Water Quality Assessment: Chloride

- Designated Use Impairment & Water Quality Standards
- Water Quality Monitoring Data & Source Assessment
- Macroinvertebrate Sampling Data
- Pollution Reduction Strategies & BMPs

In 2012 Kiefer Creek was listed as impaired for aquatic life use due to high levels of chloride, which was result of analyses of monitoring data conducted by the Missouri Department of Natural Resources. Chloride aka salt, is an essential material for life on earth, however too much salt can be very detrimental to an ecosystem. When salt migrates into lakes and streams, it can harm aquatic plants and kill off freshwater organisms. A heavy influx of sodium and chloride ions will leave aquatic organisms vulnerable to survival, growth, or reproductive risks. Salt can also inhibit plant's water absorption and stunt root growth, interfering with the uptake of plant nutrients and inhibiting the plant's long-term growth. This may in-turn, lead to habitat degradation. But we have known for a long time that salting the earth poisons soils.

Most chloride pollution enters waterways through stormwater runoff during winter months when roads, driveways, and sidewalks are heavily salted in order to de-ice and ensure safe road conditions. As the snow and ice melts, it carries the salt with it into stormwater inlets along roads and parking lots, allowing the pollution to quickly make its way into Kiefer Creek. This is an issue that follows development and is widespread among streams with developed watersheds in the St. Louis Region. Although there is a necessity in keeping routes clear for travel during winter months, there are ways to ensure that salt is not being wasted through inefficiencies.

In some cases industrial activities and poor salt storage can result in an impairment, but there are no industrial chloride effluent flows or salt storage facilities or areas that have been identified in the watershed. Another potential source are swimming pools, which are likely to be emptied into a stormwater inlet, delivering chloride to Kiefer Creek in the form of chlorine. Because the only significant chloride pulses detected in the watershed have occurred during winter months it is likely that the most acute loading comes from road salt.

The numeric water quality standard for Chloride is a little more complicated than the bacteria standard, but for the purposes of this analysis we are going to just focus on the chloride measurements from the monitoring data – DO WE NEED TO ADD HARDNESS/SULFATE??Will anyone understand it?. For reference, here is the Missouri numeric water quality standard for chloride:

Pollutant (mg/L) AQL

Non-Metals (Hardness Dependent)

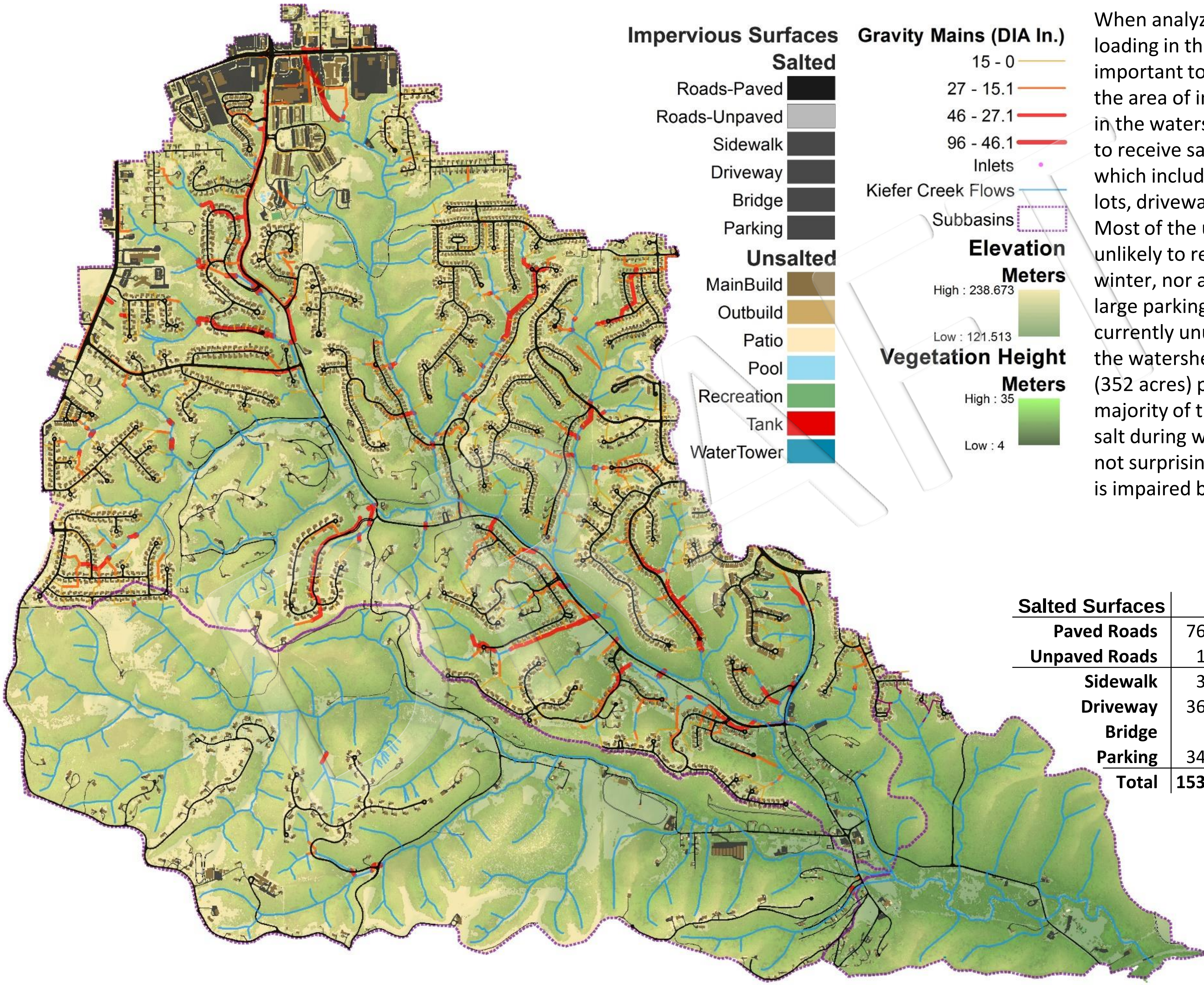
Chloride (mg/L)   Acute: $287.8 * (\text{Hardness})^{0.205797} * (\text{Sulfate})^{-0.07452}$

