Road Salt Report – 2011
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29 September 2011

Overview

The City of Madison added road salt as sodium chloride to its winter road maintenance arsenal in 1959. Concern over the environmental consequences of its use was voiced by the Common Council in just three years. Although a 1962 assessment by the Madison Department of Public Health (MDPH), found minimal environmental impact, the Common Council promulgated a resolution to reduce the use of road salt in the Lake Wingra watershed. The subsequent plan called for a 50% reduction (from the amount used in the winter of 1972-1973) in road salt use in the Lake Wingra watershed starting in December of 1973. The salt use reduction objective was extended to include all of Madison in December of 1977. MDPH was directed to monitor the effects and submit an annual report to the Madison Common Council.

Despite nearly 50 years of observation and efforts at reduction, the use of road salt continues to increase. Monitoring of surface and ground water continue to show increasing trends in chloride and sodium levels, although the levels are not yet a human health hazard. Storm water monitoring during snowmelt has identified surges of extremely high levels of chloride. As these surges enter local waterways, they have the potential of harming fish and other aquatic organisms. Additional efforts to reduce road salt applications are needed if Madison is going to achieve the goals set in the 1970s. Recent road salt reports have documented the increase in road salt use and the subsequent rise of chloride in surface waters. This report provides an in-depth look at salt use trends.

Discussion

Madison's Streets Division is responsible for maintaining safe winter driving conditions. Effective winter road maintenance is necessary to reduce traffic accidents; sustain mobility for economic stability; and ensure uninterrupted emergency services. But, what are the costs? The City of Madison spent over four million dollars on snow and ice removal during the past winter (November 1, 2010 – March 31, 2011). But there are other costs more difficult to define including, corrosion of vehicles and transportation infrastructure; and environmental degradation.

The annual road salt report has, for years, documented the exceedence of the 1977 road salt reduction goal. It has also confirmed the accumulation of salt in the environment. This report updates past information and examines how Madison's salt reduction efforts compare to some Wisconsin counties.

2011 Road Conditions

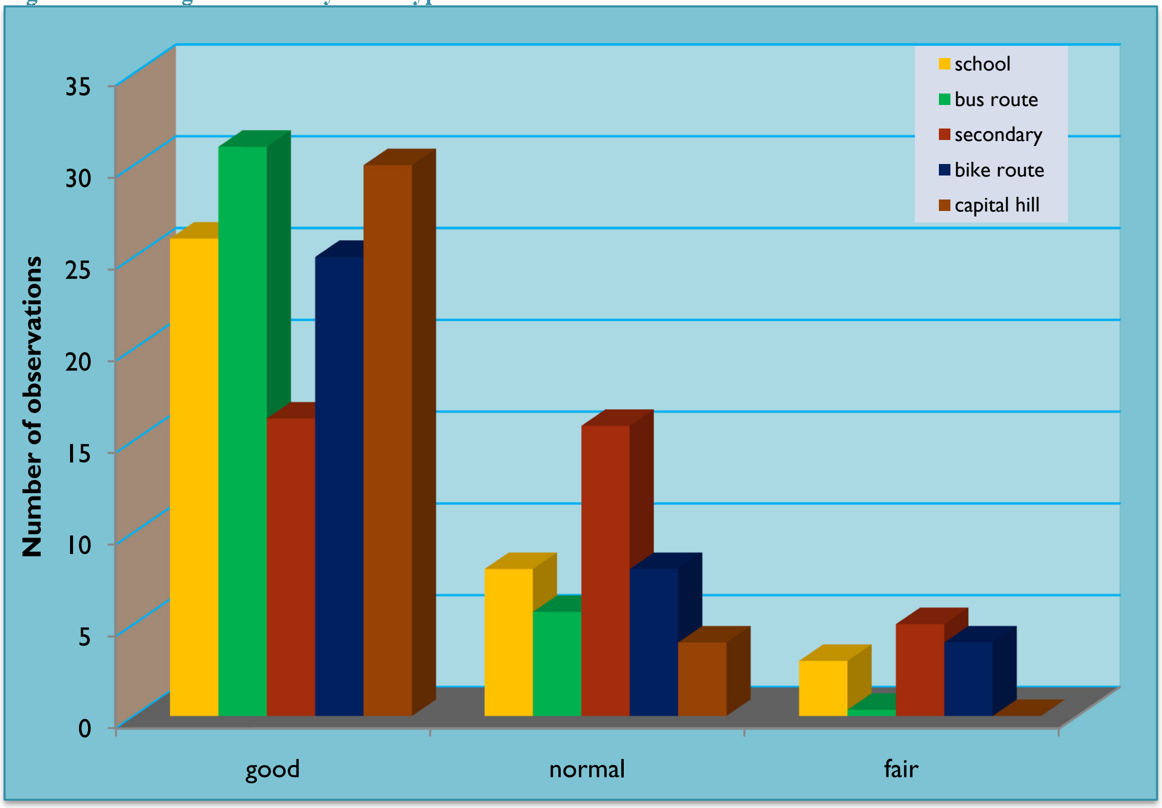
Few would criticize the quality and efficiency of the Streets Division's winter road maintenance, but what defines acceptable winter driving conditions? In an attempt to quantify driving conditions, road conditions were subjectively reported during the author's morning commute for the period of January 4, 2010 through March 10, 2010. Thirty-seven observations were recorded for five different street types.

Table 1 – Commuted route street types.

Street	Type
Agate Ln	School
Acewood Blvd	Bus Route
Diamond Dr	Secondary
Portland Pkwy	Secondary
Dempsey Rd	Bus Route
Calvert Rd	Secondary
Silver Rd	Secondary
Richard St	Secondary
Walter St	Bus Route
East Wilson St	Bike Route
East Wilson St	Capitol Hill

Twelve different road conditions were recorded. These were grouped into three separate driving condition categories. "Good" winter driving conditions were defined as a road surface that could be expected to provide traction similar to a wet or dry road in warm weather. "Normal" winter driving conditions were defined as having compromised traction requiring the driver to reduce speed in corners, or allow extra stopping distance. "Fair" winter driving conditions were defined as having tentative traction; slower speeds and extra vigilance are required. "Poor" winter driving conditions were defined as hazardous roads where a vehicle may not be able to continue because of deep snow, and/or lack of traction. The observations are summarized graphically in Figure 1.

Figure 1 – Driving conditions by street type.



No poor driving conditions were recorded for the period. However, a blizzard hit Madison on the evening of February 1, dumping over eighteen inches of snow and causing government offices to close. All roadways would have been graded as "poor" if travel was possible on February 2.

These subjective observations reflect the Streets Division's policy of salting only school zones, bus routes, main arterials, and hills and curves. The lack of deicer treatments to secondary roads is evident in the higher ratio of "normal" to "good" driving conditions. A reduction in road salt application would surely shift the driving conditions toward the "normal" range. Can this be accomplished without increasing the "fair" and "poor" numbers to unacceptable levels? Shifting the majority from "good" to normal would inconvenience motorists, but should not decrease safety.

Application Rates and Trends

The Wisconsin Department of Transportation (Wis DOT) has created a Winter Severity Index (WSI) which rates the winter weather over an entire season. It is calculated by inputting weekly weather conditions, reported by county highway departments into a weighted formula. Conditions are weighted based on the challenges they present to keeping roadways clear. The index allows the comparison of salt use to a weather standard based on a variety of road maintenance issues (number of storms, freezing rain events, storm duration, etc.) not just on seasonal snowfall amounts.

Because winter road maintenance data from other municipalities is difficult to obtain, Madison's maintenance activities were compared to county records kept by the Wisconsin Department of Transportation.

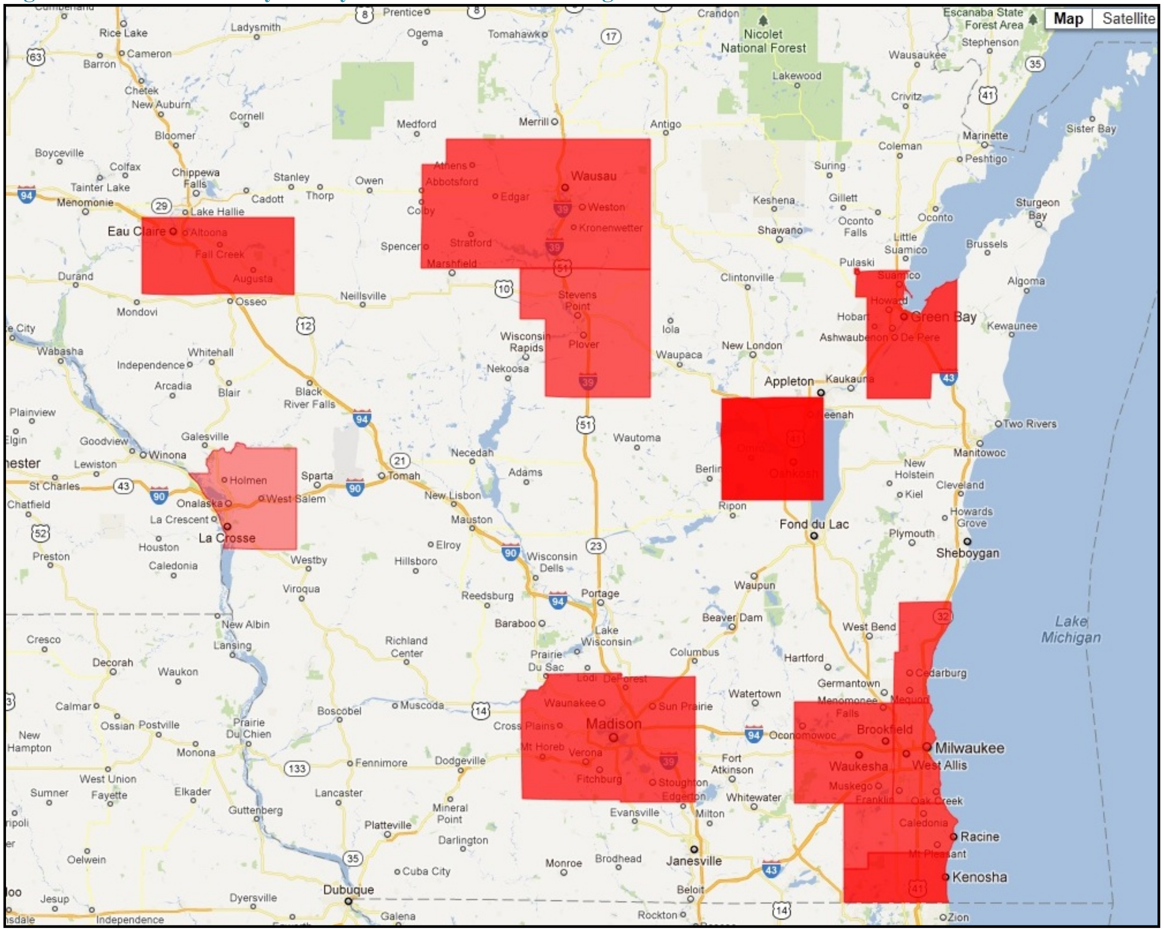
While deicer application rates for heavy volume, high speed roadways are not equivalent to the needs of city street maintenance, a comparison of trends in deicer use based on standardized weather conditions is valuable.

