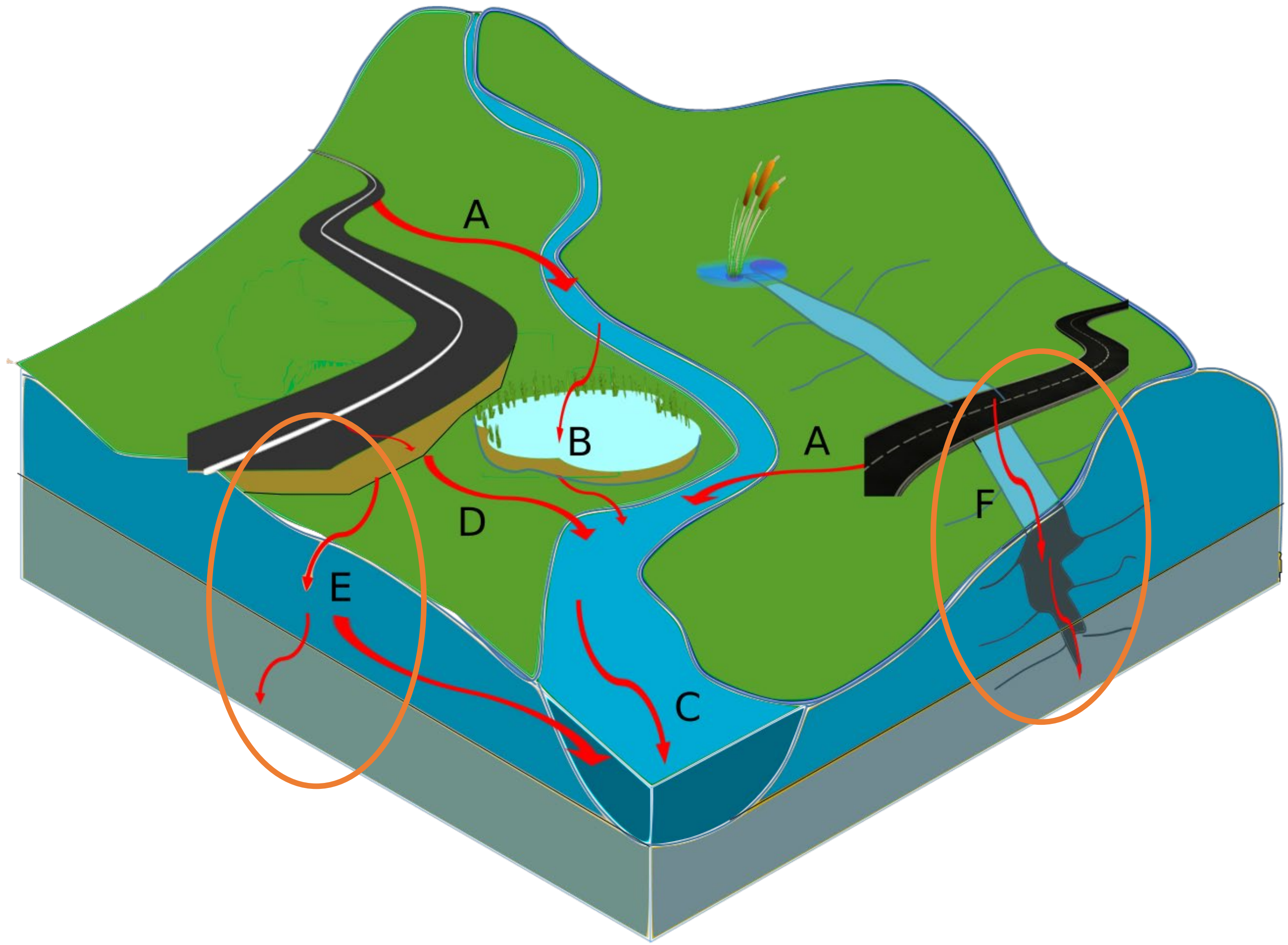
Cassanelli & Robbins 2013 J. Environ. Qual.