Chronic: $177.87 * (\text{Hardness})^{0.205797} * (\text{Sulfate})^{-0.07452}$

Sulfate (mg/L)	Chloride, Cl- (mg/L)		
Hardness, H (mg/L)	Cl- < 5	5 ≤ Cl- < 25	25 ≤ Cl- ≤ 500
H < 100	500	500	500
100 ≤ H ≤ 500	500	S1	S2
H > 500	500	2,000	2,000

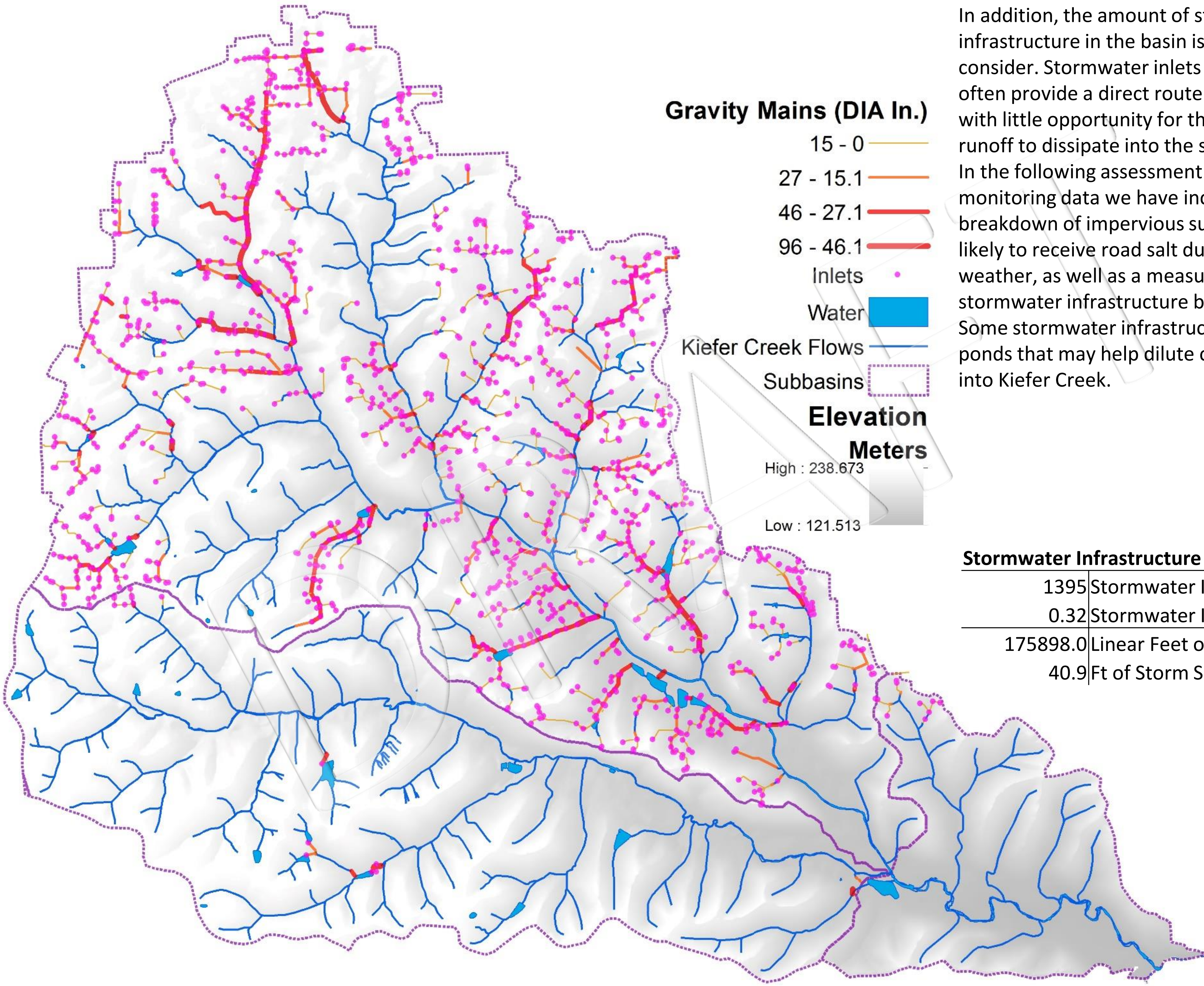
S1 = [-57.478 + 5.79 (hardness) + 54.163 (chloride)] * 0.65

S2 = [1276.7 + 5.508 (hardness) − 1.457 (chloride)] * 0.65



When analyzing the chloride loading in the watershed it is important to take into account the area of impervious surfaces in the watershed that are going to receive salt in the winter which includes roads, parking lots, driveways and sidewalks. Most of the unpaved roads are unlikely to receive salt in the winter, nor are some of the large parking areas which are currently unused. With 8.2% of the watershed surface area (352 acres) paved over, and the majority of that area receiving salt during winter months, it is not surprising that Kiefer Creek is impaired by chloride.