For comparison, Madison's salt use was evaluated against Wis DOT "winter service group A" counties (Brown, Dane, Eau Claire, Kenosha, Lacrosse, Marathon, Milwaukee, Ozaukee, Portage, Racine, Waukesha, and Winnebago). These are counties where all or most of the highways receive 24-hour coverage. Although a comparison of application rates would be tentative, comparing changes in salt use to the seasonal severity index could illustrate which agencies apply salt more prudently.

A major caveat with this comparison is that Madison reports road salt use based on street miles, while the counties all use lane miles. Ostensibly, this would seem to overestimate Madison's applications, since not all City streets are two lanes. However, a couple of factors diminish this inherent bias.

First, county highway departments deice all lane miles reported, while Madison deices only "salt routes". Madison's salt routes, in lane miles, are roughly equivalent to Madison street miles reported for 2011 (1.08:1). Secondly, in the five years that lane mile data is available for Madison, the ratio of street miles to lane miles has remained constant. Thus the salt application rate for Madison in street miles is reasonably comparable to the counties' application rates reported in lane miles. Since there is not enough historical lane mile data for Madison, its salt application trends (in street miles) was compared to the Counties' data without attempting to compensate for the difference. This may bias Madison's application rate high.

Figure 2 – 2011 Salt use by county. Darker red indicates higher salt use.



With the above qualification in mind, Madison's salt application rates and trends were compared with the Wis DOT winter service group A counties. The initial step involved a comparison of snowfall totals with the Wis DOT WSI. Snowfall is correlated with the WSI with an overall Pearson's product-moment correlation (r) of 0.65, 95% Confidence Interval of [0.55, 0.73], which indicates the WSI is a reasonable weather measurement. This is expected since snow fall totals are a component of the WSI. However, both data points were used in the analysis to minimize differences in weather monitoring and reporting between counties.

Then a multivariate analysis was conducted with an analysis of covariance (ANCOVA) which is a particular case of a multiple linear regression when the covariates include a categorical variable (County/Madison). The other covariates were continuous (snow, weather severity index (WSI) and snow-WSI interaction). The model summary shows a residual standard error of 3.416 on 153 degrees of freedom and an adjusted R-squared of 0.7318. Table 2 shows the results summary.

Table 2 – ANCOVA results.

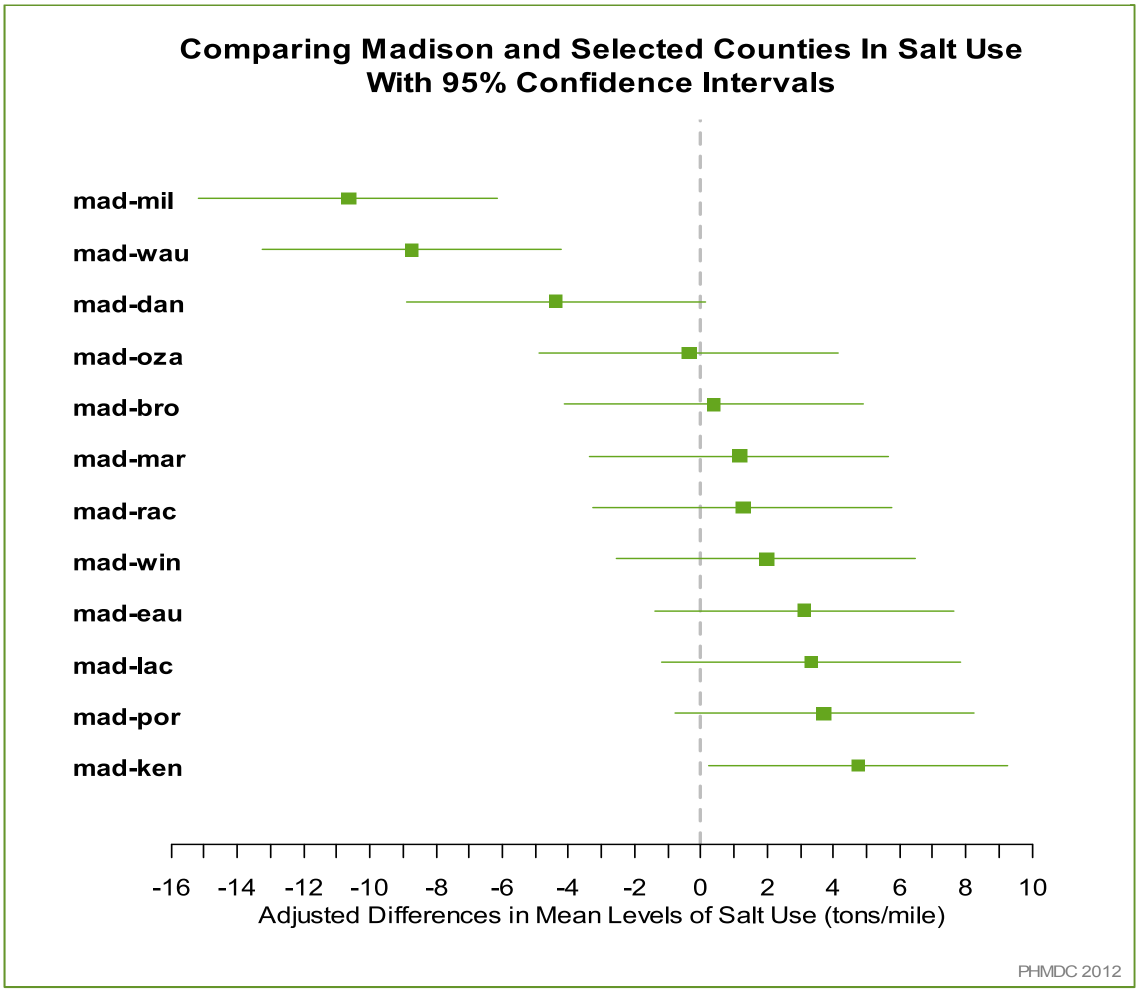
Predictors	Estimate	Std. Error	t value	p-value
(Intercept)	-4.456437598	3.127318328	-1.425002872	0.156193082
snow	0.222396271	0.057397976	3.874636124	0.000157967
WSI	0.509790697	0.11405593	4.469655331	1.51676E-05
Brown	-1.808282314	1.354889871	-1.334634166	0.183978851
Dane	4.363485654	1.340017188	3.25629081	0.001390102
Eau Claire	-3.28995194	1.360681111	-2.417871398	0.016786882
Kenosha	-3.667919017	1.388512955	-2.641616706	0.009108105
La Crosse	-5.162923668	1.362138455	-3.79030755	0.000215952
Marathon	-8.133526089	1.696981582	-4.792937163	3.85846E-06
Milwaukee	11.66708632	1.352856311	8.624039542	7.66E-15
Ozaukee	0.861882802	1.354180002	0.636461032	0.525427002
Portage	-6.792090927	1.398042692	-4.858285776	2.90312E-06
Racine	-2.21997048	1.356602193	-1.636419646	0.103807168
Waukesha	10.31018318	1.365844468	7.548577764	3.69E-12
Winnebago	-4.132981453	1.367087855	-3.023201061	0.002933557
Snow-WSI	-0.003940932	0.001710915	-2.303406512	0.022602596

Madison is the comparator. A p-value of less than 0.05 indicates a statistically significant difference. Madison's annual salt applications correlate well with the annual snow fall total (r=0.82 [95% Confidence Interval=0.50, 0.94] and even better with the WSI (r=0.84 [95% Confidence Interval=0.54, 0.95]). Brown, Ozaukee, and Racine Counties' salt use does not significantly differ from that of Madison's (p>0.05) after adjustment. But, the remaining comparisons are statistically significant.

In Table 2, the "Estimate" column shows the difference in salt use, predicted by the model, between Madison and the County. Positive values (blue font) indicate the County uses more salt than Madison under similar conditions, while a negative number (red font) indicates the County uses less than Madison.

