LID Stormwater Management Systems Demonstrate Superior Cold Climate Performance than Conventional Stormwater Management Systems

Thomas P. Ballestero, Robert M. Roseen, James J. Houle, Pedro Avellaneda, Robert Wildey, Joshua Briggs, Kris Houle, George Fowler

The UNH Stormwater Center

14 October 2010

2010 North Country Stormwater Tradeshow

Lake George, NY

UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

CICEET

Barriers to Implementation

Performance Concerns

- Cold Climate
- Long-term-clogging and durability
- Water quality performance

Construction Challenges

- Modern design specs
- Staging Issues: logistics and placement

Maintenance Misperceptions

- Cleaning frequency

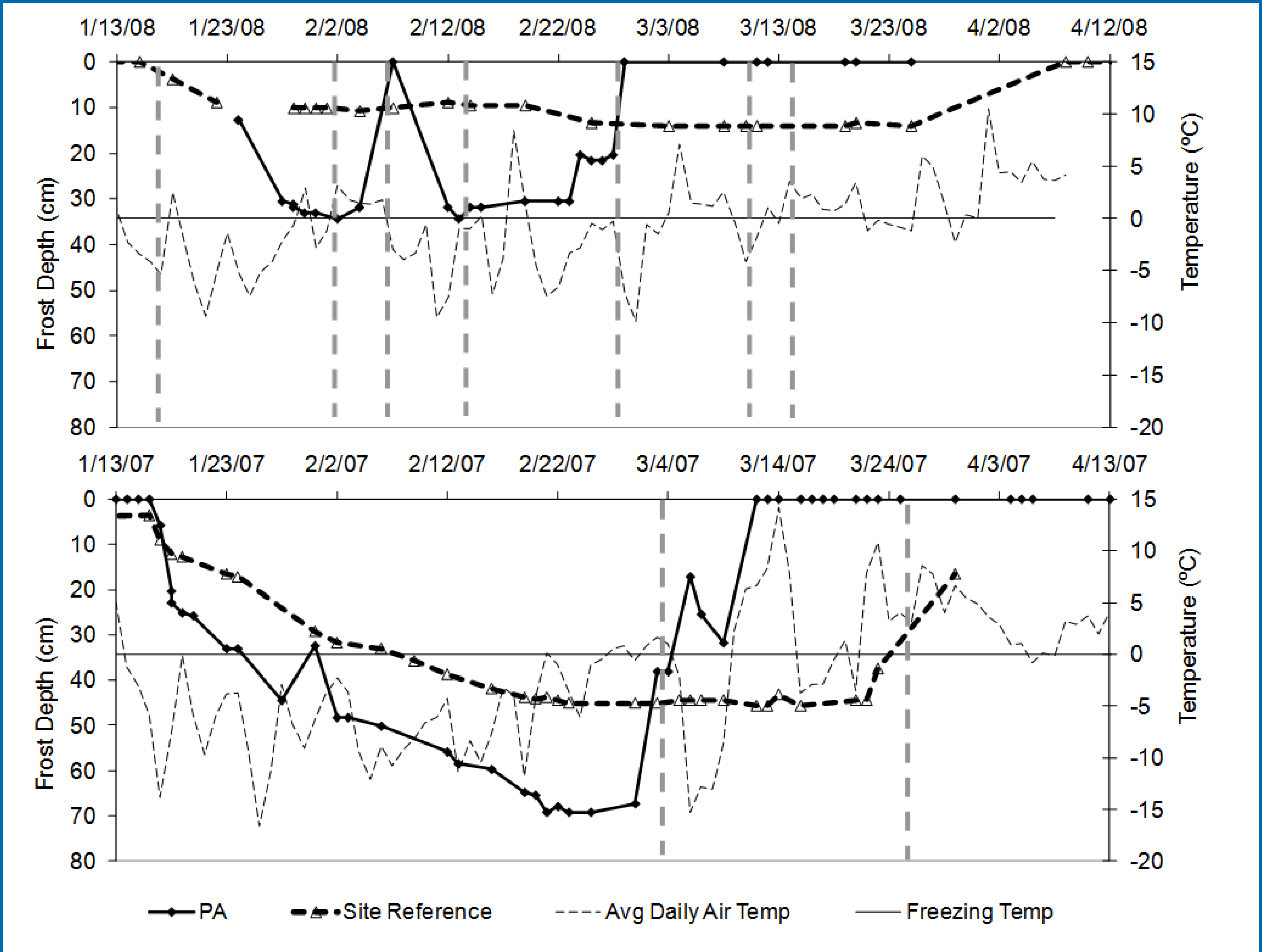
Cold Climate Performance Results

Frost Penetration

- Can be related to pavement failure
- Measured with a ‘field-assembled’ frost gauge (Ricard et al., 1976)
- Show relationships between pavements and soils

Filtration Systems Frost Penetration

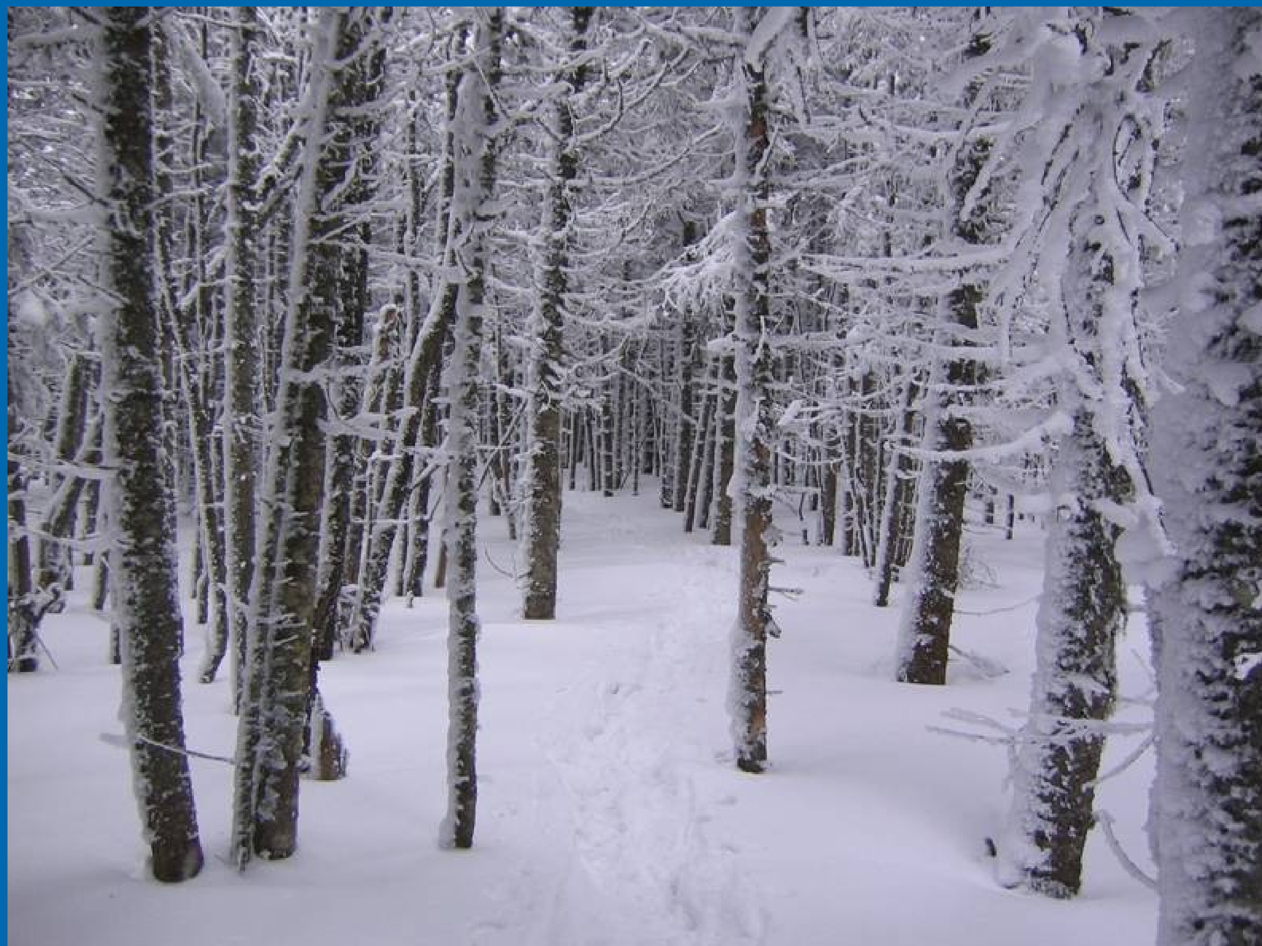
Porous Asphalt Frost Penetration



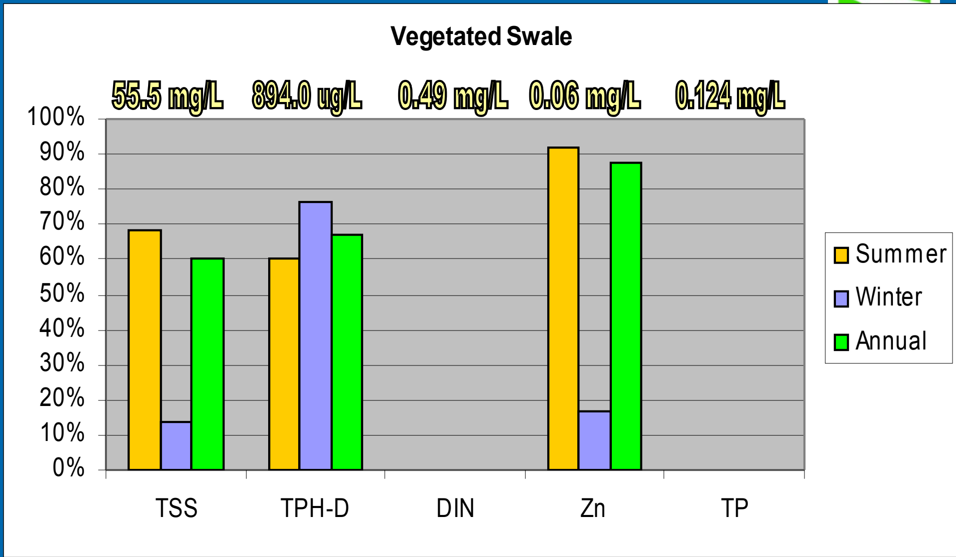
Frost Penetration does not mean or imply