# How Road Salt Gets Into Groundwater



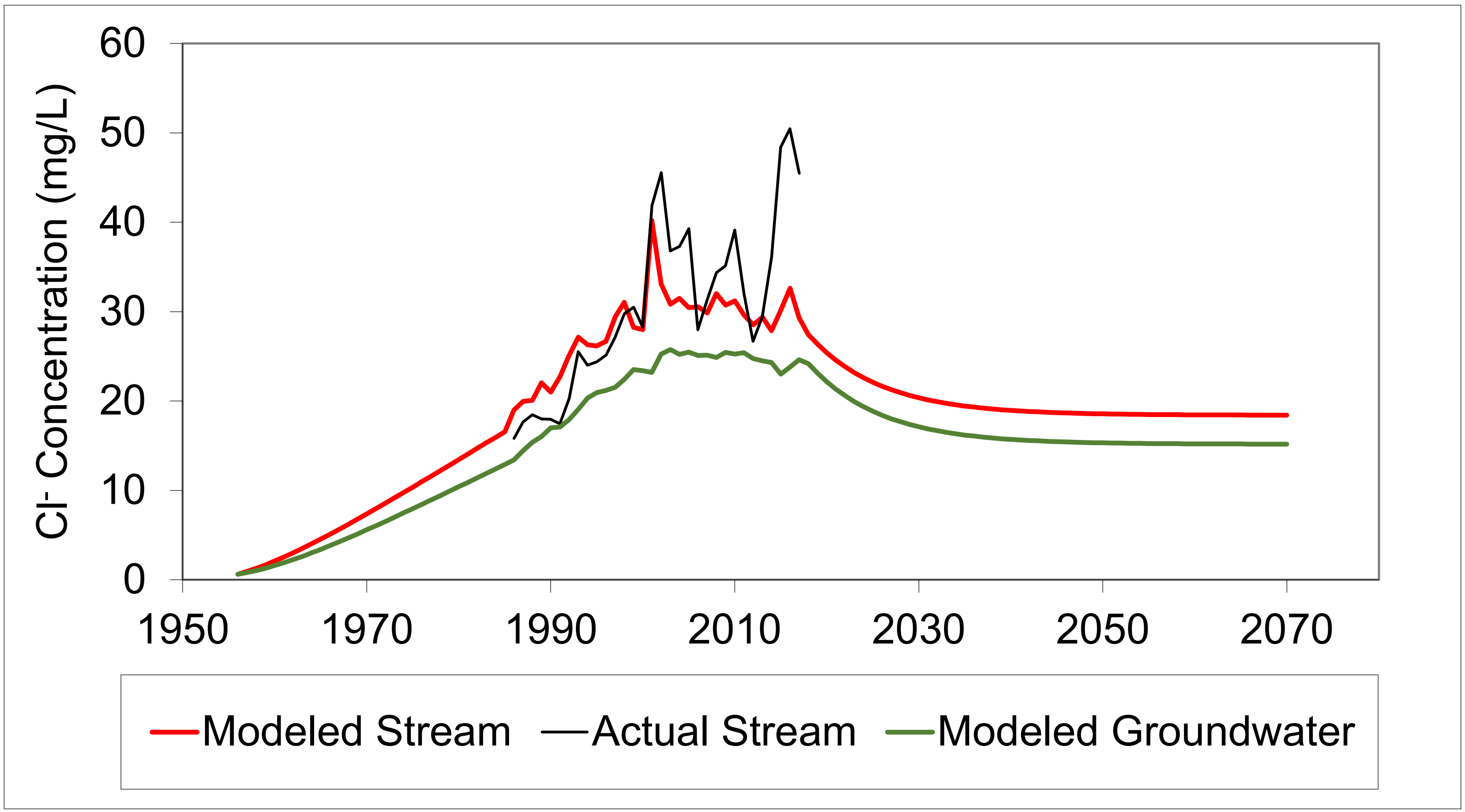

Pielou 1998

# Roadside Infiltration, Fracture Zones



# Legacy of Road Salt

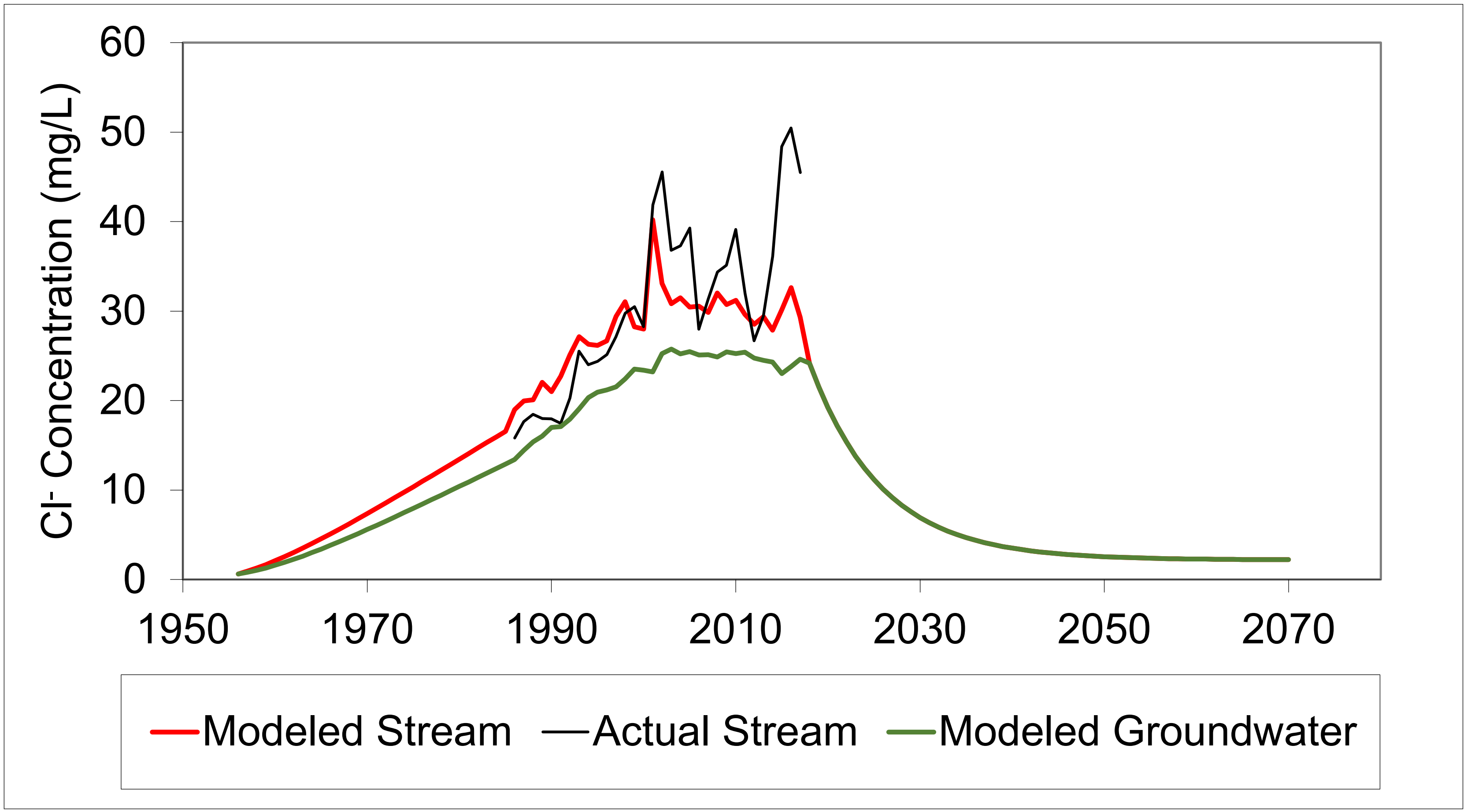
## A Case Study Wappinger Creek at Cary Institute in Millbrook NY




Kelly et al 2019 Water Air & Sol Pollution

# If Reduce Road Salt to 0

## Not Suggesting

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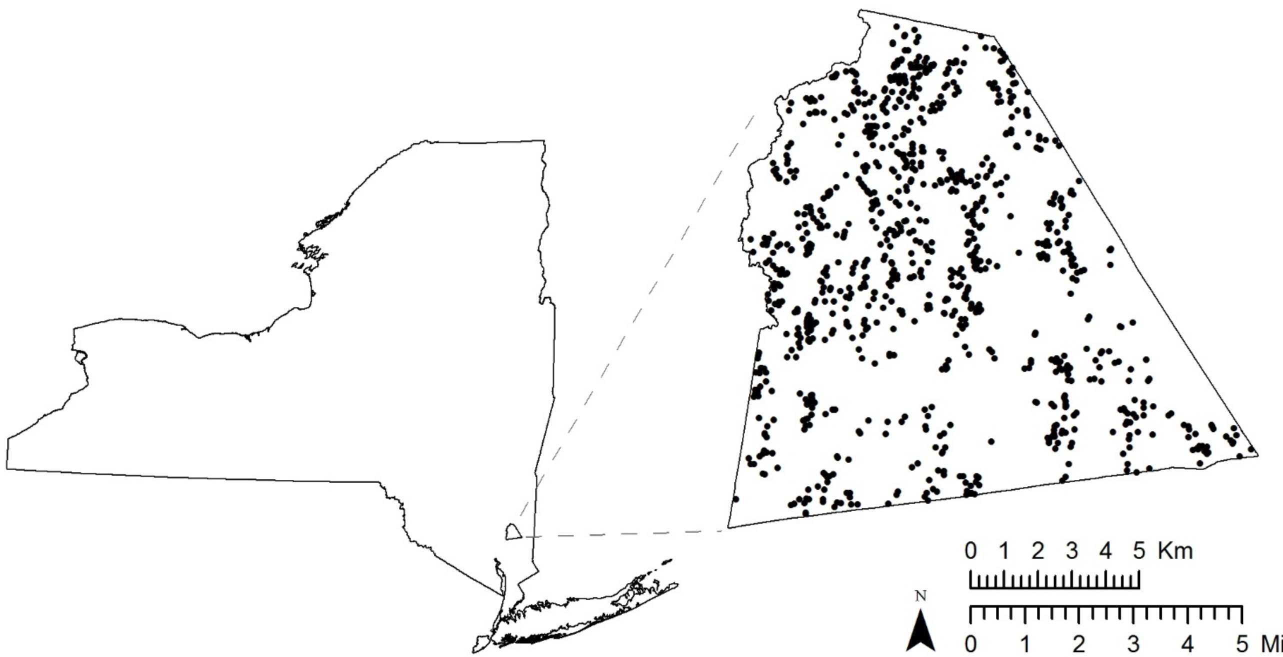
# Where salt is in groundwater