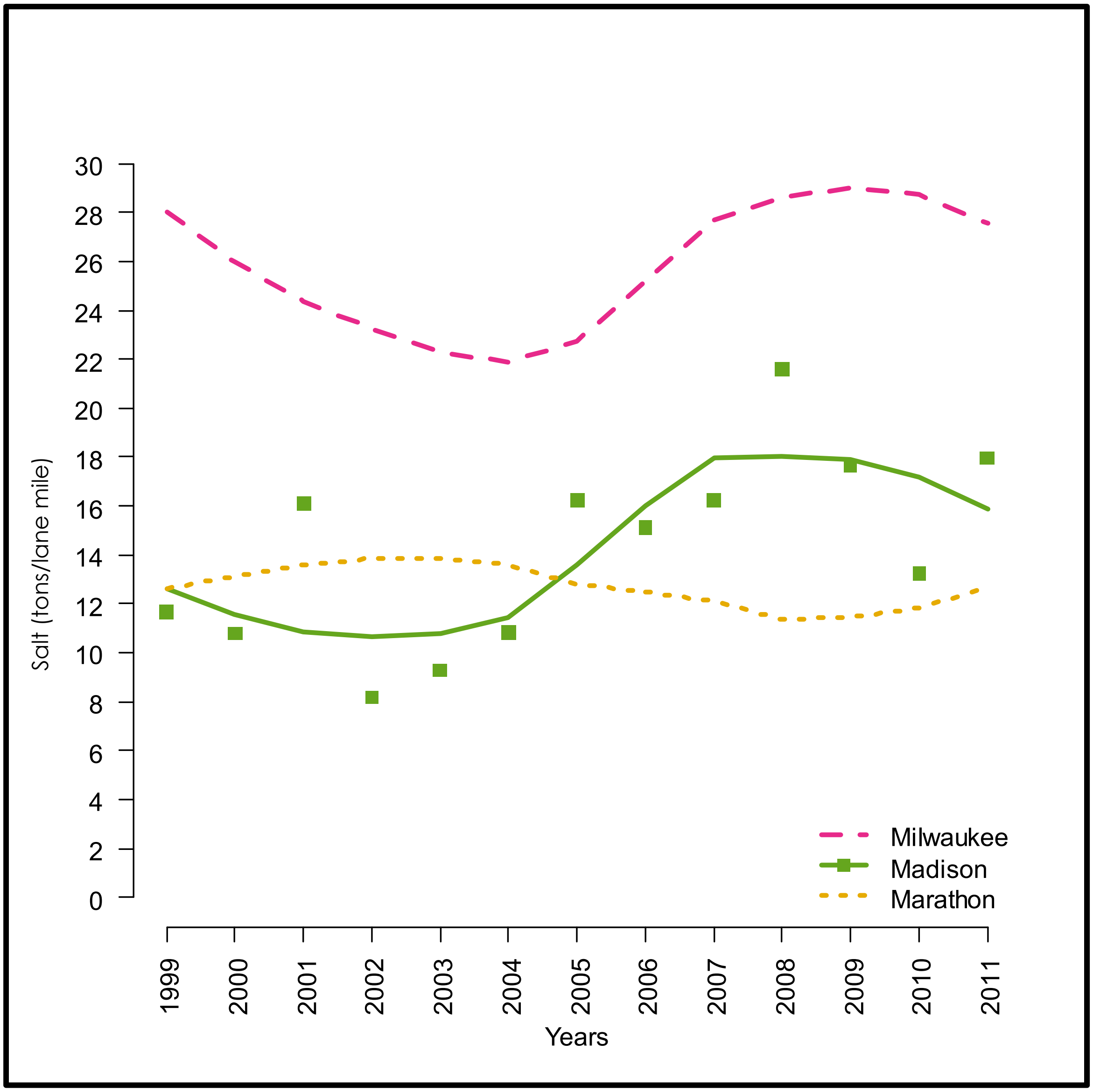
Figure 3 depicts the differences with 95% confidence intervals. Note that a confidence interval that intersects the zero line indicates that there is too much variability in the data to reach a conclusion. For example, the Madison-Winnebago County (mad-win) comparison shows Madison uses more salt than Winnebago County for the same weather conditions (green square). However, since the confidence interval intersects the 0 line, the certainty of this conclusion is suspect. We can be reasonably certain of comparisons where the confidence interval intersects the line near its end (Madison-Dane (mad-dan), Madison- Eau Claire (mad-eau), Madison-La Crosse (mad-lac), and Madison-Portage (mad-por)). We can conclude, however, that at 95% confidence, Milwaukee and Waukesha Counties use more salt than Madison for similar weather. And, Kenosha County uses less salt than Madison for similar weather.

Figure 3 – Comparing Madison salt use and 12 Wisconsin counties after adjusting for snow and WSI.



Most communities express a desire to limit salt use to minimize cost, even if environmental considerations are a low priority. With a conservative approach and efficiencies realized through advances in equipment, trends in salt use, per lane mile, should be declining. Madison's salt use trend over the last 13 years is compared to Milwaukee County and Marathon County in Figure 4. The trends are based on a regression model adjusting for snow, WSI and the interaction between snow and WSI. The smoothing lines were produced with loess (locally weighted regression).

Figure 4 – Adjusted means of salt use trends (smoothing lines with Loess Regression).



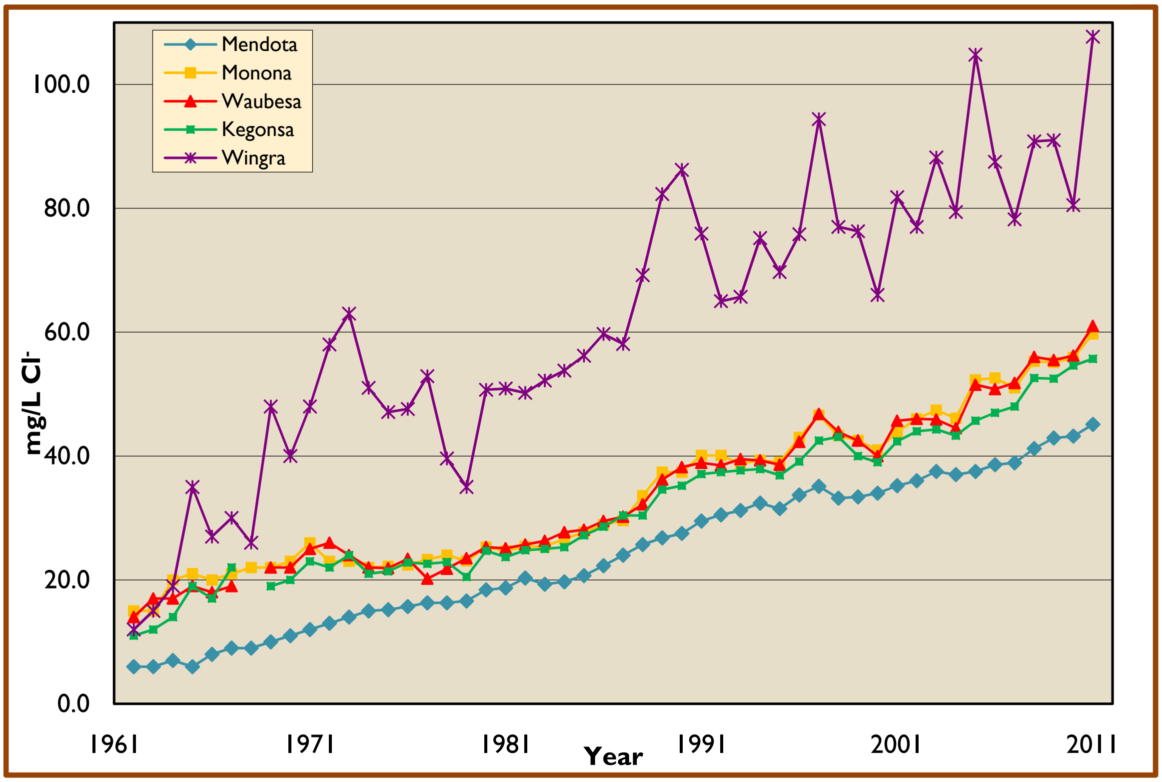
It is important to remember that the Madison data is in street miles as stated above. However, even with a 5-10% high bias, Madison's use of road salt is similar to that of the Group A County Highway Departments. Yet, the City should be using far less. The counties are maintaining roadways that see a high volume of traffic at higher speeds. Their flexibility in deicing applications is further limited by the State's bare pavement policy, which requires the county crews to quickly clear snow covered highways.

The ANCOVA also suggests the City considers additional weather factors beyond snowfall when using road salt. If this is the case, it would also contribute to expectations of declining salt use. Yet the trend over the last thirteen years has been to use more salt under the same conditions.

Environmental Impacts

As expected, environmental levels of sodium and chloride continue to rise as a result. Yearly average chloride concentration in Lake Wingra reached a new high of almost 108 mg/L (see Figure 5), and the December 2011 concentration of 132 mg/L represents an increase of 15% over the previous monthly high observed in 2005. While the chloride concentration of Lake Mendota has increased 750% in the 50 years of road salt use in Madison.

Figure 5 – Fifty year trend in Yahara Lakes chloride concentrations.



