Winter Highway Maintenance Operations: Connecticut

Study Briefing - CTDOT
September 15, 2015

Study Mandate

- Connecticut trucking industry concerned about corrosion to truck fleet
- CT General Assembly adopts legislation – mandates CTDOT to conduct study
- Connecticut Academy of Science and Engineering (CASE) engaged – independent perspective on issues
- Follow-up to CASE 2006 Winter Highway Maintenance Study

The Legislation

Connecticut General Assembly mandated CTDOT to conduct an analysis of the corrosive effects of chemical road treatments on

1. **state snow and ice equipment vehicles;**
2. **state bridges, highways and other infrastructure; and**
3. **the environment**

The analysis shall determine the cost of corrosion created by road treatments; and shall include an evaluation of alternative techniques and products, such as, but not limited, to rust inhibitors, with a comparison of cost and effectiveness

The Process

- **Research Team: Connecticut Transportation Institute, UConn**
  - **James Mahoney, Executive Director (Study Manager) with professors and staff**
- **CASE Staff**
- **Study Committee**
- **Study Reviewers**
- **Study Contacts/Stakeholders**
- **Guest Speaker Presentations**

The Study Committee

- **Paul Brown,** MassDOT
- **Brian Burne,** Maine DOT
- **Sten Caspersson**
  (CASE Member), Consultant, Nuclear Power
- **Michael Gantick,**
  Town of South Windsor, CT
- **Monty Mills**
  Washington State DOT (ret.)
- **Richard Nelson**
  Coordinator, Snow and Ice Pooled Fund Cooperative Program, AASHTO
- **Laura E. Pence**
  Professor, Department of Chemistry, University of Hartford
- **Leland Smithson**
  Snow and Ice Pooled Fund Cooperative Program, AASHTO; Iowa DOT (ret.)
- **Ex-Officio Member**
  Robert W. Turner
  Safety/Area Engineer, FHWA, CT Division

Study Research Team

➢ Connecticut Transportation Institute (CTI)

- **Study Manager: James Mahoney,** Executive Director, CTI
- **Research Engineers**
  - ✓ **Eric Jackson, PhD,** Director, Connecticut Transportation Safety Research Center
  - ✓ **Donald A. Larsen, PE,** Temporary University Specialist**,** CTI
  - ✓ **Timothy Vadas, PhD,** Assistant Professor, Civil and Environmental Engineering
  - ✓ **Kay Wille, PhD,** Assistant Professor, Civil and Environmental Engineering
  - ✓ **Scott Zinke,** Research Engineer**,** Connecticut Advanced Pavement Laboratory, CTI

➢ ***CASE Staff***

- ✓ **Richard Strauss**, Executive Director
- ✓ **Terri Clark,** Associate Director
- ✓ **Ann Bertini,** Assistant Director for Programs

Reviewers

Academy Member Reviewers

- **John N. Ivan, PhD**
  Professor and Associate Department Head, Civil & Environmental Engineering, UConn

- **Herbert S. Levinson, DrEng, PE**
  Professor of Civil Engineering (ret.), UConn

External Reviewer

- **Ron Wright**
  Central Laboratory Manager, Division of Engineering Products & Plans, Idaho Transportation Department

The Study

- Overview of Snow and Ice Control Operations on Connecticut Roadways: CTDOT and Municipalities
- Deicing Chemicals Currently in Use in North America
- Winter Highway Maintenance Practices in Surrounding States
- Environmental Impacts and Mitigation of Deicing Chemical Applications for Winter Highway Maintenance
- Effects of Deicer Corrosion on Infrastructure & Vehicles
- Best Practices and New Technologies
- Winter Highway Safety Analysis and Overview of Economic and Societal Impacts
- Summary of Findings
- Conclusions and Recommendations

The Study: Appendices

- **Appendix A: Glossary of Terms**
- **Appendix B: Study Committee Meetings and Guest Speakers**
- **Appendix C: An Overview of Snow and Ice Control Operations on State Highways in Connecticut(CTDOT)**
- **Appendix D: Questions Asked in Survey of Connecticut Municipalities**
- **Appendix E: Summary of Advantages and Disadvantages of Deicers**
- **Appendix F: Pacific Northwest Snow Fighters Qualified Product List - Products**
- **Appendix G: Summary of Laboratory Study Literature for Deicer Chemicals and Portland Cement Concrete**

Brief Statement of Primary Conclusion

- **Ensuring safety and mobility of traveling public requires most effective winter highway maintenance practices possible**

- **This is a shared responsibility — to achieve comprehensive and sustainable success, competing factors must be considered, including**
  - ✓ **safety; cost; corrosion; operating practices; materials and equipment; environmental and economic impacts; & communication with the general public, stakeholders, & government leaders**

- **Balancing these factors presents a challenge that can be met through ongoing monitoring and continuous improvement based on evolving best practices**

Brief Statement of Primary Conclusion

- **CTDOT winter highway maintenance operations are consistent with the practices of other states with similar weather conditions**
- **CTDOT engages in an ongoing process of monitoring current practices, identifying areas for improvement, and instituting improvements based on best practices to increase safety, mobility and overall roadway conditions while reducing the amount of deicing chemicals used**
- **CTDOT has been proactive by testing new technologies and implementing those shown to be effective**
- **Additionally, municipalities can benefit from CTDOT's experience with implementation of state-of-the-art technologies shown to be effective — providing opportunities for achieving higher levels of service to the traveling public**