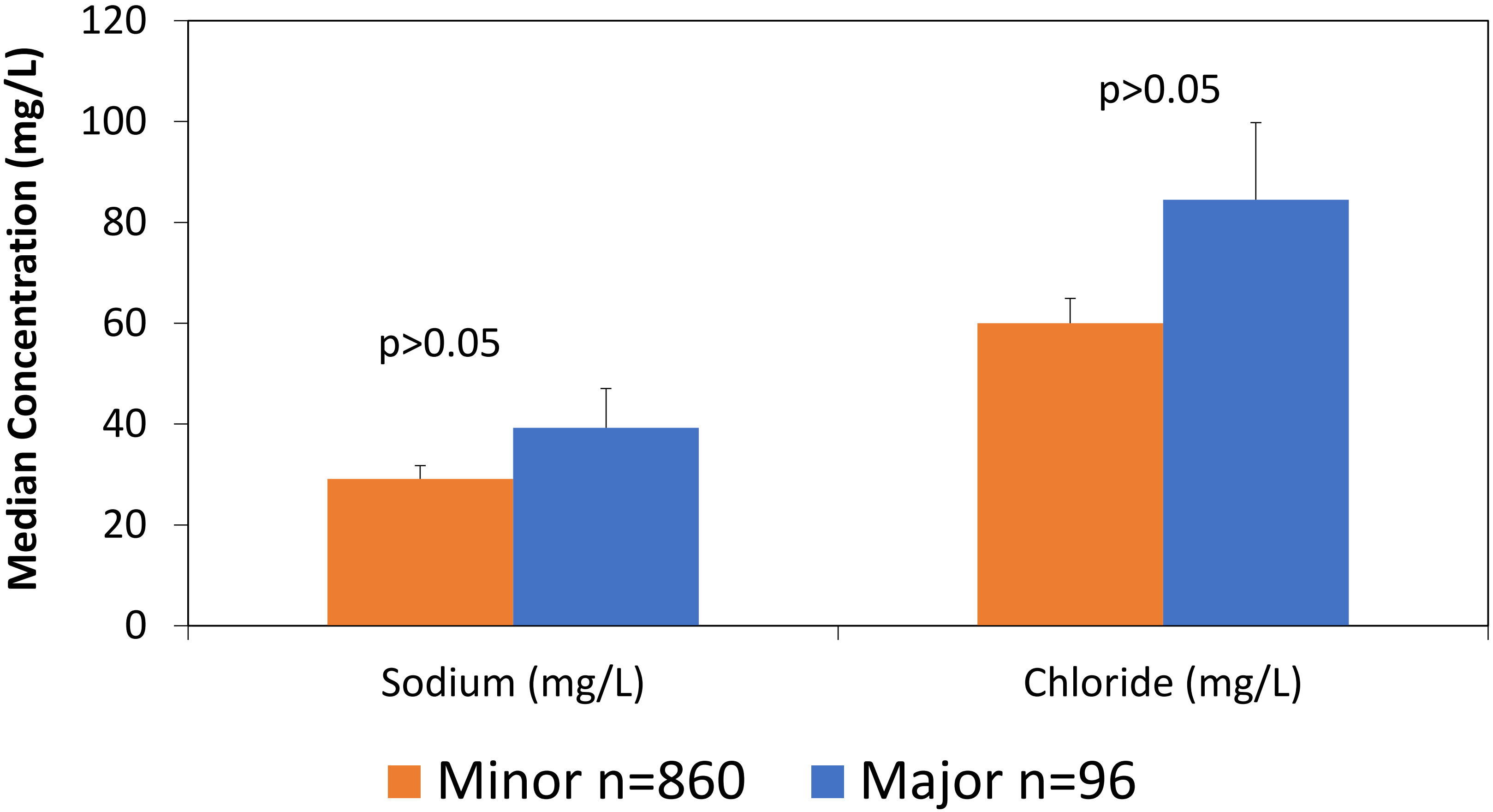
## Case Study from East Fishkill NY



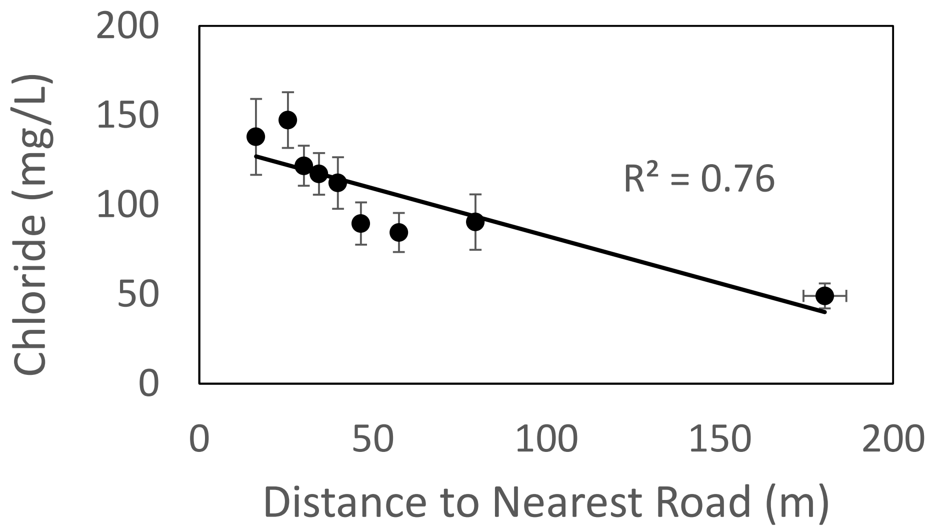

Kelly et al 2018 J. Environ. Qual.

# Major vs. Minor Roads

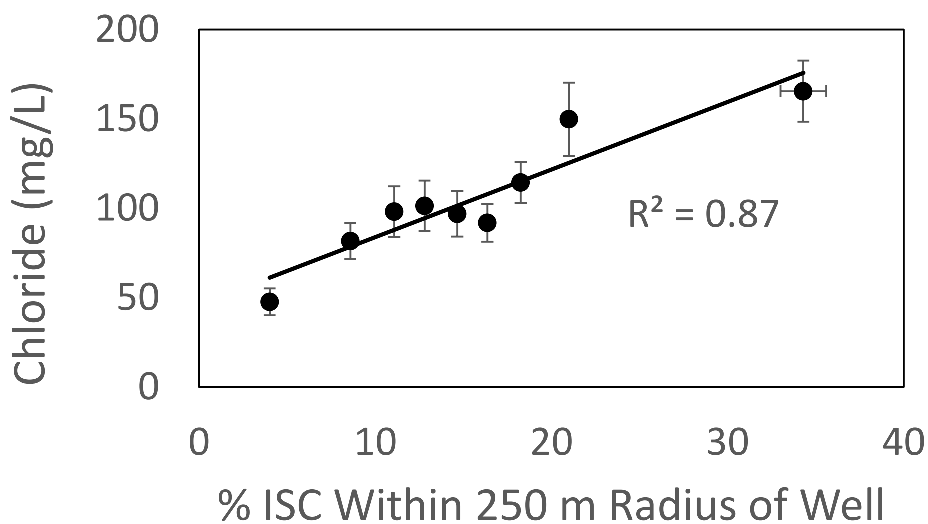
## Not Significant in This Study, Significant in Others




Kelly et al 2018 J. Environ. Qual.