Smaller urban surface waters, such as Dunn's Marsh, Starkweather Creek, and University Bay Creek continue to be degraded by toxic levels of chloride. Chloride concentrations of 1000 mg/L, 680 mg/L and 1900 mg/L respectively, were observed in February of 2011. The Wisconsin chronic toxicity criterion for chloride (395 mg/L) has been exceeded on these waters in each of the last five years. Biodiversity monitoring of Starkweather Creek in 2002 (Water Action Volunteers program) indicated poor habitat conditions. Undoubtedly, the flora and fauna of all three of these water ways have been partially affected by chloride.

Madison's drinking water continues to show increasing levels of sodium and chloride as well (see Table 2. For an interactive display go to http://www.mrcaps.com/proj/MDCVisualization/files/). Most of the City's drinking water wells have sodium levels that are trending higher. Four wells are above the United States Environmental Protection Agency's drinking water guideline of 20 mg/L or less of sodium for individuals with a restricted sodium diet. A taste threshold for sodium is 30 to 60 mg/L. In 2011, well 14 had a sodium level of 36.3 mg/L (up from 34 mg/L in 2010). It should be noted that a person consuming three liters of water (Medical Institute's daily intake recommendation for men) from well 14 would increase their sodium intake by less than that contained in a slice of white bread.

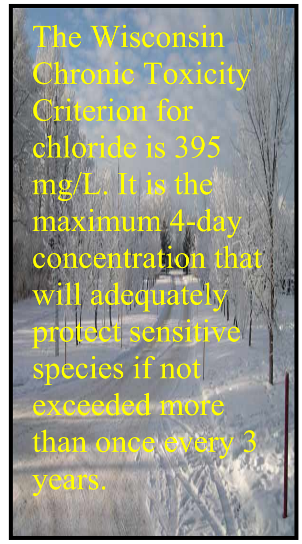


Table 2 – Sodium and chloride in Madison's drinking water.

Year	UW #6		UW #7		UW #8		UW #9		UW #11		UW #12		UW #13		UW#14		UW #15		UW #16		UW #17	
	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-
1995	8.0	23.0	5.0	9.0	9.0	17.0	10.0	35.0	6.0	18.0	2.0	1.0	4.0	6.0	14.0	41.0	9.0	22.0	5.0	14.0	11.0	21.0
1996	7.8	24.6	6.6	17.7	6.9	14.1	11.0	31.3	7.4	23.0	2.1	1.3	4.2	6.5	15.0	51.7	8.8	23.7	5.2	14.8	21.0	52.8
1997	7.7	22.7	5.5	10.6	7.4	14.4	12.0	31.0	8.2	25.6	2.2	1.1	4.5	6.7	16.0	52.5	10.0	25.9	5.7	15.4	22.0	54.4
1998	7.9	23.7	9.5	23.9	7.5	14.1	12.0	30.9	9.2	27.8	2.2	1.2	4.5	6.6	17.0	54.7	10.0	26.5		16.5	12.0	25.9
1999	8.0	25.1	6.1	13.0	7.5	14.8	12.0	33.1	11.0	38.4	2.1	1.3	4.3	6.9	18.0	59.1	10.0	29.5	6.2	18.2	20.0	49.6
2000	8.9	25.8	6.2	11.1	7.6	13.2	12.0	31.1	12.0	37.5	2.2	2.0	4.5	6.3	19.0	58.3	11.0	29.6	6.9	18.3	23.0	53.5
2001	9.1	26.2	7.1	13.6	8.0	14.0	14.0	34.5	11.0	33.6	2.3	2.2	4.7	7.1	21.0	60.1	12.0	32.2	8.0	21.7	12.0	23.6
2002	9.4	26.2	9.4	19.2		19.2	14.1	33.3	12.0	33.5	2.4	2.4			22.7	64.1	12.8	34.4	9.0	24.5		23.5
2003	9.5	27.5	10.5	22.3	11.6	22.1	13.6	33.4	12.6	37.2	2.3	2.3	4.8	7.6	22.4	68.8	13.6	36.5	9.9	27.0	25.2	58.1
2004	9.4	28.4	7.4	15.0	8.9	17.0	13.4	34.4	12.7	39.0	2.3	2.5	4.8	7.8	21.7	69.2	14.0	38.7	10.4	29.6	20.0	49.7
2005	9.6	28.9	7.4	14.8	8.4	15.8	13.0	31.4	13.4	40.3	2.2	2.4	4.8	7.9	25.2	69.9	14.8	40.6	11.0	29.1	21.0	55.6
2006	9.8	28.9	7.1	13.4	8.7	16.0	13.8	33.0	15.4	47.3	2.2	2.5	4.9	8.3	26.5	76.8	15.5	41.6	12.5	34.2	17.6	43.9
2007	11.4	33.4	6.7	12.5	9.6	18.0	13.7	32.0	15.6	45.9	2.3	2.5	5.1	8.4	27.1	75.0	16.3	42.9	13.5	35.6	14.8	32.8
2008	11.2	30.7	6.6	5.9	10.4	22.3	13.9	30.9	16.0	45.2	2.2	2.6	4.9	8.5	30.5	88.1	17.3	44.6	13.0	34.3	16.8	38.4
2009	12.7	38.8	7.9	15.3	11.7	21.6	14.5	33.9	18.0	51.7	2.4	2.9	5.3	8.5	32.5	92.0	18.2	47.8	15.7	39.4	20.8	50.4
2010	13.1	37.8	7.2	14.3	9.0	17.0	15.4	36.4	17.9	52.4	2.3	3.5	5.1	9.2	34.0	94.0	19.0	49.3	16.1	43.7	22.6	55.5
2011	14.7	44.0	6.8	11.9	9.3	18.4	14.8	36.1	20.3	56.8	2.4	3.0	5.2	8.9	36.3	103.0	18.9	48.5	20.1	46.4	19.3	50.6

Year	UW #18		UW #19		UW #20		UW #23		UW #24		UW #25		UW #26		UW #27		UW #28		UW #29		UW #30	
	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-	Na	Cl^-
1995	4.0	7.0	3.0	4.0	2.0	1.0	15.0	49.0	4.0	5.0	3.0	1.0	2.0	3.0	12.0	30.0						
1996	6.4	18.6	3.3	4.1	2.2	0.8	15.0	51.8	4.4	4.9	3.0	1.6	2.6	3.5	11.0	25.9						
1997	4.0	7.2	3.4	4.0	2.2	0.7			4.5	5.3	3.1	1.6	2.8	3.7	11.0	24.8						
1998	4.2	7.6	3.3	4.1	2.2	0.7	16.0	54.8	4.5	4.4	3.1	1.2	2.8	3.8		23.4						
1999	4.3	8.5	3.3	4.3	2.2	0.8	13.0	39.8	4.6	4.8	3.0	1.2	2.9	4.5	10.0	23.1						
2000	4.2	6.9	3.5	4.4	2.2	1.6	13.0	39.4	4.5	4.5	3.2	1.9	3.2	4.7	9.7	19.5						
2001	4.4	7.4	3.6	4.7	2.2	1.7	14.0	45.0	4.6	4.7	3.3	2.3	3.4	5.5	11.0	22.6						
2002	4.5	7.4	3.7	5.0	2.3	2.0	16.2	46.6	4.7	4.7	3.3	2.5	3.7	6.1	11.0	21.8						
2003	4.5	7.6	3.8	5.1	2.7	2.0	15.6	46.4	4.8	4.8	3.3	2.5	4.0	6.8	11.6	24.4	2.4	2.3				
2004	4.7	8.9	3.7	5.1	2.2	1.9	22.5	72.6	4.7	4.6	3.3	2.3	4.4	8.8	13.7	31.0	2.3	2.2				
2005	4.8	8.4	3.6	5.3	2.2	2.1	17.6	56.0	4.6	4.8	3.2	2.5	4.5	8.3	17.8	31.6	2.3	2.4				
2006	5.0	9.5	3.7	5.4	12.6	2.1	27.0	82.0	4.6	5.1	3.2	2.6	5.7	11.4	16.7	38.6	2.3	2.5	3.0	2.6	3.9	4.6
2007	5.2	9.6	3.8	5.7	2.2	2.0	19.1	54.2	4.7	5.4	3.3	2.7	4.5	7.9	18.5	43.4	2.4	2.5	3.2	3.5	3.8	4.1
2008	7.0	16.6	3.7	5.9	2.2	2.3	21.7	62.6	4.8	5.7	3.2	2.9	7.1	15.3	28.9	64.5	2.3	2.6	2.9	2.9	3.7	4.4
2009	5.2	8.7	4.0	5.8	2.3	1.6	35.2	103.1	5.0	5.3	3.2	2.4	4.8	8.0	16.8	34.5	2.4	2.2	3.0	2.5	3.8	4.1
2010	4.8	8.9	4.0	6.4	2.4	2.7	26.5	72.9	5.2	6.2	3.3	3.0	6.4	12.6	16.4	38.7	2.4	2.7	3.1	2.5	3.6	4.9
2011	6.7	15.6	3.9	6.4	2.1	2.0	23.0	66.2	5.0	6.0	3.3	2.8	6.7	12.8	16.1	34.1	2.4	2.4	3.1	3.1	3.8	4.4

Summary and Recommendations

Madison has been monitoring the road salt induced environmental increase in sodium and chloride for over forty years. The City strives to utilize mechanical and procedural efficiencies in road salt application. Nearly half the City streets are not treated with road salt. Yet, the streets that are treated with road salt are maintained similarly to interstate freeways and county highways. Even more disheartening is that even when standardized for weather, City road salting rates are increasing.