Brief Statement of Primary Conclusion

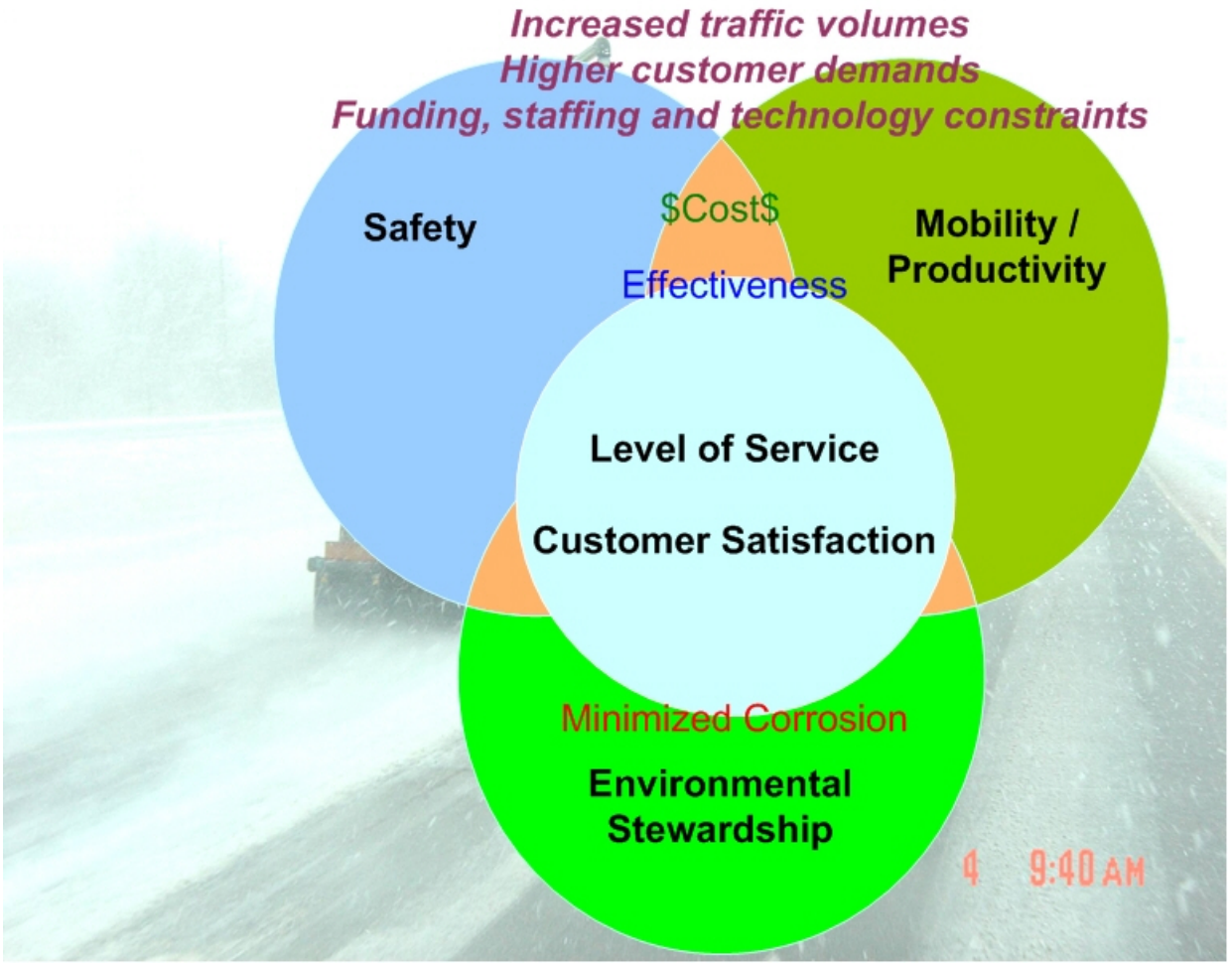
- **While use of chloride-based deicing chemicals for winter highway maintenance has raised concerns regarding impacts on vehicles, infrastructure and the environment, alternative products also have environmental, corrosion and expense impacts**

- **Although corrosion inhibitors are available for use with deicers, evidence of their effectiveness in the field based on literature reviewed was not found. Research is needed to confirm their effectiveness before considering use.**

Brief Statement of Primary Conclusion

- **CTDOT's participation in national initiatives, and ongoing communication with neighboring states, Connecticut municipalities, and other stakeholders, should be continued and strengthened to help balance the noted competing factors by using the most effective practices**

The multiple, sometimes conflicting, objectives of winter road maintenance

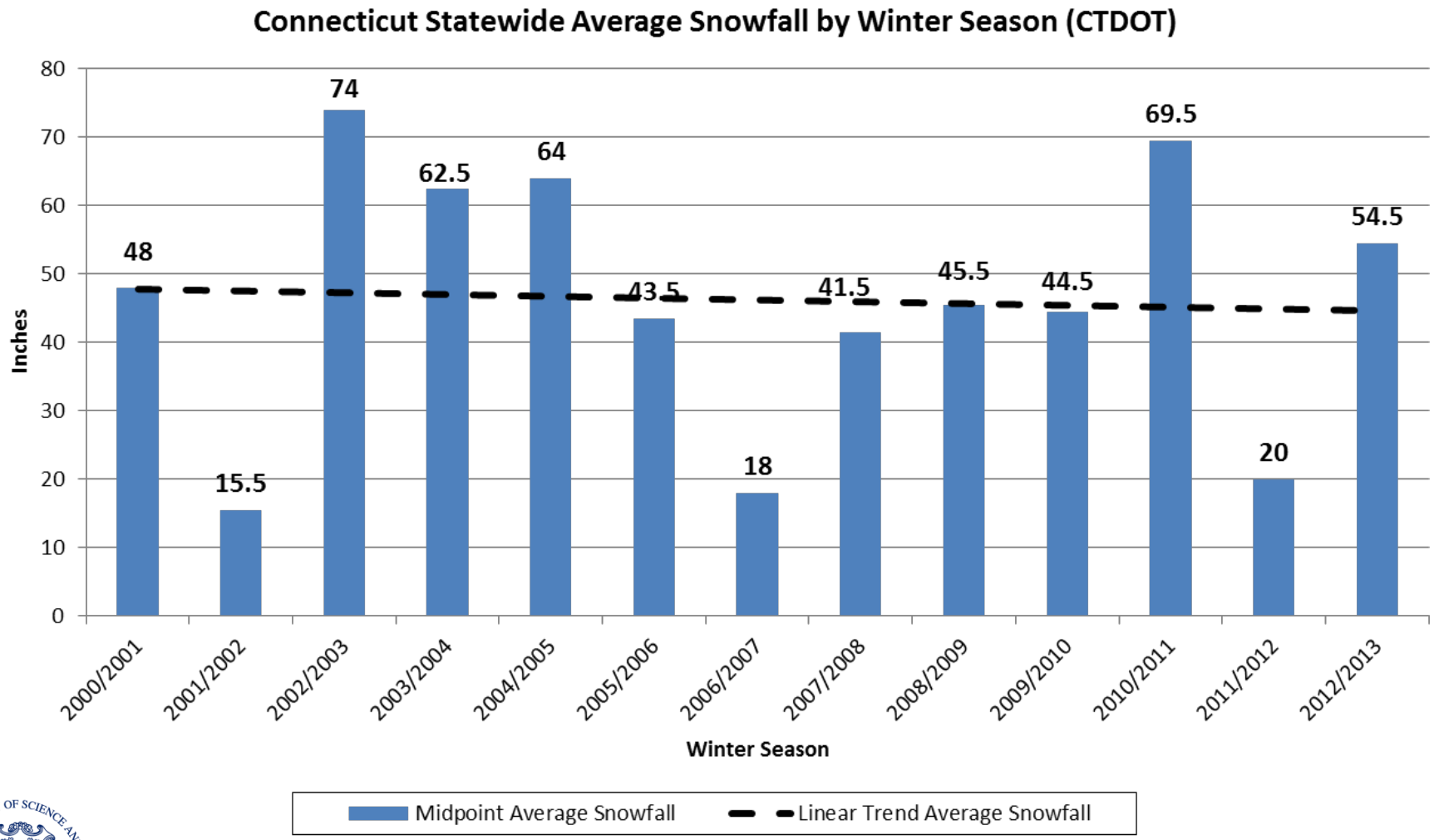


Source: An Article "Winter Road Maintenance, Snow and Ice Control, Best Practices, Emerging Challenges, and Research Needs" by Xianming Shi, Ph.D., P.E., Associate Professor, Department of Civil & Environmental Engineering, Washington State University

Overview of Snow & Ice Control Operations on Connecticut Roadways

- **Connecticut is the third smallest state (almost a rectangle 100 miles wide by 50 miles)**
- **Wide variation of winter weather**
  - **SE CT averages 20-25 inches of snow per year — NW CT averages 90+ inches of snow**
- **Connecticut lane-miles: approximately 46,000**
  - ***CTDOT 10,800 lane-miles (23.5%)***
  - ***Municipalities maintain approximately 35,200 lane-miles (76.5%)***
- **No county or regional agencies maintaining roadways**