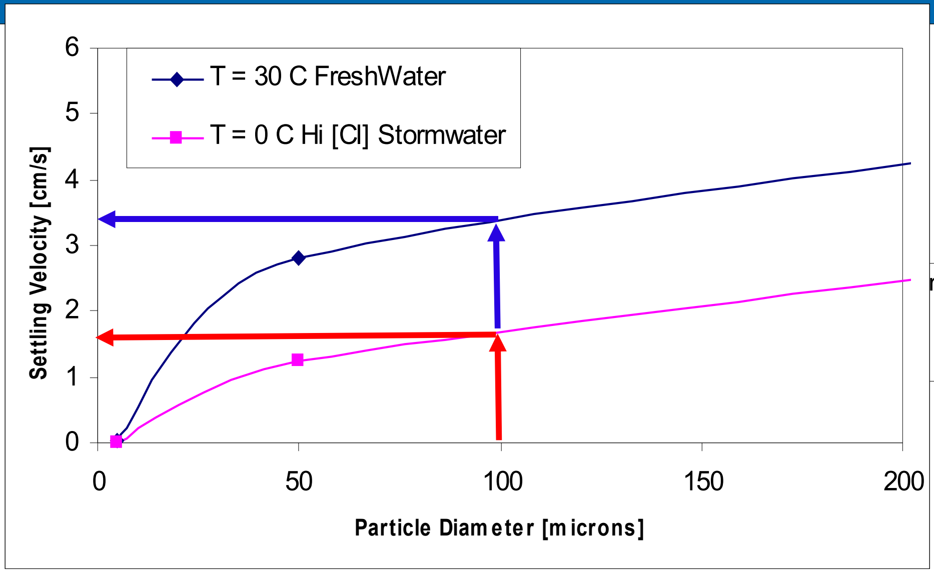
Impermeable

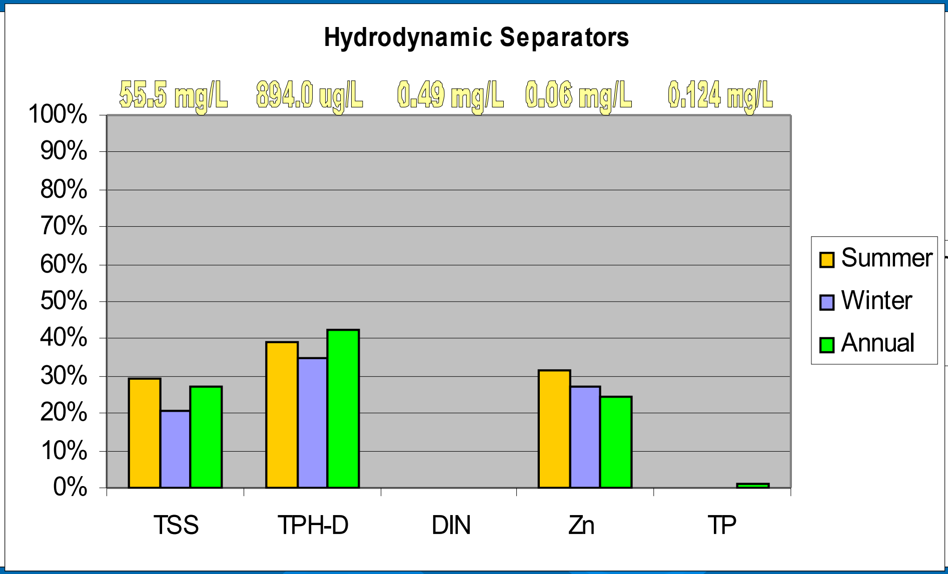
Seasonal Monitoring



Seasonal Variations in Performance



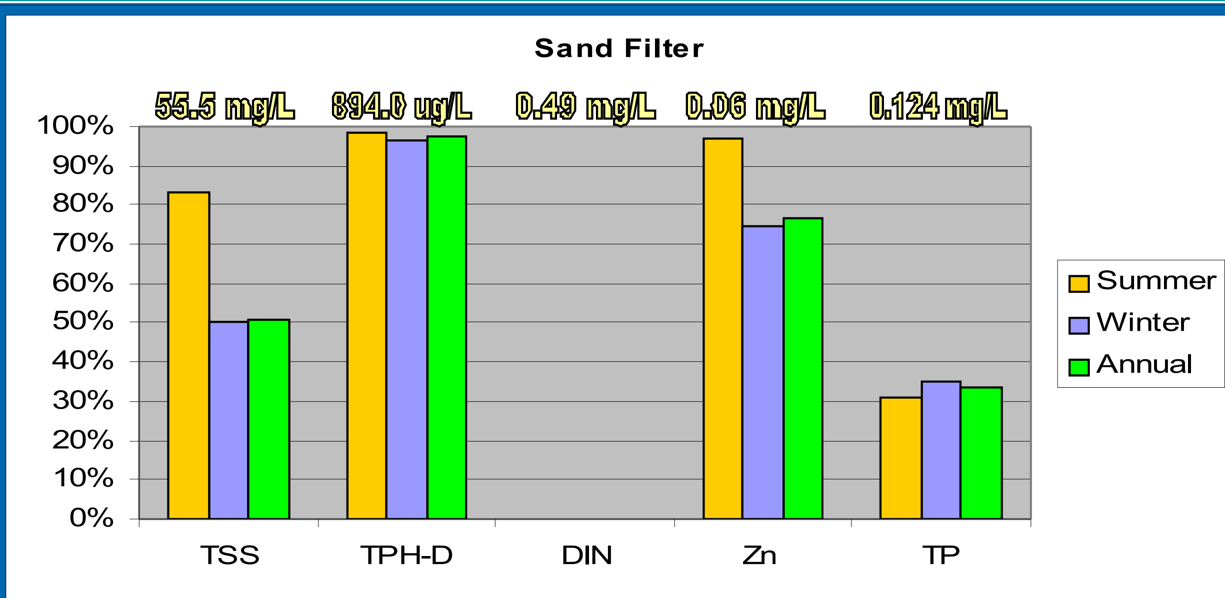


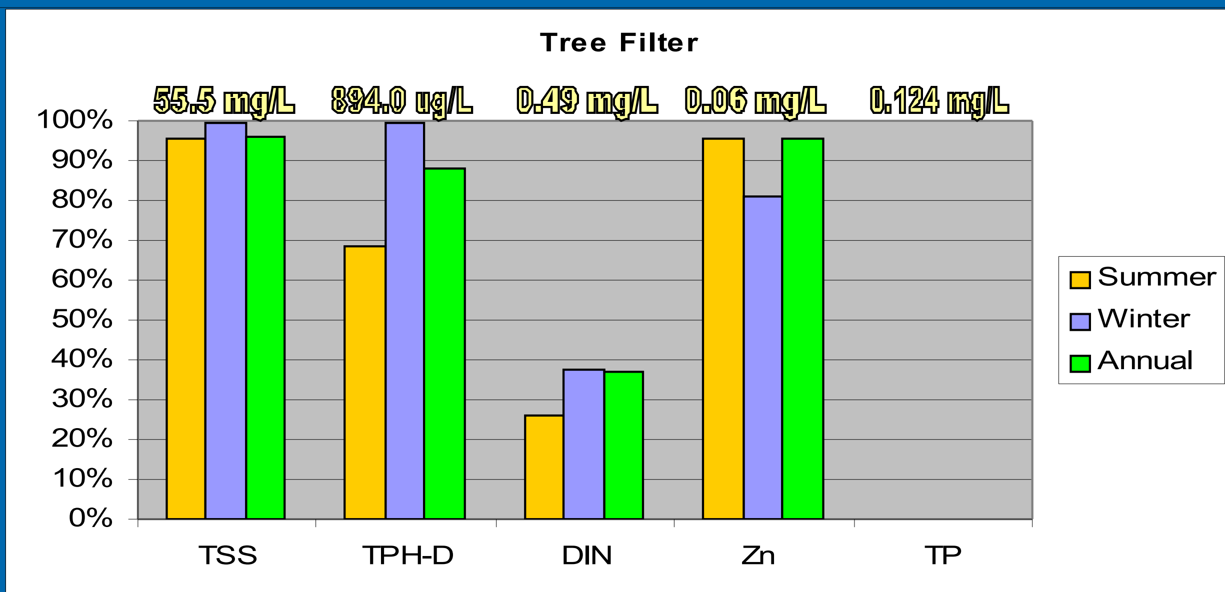


The effect of T and [Cl-] is to nearly double the settling time from 1.6 to 3.4 cm/sec

ormwater

Performance Efficiencies –Filtration/Infiltration





Center 2007

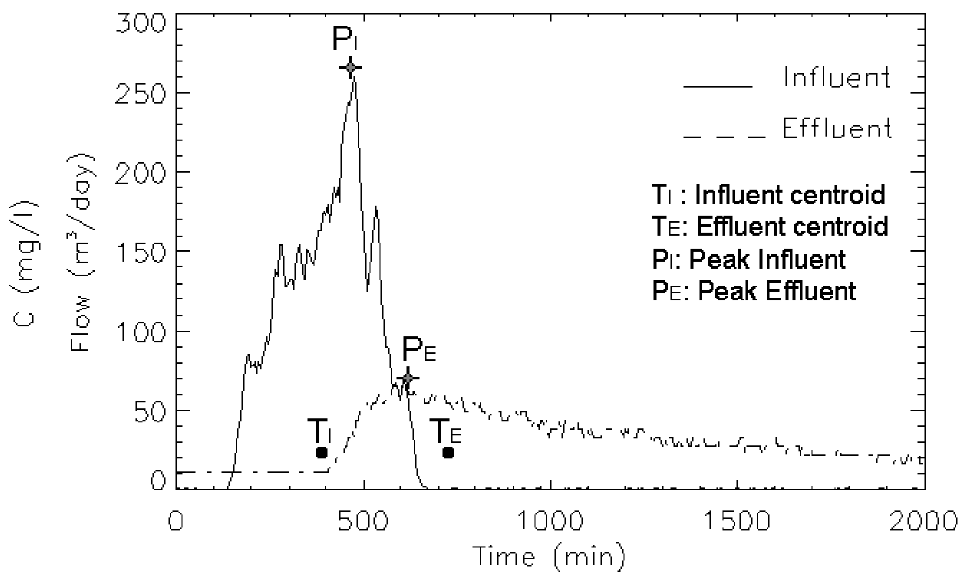
Seasonal Hydraulic Efficiency

Equation 1: Peak reduction coefficient

$$k_p = \frac{Q_{p,effluent}}{Q_{p,\inf luent}} \leq 1$$

Equation 2: Lag coefficient

$$k_L = \frac{t_{c,effluent}}{t_{c,\inf luent}} \geq 1$$



Peak Reduction = 1 – (P_E / P_I)

Lag Time = T_E - T_I

Hydraulic Efficiency

Annual and Seasonal lag (kL) and delay (kP) coefficients

Device		Annual	winter(6)	summer(6)
Subsurface Infiltration	Kl	1.60	1.68	1.46
	Kp	0.17	0.17	0.16
Surface Sand Filter	Kl	1.47	1.56	1.27
	Kp	0.40	0.45	0.29
Retention Pond	Kl	2.02	2.11	1.77
	Kp	0.15	0.16	0.11
Bioretention	Kl	2.16	2.27	1.81
	Kp	0.15	0.18	0.06
Gravel Wetland	Kl	1.58	1.56	1.61
	Kp	0.15	0.16	0.14
Stone-Lined Swale	Kl	1.02	1.00	1.25
	Kp	1.03	1.13	0.79

MIN IMPACT

GREATEST IMPACT

Winter Maintenance

- Plowing
- De-icing
- Sanding

Why is Deicing Practiced?