What can be done? Applying science and changing attitudes can move us closer to a sustainable level of salt use. Connie Fortin, founder of a consulting firm that trains winter maintenance managers and operators, says when applying salt, speed is the key. For a truck traveling over 30 miles per hour, Fortin claims 30% of the salt has enough momentum to bounce off the roadway. Another simple reduction is offered by Mark Devries, winter maintenance chair for the American Public Works Association. Since drivers tend to use whatever is loaded on their truck, loading the truck with the precise amount required for the route discourages over application.

Training operators to change the paradigm of "less salt equals decreased service" is essential to any reduction effort. But, changing drivers' expectations of clear pavement is paramount to achieving substantive salt reduction. Today's vehicles are equipped with anti-lock braking systems; many have traction control or all-wheel drive. Advances in tire construction have also improved handling. Motorists simply don't want to be troubled with longer commute times and the diligence required to drive in adverse conditions.

Madison is one of thirteen communities using road salt in the Lake Mendota and Lake Monona watersheds. Reducing the influence of road salt on these waters will take a basin-wide effort. However, Dane County and the City of Madison are the only public agencies applying road salt in the Lake Wingra basin (see appendix for assessment of commercial applications). The City can positively affect the chloride concentration in Lake Wingra, protect its drinking water, and serve as a model to neighboring municipalities, with a committed effort to reduce road salt use. However, mechanical and procedural improvements will not suffice. A clear reduction policy must be defined and implemented.

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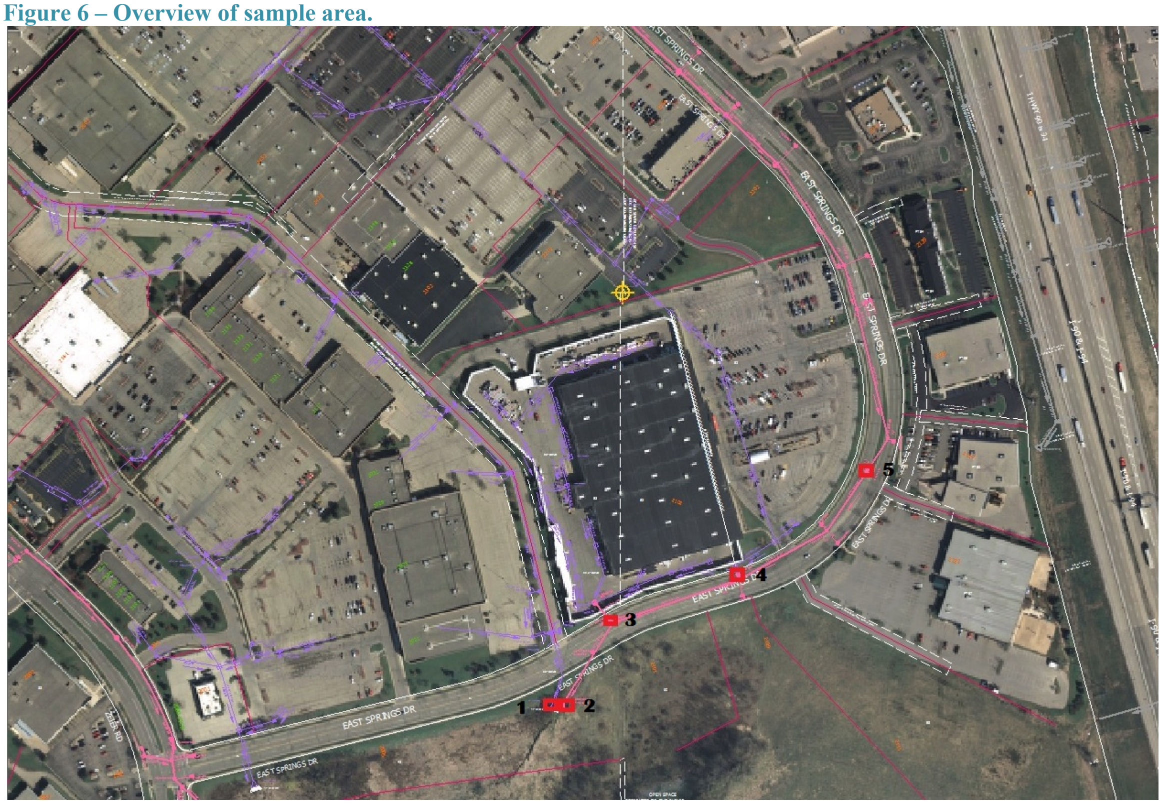
Appendix

Comparison of East Towne Area and Madison Street Salt Application - 2010

The objective of this study was to obtain an indication of salt application rates on private property. The study site was chosen because the mall parking lots and access roads represent a substantive area of impervious surface that is maintained by private contractor.

Three private storm drainages from the East Towne Mall area and two City storm drainages from East Springs Drive were sampled for chloride during periods of snow melt (see Figure 1). Sampling was limited by the collection method as storm sewer flows were obtained with a peristaltic pump.

Figure 6 – Overview of sample area.

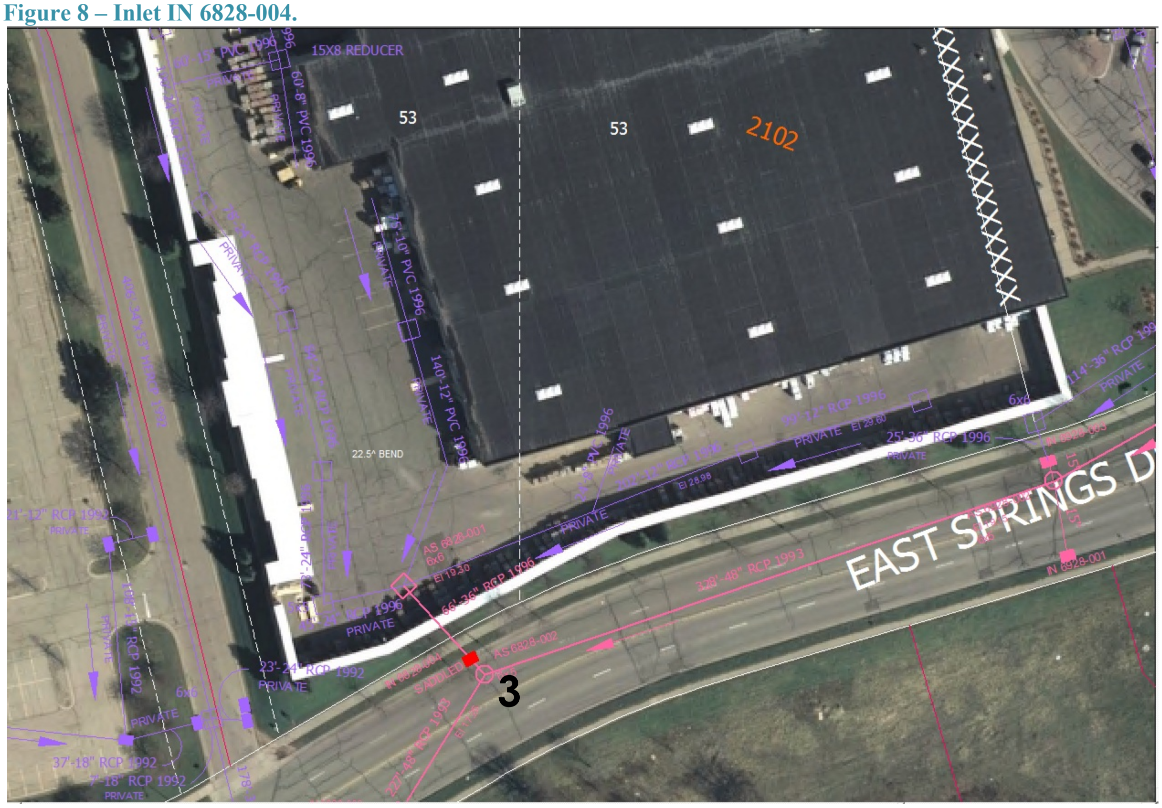


Sample point 1 (see Figure 2) is a private apron end draining to the east branch of Starkweather Creek. It collects runoff from parking lots and the access road west and north of Menard's. Sample point 2 is a City apron end (AE 6829-001) that discharges in the same location as sample point 1. It contains runoff from East Springs Drive and runoff from parking lots at Menard's and lots and access roads to the north. Grab samples were collected at these sample points.

Figure 7 – Apron end sample points draining to east branch of Starkweather Creek.

