Use of Winter Severity Index (WSI) to Measure the Efficiency of Road Salt Use in Massachusetts

North American Snow Conference  Hartford, CT

Presented by
Bill Arcieri, VHB Senior Water Resource Specialist

May 23, 2016
Public Scrutiny Continues to Rise

“What Happens to All the Salt We Dump On the Roads?
In the U.S., road crews scatter about 137 pounds of salt per person annually to melt ice. Where does it go after that? Smithsonian Magazine, January 5, 2014.

“Road Salt Polluting our Rivers”
Wired Magazine; Gwen Pearson, March 12, 2015

Increased Road Salt Usage Has Affected Water Quality, Wildlife USGS Study Discussed on Wisconsin NPR Dec 14, 2014


State and local agencies spend more than $2.3 billion on snow and ice control operations annually. Anita Balakrishnan, CNBC, Feb 19, 2015

MassDOT Annual Statewide Salt Usage (tons)

![MassDOT Annual Statewide Salt Usage (tons)](chart.png)

- **Applied Salt (tons)**
  - FY01: 626
  - FY02: 304
  - FY03: 734
  - FY04: 726
  - FY05: 475
  - FY06: 413
  - FY07: 310
  - FY08: 535
  - FY09: 607
  - FY10: 367
  - FY11: 557
  - FY12: 218
  - FY13: 458
  - FY14: 573
  - FY15: 610

**Thousands**

**Annual Salt Use tons**

[MassDOT Logo]
MassDOT Annual Statewide Salt Usage (tons)

- **Applied Salt (tons)**
- **Thousands**
- **Statewide Average WSI**

### Years
- FY01
- FY02
- FY03
- FY04
- FY05
- FY06
- FY07
- FY08
- FY09
- FY10
- FY11
- FY12
- FY13
- FY14
- FY15

### Salt Usage
- **FY01:** 626,000
- **FY02:** 304,000
- **FY03:** 734,000
- **FY04:** 475,000
- **FY05:** 726,000
- **FY06:** 413,000
- **FY07:** 310,000
- **FY08:** 535,000
- **FY09:** 607,000
- **FY10:** 367,000
- **FY11:** 557,000
- **FY12:** 218,000
- **FY13:** 458,000
- **FY14:** 573,000
- **FY15:** 610,000
Regression Correlation of Salt Use to WSI Value from 2001 to 2010

Salt Usage (tons per lane mile) vs. WSI

- Mild
- Moderate
- Severe

Equation: $y = -1.4829x + 12.857$

$R^2 = 0.9633$
Clear Roads Project #10-02: Mapping Weather Severity Zones

Submitted to the

Clear Roads Pooled Fund Project &
Minnesota Department of Transportation

Report Date: July 31st, 2012

John Mewes, Chief Scientist
Meridian Environmental Technology
4324 University Ave.
Grand Forks, ND 58203
Phone: 701-792-1800
Clear Roads: Regional WSI Mapping

- Average annual snowfall accumulation
- Average annual duration of snowfall
- Average annual duration of freezing rain
- Average annual duration of blowing/drifting snow
- A combined measure of overall winter severity based on these parameters
Figure 5: Map of Overall Winter Severity as developed under this project.
WSI Background and Calculation Method

- Three Daily Weather Measurements:
  - Minimum Temperature, Maximum Temperature, Snowfall
- Calculated on Monthly Basis (Nov – Mar)
- Seasonal WSI Value is Based on Average over 5 Months

\[
WSI = (a \times \sqrt{TI}) + (b \times (\ln(S/10)+1)) + (c \times \sqrt{N/(R+10)}) + d
\]

**Temperature Index (TI):** TI provides a relative index of how cold it is based on the observed daily min and max temperature. TI ranges from 0 to 2 with 2 indicating colder temps. The TI = 0 if the minimum temp is above 32 °F (0 °C); The TI = 1 if the minimum temp is at or below 32°F (0 °C) but the max temp is above 32°F. The TI = 2 if both the max and min are below 32°F. The average daily value for the entire month is used in the WSI equation.

**Snowfall (S):** S represents the mean daily snowfall in millimeters for the month.

**Number of Potential Frosts (N):** Based on the average number of days with minimum temperatures at or below 32°F. The daily N value = 1 for each day with a min temp below 32 °F and 0 if the min temperature is > 31 F. The monthly mean will be between 0 and 1.

**Temperature Range (R):** The value of the mean monthly maximum air temperature minus the mean monthly minimum air temperature in °C.
## Calculation Method (cont.)