- For as many as 3-6 months per year, deicing is used routinely :
  - To control ice development caused by the pooling of the meltwater followed by freezing air temperatures, and
  - To control accumulation of compact snow and ice not removed manually.
- On standard pavements, salt is easily dissolved in standing meltwater or washed away with runoff.

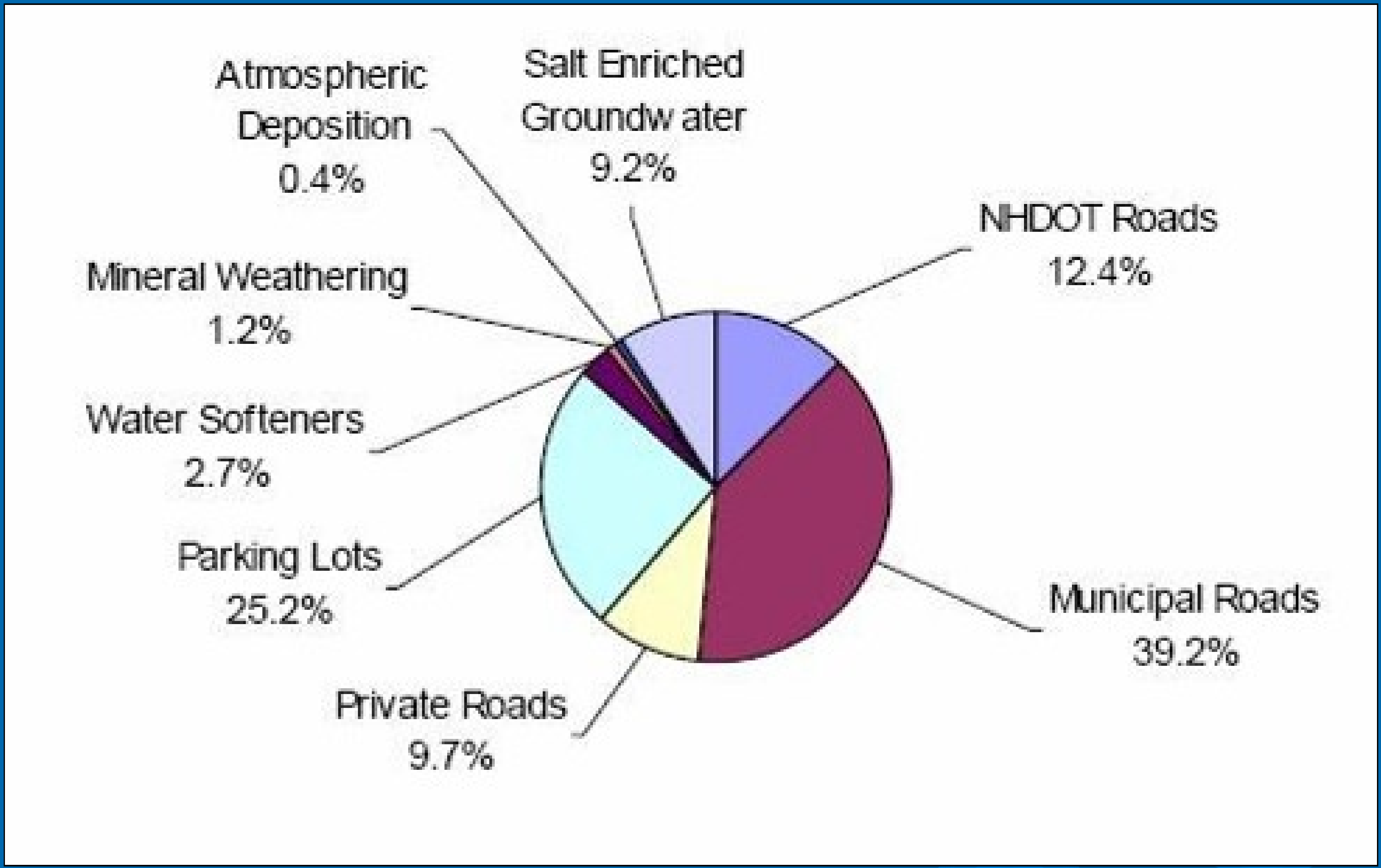
Why are we concerned about

- No stormwater treatment removes chloride
- Usage is on the rise
  - Need for public safety
  - Presumably because 80% TSS reduction is easily achieved by replacing sand with chloride
  - Easier to clean—no spring clean up
- Some DOT's use a 100% salt mix

Chloride TMDLs

- There are presently 6 TMDL's for salt in the USA – 4 are in NH
- NHDES is preparing a Chloride TMDL for salt impaired waters
- Limited flexibility for salt reduction due to concerns for safety
  - Substitute
  - Reduced use

% Salt Load by Source



NHDES Estimate, 2006

CHLORIDE TOXICITY DEFINED

Courtesy of Doug Heath, USEPA Region 1

- ***CHRONIC*** **– "THE FOUR-DAY AVERAGE CONCENTRATION OF DISSOLVED CHLORIDE, WHEN ASSOCIATED WITH SODIUM, DOES NOT EXCEED 230 MG/L (~850 uS/cm) MORE THAN ONCE EVERY 3 YEARS ON THE AVERAGE"**

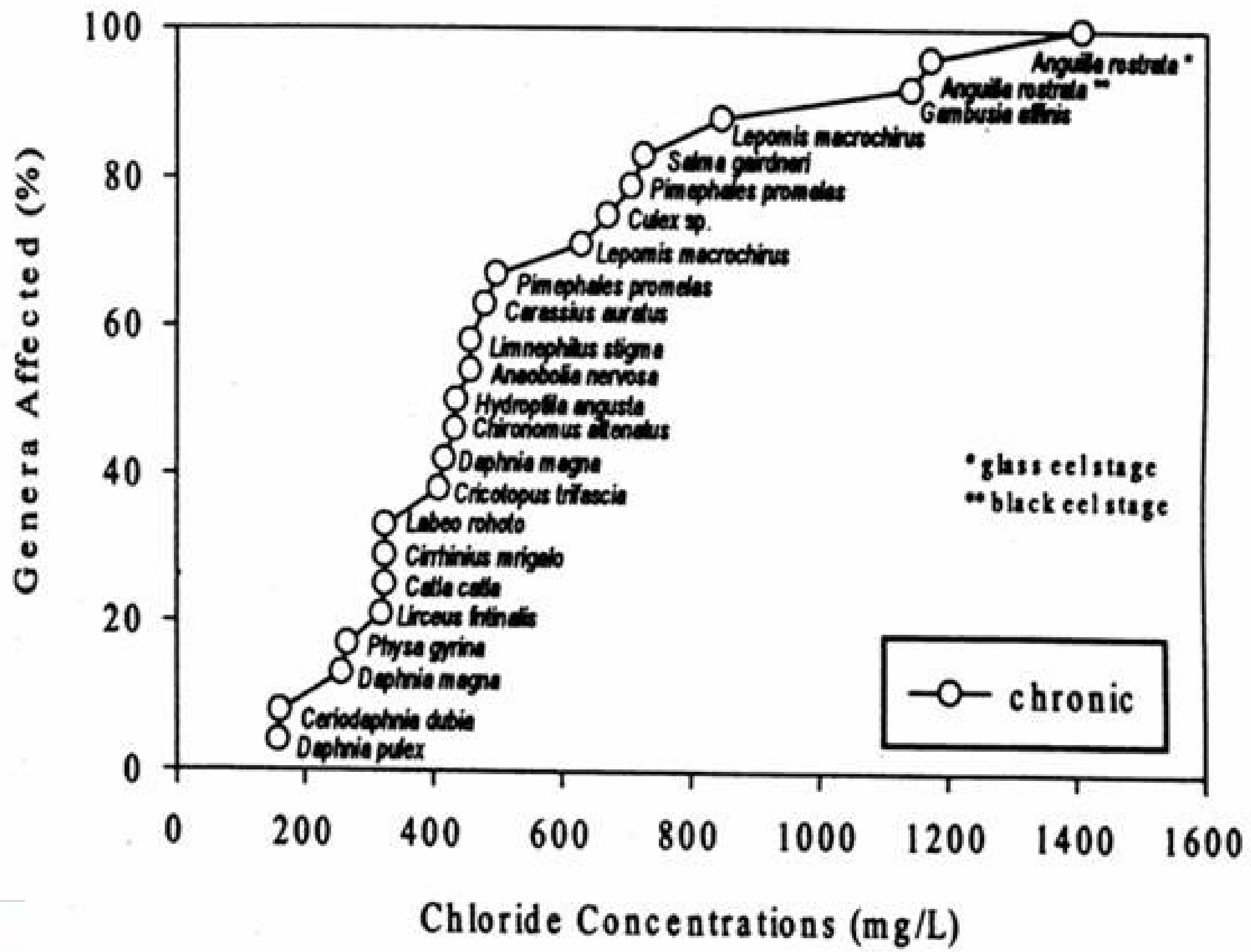
- ***ACUTE*** **– "THE ONE-HOUR AVERAGE CONCENTRATION DOES NOT EXCEED 860 MG/L (2855 uS/cm) MORE THAN ONCE EVERY 3 YEARS ON THE AVERAGE."**

[SOURCE: USEPA, 1988, *AMBIENT WATER QUALITY CRITERIA FOR CHLORIDE – 1988*: OFFICE OF WATER REGULATIONS AND STANDARDS, CRITERIA AND STANDARDS DIVISION, WASHINGTON, DC, EPA 440/5-88-001, P. 8]

Organism	Chloride (mg/L)	EC25 (uS/cm)	Test
Aquatic Species	>220	>900	synthesis of many tests; prolonged exposure (>30 days) will eliminate 10% of the species
Rainbow Trout	230	1,000	Minnesota chronic standard for trout (assumed to be for a >100 day adult exposure)
Humans	250	1,000	Federal & State Secondary Drinking Water Standard (mostly for taste)
Daphnids	210- 372	900-1,400	chronic toxicity (>30 day exposure)
Fathead minnows	433	1,600	chronic toxicity (>30 day exposure)
Rainbow Trout	> 900	3,000	significant (25%) adverse effects on trout eggs, embryos & adults in 7 days
Fathead minnows	1,280	4,100	lowest observed effects after 7 days
Daphnids	1,400	4,400	acute toxicity (50% mortality in 4 days)
Mayflies	2100-4300	6500-13,000	lowest observed effects after 7 days
Rainbow Trout	6,743	20,300	acute toxicity (50% mortality in 4 days)