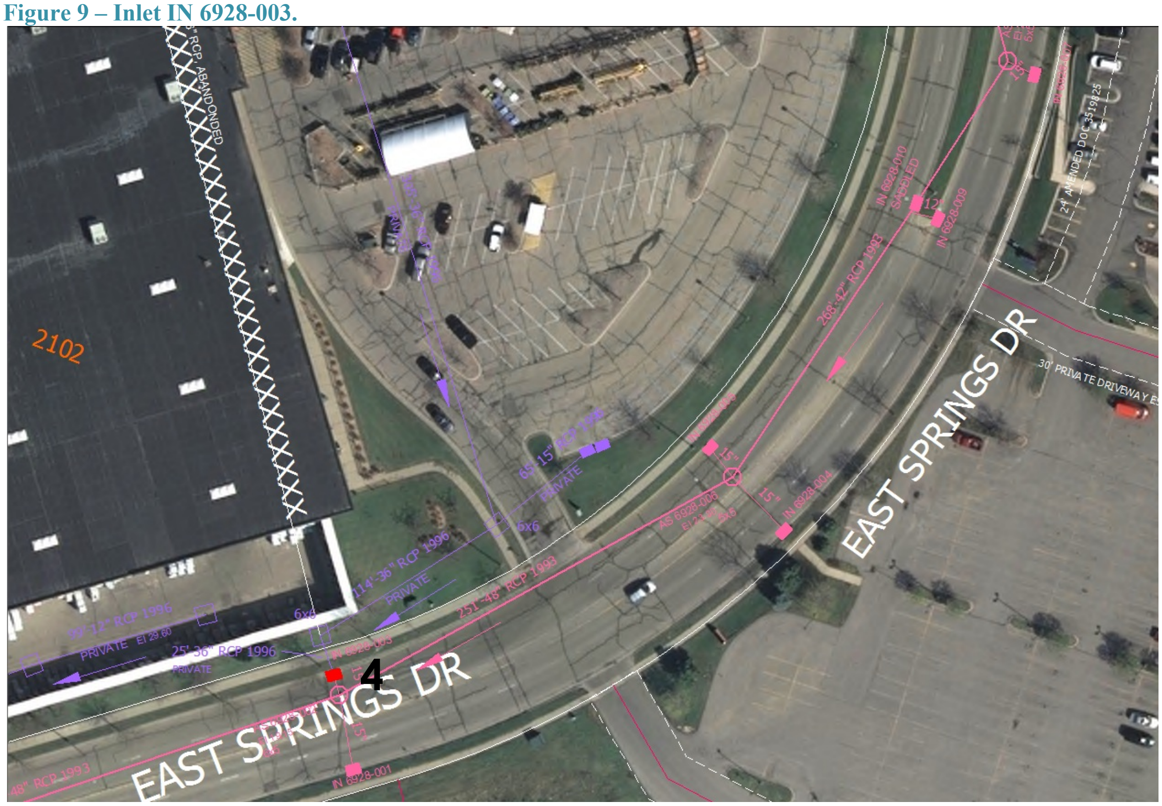
Sample point 3 (see Figure 3) is a City storm inlet (IN 6828-004) that collects runoff from the gutter and conveys storm water from Menard's outside storage area.

Figure 8 – Inlet IN 6828-004.



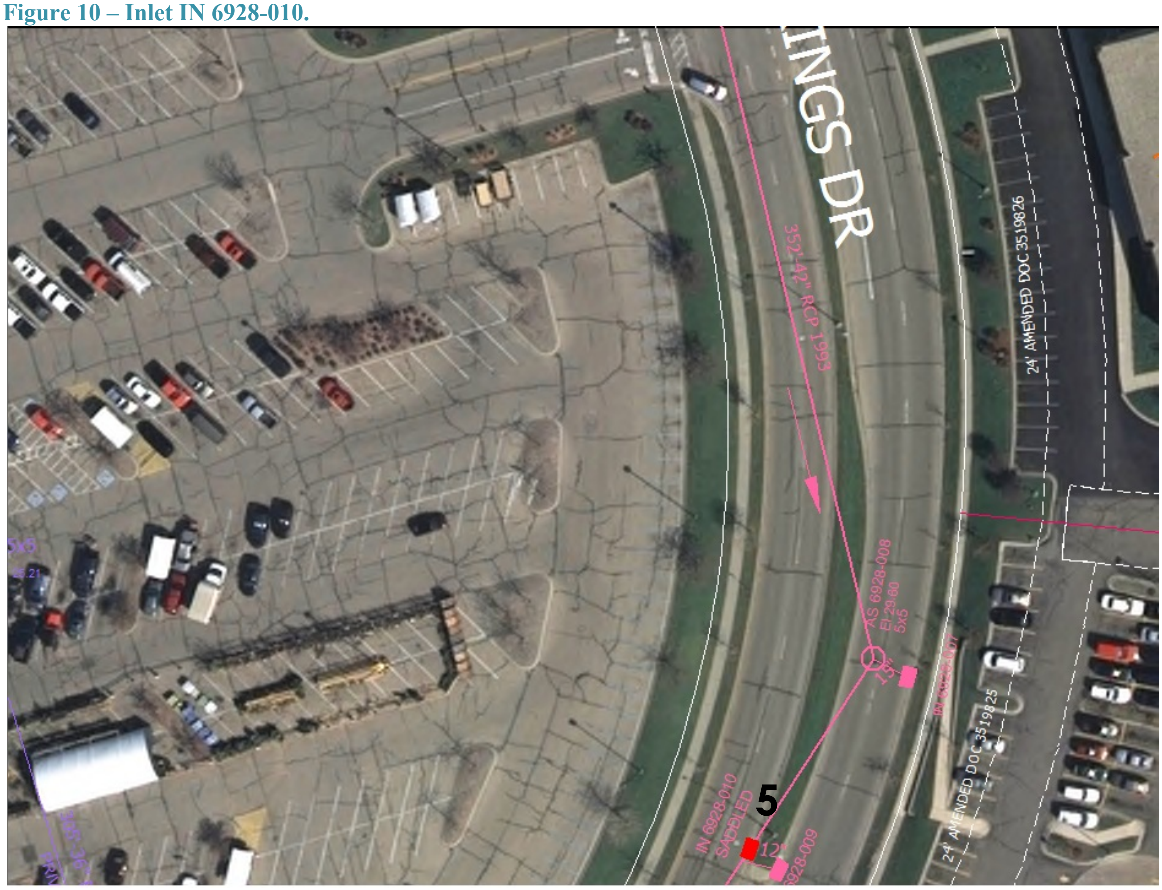
Sample point 4 (see Figure 9) is a City storm inlet (IN 6928-003) that collects runoff from the gutter (some of which is from Menard's parking lot) and conveys storm water from Menard's parking lot and most of the parking lot and access roads north of Menard's.

Figure 9 – Inlet IN 6928-003.



The final sample point (see Figure 10) is a City storm inlet (IN 6928-010) that collects street runoff and conveys storm water from: the north on East Springs Drive; Anamark Drive; High Crossing Boulevard; East Washington Avenue from about the 4700 block to the interchange.

Figure 10 – Inlet IN 6928-010.



Sampling began in February. Sewers were inspected for flow whenever conditions were favorable. Several of the sample points were well below the street surface, requiring the use of a peristaltic pump. Consequently, samples were only taken when the flow was deep enough for the pump to draw water; standing water was not sampled.

Results are tabulated in Table 3 below.

Table 3 – Conductivity and chloride results.

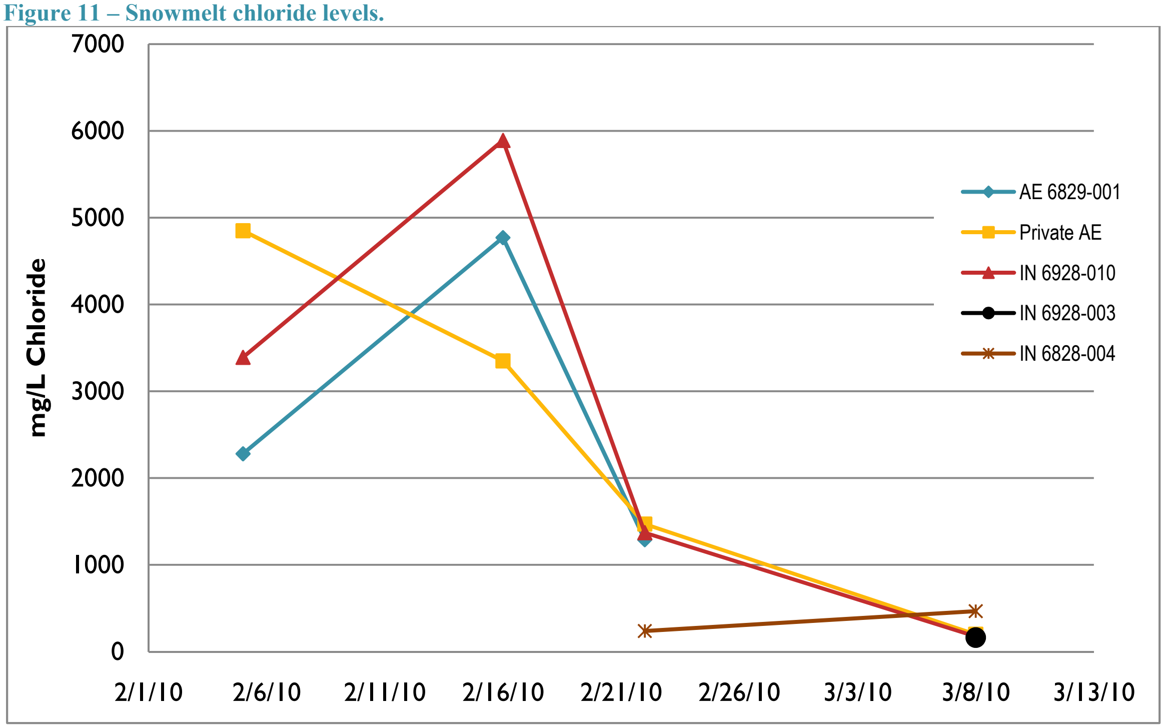
Structure	Date	Cl^- mg/L	Cond mmhos/cm	Source
IN 6928-010	2/5/10	3390	11400	City street runoff
Private AE	2/5/10	4850	15600	Mall parking and access road
AE 6829-001	2/5/10	2280	8480	Private and City runoff
IN 6928-010	2/16/10	5890	19700	City street runoff
Private AE	2/16/10	3350	11900	Mall parking and access road
AE 6829-001	2/16/10	4770	1720	Private and City runoff
IN 6928-010	2/22/10	1370		City street runoff
Private AE	2/22/10	1470		Mall parking and access road
AE 6829-001	2/22/10	1290		Private and City runoff
IN 6828-004	2/22/10	238		Menard's storage
IN 6928-010	3/8/10	175	760	City street runoff
Private AE	3/8/10	200	864	Mall parking and access road
IN 6828-004	3/8/10	467	1540	Menard's storage
IN 6928-003	3/8/10	162	687	Mall parking and access road

Figure 11 displays the results graphically. On February 2, meltwater from the strip mall area west of Menard's (private apron end) contained the highest level of chloride. However, the isolated street runoff (IN 6928-010) was higher than that of the combined city/private flow of AE 6829-001. This would suggest that the runoff from Menard's parking lot and areas north diluted the street runoff significantly.