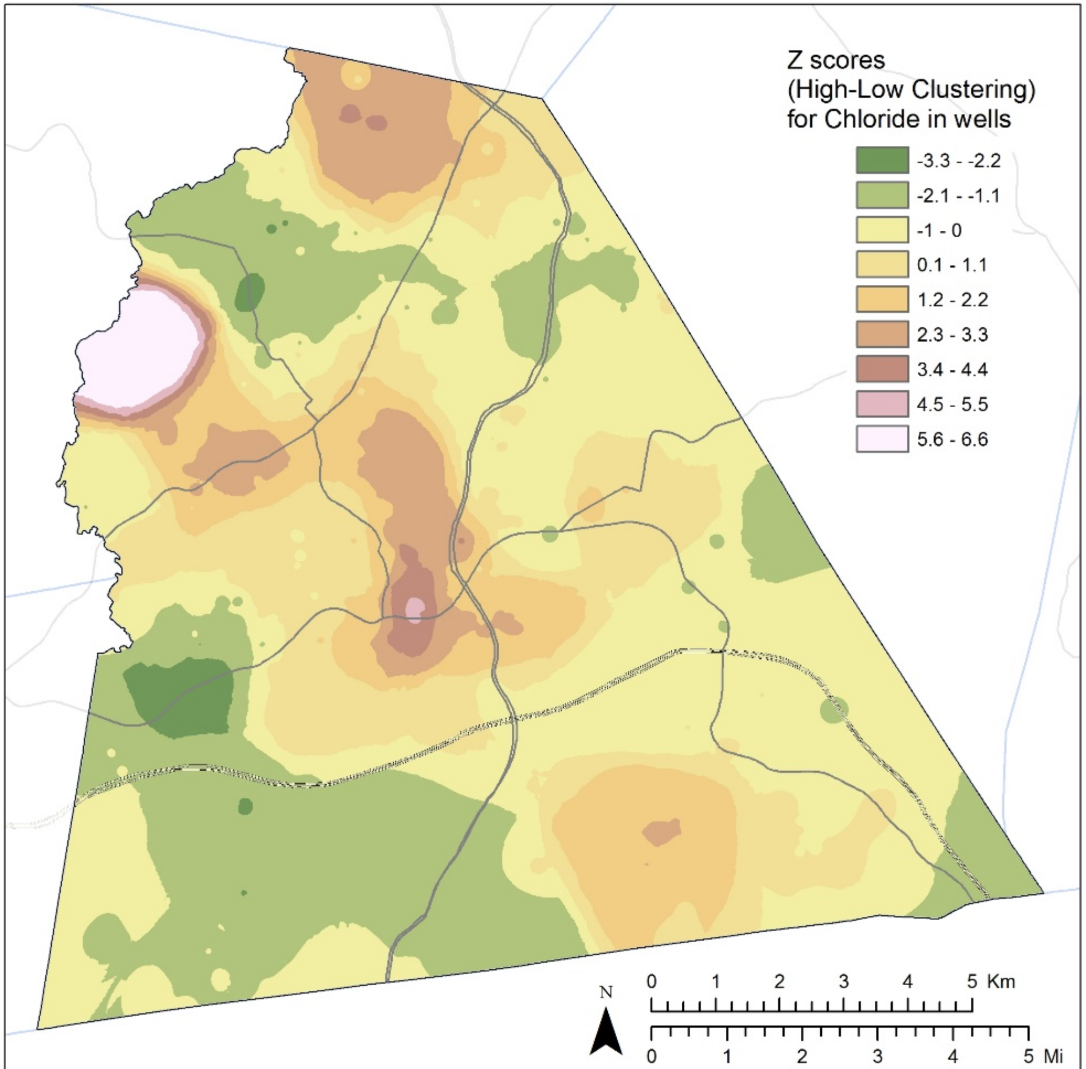

Distance to Nearest Road




% Impervious Surface Cover

Kelly et al 2018 J. Environ. Qual.

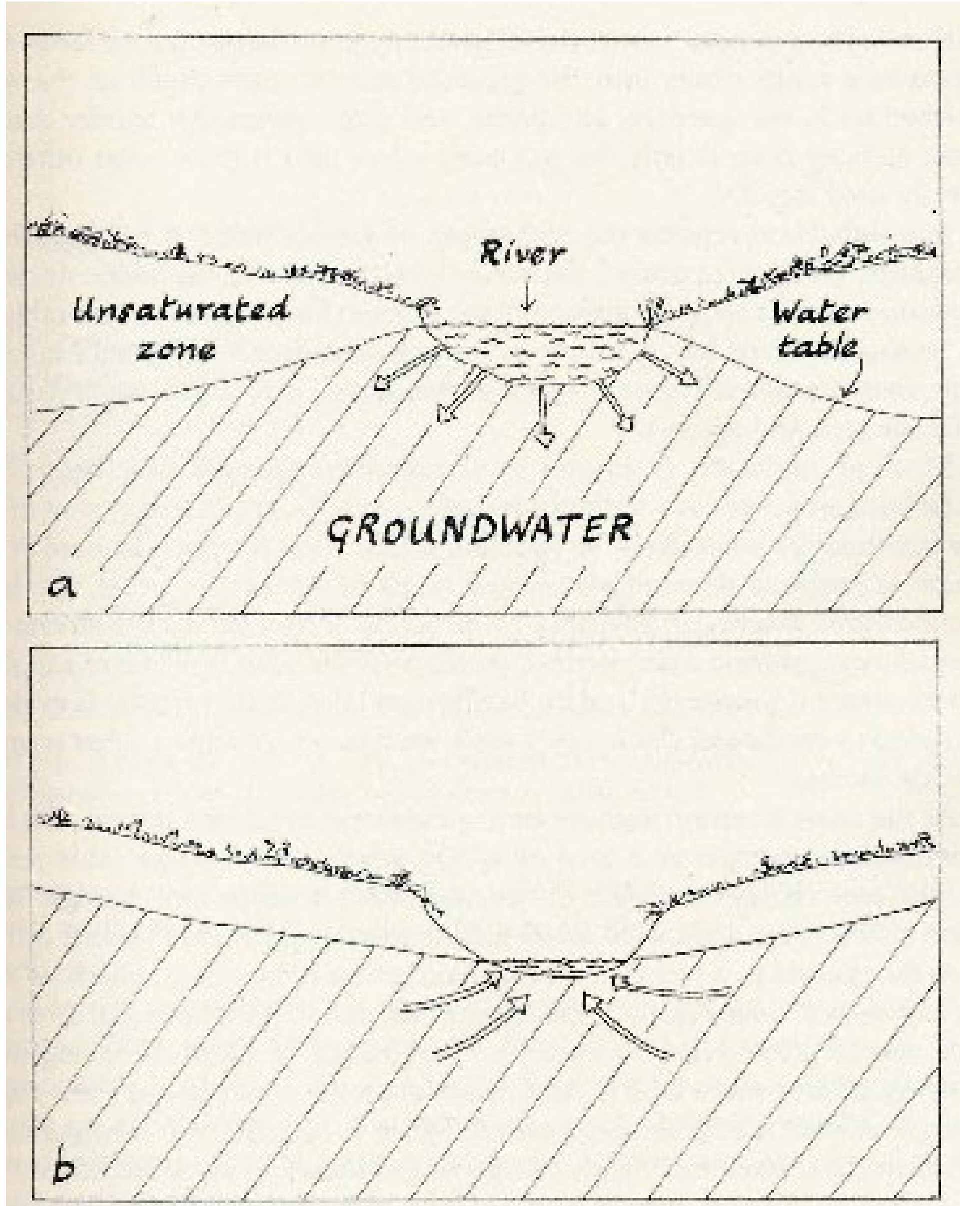
# Hot Spots / Cold Spots




Kelly et al 2018 J. Environ. Qual.