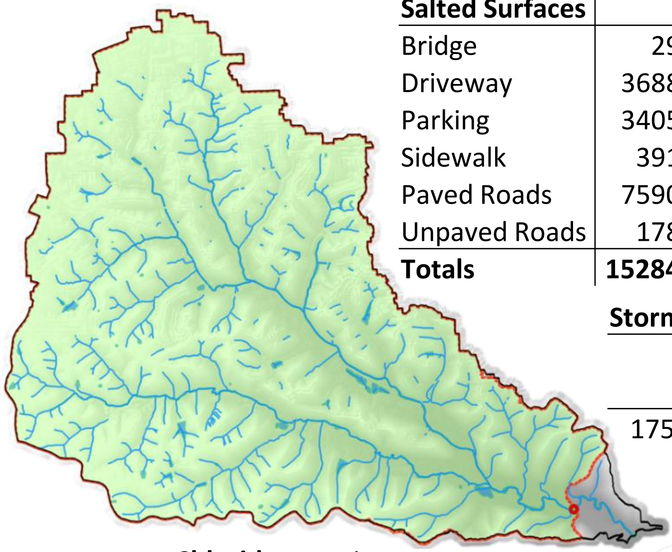
Salted Surfaces	Ft^2	% of Watershed
Paved Roads	7604492	4.062%
Unpaved Roads	188720	0.101%
Sidewalk	396318	0.212%
Driveway	3688761	1.970%
Bridge	29051	0.016%
Parking	3436259	1.835%
Total	**15343601**	**8.195%**



In addition, the amount of stormwater infrastructure in the basin is also important to consider. Stormwater inlets and storm sewers often provide a direct route to the stream with little opportunity for the concentrated runoff to dissipate into the soils.

In the following assessment of the chloride monitoring data we have included the breakdown of impervious surfaces that are likely to receive road salt during winter weather, as well as a measurement of the stormwater infrastructure by catchment area. Some stormwater infrastructure includes ponds that may help dilute chloride pulses into Kiefer Creek.

Stormwater Infrastructure	
1395	Stormwater Inlets
0.32	Stormwater Inlets/Acre
175898.0	Linear Feet of Storm Sewers
40.9	Ft of Storm Sewers/Acre



Salted Surfaces	Ft²	% of Total Salted Surfaces	Ft² Per Acre of Catchment
Bridge	29050.7	0.189%	6.83
Driveway	3688760.9	24.041%	867.54
Parking	3405677.3	22.196%	800.96
Sidewalk	391814.6	2.554%	92.15
Paved Roads	7590523.8	49.470%	1785.17
Unpaved Roads	178349.9	1.162%	41.94
Totals	**15284177.3**	**99.613%**	**3594.59**