Overview of Snow & Ice Control Operations on Connecticut Roadways



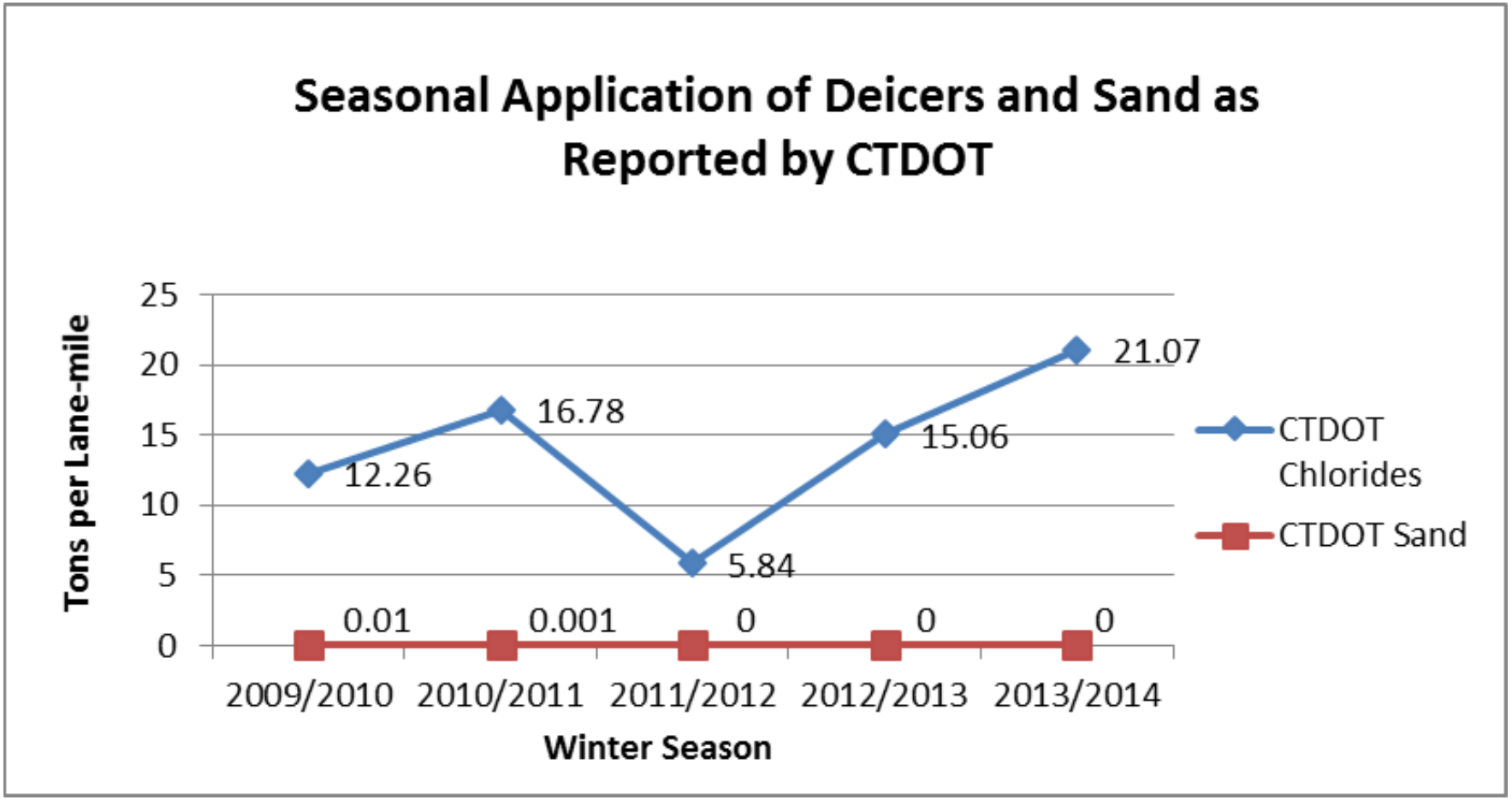
Overview of Snow & Ice Control Operations on Connecticut Roadways: CTDOT

- **CTDOT: 632 plow trucks; ~ 200 contractor plow trucks available**
- **Before winter of 2006/7 — CTDOT used sand/salt *(sodium chloride)* mix**
- **Starting with winter 2006/7 — CTDOT adopted anti-icing strategy and moved to eliminate sand**
- **Began pre-wetting rock salt with 32% calcium chloride solution with corrosion inhibitor *(1 gallon per 200 pounds rock salt per lane-mile)***

Overview of Snow & Ice Control Operations on Connecticut Roadways: CTDOT

- After 2 years — inhibitor dropped due to issues with storage, clogged nozzles and reports of low oxygen levels in streams receiving runoff
- Began transition to 30% magnesium chloride solution in 2010/11; completed in 2012/13
- CTDOT pretreats bridges and problematic areas with a sodium chloride brine

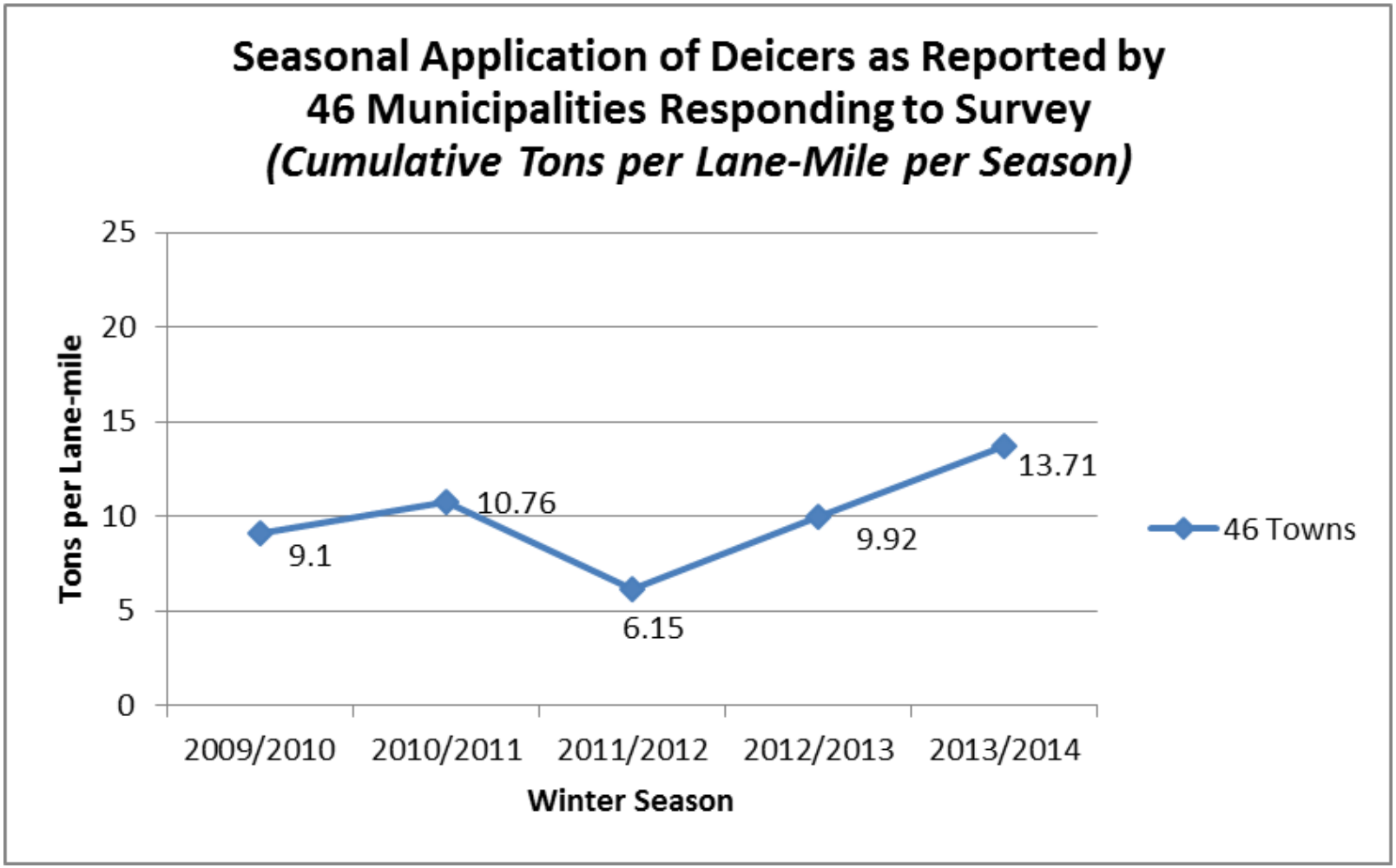
Overview of Snow & Ice Control Operations on Connecticut Roadways: CTDOT