# Seasonality

# Stream Baseflow = Groundwater

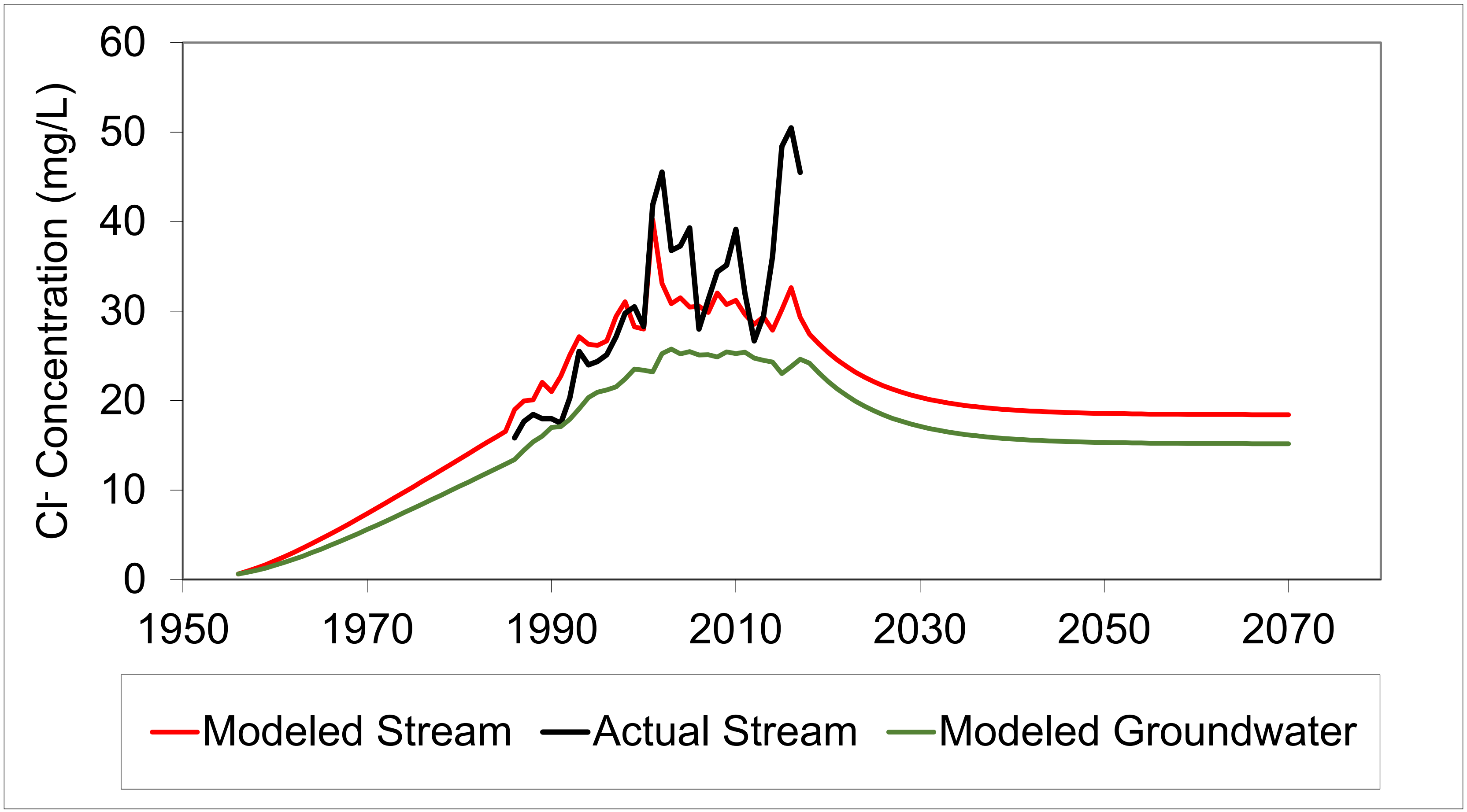



Winter

Summer

Pielou 1998

# Stabile Concentration but High Inter-Annual Variability

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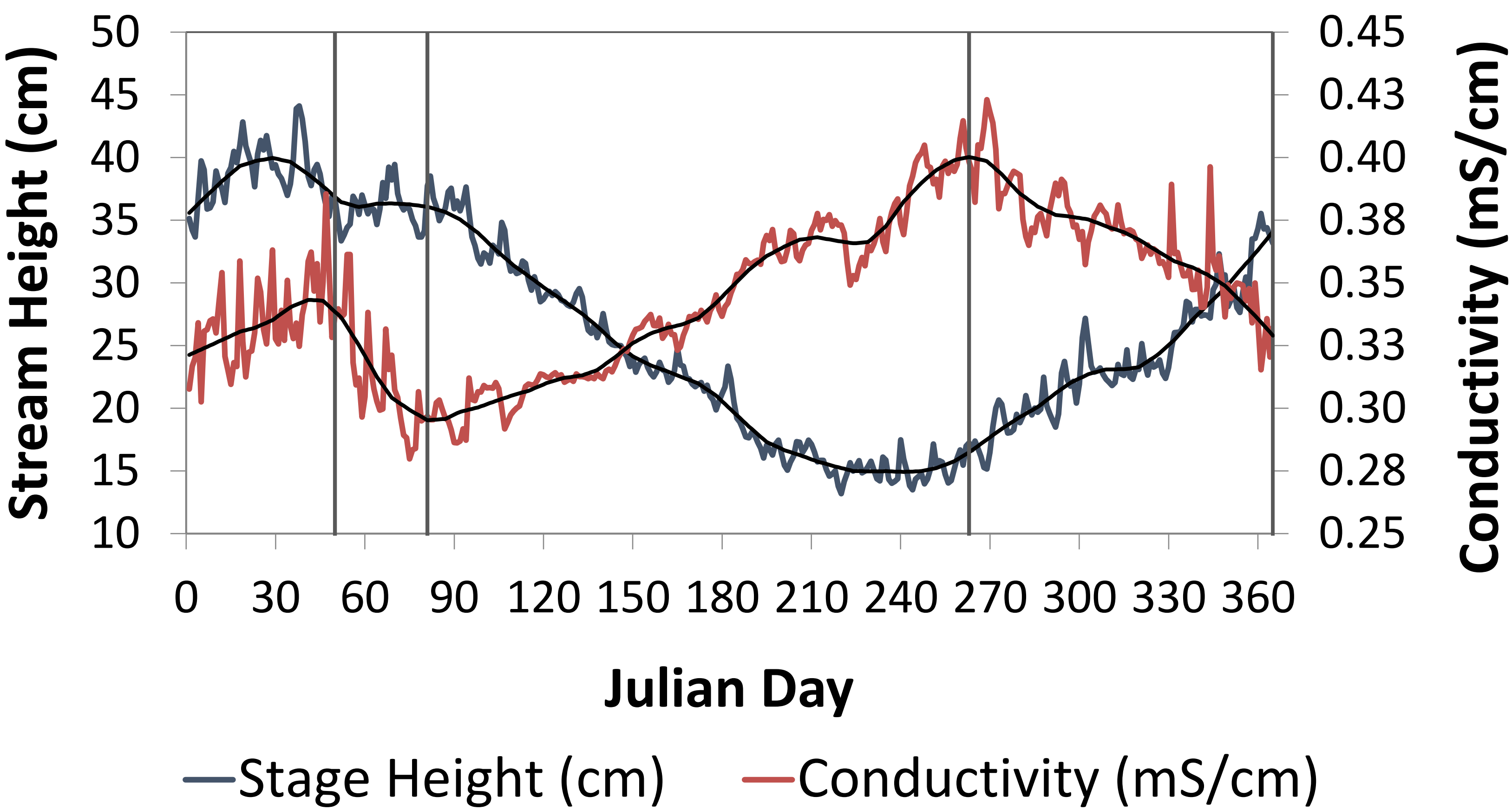
# Seasonality

## Strong Intra-Annual Pattern - Water Volume & Concentration

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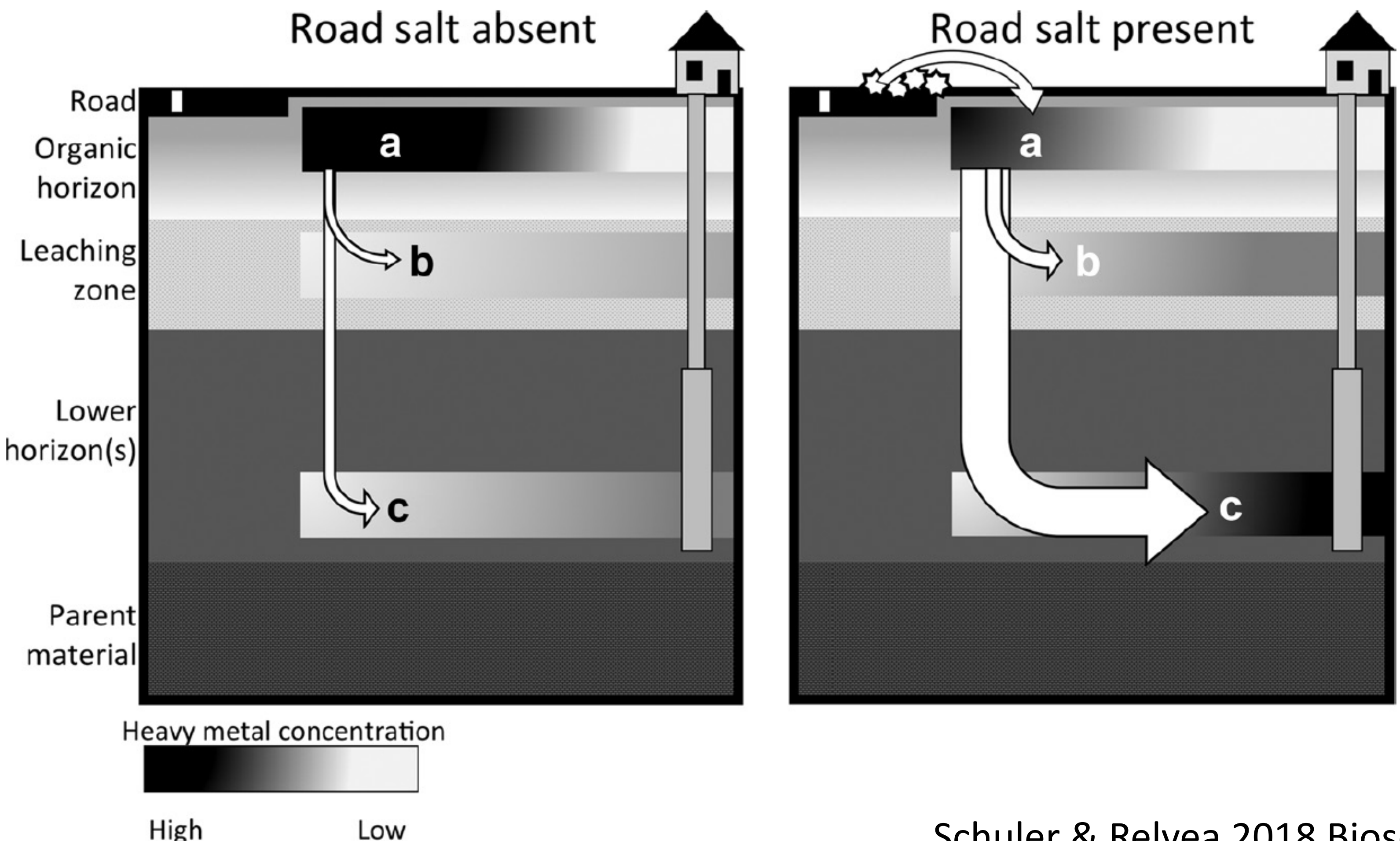
# Other Contaminants Associated with Road Salt