Chloride Toxicity

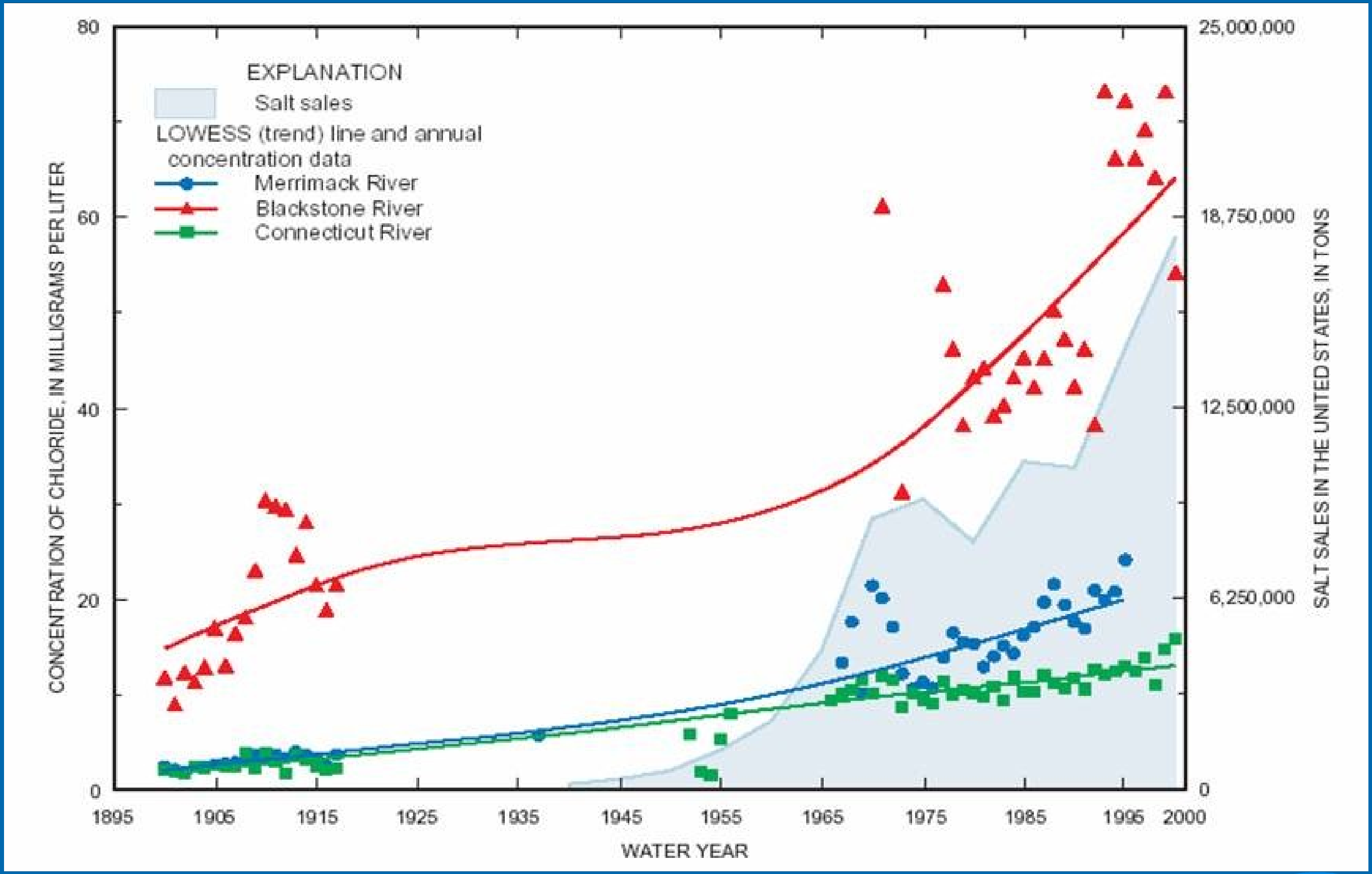
Courtesy of Doug Heath, USEPA, Region 1



PREDICTED CHRONIC TOXICITY FOR AQUATIC TAXA

SOURCE: *ENVIRONMENT CANADA, 2000, CANADIAN ENVIRONMENTAL PROTECTION ACT, 1999, PRIORITY SUBSTANCE LIST ASSESSMENT REPORT, ROAD SALTS; FIGURE 20, P. 166.*

New England Chloride Trends



Courtesy of Doug Heath, USEPA, Region 1

SOURCE: ROBINSON, K. ET AL., 2003, *WATER-QUALITY TRENDS IN NEW ENGLAND RIVERS DURING THE 20TH CENTURY*: U.S. GEOLOGICAL SURVEY WRIR 03-4012, 20 P.

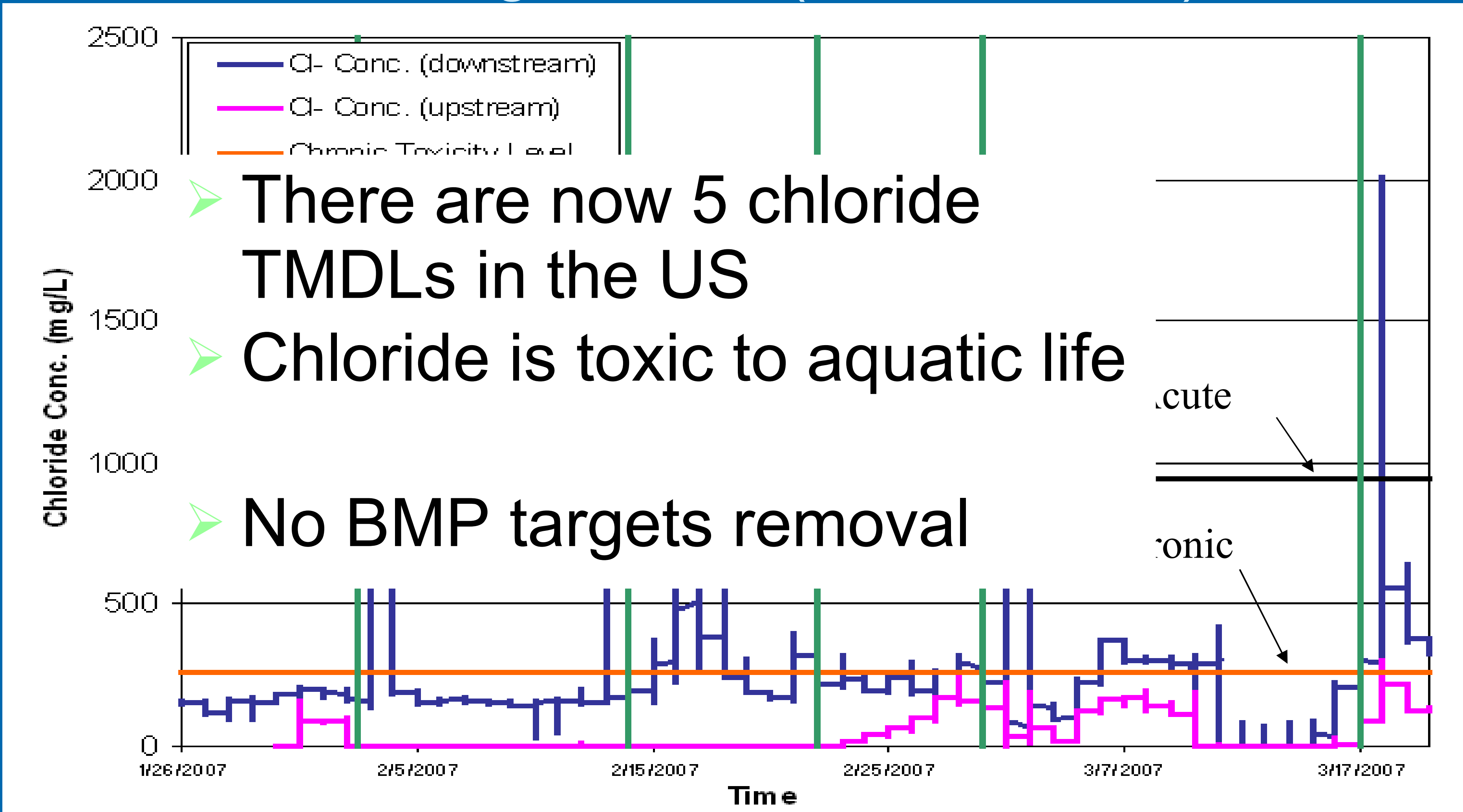
What Runs Off the Impervious Areas?