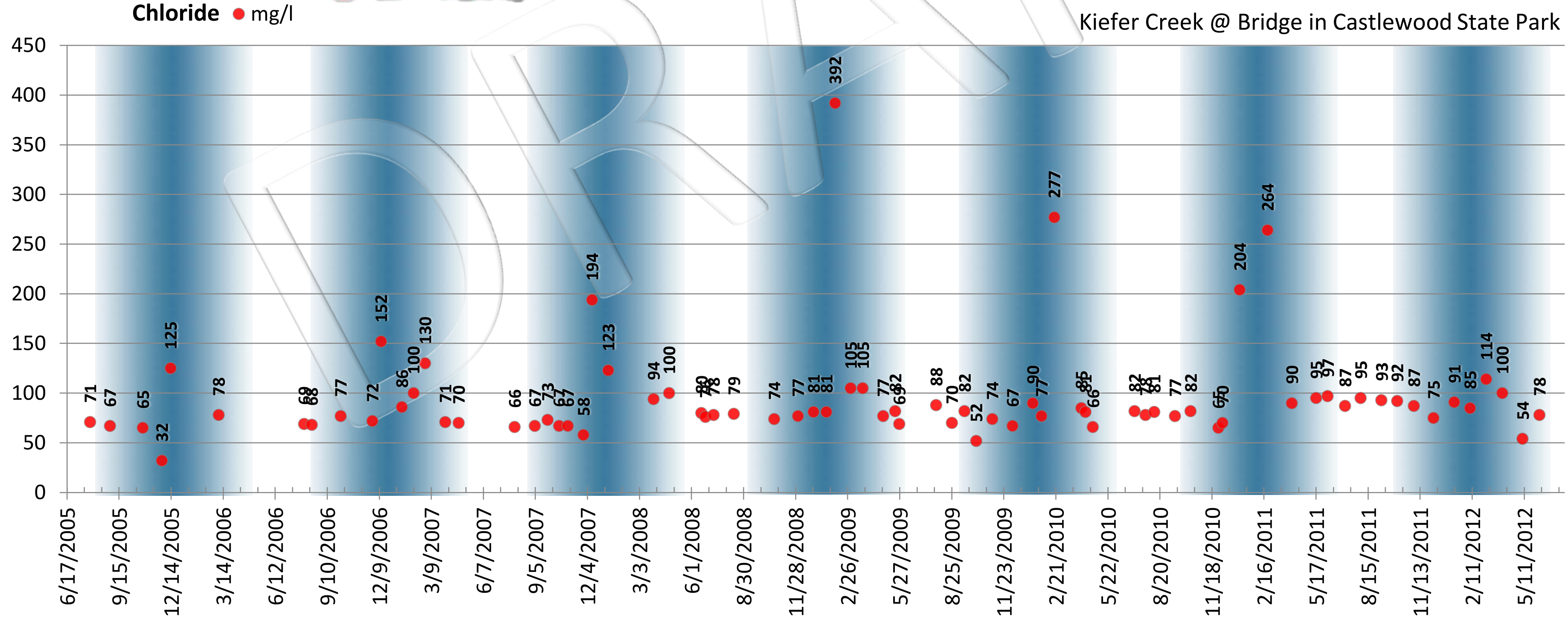
Stormwater Infrastructure

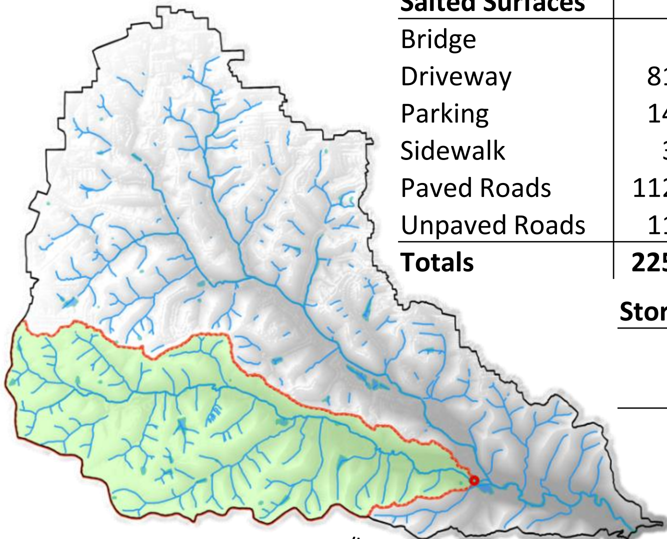
1395	Stormwater Inlets
0.33	Stormwater Inlets per Acre
175898.0	Feet of Storm Sewers
41.4	Ft of Storm Sewers per Acre

The data from the Kiefer Main Branch shows a clear increase during winter months. This testing location is below the confluence of the two subbasins, so all of the upstream surfaces essentially drain to this point. We can infer that the majority of this loading is coming from the Kiefer Spring Branch, because the Sontag Spring Branch does not display the same acute levels as we see below, and because the Kiefer Spring Branch of the watershed receives runoff from 82% of the salted impervious surfaces in the watershed, which must make the majority contribution of chloride during winter months. Because the data collected on the main branch is diluted by the lower concentration of chloride in the Sontag Spring Branch, the load coming from the Kiefer Spring Branch must be of a higher concentration measured in the Kiefer Main Branch.