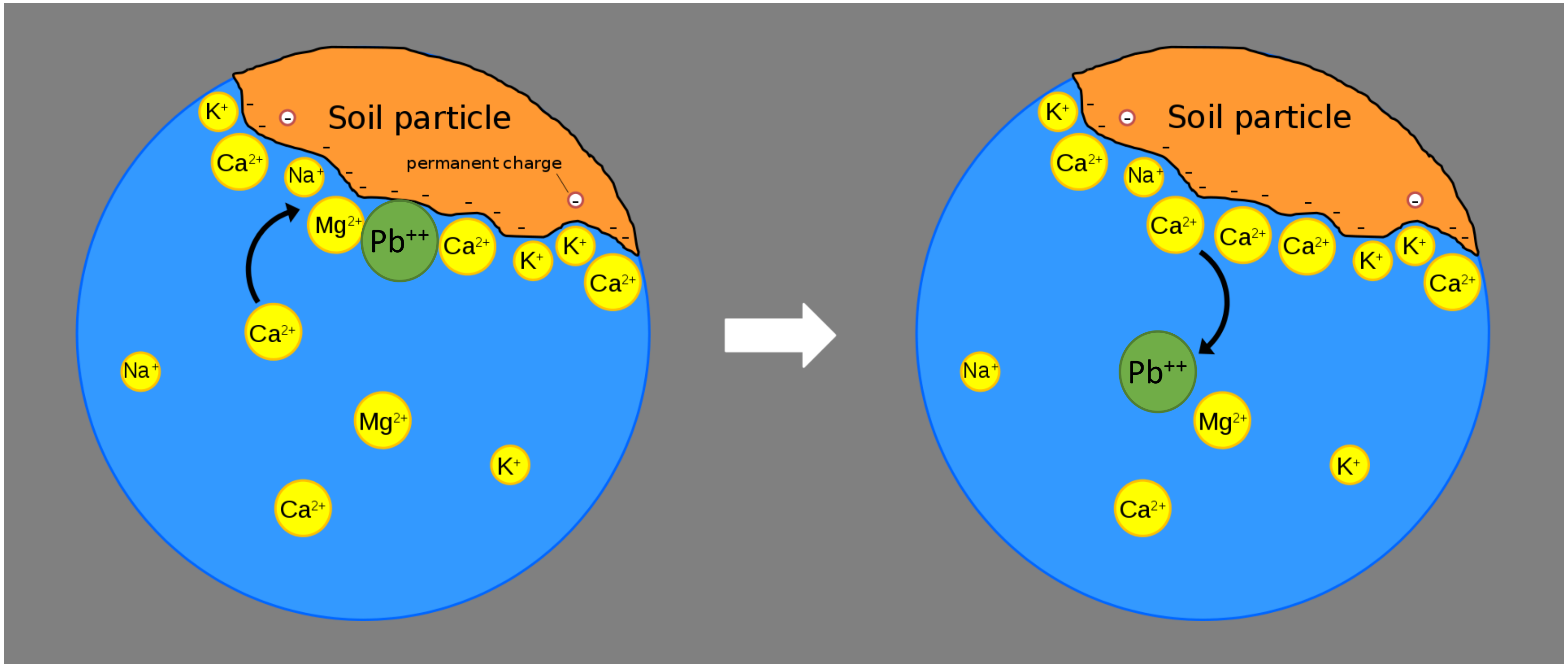
# The Lead, Road Salt Connection

# Road Salt Enhances Leaching of Heavy Metals from Soil

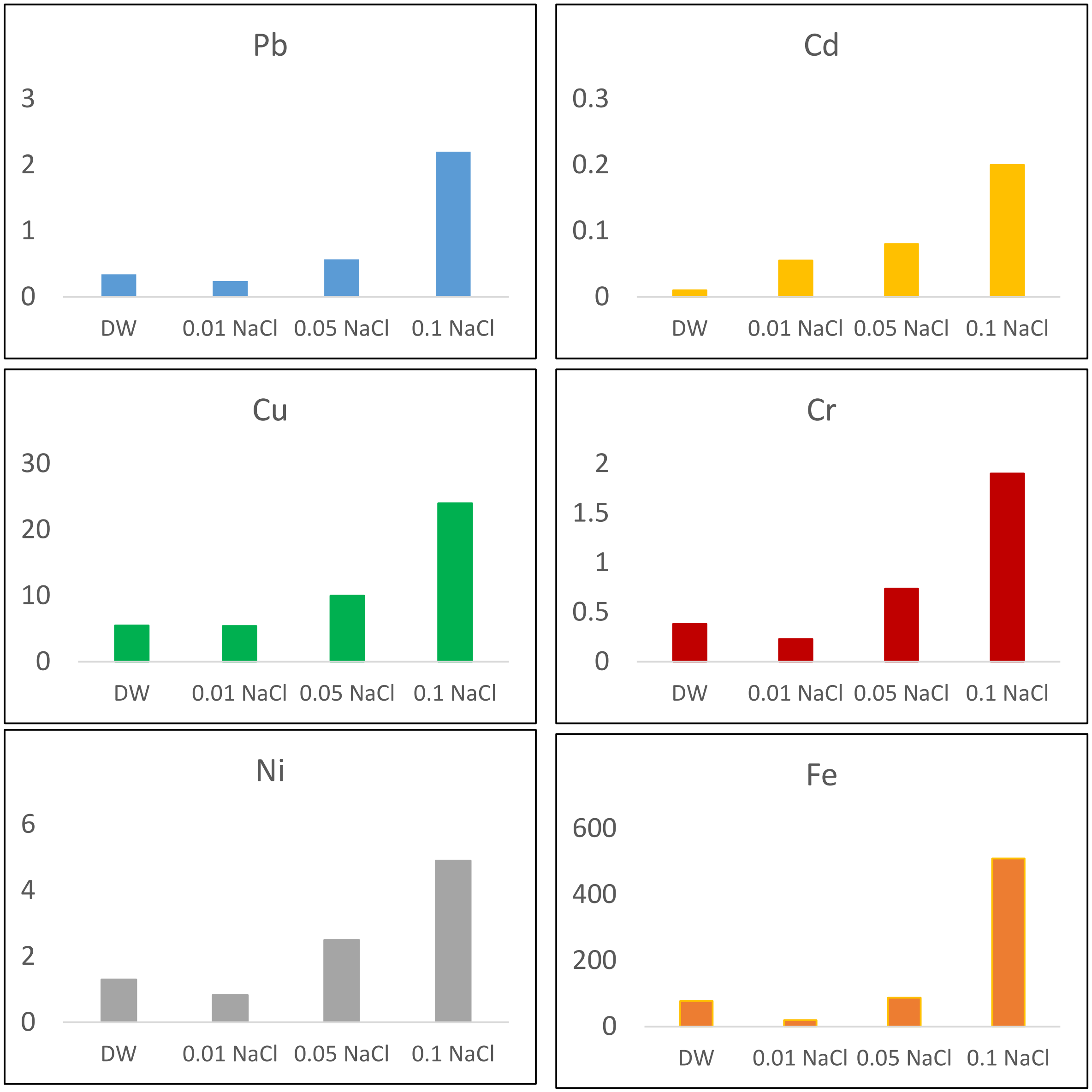



Schuler & Relyea 2018 Bioscience

# Soil Leaching Mechanism
# Ion Exchange

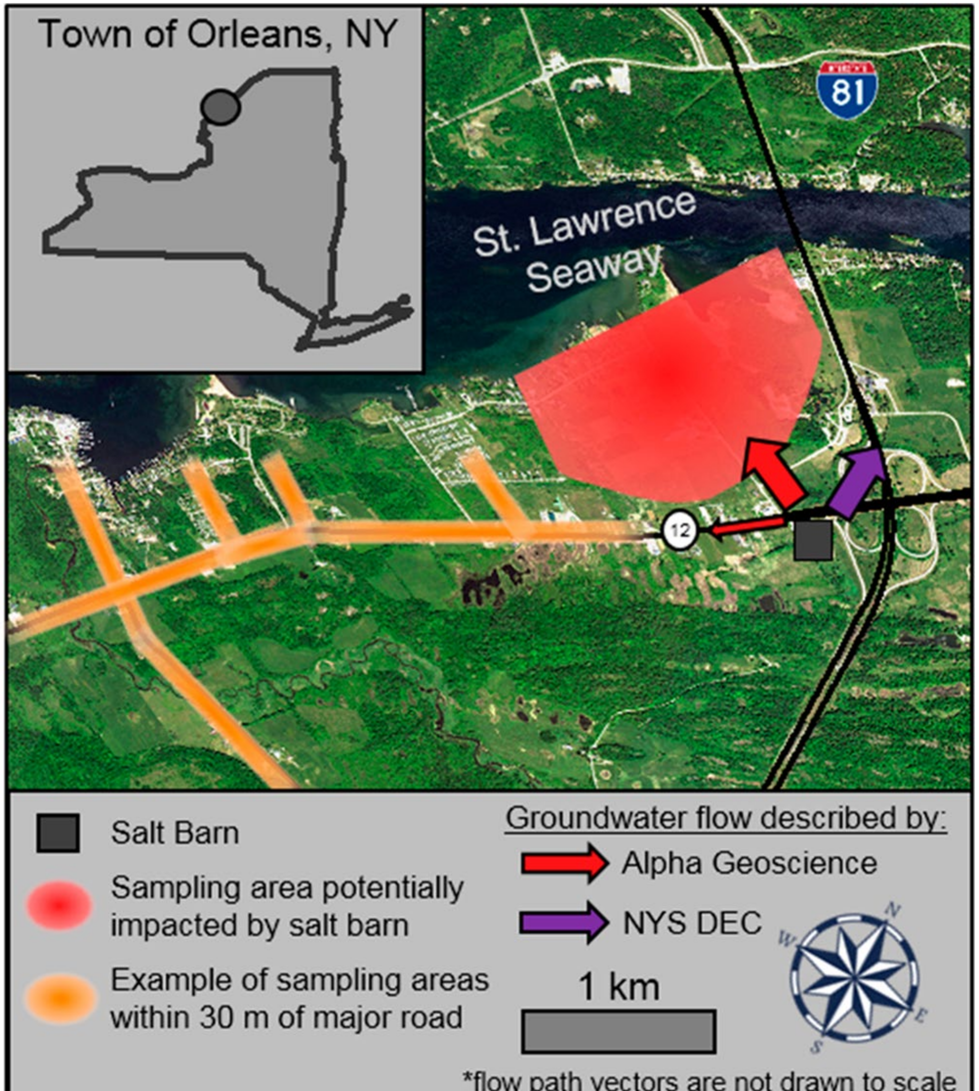


# Metals Leached From Soil (µg)



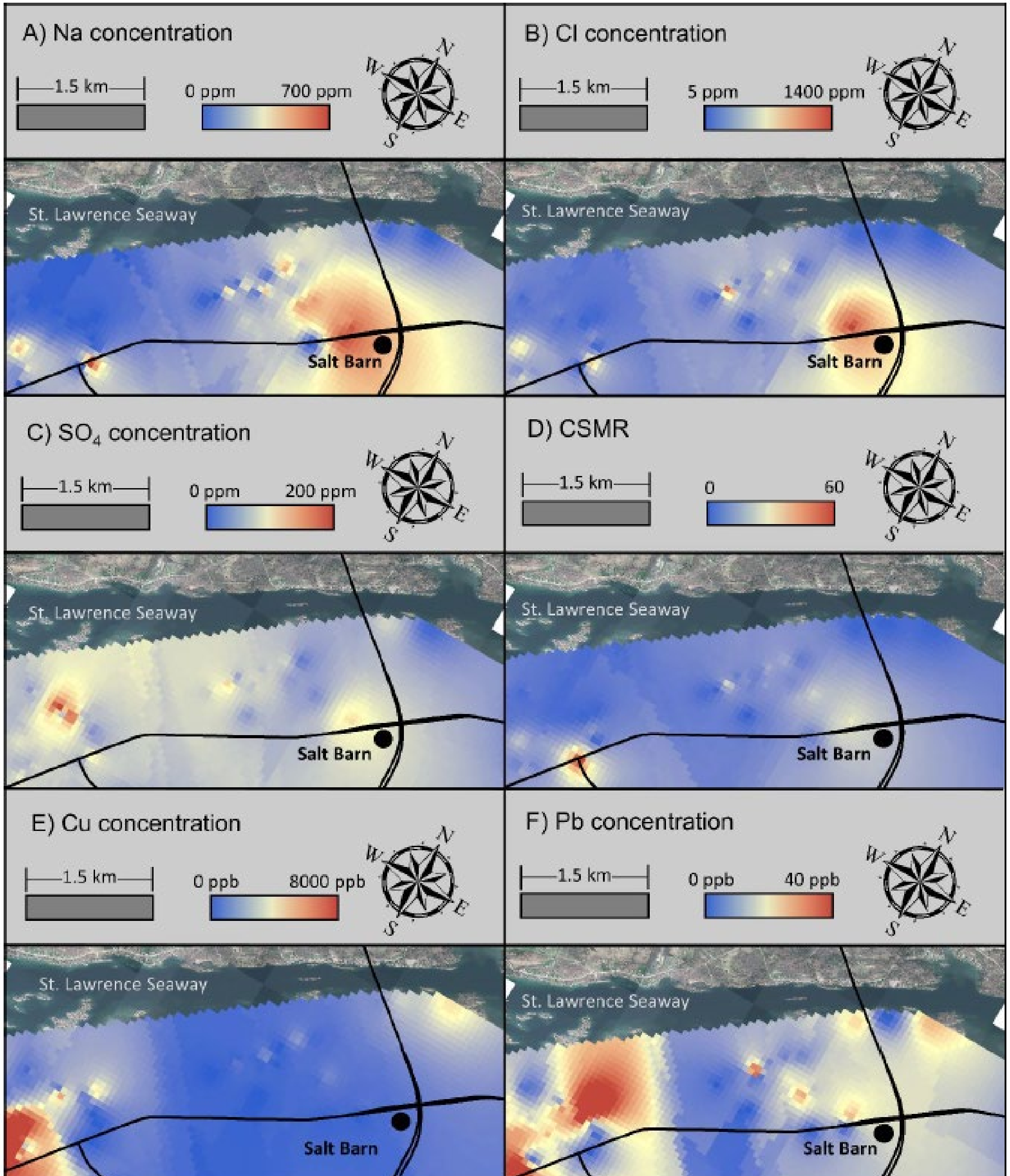

Amrhein et al 1992
ES&T

# Does Road Salt Cause Lead to be Leached from Drinking Water Pipes?




Case Study in Orleans NY

Pieper et al 2018 ES&T




# Groundwater

Na

Cl

SO4

CSMR*

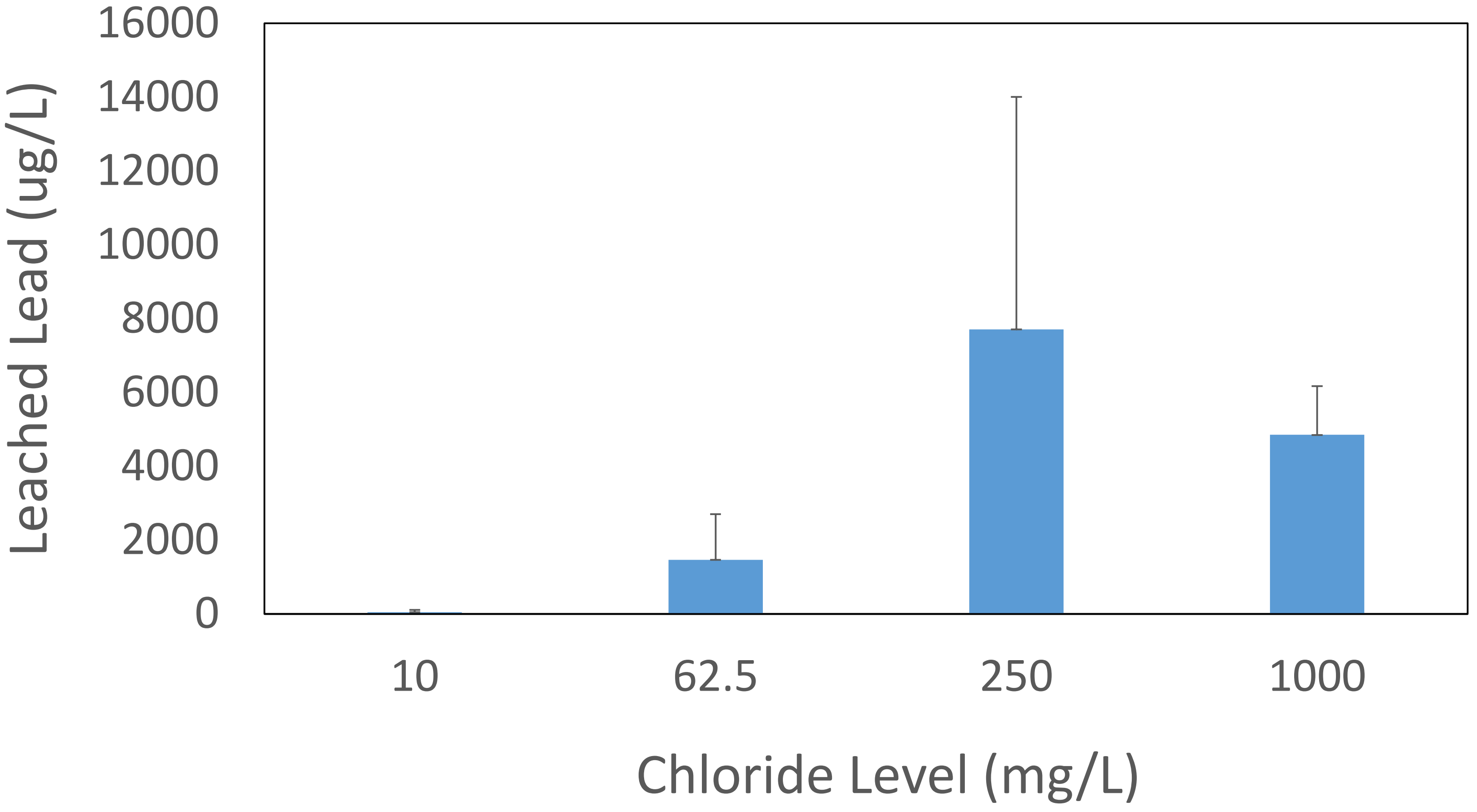
Cu

Pb

*Chloride to Sulfate Mass Ratio