The second sampling event, on February 16, showed chloride levels from the strip mall area had dropped. The isolated street runoff sample again was higher than the combined sample at AE 6829-001. Dilution from the Menard's parking lot sewer again appears to provide significant dilution. Subsequent sampling events yielded similar results for all sample points suggesting that the majority of the road salt had already been flushed from the system.

Although limited in scope and ability to quantify road salt application, the results suggest that large scale commercial areas probably contribute similar levels of chloride to meltwater as City deicing operations on main arterial roadways.

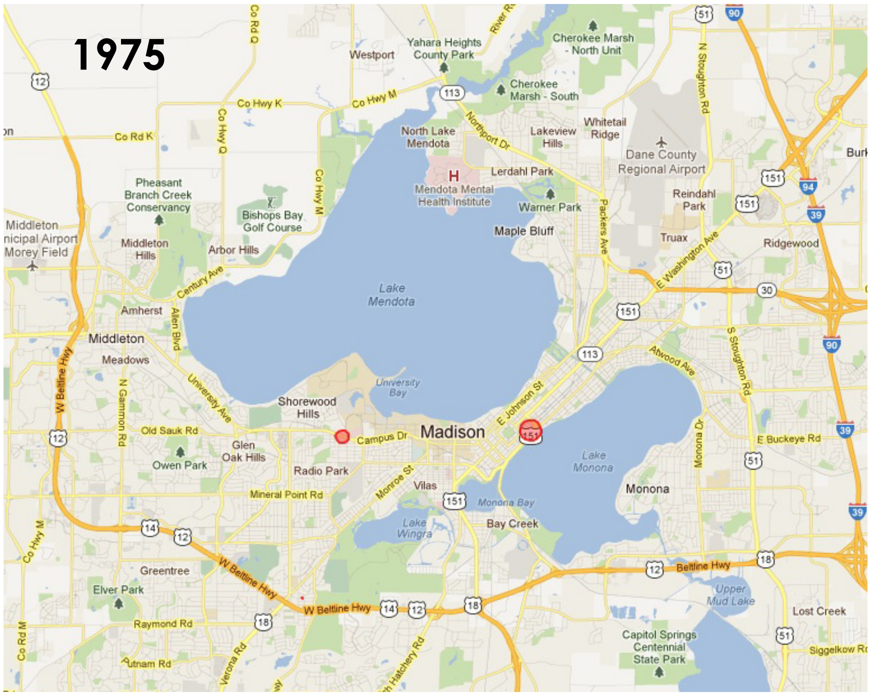
Figure 11 – Snowmelt chloride levels.

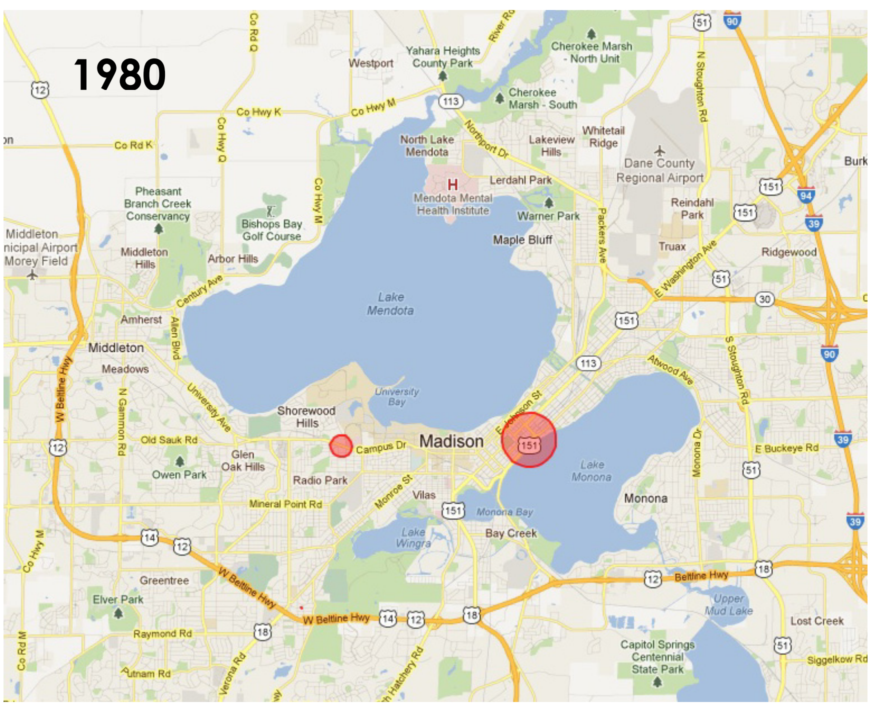


Additional Data

CITY OF MADISON STREET DIVISION SALT USE							
YEAR	**Snow (in)**	**Salt (tons)**	**Brine (gals)**	**Street Miles**	**Tons/Mile**	**Salt + Brine (tons)**	**decade average**
1972	44.0	5,691.25		511.9	11.1	5,691.25	3,318.04
1973	42.5	3,755.20		517.3	7.3	3,755.20	
1974	60.4	4,853.80		517.4	9.4	4,853.80	
1975	30.8	2,486.18		525.4	4.7	2,486.18	
1976	26.3	1,519.96		529.1	2.9	1,519.96	
1977	56.7	2,275.74		538.0	4.2	2,275.74	
1978	76.1	3,282.40		547.7	6.0	3,282.40	
1979	30.8	2,679.78		557.6	4.8	2,679.78	
1980	26.5	1,617.76		562.6	2.9	1,617.76	3,973.29
1981	49.8	4,010.05		565.4	7.1	4,010.05	
1982	41.4	2,890.53		567.8	5.1	2,890.53	
1983	42.2	4,980.10		552.1	9.0	4,980.10	
1984	54.2	2,896.65		567.8	5.1	2,896.65	
1985	72.4	5,574.10		561.1	9.9	5,574.10	
1986	34.5	3,274.20		564.3	5.8	3,274.20	
1987	62.2	4,491.30		571.0	7.9	4,491.30	
1988	36.0	4,393.28		580.0	7.6	4,393.28	
1989	34.8	5,604.95		587.4	9.5	5,604.95	
1990	55.0	5,836.00		587.4	9.9	5,836.00	7,070.67
1991	42.4	4,950.28		591.2	8.4	4,950.28	
1992	71.2	7,146.88		595.2	12.0	7,146.88	
1993	73.7	6,825.06		621.3	11.0	6,825.06	
1994	52.8	5,919.64		627.8	9.4	5,919.64	
1995	60.5	8,093.81		632.0	12.8	8,093.81	
1996	50.9	9,862.15		636.0	15.5	9,862.15	
1997	53.9	7,451.00		643.0	11.6	7,451.00	
1998	38.1	6,644.03		655.0	10.1	6,644.03	
1999	34.1	7,977.86		655.0	12.2	7,977.86	
2000	52.2	12,485.03		707.1	17.7	12,485.03	10,724.61
2001	31.8	6,423.02		710.0	9.0	6,423.02	
2002	28.8	9,010.33		731.0	12.3	9,010.33	
2003	31.6	7,852.65		732.1	10.7	7,852.65	
2004	43.9	12,037.06	8,066	733.5	16.4	12,047.14	
2005	47.6	9,762.38	2,040	750.0	13.0	9,764.93	
2006	55.1	10,984.19	30,325	758.0	14.5	11,022.10	
2007	101.4	17,945.94	37,669	758.1	23.7	17,993.03	
2008	72.0	9,780.84	29,456	764.1	12.8	9,817.66	
2009	51.6	10,751.98	62,571	765.7	14.0	10,830.19	
2010	73.4	13,837.01	128,955	769.1	18.2	13,998.20	13,998.20

Chloride in Madison drinking water wells. Concentration is proportional to bubble radius.