Retrieved From Online Weather Source Values Calculated by Excel Spreadsheet

<table>
<thead>
<tr>
<th>DATE</th>
<th>T-MAX</th>
<th>T-MIN</th>
<th>Snow (inches)</th>
<th>TMAX- °C</th>
<th>TMIN- °C</th>
<th>SNOW-MM</th>
<th>TI</th>
<th>S</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/1/2015</td>
<td>41</td>
<td>38</td>
<td>0.0</td>
<td>5.00</td>
<td>3.33</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/2/2015</td>
<td>52</td>
<td>38</td>
<td>0.0</td>
<td>11.11</td>
<td>3.33</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/3/2015</td>
<td>61</td>
<td>42</td>
<td>0.0</td>
<td>16.11</td>
<td>5.56</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/4/2015</td>
<td>58</td>
<td>46</td>
<td>0.0</td>
<td>14.44</td>
<td>7.78</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/5/2015</td>
<td>59</td>
<td>42</td>
<td>0.0</td>
<td>15.00</td>
<td>5.56</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/6/2015</td>
<td>44</td>
<td>37</td>
<td>0.0</td>
<td>6.67</td>
<td>2.78</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/7/2015</td>
<td>50</td>
<td>36</td>
<td>0.0</td>
<td>10.00</td>
<td>2.22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/8/2015</td>
<td>57</td>
<td>38</td>
<td>0.0</td>
<td>13.89</td>
<td>3.33</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/9/2015</td>
<td>53</td>
<td>43</td>
<td>0.0</td>
<td>11.67</td>
<td>6.11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11/30/2015</td>
<td>48</td>
<td>34</td>
<td>0.0</td>
<td>8.89</td>
<td>1.11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Monthly Averages</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>9.91</strong></td>
<td><strong>1.02</strong></td>
<td><strong>0</strong></td>
<td><strong>0.37</strong></td>
<td><strong>0</strong></td>
<td><strong>0.33</strong></td>
</tr>
</tbody>
</table>
WSI Background and Calculation Method

\[ R = 9.91 - 1.02 = 8.89 \]

Thus, \[ TI = 0.37 \]
\[ S = 0 \]
\[ N = 0.33 \]
\[ R = 8.89 \]

\[ WSI = (-25.58 \times \sqrt{0.37}) + (-35.68 \times (\ln(0/10)+1)) + (-99.5 \times \sqrt{(0.33/(8.89+10))}) + 50 \]

\[ WSI = (-15.56) + (0) + (-13.15) + 50 \]

\[ = 21.29 \]
Figure 1-1
MassDOT
Highway Districts
Commonwealth of Massachusetts
WSI Differences Amongst Districts

Average Annual WSI Value By District

<table>
<thead>
<tr>
<th>District</th>
<th>Average Annual WSI Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-20.8</td>
</tr>
<tr>
<td>2</td>
<td>-14.3</td>
</tr>
<tr>
<td>3</td>
<td>-21.3</td>
</tr>
<tr>
<td>4</td>
<td>-16.7</td>
</tr>
<tr>
<td>5</td>
<td>-9.3</td>
</tr>
<tr>
<td>6</td>
<td>-14.3</td>
</tr>
</tbody>
</table>
U.S. Winter Severity - Massachusetts
for Winter Road Maintenance

Severity data as portrayed in this map were generated from gridded datasets of mean annual snowfall amounts, mean annual durations of snowfall, freezing rain, and blowing snow (each for which maps are separately given approximately equal weighting to the snowfall amount and the duration of these wintry weather events. Particular winter severity values have no specific interpretation and are intended only to facilitate comparison between locations. More information as to the specific process used to develop this map is available from...
Post-2011 Comparison
New Innovations – Beginning in 2011

• Pre-treatment
• Pre-wetting
• Closed-loop Controllers
• Pavement Friction Sensors/Meters
• RWIS Stations w/ cameras
• Segmented Plow Blades
• Vaisala Road Surface Sensors
Major S&I Policy Changes Since FY2011

- Contractors: Required Pre-wetting Equipment
- Elimination of Plow-Only Equipment
- Incentives of Closed-Loop Controllers
  - All Contractors now have CL controllers
- Use of MgCl/Brine for Pre-treatment
- Increased Supervision for Key Routes
- Replacement of Storage Sheds
Regression Correlation of Salt Use to WSI Value from 2001 to 2010

Salt Usage (tons per lane mile) vs. WSI

y = -1.4829x + 12.857
R² = 0.9633

Mild ⬛ Moderate ⬛ Severe
Post 2011 Statewide Salt Usage to WSI Values

Comparison of Annual Salt Usage in Last 5 years to Previous 10 Years

Salt Usage (tons per lane mile)