Kiefer Main Branch

Kiefer Creek @ Bridge in Castlewood State Park



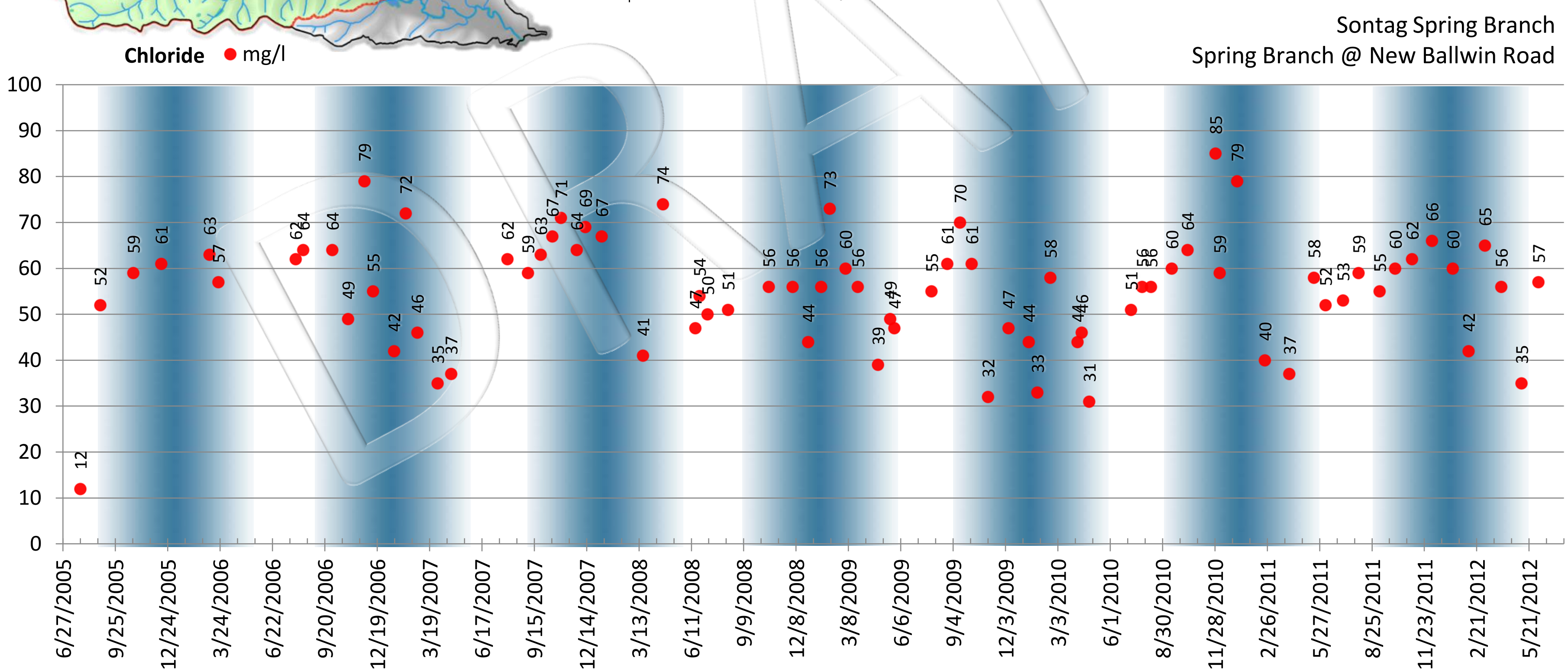


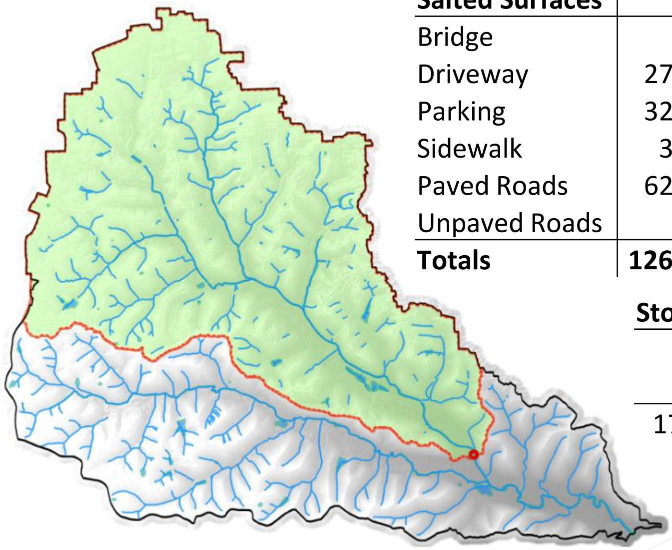
Salted Surfaces	Ft²	% of Total Salted Surfaces	Ft² Per Acre of Catchment
Bridge	6120.1	0.040%	4.62
Driveway	815598.2	5.316%	615.08
Parking	149581.9	0.975%	112.81
Sidewalk	37329.5	0.243%	28.15
Paved Roads	1126006.3	7.339%	849.18
Unpaved Roads	119043.6	0.776%	89.78
Totals	**2253679.6**	**14.688%**	**1699.61**

Stormwater Infrastructure

18	Stormwater Inlets
0.014	Stormwater Inlets per Acre
2078.6	Feet of Storm Sewers
1.6	Ft of Storm Sewers per Acre

The data from the Sontag Spring Branch seems to reflect the low amount of impervious surfaces that receive road salt in the winter. This sub-basin also has much less stormwater infrastructure than the Kiefer Spring Branch. This increases the likelihood that most chloride rich runoff will dissipate into the soils instead of being delivered directly to the stream channel. There is still a perceptible upswing during winter months, but the highest values are still well within the parameters of the water quality standard. If there is an increase in development in the Sontag Spring Branch we can expect to see an increase in the chloride load during winter months.