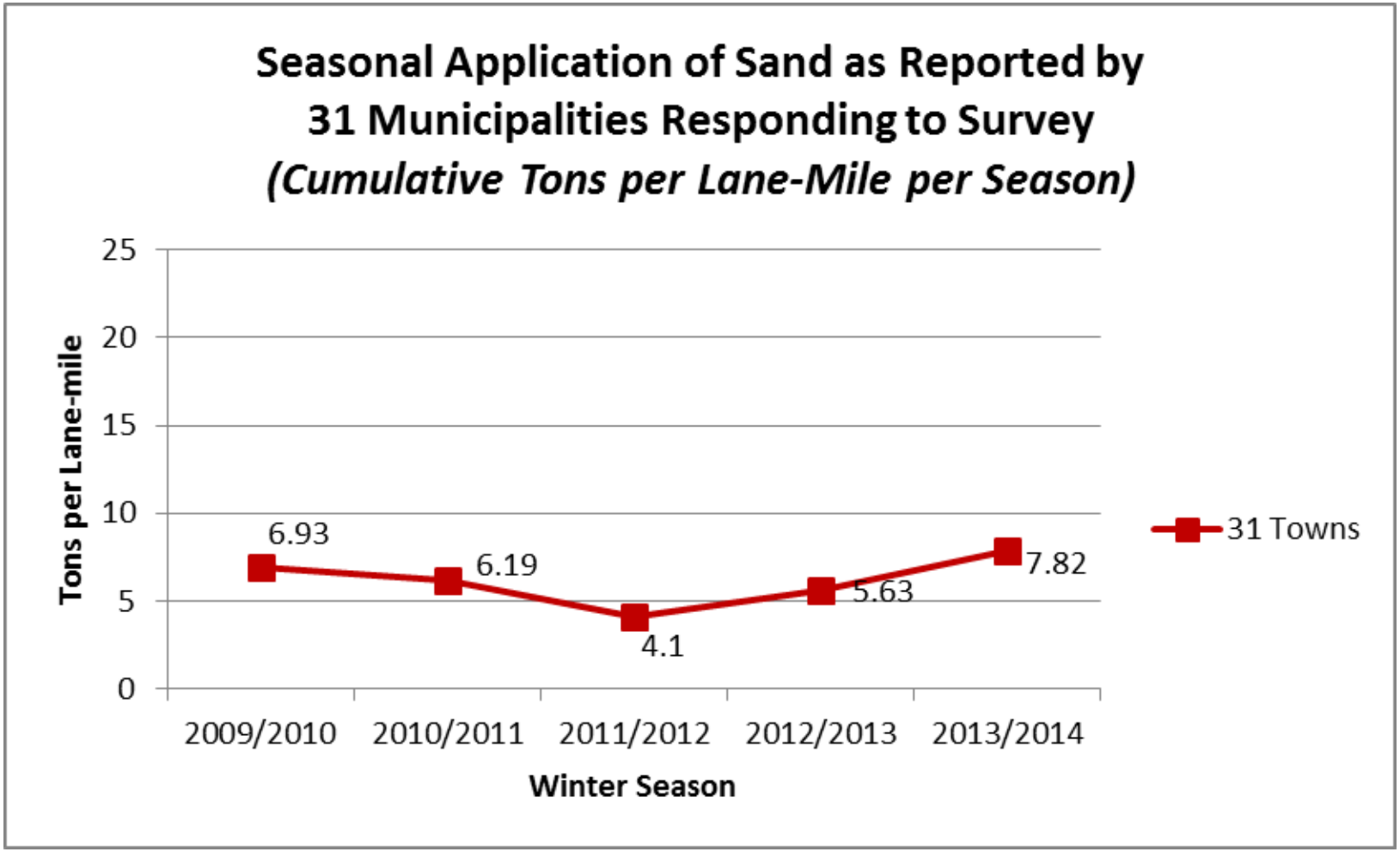
Overview of Snow & Ice Control Operations on Connecticut Roadways: CT Municipalities

- 46 of 169 CT municipalities surveyed provided data on quantity of deicers and sand used over 5 recent winters
- 31 of the 46 responding municipalities used sand abrasives at some point during that 5 year period
- 46% to 56% of municipalities used solid sodium chloride deicer during any given year
- 54% to 65% used 'treated road salt'
- 6 Towns used liquid deicers for pre-treating roads
- 56% of municipalities pre-treat with solid deicers prior to start of winter weather event
- 63% use ground speed control on vehicles for spreading sand and/or salt

Overview of Snow & Ice Control Operations on Connecticut Roadways: CT Municipalities



Overview of Snow & Ice Control Operations on Connecticut Roadways: CT Municipalities



Deicing Chemicals in Use in North America

- Examined various deicing chemicals used in North America
- Found alternatives to the chlorides exist, but they come with own set of concerns that include
  - Some attack different metals, are not as effective or easy to use, and are extremely expensive *($1 per pound)*
  - Potential environmental impacts

Winter Highway Maintenance Practices: Surrounding States

- Requested information from DOTs in New England States, New York and New Jersey regarding use of deicing chemicals
- Worth noting — each state is responsible for different types of roads, traffic, service levels and climate
- Found chlorides were virtually all that was used in region
- When total chlorides applied were divided into lane- miles, CTDOT had the third lowest yearly chloride usage rate per lane-mile in the region

Environmental Impacts and Mitigation of Deicing Chemical Applications

- Environmental impacts of chloride salts depend on pathways and rates at which chlorides travel through environments adjacent to roads
- Aerosols (traffic-generated road sprays) containing chloride salts can transport short distances, potentially impacting roadside wetlands/ soils/vegetation
- Surface runoff can travel greater distances, impacting lakes/streams
- Groundwater can travel greater distances — the rate at which it travels and its impacts depend on whether the aquifer is shallow or deep
- The transport of chloride salts through these pathways depends on numerous physical/chemical characteristics of landscapes (soil texture, vegetation density, slopes, etc.), the chloride salt (e.g., chemical form, particle size), and weather conditions (e.g., temperature, humidity, rainfall volumes and rates)