Click to edit Master subtitle style

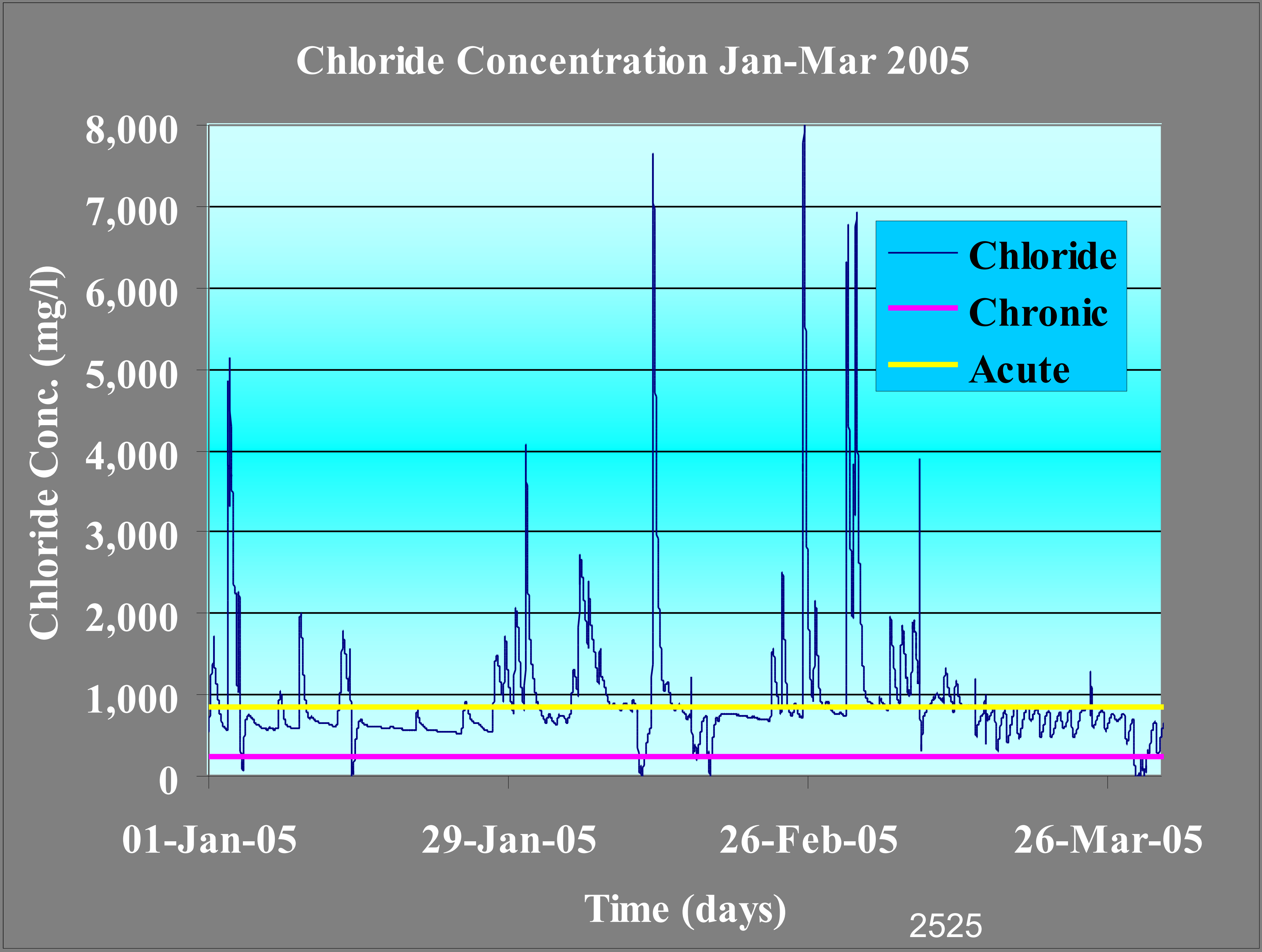
UNHSC Parking Lot Data

EPA Criteria for Chloride Are For the Receiving Stream

Chloride Levels in First Order Receiving Stream (Durham, NH)



- There are now 5 chloride TMDLs in the US
- Chloride is toxic to aquatic life
- No BMP targets removal

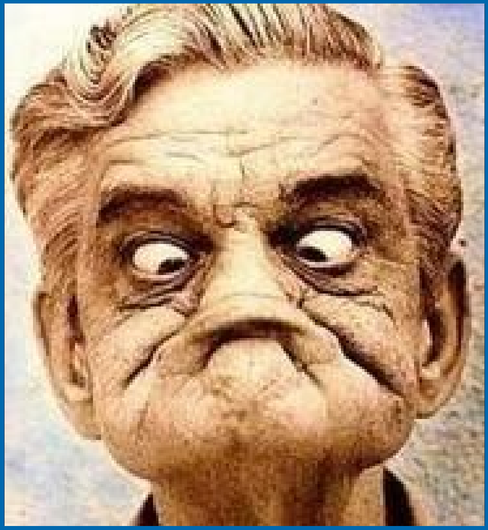

Chloride Concentration Jan-Mar 2005
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Chloride Conc. (mg/l)
Chloride
Chronic
Acute
01-Jan-05
29-Jan-05
26-Feb-05
26-Mar-05
Time (days)

Chloride in Parking Lot Runoff

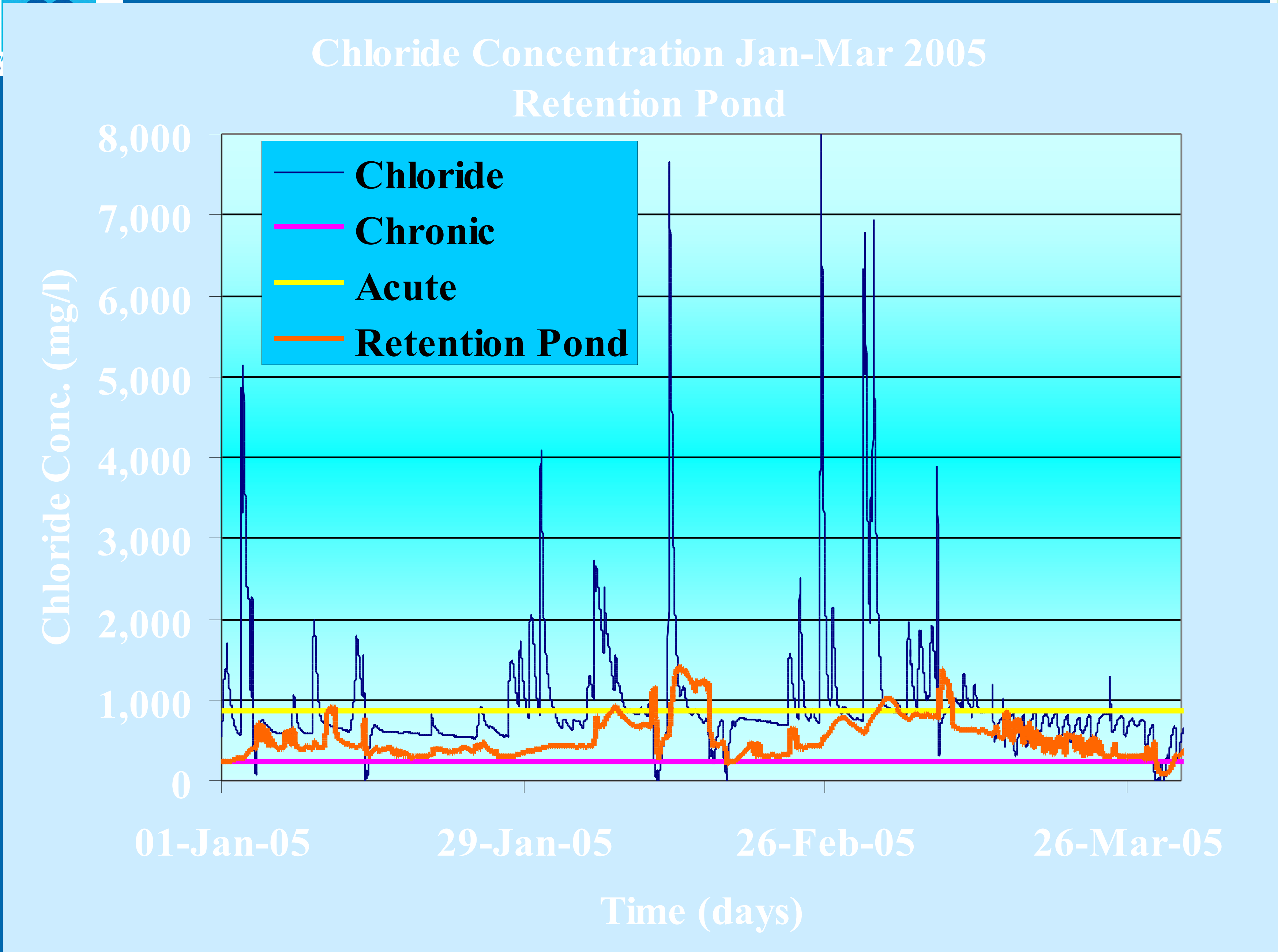
- 95% of the 3 month period Chloride was above the chronic level (230 mg/l)
- 33% of the 3 month period Chloride was above the acute level (860 mg/l)
- Routinely observed over 5,000 mg/l, with recorded peaks of 18,745 mg/l

{Saltwater = 28,000-32,000 mg/l}

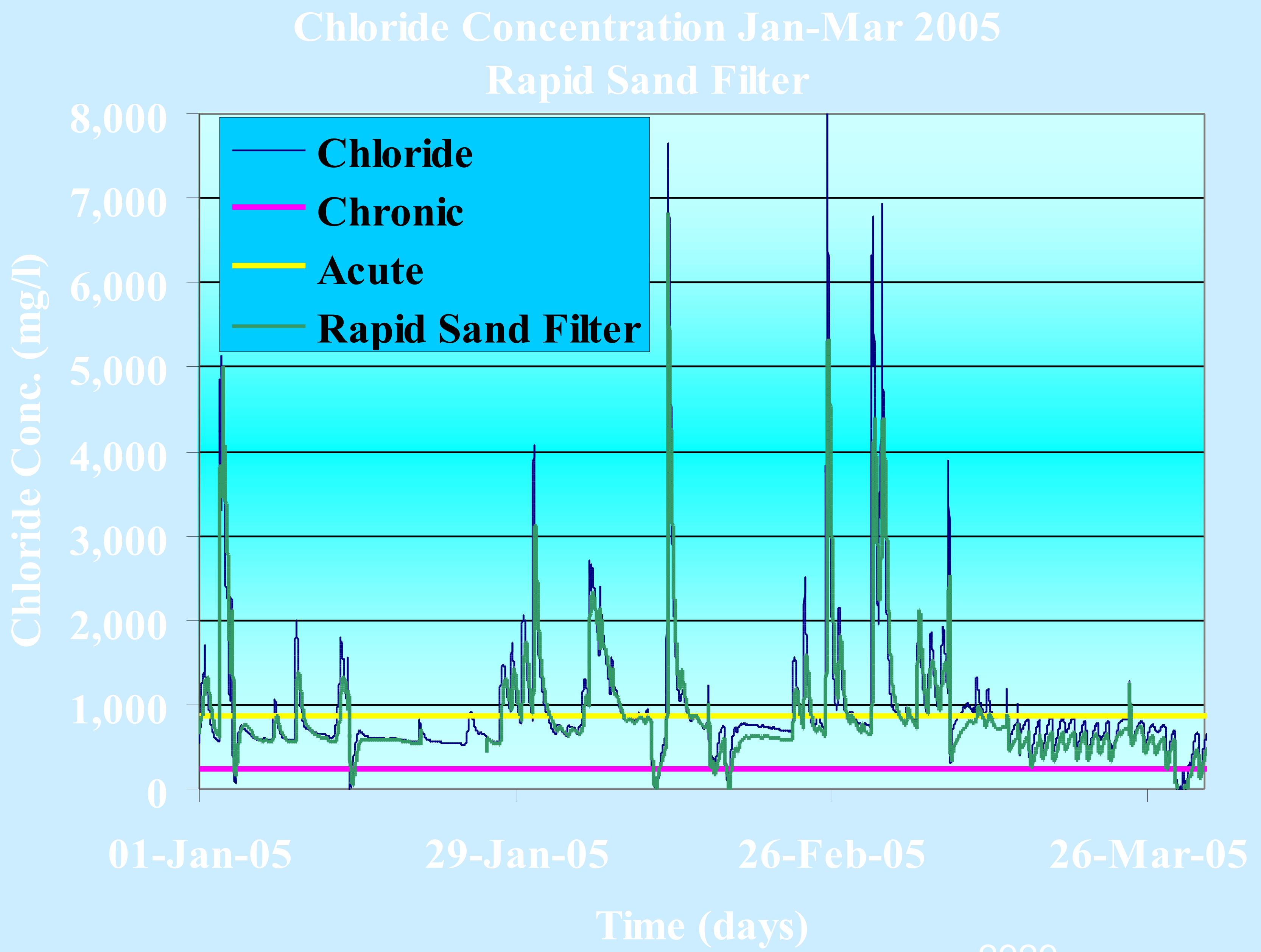
Do Stormwater Management Technologies Remove Salt?