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Cherokee Marsh - South
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Lakeview Hills
Whitetail Ridge
Dane County Regional Airport
Mendota Mental Health Institute
Lerdahl Park
Warner Park
Maple Bluff
Reindahl Park
Truax
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Pheasant Branch Creek Conservancy
Bishops Bay Golf Course
Middleton Municipal Airport Morey Field
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Lake Mendota
Amherst
Middleton
Meadows
University Bay
Shorewood Hills
Madison
Campus Dr
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Owen Park
Radio Park
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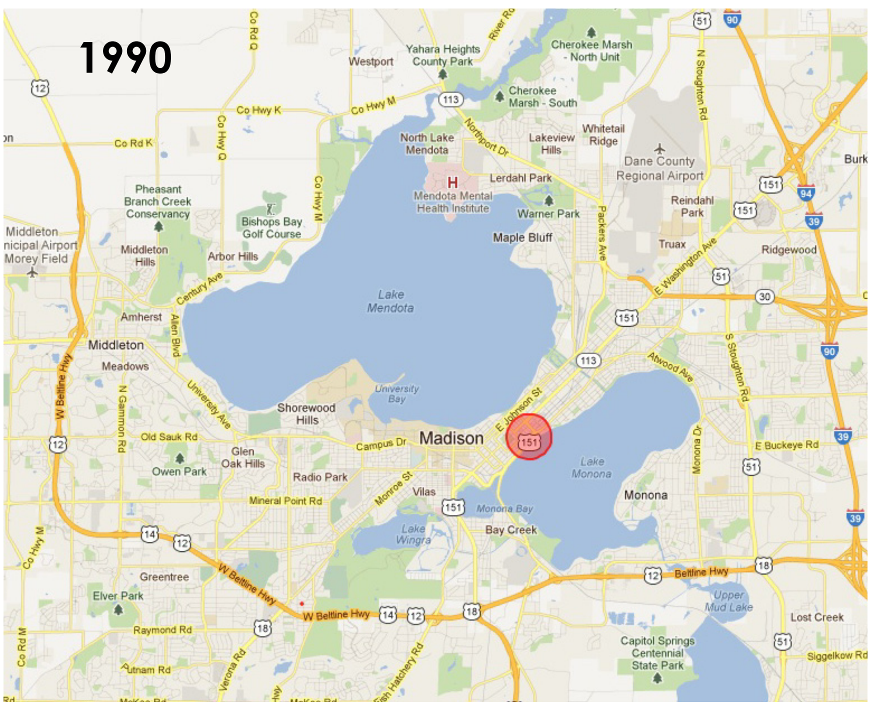
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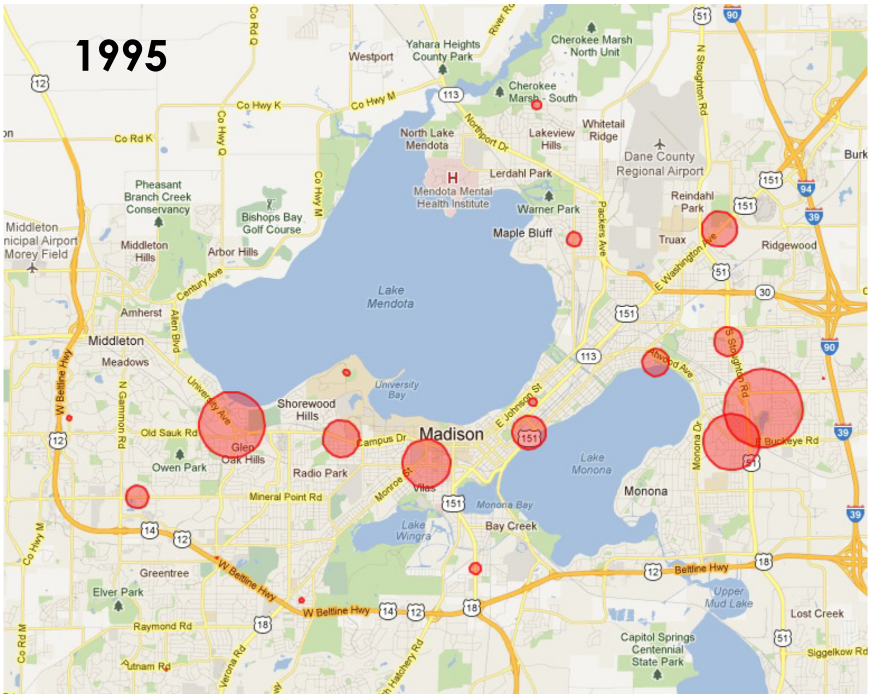
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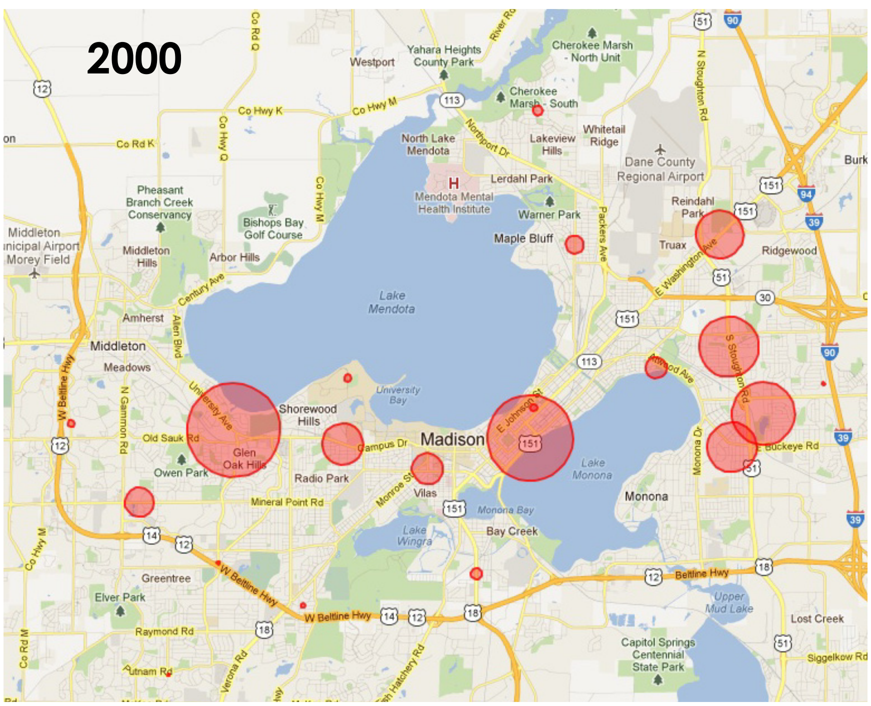
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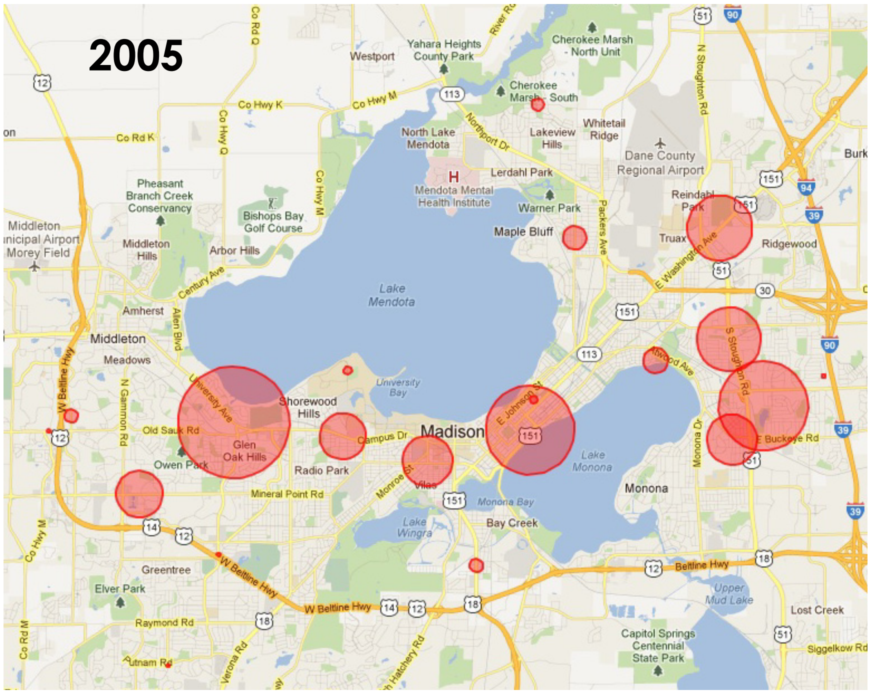
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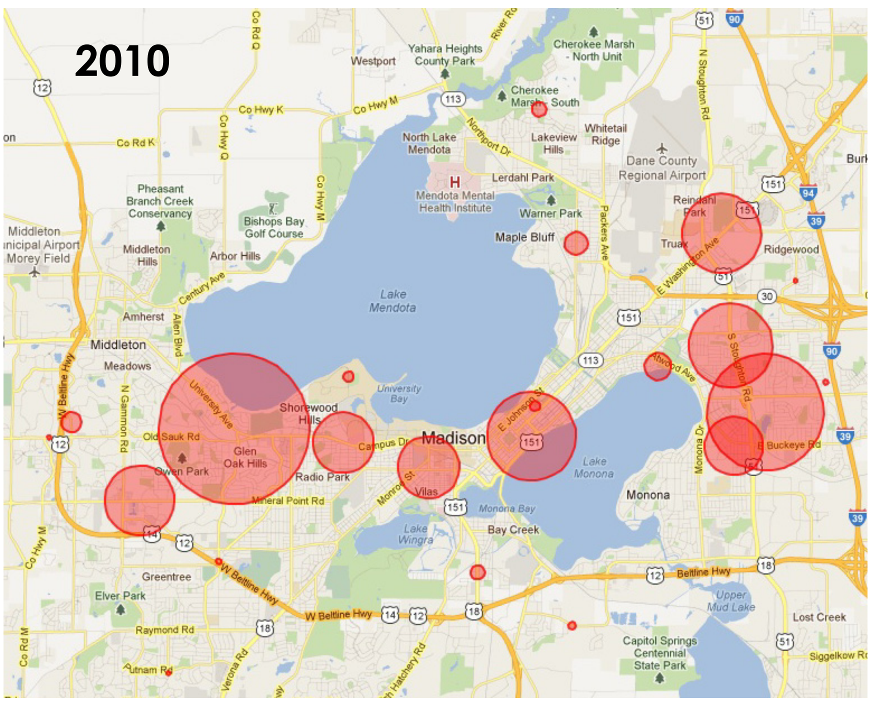
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