Environmental Impacts and Mitigation of Deicing Chemical Applications

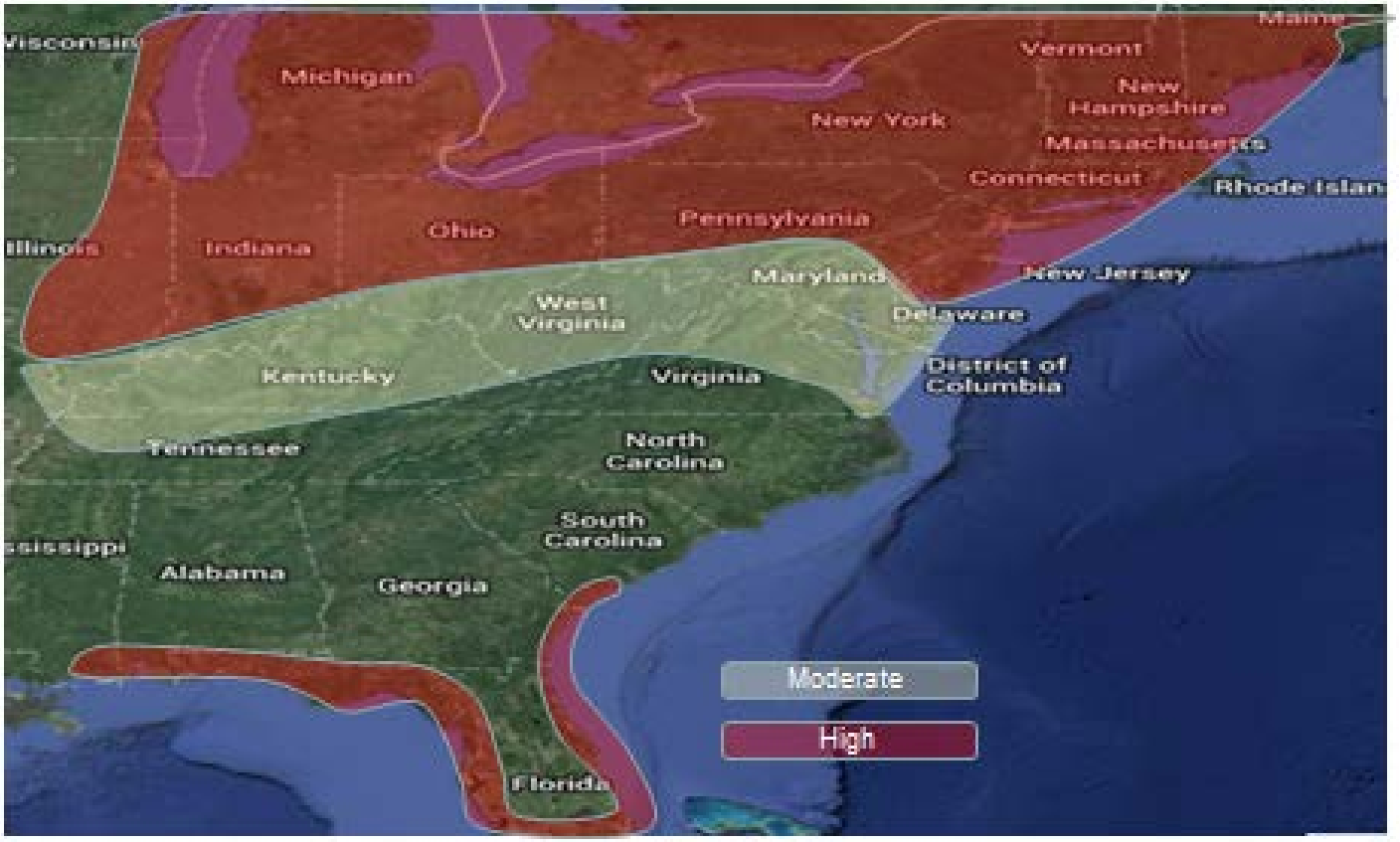
- **Several environmental observations noted throughout Connecticut and the snowbelt states have raised awareness of possible environmental impacts from the use of anti-icing and deicing materials for winter highway maintenance**
- **Currently in Connecticut**
  - ✓ **Previous studies by USGS and DEEP on water bodies expected to receive high chloride concentrations and loads *have not shown* chloride levels to exceed the acute or chronic toxicity criterion**
  - ✓ **Only one chloride impaired waterway *(due to mining)* listed as part of Federal Clean Water Act**
- **Targeted monitoring and long-term trend data should be collected to guard against future environmental issues**
- **For environmentally sensitive areas limiting application rates and preventing high concentrations of chlorides through established best management practices should be the goal**

Effects of Deicer Corrosion Infrastructure & Vehicles

- All chloride deicing chemicals accelerate rate of corrosion of steel
- Average age of passenger vehicles in 1969—5.1 years
- Average age of passenger vehicles in 2013—11.4 years
- Elimination of hexavalent chromium as corrosion resistant coating on vehicle parts occurred around 2006
- Elimination/reduction of lead and cadmium occurred in same time frame

Effects of Deicer Corrosion Infrastructure & Vehicles

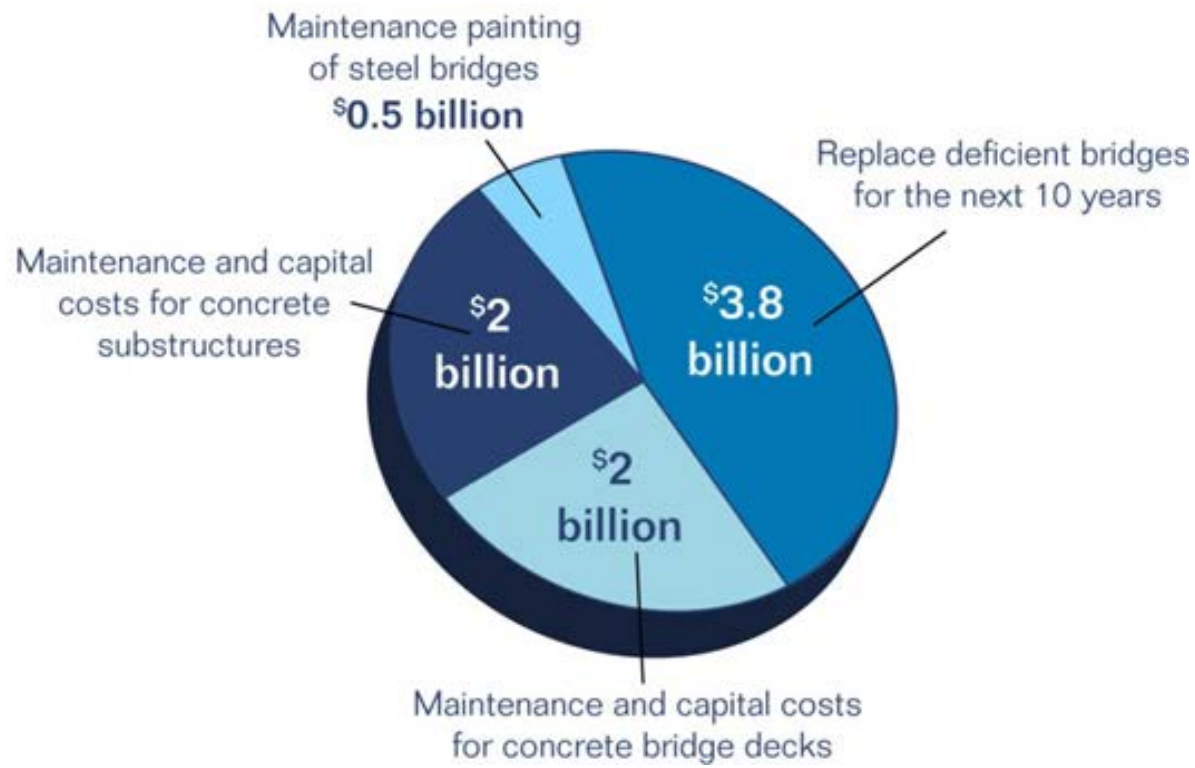
Generalized Map of Regions Prone to Corrosion