WSI – More Severe

~14 tons or 28%

y = -1.4829x + 12.857
R² = 0.9633
Comparison of Actual Usage vs Predicted Usage (lbs per lane-mi) based on Pre-2011 Correlation

<table>
<thead>
<tr>
<th>Year</th>
<th>Predicted Use by Ln-mi (older)</th>
<th>Salt Usage per Ln-mi</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY11</td>
<td>49.2</td>
<td>34.8</td>
</tr>
<tr>
<td>FY12</td>
<td>14.5</td>
<td>13.7</td>
</tr>
<tr>
<td>FY13</td>
<td>44.2</td>
<td>28.7</td>
</tr>
<tr>
<td>FY14</td>
<td>44.8</td>
<td>35.8</td>
</tr>
<tr>
<td>FY15</td>
<td>53.2</td>
<td>38.1</td>
</tr>
</tbody>
</table>
## Estimated Annual Material and Cost Savings Using Efficiency Measures

<table>
<thead>
<tr>
<th>Year</th>
<th>Road Salt (tons)</th>
<th>Material Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY11</td>
<td>125,572</td>
<td>$8,162,154</td>
</tr>
<tr>
<td>FY12</td>
<td>(17,033)</td>
<td>$(1,107,121)</td>
</tr>
<tr>
<td>FY13</td>
<td>155,160</td>
<td>$10,085,431</td>
</tr>
<tr>
<td>FY14</td>
<td>48,466</td>
<td>$3,150,290</td>
</tr>
<tr>
<td>FY15</td>
<td>127,388</td>
<td>$8,280,247</td>
</tr>
</tbody>
</table>

### Annual Material Use and Cost Savings from Efficiency Measures

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Salt Reduction (tons)</th>
<th>Annual Cost Savings (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY11</td>
<td>125,572</td>
<td>$8,162,154</td>
</tr>
<tr>
<td>FY12</td>
<td>(17,033)</td>
<td>$(1,107,121)</td>
</tr>
<tr>
<td>FY13</td>
<td>155,160</td>
<td>$10,085,431</td>
</tr>
<tr>
<td>FY14</td>
<td>48,466</td>
<td>$3,150,290</td>
</tr>
<tr>
<td>FY15</td>
<td>127,388</td>
<td>$8,280,247</td>
</tr>
</tbody>
</table>
Climate Change Effects
**Average Monthly WSI Values in 2001-10 vs. Last 6 Years**

**District 3**

<table>
<thead>
<tr>
<th></th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-10 ave</td>
<td>-35.49</td>
<td>-38.58</td>
<td>-39.05</td>
<td>-19.44</td>
</tr>
<tr>
<td>2011-16 ave</td>
<td>-18.75</td>
<td>-42.89</td>
<td>-62.57</td>
<td>-15.46</td>
</tr>
</tbody>
</table>

**District 4**

<table>
<thead>
<tr>
<th></th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-10</td>
<td>-30.28</td>
<td>-32.67</td>
<td>-28.06</td>
<td>-16.44</td>
</tr>
<tr>
<td>2011-16 ave</td>
<td>-14.73</td>
<td>-33.02</td>
<td>-43.24</td>
<td>-8.94</td>
</tr>
</tbody>
</table>
### Comparison of Average Monthly WSI Values in 2001-10 vs. 2011-16
#### District 5

<table>
<thead>
<tr>
<th></th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-16 ave</td>
<td>-2.14</td>
<td>-30.32</td>
<td>-37.51</td>
<td>-6.42</td>
</tr>
</tbody>
</table>

### Comparison of Average Monthly WSI Values in 2001-10 vs. 2011-16
#### District 6

<table>
<thead>
<tr>
<th></th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-2010 Avg</td>
<td>-24.3</td>
<td>-25.2</td>
<td>-24.6</td>
<td>-10.9</td>
</tr>
<tr>
<td>2011-16 Avg</td>
<td>-7.2</td>
<td>-30.2</td>
<td>-37.1</td>
<td>-3.9</td>
</tr>
</tbody>
</table>
How Might Climate Change Trends Effect Operations?

- Additional Personnel and Equipment for Short Periods in February
- Maintain Adequate Material Stockpiles Later into Season
- Contingency Planning for Interstate or Agency Mutual Aid: Sharing of Resources
- Review of Policies for Extreme Weather Conditions
Questions?
Stay connected

Like VHB on Facebook
www.facebook.com/VHBNNow

Follow us @vhbnow
www.twitter.com/VHBnow

Connect with VHB on Linkedin
www.linkedin.com/company/vhb