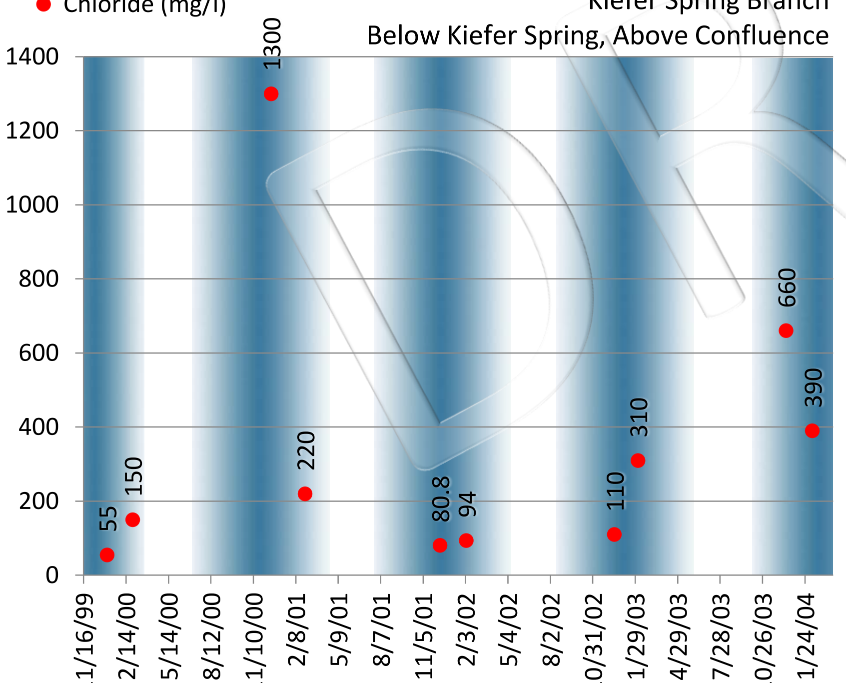


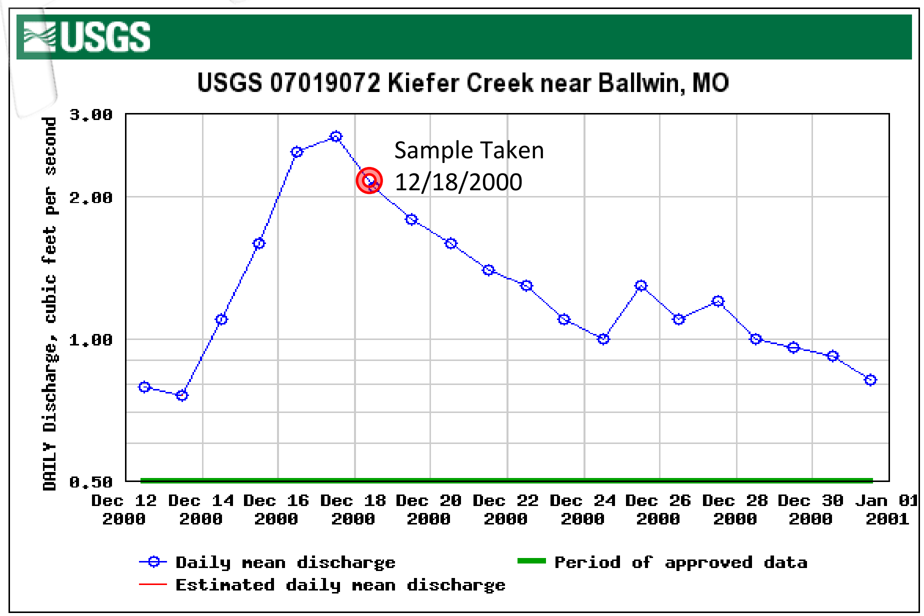
Salted Surfaces	Ft²	% of Total Salted Surfaces	Ft² Per Acre of Catchment
Bridge	16285.8	0.106%	6.37
Driveway	2774774.0	18.084%	1085.17
Parking	3204510.0	20.885%	1253.23
Sidewalk	348403.2	2.271%	136.25
Paved Roads	6229497.5	40.600%	2436.25
Unpaved Roads	59306.3	0.387%	23.19
Totals	**12632776.7**	**82.333%**	**4940.47**

Stormwater Infrastructure	
1368	Stormwater Inlets
0.54	Stormwater Inlets per Acre
172227.3	Feet of Storm Sewers
67.4	Ft of Storm Sewers per Acre

Unfortunately there is not more data from the Kiefer Spring Branch, however the data that was collected by the USGS between 1999 and 2004 shows a significant chloride issue. The USGS only measure chloride concentrations during winter months and managed to capture the highest levels measured in Kiefer Creek. We looked into the USGS hydrograph and NOAA weather data from December 12, 2000- the date of the highest chloride measurement. This sample captured the chloride runoff following significant winter weather and snow melt.

Date	Max Temp.	Min. Temp.	Ave. Temp.	Precip.	New Snow	Snow Depth
12/12/00	18	6	12	T	T	T
12/13/00	24	16	20	0.53	7.6	T
12/14/00	24	12	18	T	0.1	7
12/15/00	32	15	23.5	0.16	0.1	6
12/16/00	36	5	20.5	0.07	1.8	5
12/17/00	15	2	8.5	T	0.1	6
12/18/00	26	10	18	0.04	1	5