Effects of Deicer Corrosion Infrastructure & Vehicles

Estimated Annual Cost in Dollars (1999) in the United States Due to Corrosion of Bridges

Estimated Total Annual Cost for Bridges is $8.3 billion



Source*: Koch, Gerhardus, et al, Corrosion Cost and Preventive Strategies in the United States, Federal Highway Administration, USDOT, Report # FHWA RD-01-156, September 2001*

Effects of Deicer Corrosion Infrastructure & Vehicles

- Magnesium chloride more destructive to concrete than calcium chloride or sodium chloride
- Need to work towards reducing penetration of chlorides into concrete
  - Sealers such as silanes and methacrylate to seal concrete and microcracks
- Bridge washing/rinsing to remove chlorides and debris that hold moisture & induce corrosion

Effects of Deicer Corrosion Infrastructure & Vehicles

- Protection of infrastructure and vehicles is a shared responsibility
- Transportation agencies should use the least amount of deicing chemicals as needed to maintain safe travel and level of service goals
- Vehicle owners need to periodically wash vehicles to remove salt from undercarriage
- Work with trucking industry to open additional public commercial vehicle washing stations
- Inspection of infrastructure and vehicles to identify issues before they become significant

Best Practices and New Technologies

- **Provide for safety of the public as best as possible**
- **Provide highest level of service for the conditions**
- **Maximize effectiveness of winter highway operations through efficient use of resources**
- **Minimize environmental impacts**
- **Test new technologies that are being considered for implementation *(many enhancements available)***
  - **Salt slurry generators**
  - **Underbody scraper blades**

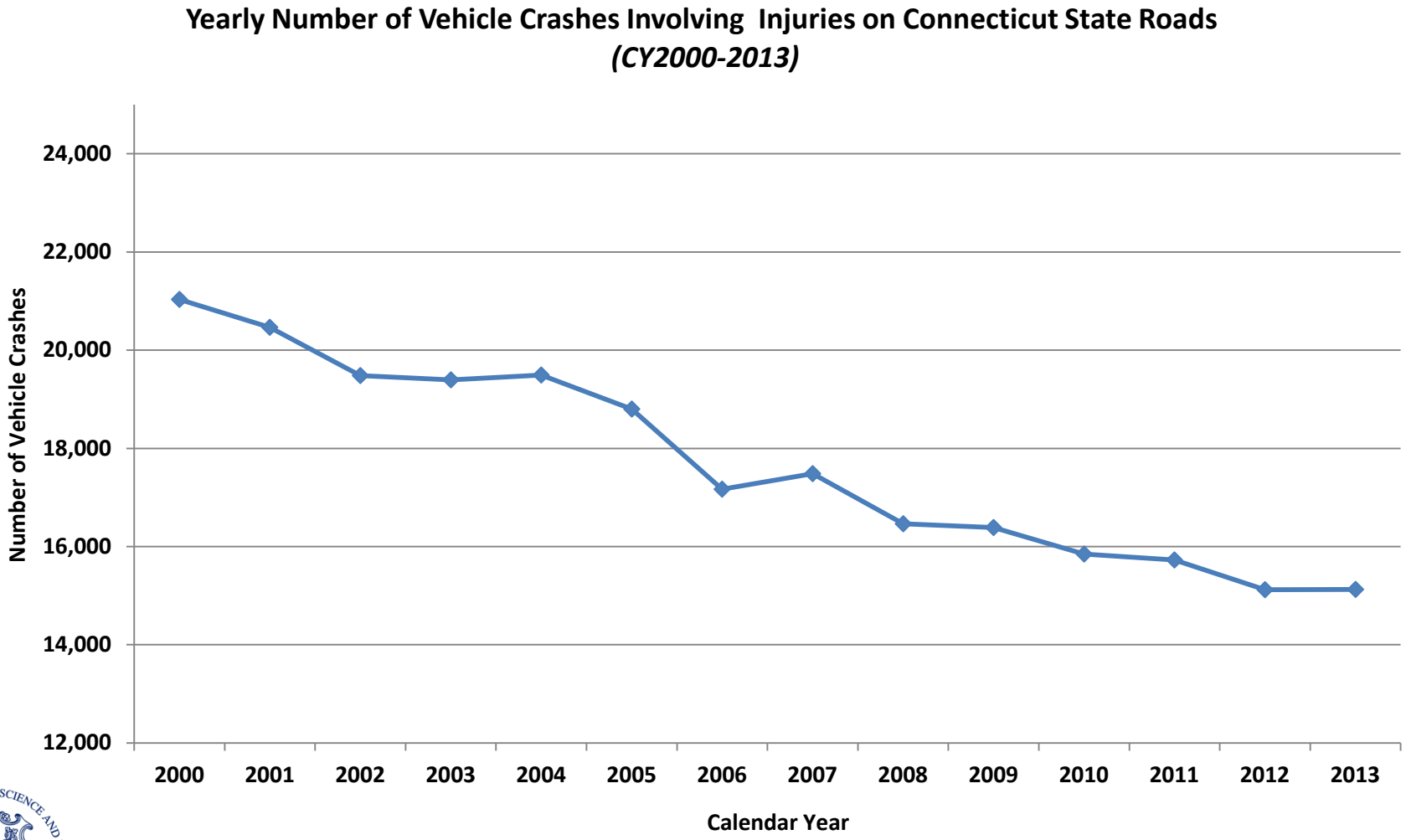
Winter Highway Safety Analysis & Overview of Economic & Societal Impacts

- Analyzed number of crashes with injuries that occurred for 7 years before and after adoption of anti-icing strategy
- Found decrease in number of crashes greater than would be expected from trend of fewer crashes
- Given data available — not possible to definitively conclude anti-icing responsible for drop in number of crashes occurring during winter months
- Decrease in crashes with injuries after anti-icing implemented compared to before anti-icing = 2,449

Winter Highway Safety Analysis & Overview of Economic & Societal Impacts

- Using NHTSA estimates cost of a crash with a non-incapacitating injury = $276,000
- Assuming all injury crashes resulted in non-incapacitating injuries — savings to Connecticut from reduction of 2,449 crashes = $676 million
- For each crash with critically injured survivors, costs jump to $1 million per survivor