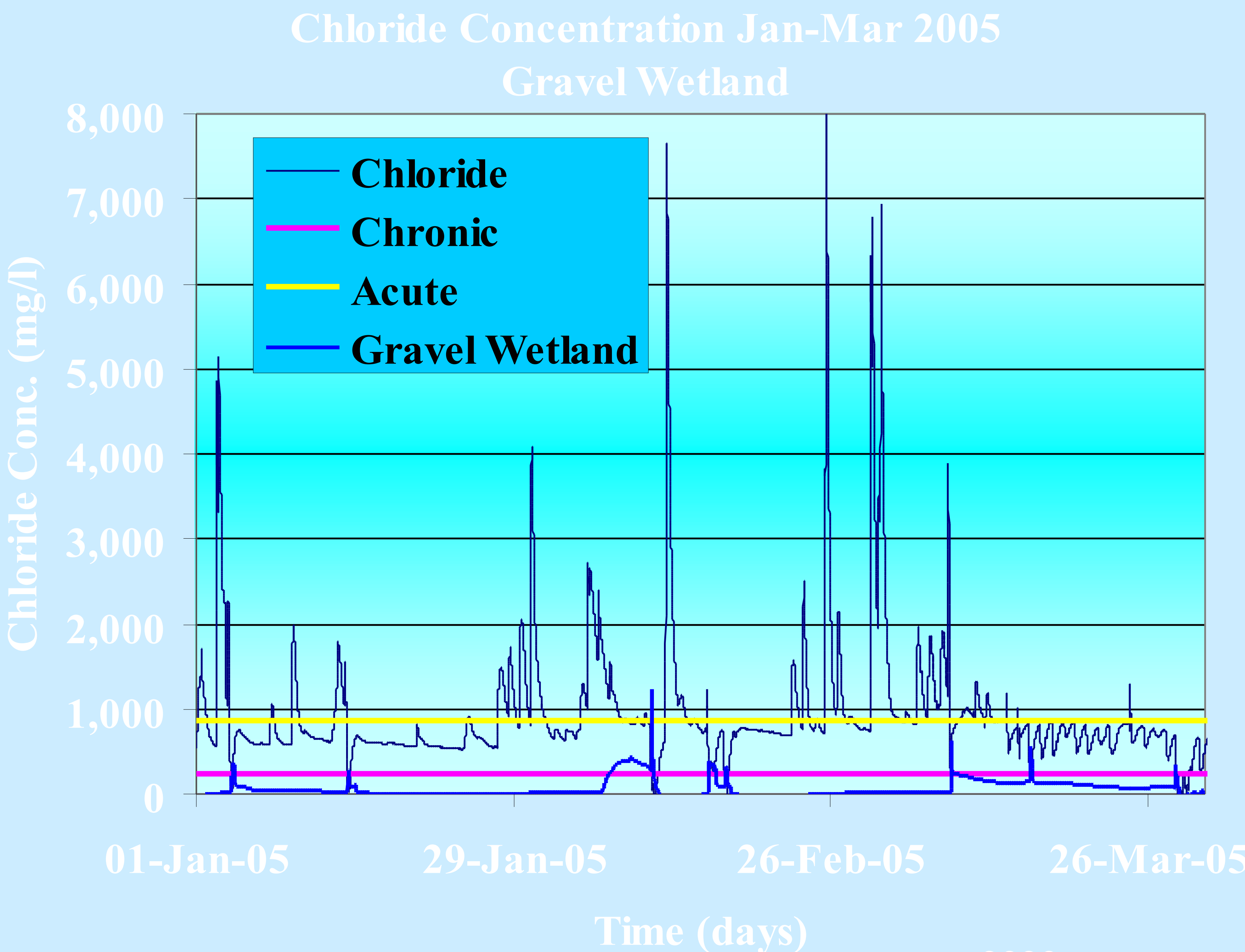
Give neither advice nor salt, until you are asked for it.
English proverb



Chloride Concentration Jan-Mar 2005
Retention Pond
Chloride
Chronic
Acute
Retention Pond
Chloride Conc. (mg/l)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01-Jan-05
29-Jan-05
26-Feb-05
26-Mar-05
Time (days)


Chloride Concentration Jan-Mar 2005
Rapid Sand Filter
Chloride
Chronic
Acute
Rapid Sand Filter
Chloride Conc. (mg/l)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01-Jan-05
29-Jan-05
26-Feb-05
26-Mar-05
Time (days)

Cantor 2007



3030

Center 2007

Where should reductions occur?

How Do Porous Pavements Fit In With Salt?

Click

Center 2007

Potential Salt Reduction

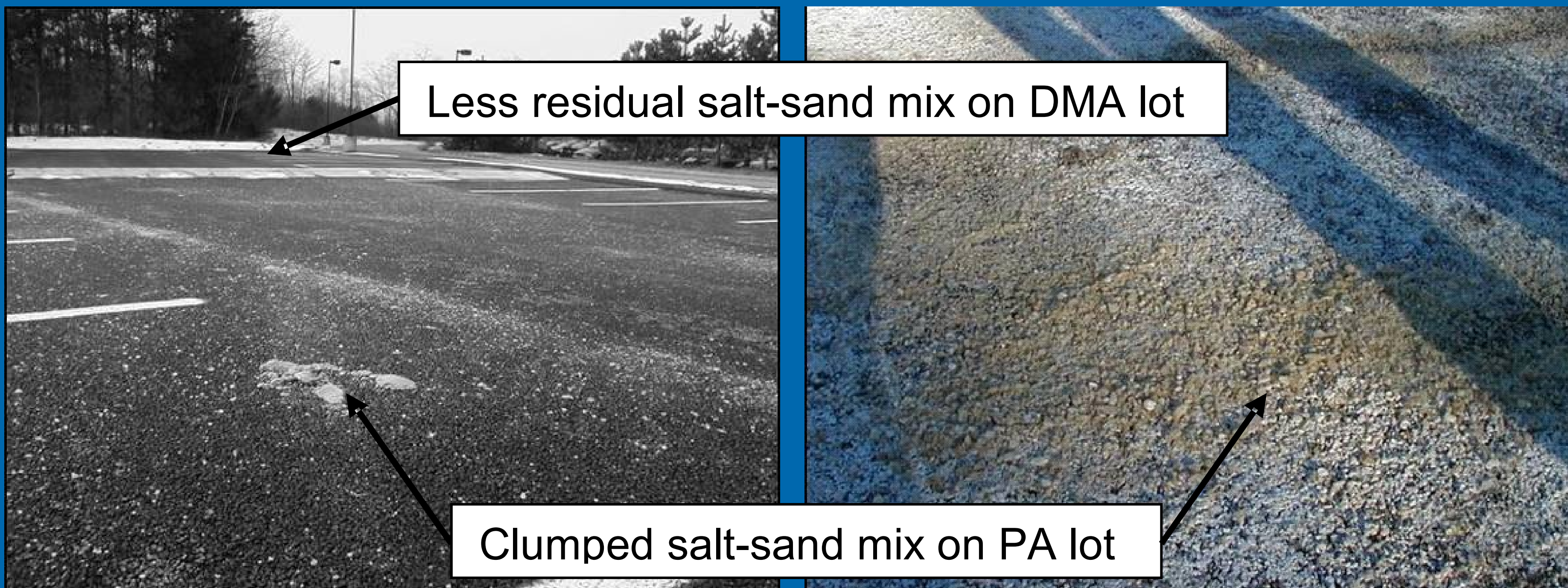


Figure 1. Residual sand and salt mix on PA lot, winter 2005. Clumped mix (top) and close up of mix (bottom).

Winter Maintenance & Performance

- No special maintenance arrangements w/ UNH
- Applied mix: 56% Cl, 10% sand
- 21 applications winter 2006
- Snow/Ice melted more quickly on PA than on DMA
- Excessive mix application

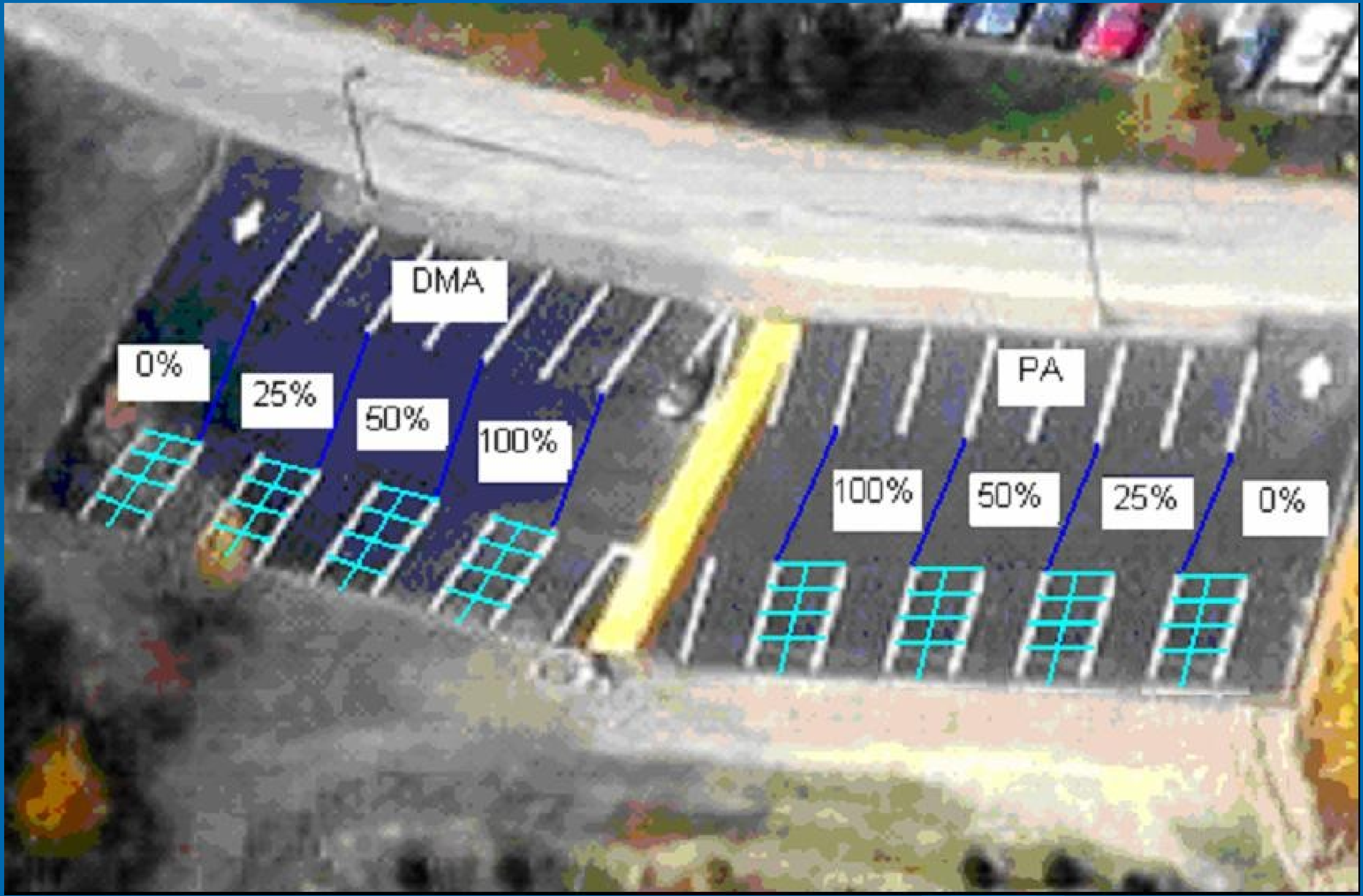
Uneven Mix Spread

Residual Mix

Study Details

- March 2005-Jan 2007: A paired design: half dense mix asphalt, half porous asphalt
- Oct 2007 – present: similar studies on PC
- Located at the UNH Stormwater Center in Durham.
- Activity is a combination of passenger vehicles and routine bus traffic.
- Frequent plowing, salting, and sanding during the winter months.