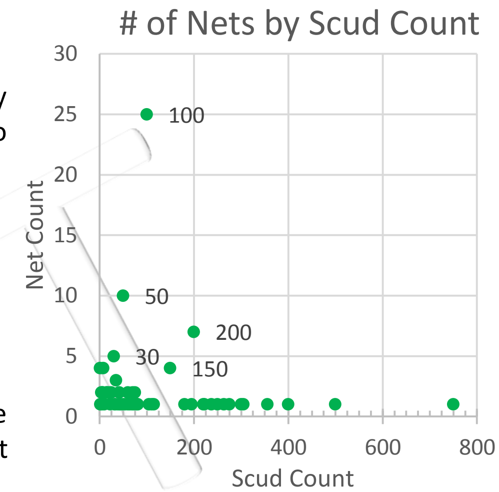


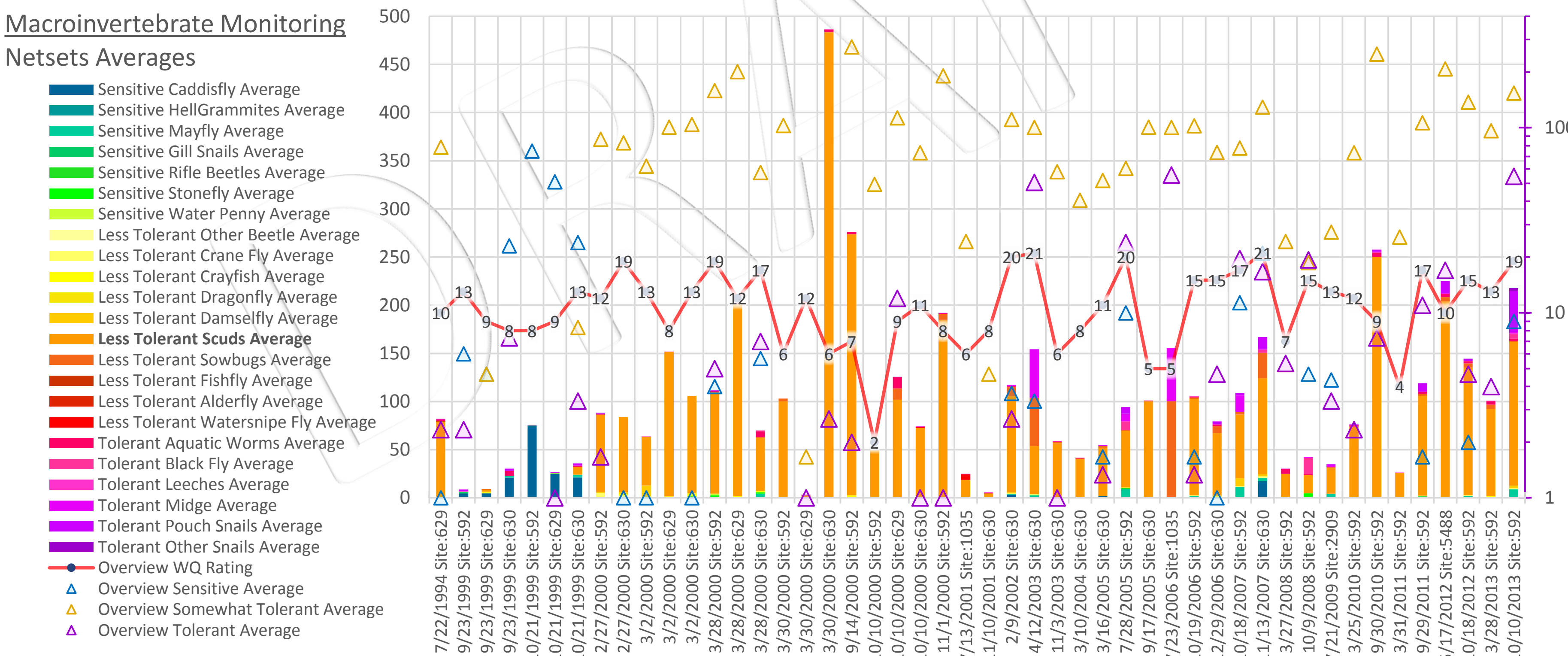


Since the chloride levels impair the aquatic life use it is important to take a look at the macro (macroinvertebrate) data that has been collected from the creek. Macros are the small insects that inhabit a healthy stream and serve play a key role in the ecosystem. Not only do they build the foundation for the stream food chain, they also tell us about the condition of an aquatic ecosystem. Some macros are highly sensitive to pollution while others are not, some are sensitive to certain pollutants more than others. Trained Missouri Stream Team Volunteers have used nets to collect 141 macro samples from Kiefer Creek from 6 different sites. In the map below we can see the general locations of each monitoring site. All of the locations selected are either within, or on the border of Castlewood State Park, where people can easily access perennial reaches of Kiefer Creek. Using a standardized methodology, volunteer monitors select a riffle in the streambed, then the streambed of the riffle is disturbed while a net placed directly downstream is used to collect the macros released by the disturbance. The macros are collected from the net and sorted by species, the number of each species is tallied up. The variety and pollution tolerance of the species collected is used to calculate an overall stream health score. This method of sampling the ecosystem is highly dependent on a wide range of variables. The disturbance of riffles could have a big impact on most of the monitoring sites due to the high number of recreational users in Castlewood State Park. The sampling date, and variation in seasonal and climatic conditions, can impact the prevalence of species only spend a part of their life-cycle in the stream during certain seasons. The expertise, skill and thoroughness of a Stream Team volunteer may vary significantly as well. In some cases, species may be misidentified or monitors may have selected poor sites for monitoring.

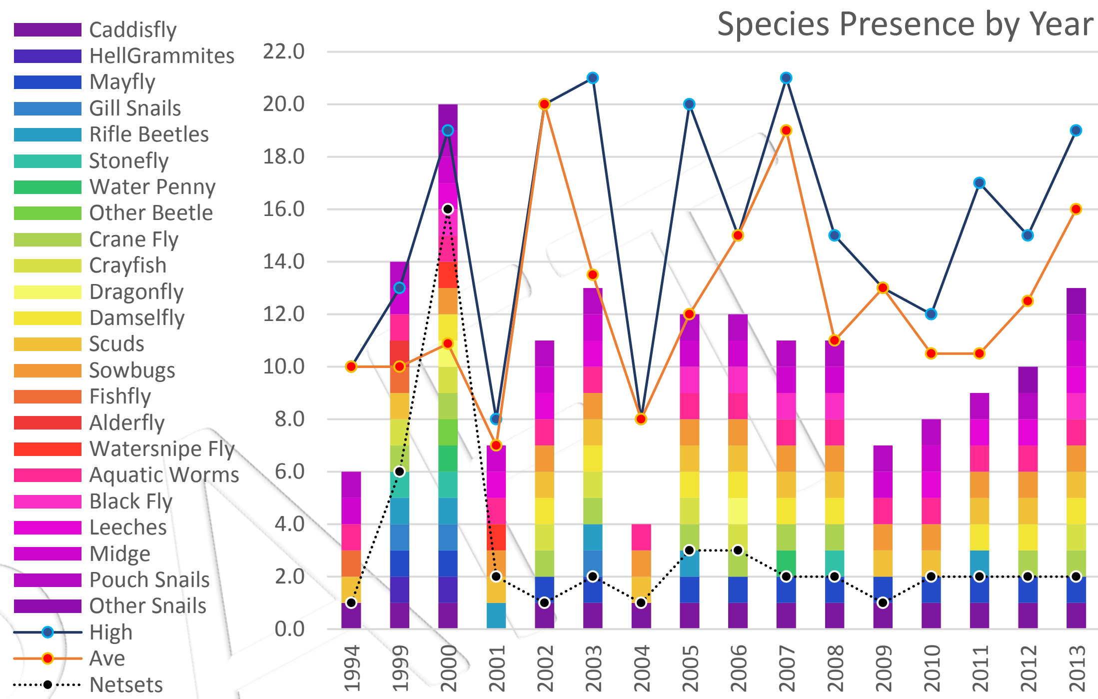
On the map below we have included the stream health score from each monitoring event at each site. Kiefer Creek has an average stream health score of about 12 out of a possible 49, which is on the high end of poor. If we only consider the highest stream health score from each year the average comes to XX With about 15% impervious surface cover in the watershed and a high rate of human disturbance in the streambed in Castlewood State Park, it is not surprising that Kiefer is not host to a more robust aquatic ecosystem.