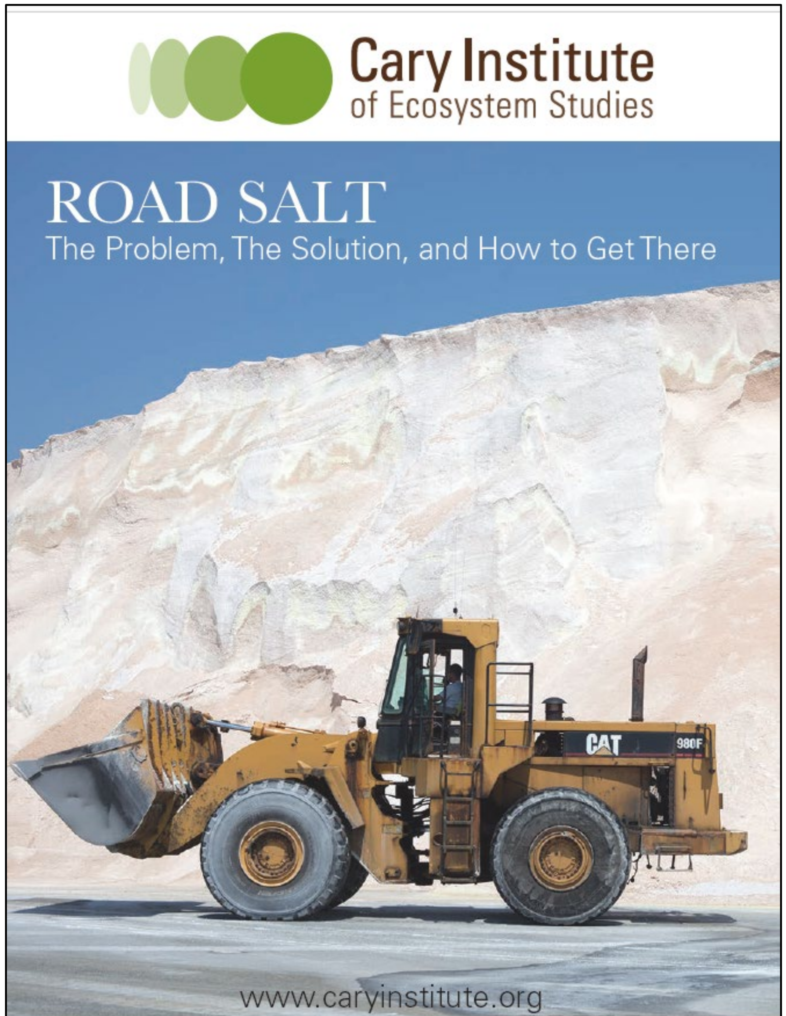
Pieper et al 2018 ES&T

# Pb Leached From Simulated Lead-Tin Solder Joints




Pieper et al 2018 ES&T

# Change is Needed
# Some Recommendations



# Salt Storage Facilities

# Best Management Practices



# Contaminant Candidate List Status of Na

- US SDWA – primary & secondary standards & CCL
- Primary – enforced standards
- Secondary – non-enforceable guidelines, aesthetic, Chloride 250 mg/L
- CCL under review, may require regulation, Sodium recommended limit 20 mg/L
- Some states require public notification if Na exceeds 20 mg/L
- Shift Na from CCL to Primary Standard
- All standards only for public drinking water supplies

# Private Drinking Water Wells

- Not protected by Safe Drinking Water Act
- In East Fishkill NY ½ wells sampled Na exceeded 20 mg/L
- Regular testing for suite of potential contaminants, including sodium, chloride & lead

# Thank You
# Questions

Stuart Findlay, Kathie Weathers, Gary Lovett, Steve Hamilton, Cary Institute
Mary Ann Cunningham, Vassar College
Neil Curri, Vassar College
Sean Carroll, Cornell Cooperative Extension, Dutchess County
Funding support from the Dr. Robert C. and Tina Sohn Foundation

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