Salt Reduction and Porous Asphalt



UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

Measuring Skid Resistance w/ BPT

CICEET

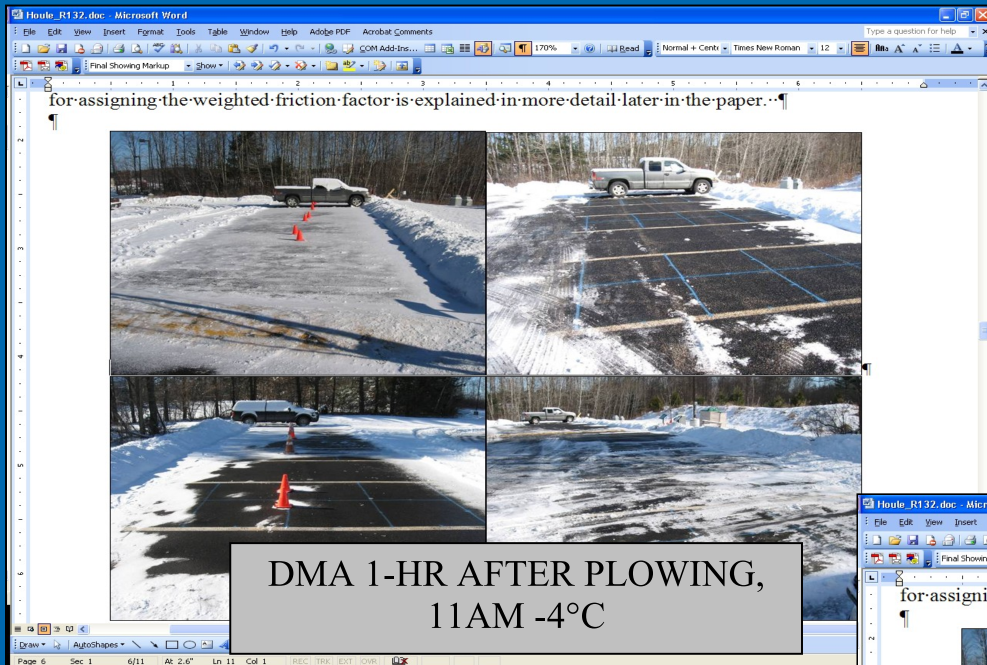
ASTM STANDARD E303-93

Chloride (Salt) Recovery

- Vacuumed salt
- Dissolved material in warm water
- Measured specific conductivity
- Applied value to UNHSC regression
- Compared results for

38

Observations of Surface Cover



DMA 1-HR AFTER PLOWING, 11AM -4°C

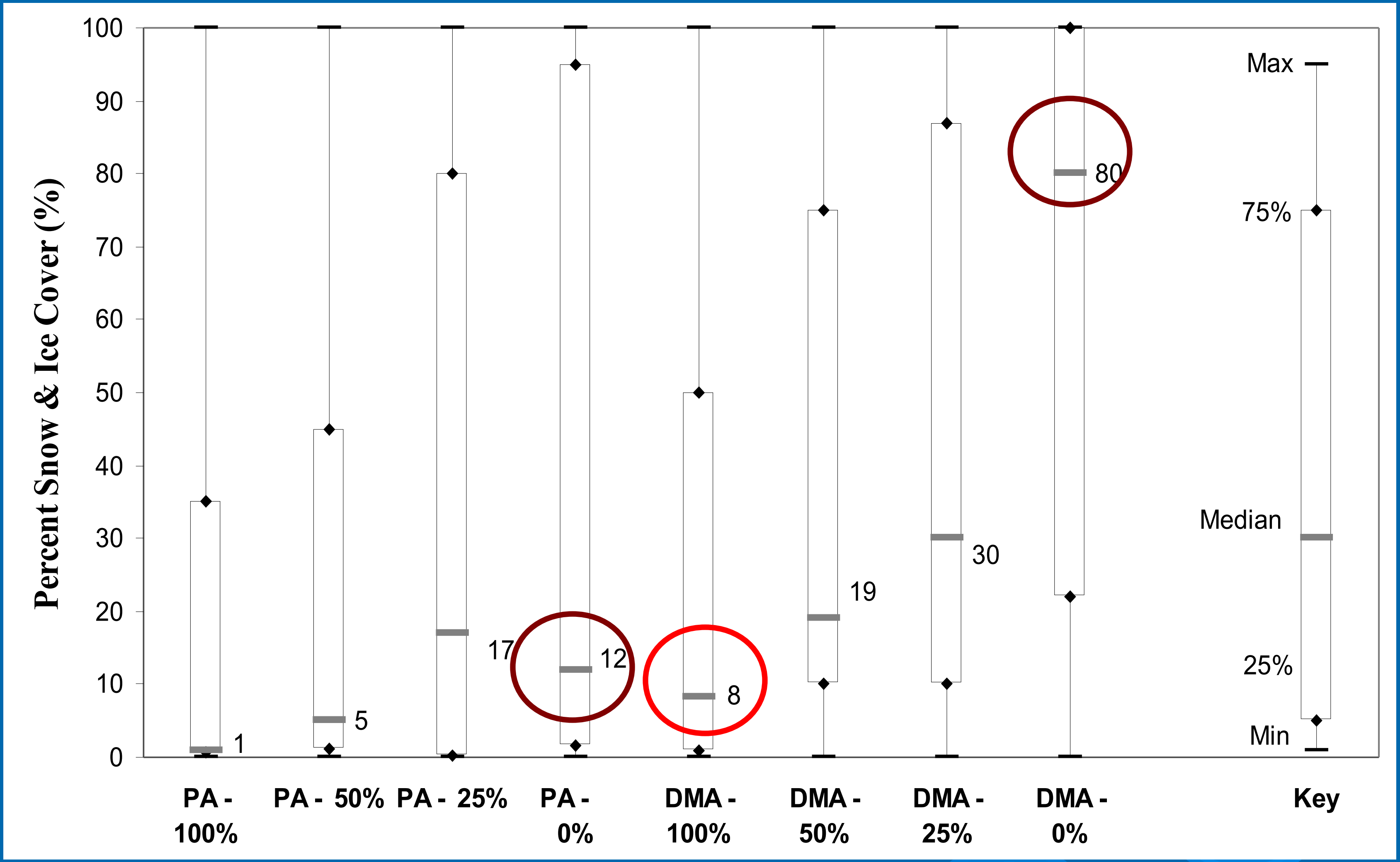
PA 1-HR AFTER PLOWING, 11 AM -4°C

Observations of Surface Cover

Conditions after thawing and refreezing of melt-water (3/18/07)(a) PA at 9AM (left); (b) DMA at 9AM (rt)

Conditions after thawing and refreezing of melt-water (2/16/08) (a) PC at 1PM (left); (b) DMA at 1PM (rt)

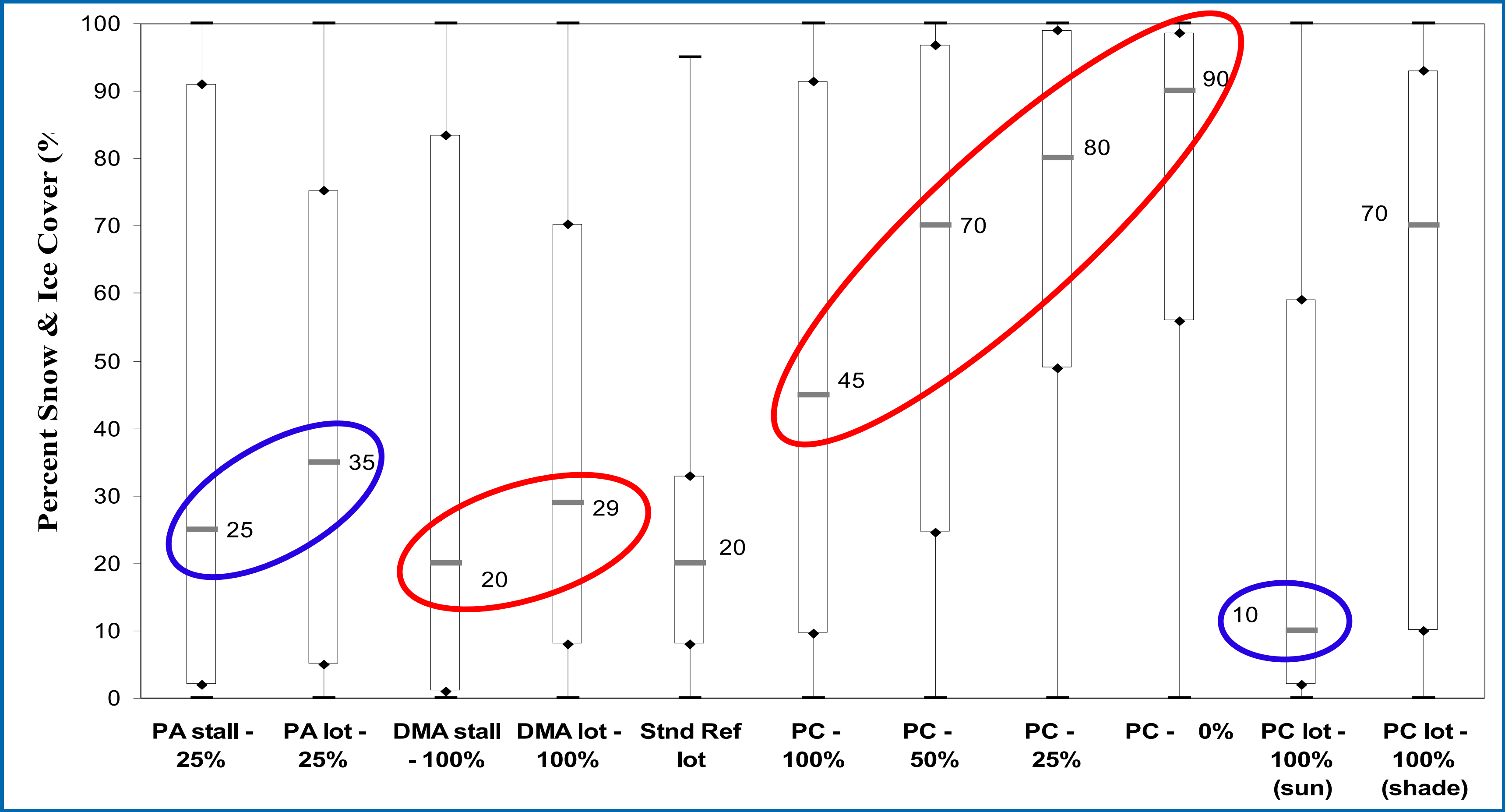
Comparison of snow/ice percent cover for study areas on all lots (winter '06-'07)