Winter Highway Safety Analysis & Overview of Economic & Societal Impacts



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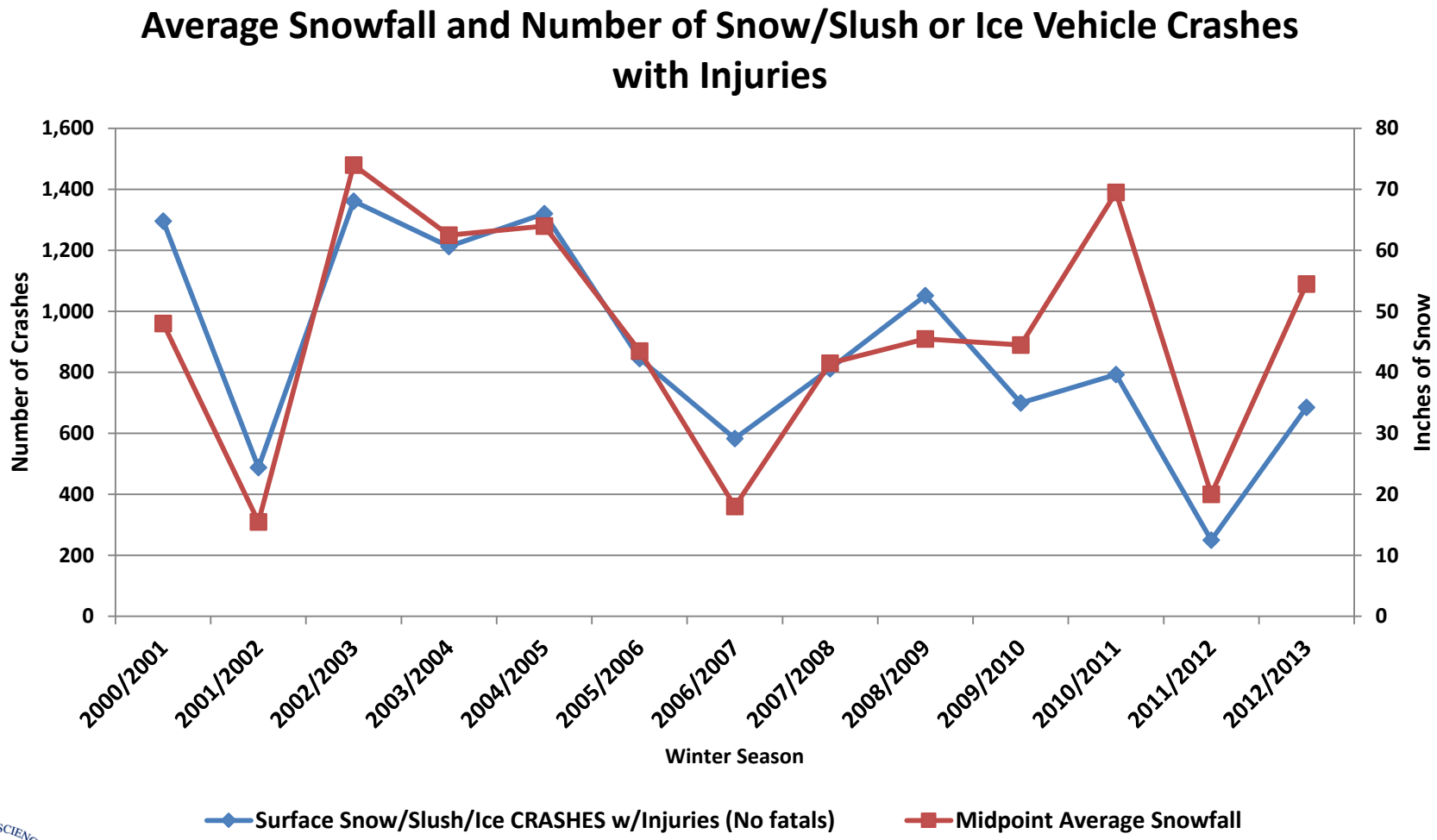

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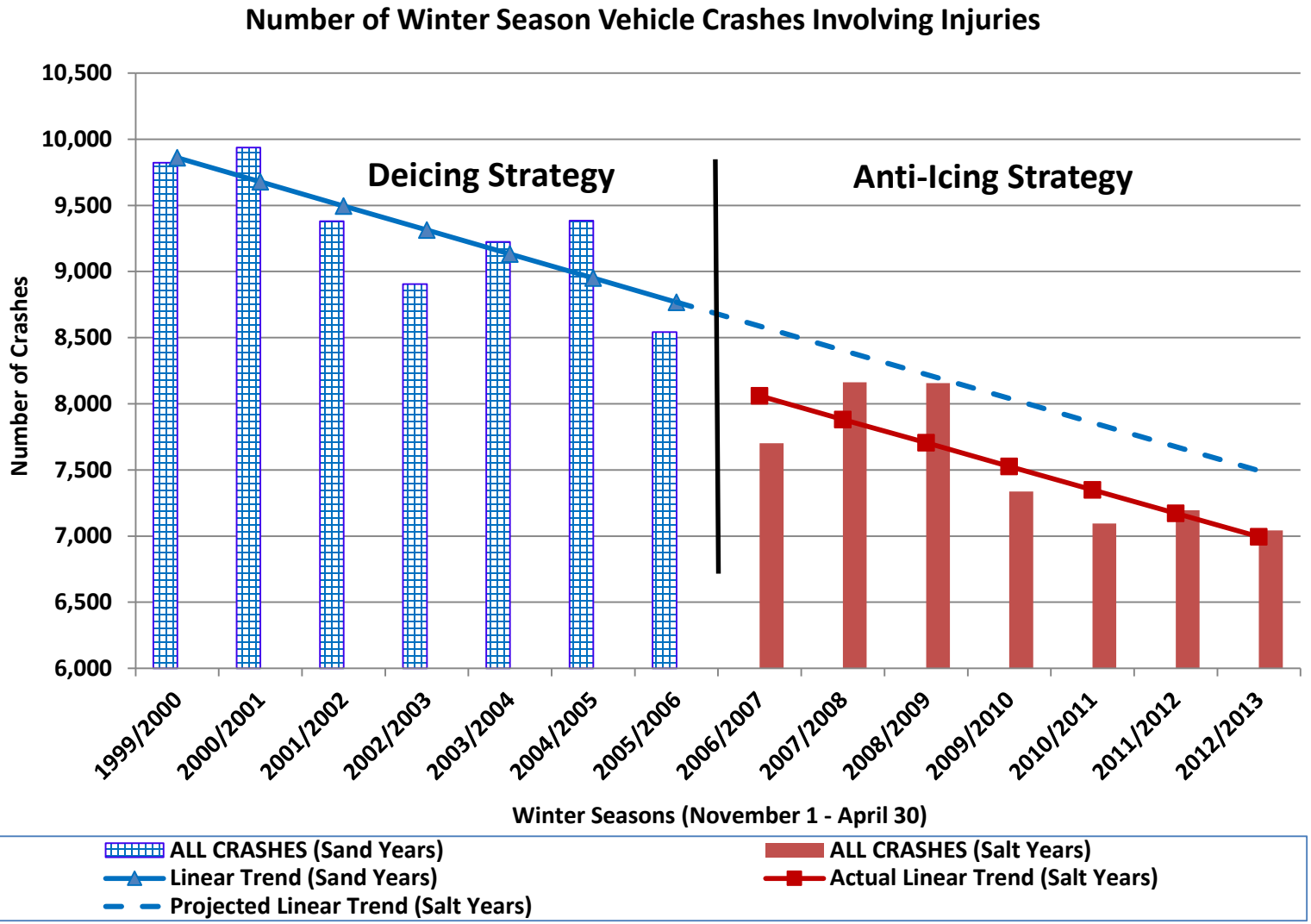