- More snow & ice present on DMA

The UNH Stormwater Center 2007

Comparison of snow/ice percent cover for study areas on all lots (winter '07-'08)



- Snow and Ice Cover is comparable for PA 25%, PC 100% (full sun) and DMA 100% application
- PC does poorly in shaded areas

Results: Frictional Properties of Varying Surface Cover

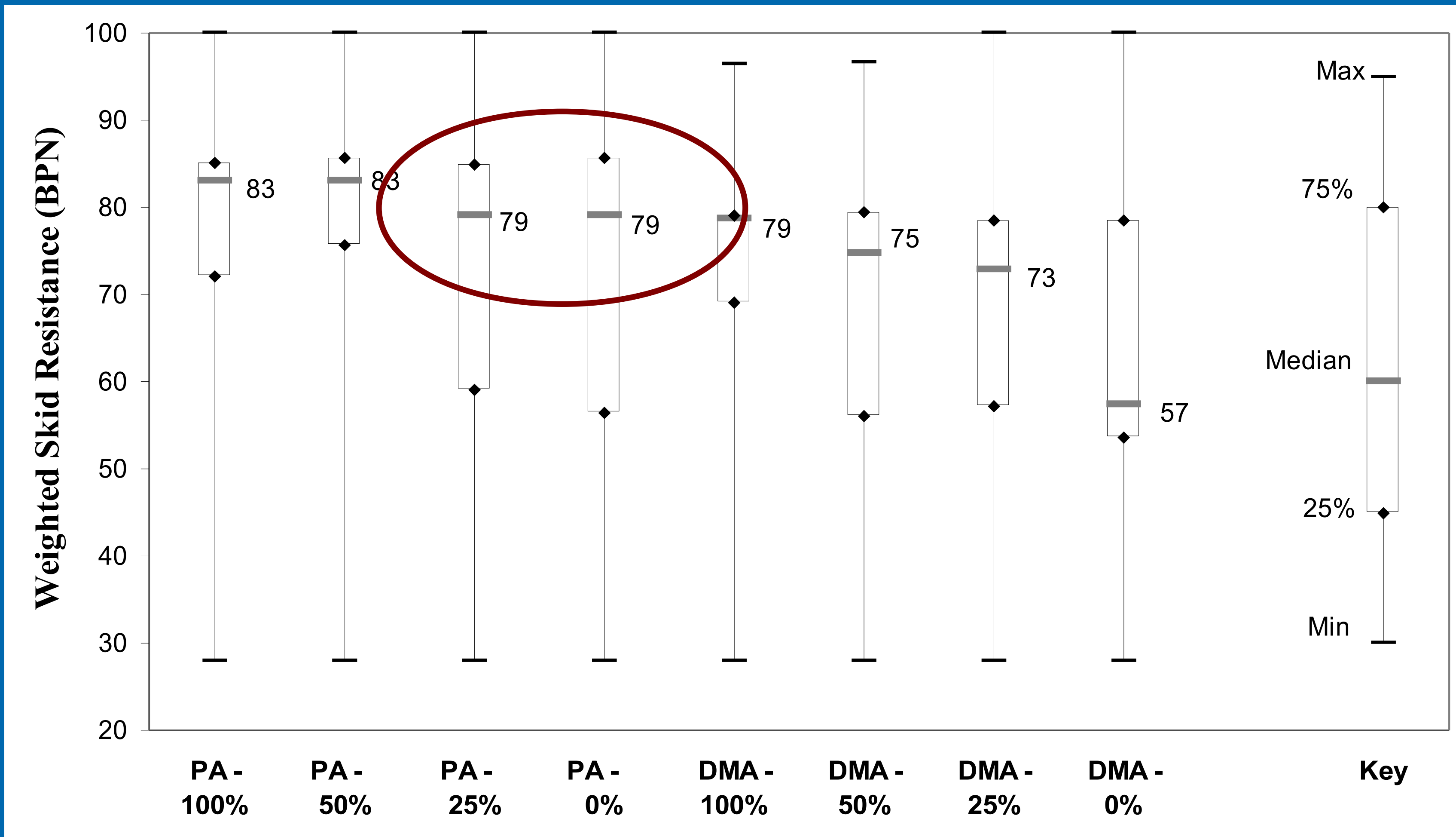
dry pavement

wet pavement

snow-covered

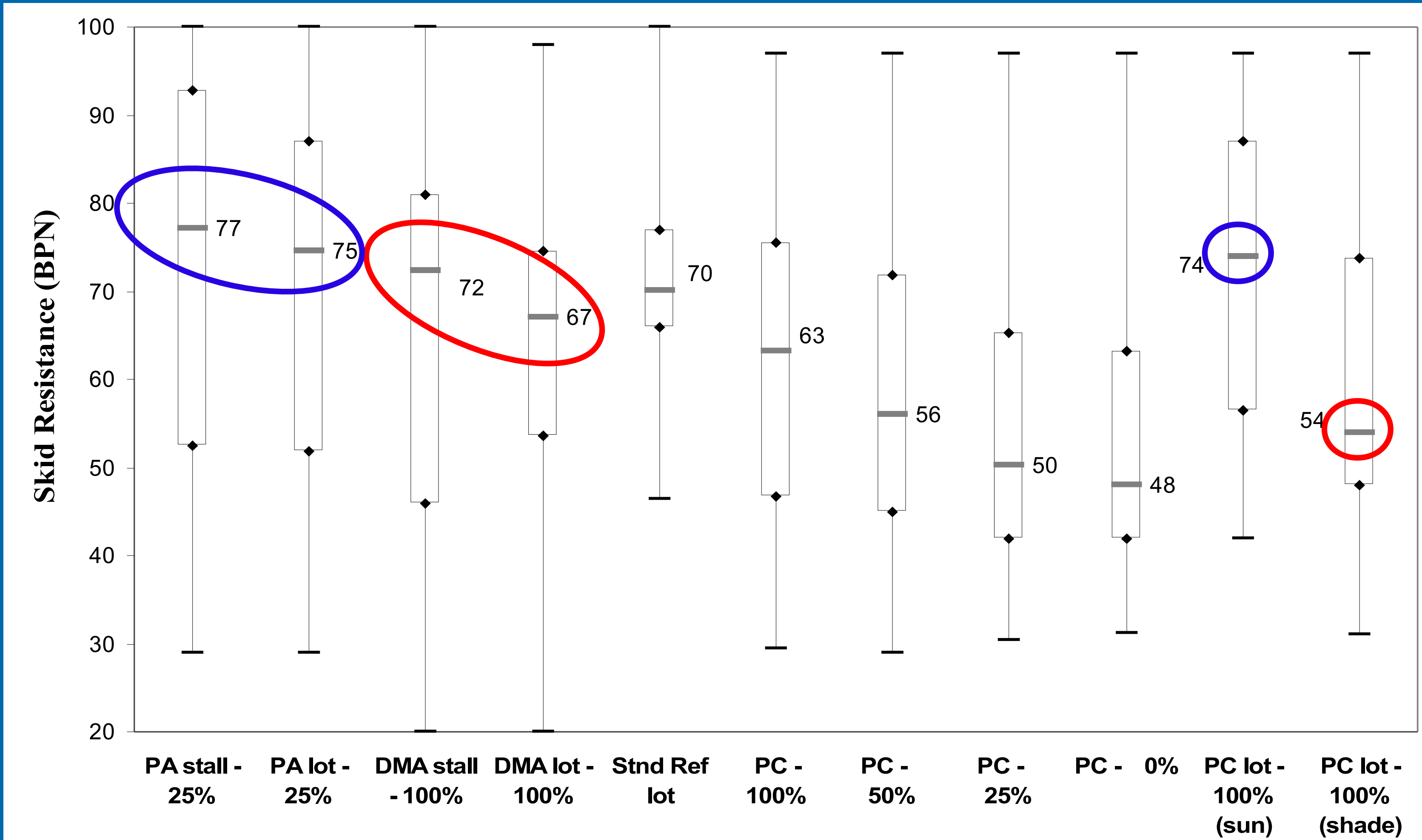
ice-covered

Weighted skid resistance values as a function of surface cover for all pavement types ('06-'07)



- Weighted SR as a measure of safety
- Higher BPN = safer pavement

Weighted skid resistance values as a function of surface cover for all pavement types ('07-'08)



- Skid resistance is higher for all conditions for PA
- PC has higher skid resistance (sun only) and is very sensitive to sun exposure

Conclusion About Friction

- Higher frictional properties on PA and PC
- Salt reductions possible during freeze-thaw conditions
  - No standing water
- Little to no salt needed if plowing occurs
- Up to 75% salt reduction from SOP possible
- Deicing may still be necessary after freezing-rain
- PA and PC are currently the only stormwater strategies that can minimize chloride threat to

The Barriers

- Cold climate performance suspicions
- Snow and ice treatments
- Long term clogging and durability concerns
- Ignorance of water quality performance
- Construction challenges
- Modern design specs
- The impossible challenges

More Barriers

- Maintenance misperceptions
- Ease of permitting traditional technologies
- Maintenance practices
- Cleaning frequency
- Designer unfamiliarity
- Costs
- **Folklore and Misinformation**

Summary Conclusions

- LID designs have a high level of functionality during winter months and frozen filter media does not reduce performance
- Infiltration and filtration systems have the highest removal efficiency
- It is interesting to note that many of the systems used routinely, without concern for reduced winter performance, are showing otherwise.
- Future designs focusing on the use of :
  - Storm volume reduction through infiltration
  - Water quality treatment by filtration
- Filtration addresses the primary cause of water quality degradation

Acknowledgements

Funding Source:

Manufacturers:
Hydro International, Stormtech, CONTECH, ADS, CDS, Environment 21, AquaShield

Questions?

View of Mt Washington by moonlight 2/06 from Mt Zealand, NH