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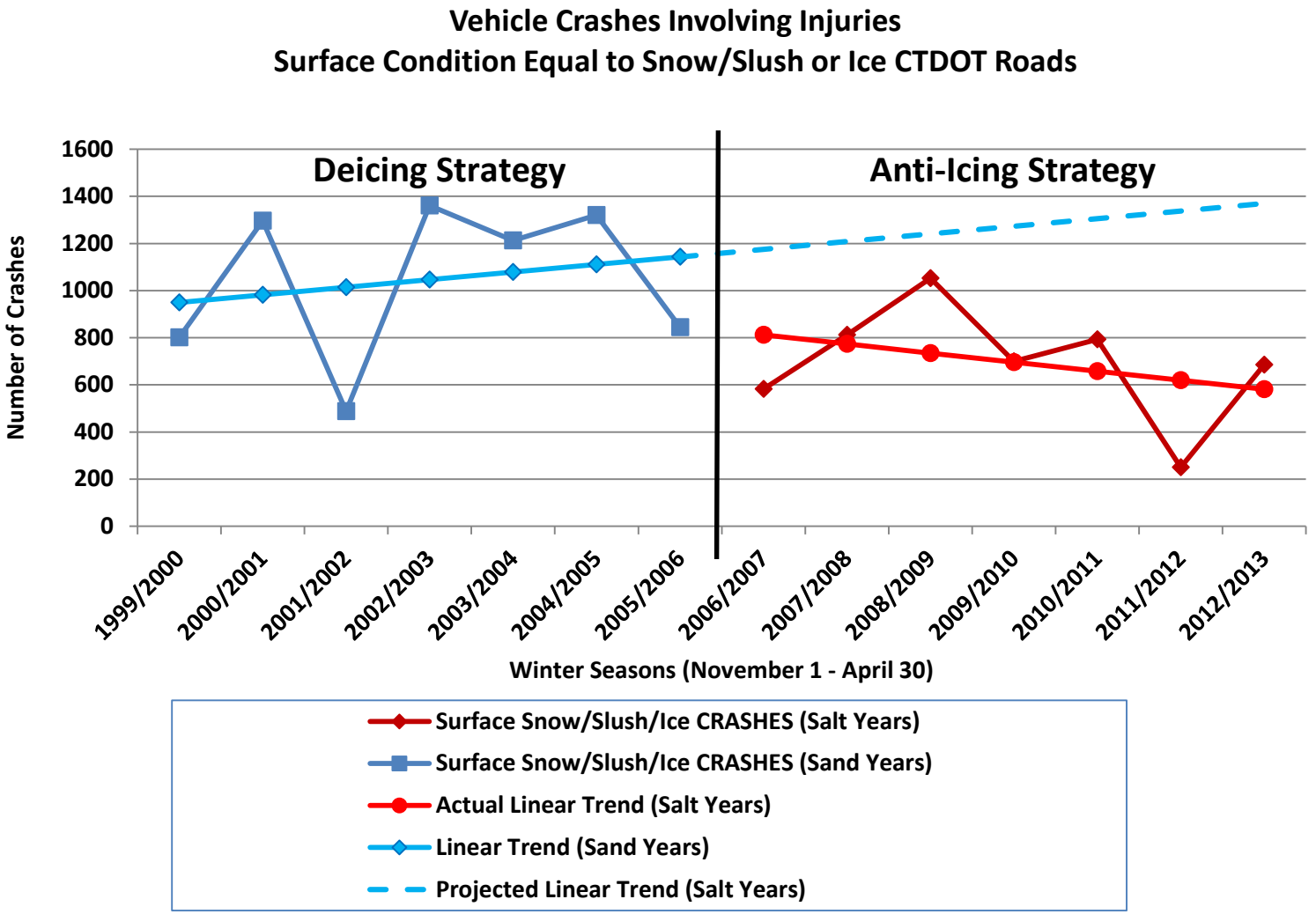

Summary of Findings

- **Chloride based deicing chemicals will be standard for the foreseeable future**
- **There is a need for everyone to understand that winter highway maintenance is a shared responsibility for dealing with effects of deicing chemicals**
- **There is limited *(peer-reviewed)* literature on effectiveness of corrosion inhibitors for non-application vehicles**
- **Vehicle washing is best line of defense**
- **Magnesium chloride/calcium chloride ~ 1% of chlorides applied by CTDOT over last five years**

Conclusions

- CTDOT's anti-icing strategy has reduced number of injury crashes during winter weather events — possibly by speeding up cleanup after event
- Pretreating with sodium chloride brine is adequate — no need to use magnesium chloride or calcium chloride for pretreatment
- There are many variables associated with winter weather events that make them difficult to compare
- Salt neutralizing washes and wash additives may or may not be effective at recommended dosage rates

Recommendations

- CTDOT should continue to use sodium chloride as primary deicing chemical
- For pre-wetting to protect concrete: If sodium chloride is not used —CTDOT should consider using uninhibited calcium chloride if available and cost effective as compared to magnesium chloride
- CTDOT and DEEP should play leadership role in working with municipalities to ensure technology transfer and adoption of best practices as municipalities are responsible for majority of lane-miles in Connecticut

Recommendations *(continued)*

- **Infrastructure**
  - Implement bridge washing/rinsing program
  - Use corrosion resistant steel such as stainless or galvanized for reinforcement of high volume concrete structures
  - Use polymerized concrete wearing surfaces to reduce chloride penetration
  - Inspect vulnerable areas on bridges and make proactive repairs to limit water penetration through joints, etc
  - CTDOT should re-establish a bridge painting program for steel structures

Recommendations *(continued)*

➢ Vehicles

- **Need to educate public on need to wash vehicles including undercarriage**
  - ✓ **It is unclear what the salt concentration is in recycled wash water in commercial car washes**
- **Should have undercarriage inspected periodically for signs of corrosion damage**
- **Need for better undercoatings and paints to prevent corrosion**
- **Implement designs that prevent materials from collecting in "dead" areas**

Recommendations *(continued)*

➢ Operations

- **Need to maximize the effectiveness of use of deicing chemical applications**
- **Identify chloride sensitive areas and consider reduced application rates or alternate chemicals**
- **Ensure private suppliers of deicing chemicals cover their stockpiles *(CTDOT and municipalities have covered salt sheds)***
- **Require annual reporting of deicing chemical usage by CTDOT and municipalities — make information available online *(website)* for comparative analysis and continuous improvement**

Recommendations *(continued)*

- **Education of the public and media regarding practices and materials used**
- **Communication of conditions and what the public should expect in terms of road conditions in near-term**
- **Development of a voluntary certification program for private contractors applying deicing chemical**
- **Stay abreast of new technology and best practices**
- **Communication and coordination with other states and municipalities regarding winter weather events and winter highway maintenance**

Developments Post Study Completion

- **13-04: Best Practices for the Prevention of Corrosion to DOT Equipment: A User's Manual; Western Transportation Institute; Published by: MNDOT**
  - ✓ http://clearroads.org/project/best-practices-for-the-prevention-of-corrosion-to-dot-equipment-a-users-manual/
- **Interest in Presentation of Study Results**
  - ✓ **2015 CASHO (CT Association of Street and Highway Officials Conference**
  - ✓ **2016 TRB Annual Meeting – Winter Maintenance Committee (AHD65) – *Informal Presentation***
  - ✓ **2016 Pacific Northwest Snowfighters Conference**
  - ✓ **2016 American Public Works Association: North American Snow Conference**

Thank You

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