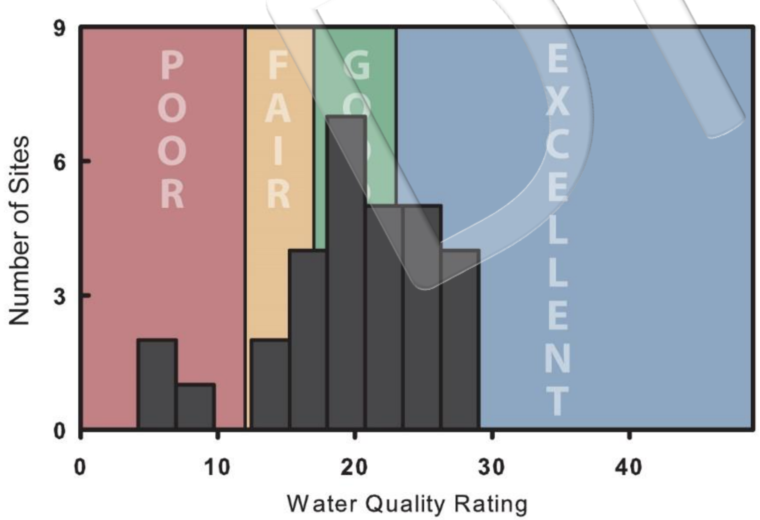
Below is a graph summarizing the results of their macroinvertebrate testing in 6 locations along Kiefer Creek. Plotted along the left y-axis are the average number of species collected per each netset monitoring event, this was calculated by dividing the number of each species collected in all nets in a netset by the number of nets collected, which is typically 3 – however there were four sets with 2 nets collected and one with 6. This graph also includes the averages for each category of tolerance, which was calculated by dividing the number of each species collected in all nets by the number of nets collected then adding up all species averages in each category. This table shows us that there is a downward trend in sensitive species, an upward trend in tolerant species and a steady increase in somewhat tolerant species. One particular species, the scud, is especially prominent in Kiefer Creek, while most other species only show up inconsistently and in small numbers. In the graph to the right It also appears that some monitors used different judgement regarding when to stop counting scuds, with 100 being a popular stopping point. In the graph below we are looking only at the presence of species in the creek. In this table we see that there seems to be a shift towards greater diversity due consistent presence of tolerant and somewhat tolerant species. The range of sensitive species in the stream seems to be declining slightly, with consistent appearances of only caddisflies and mayflies.

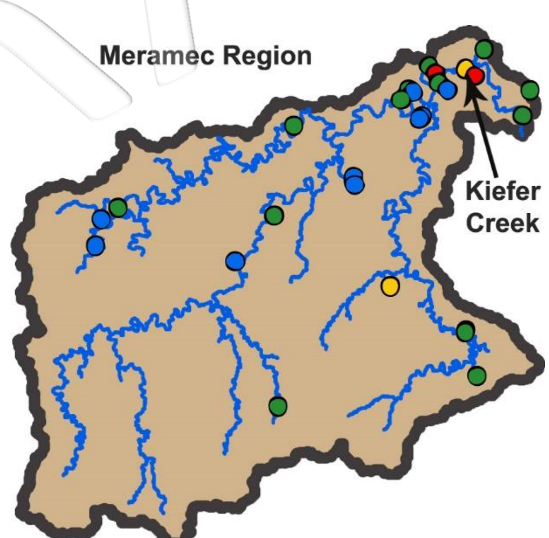




Net sets from 1999 and 2000 depict the highest level of diversity and the highest number of netsets, indication that there is a correlation between the species found each year and the number of net sets completed. A number of sensitive species found in 1999 and 2000 have not been found in the stream since, and the overall trend in diversity shows a stable presence of somewhat tolerant and tolerant species and a decline in sensitive species. On this chart we have also included two water quality ratings, the 'High' rating is the highest water quality rating found each year and the 'Average' is the average of water quality ratings from the netsets collected each year. The Missouri Stream Team Watershed Coalition has mined statewide monitoring data to give insight into the overall condition of our watershed. In their methodology they employ the 'High' method of determining the water quality rating. Below is a table and a map of the Meramec Region from the Missouri Stream Team Watershed Coalition's report on the 'State of Missouri's Streams: Summary of Invertebrate Data 1993 - 2000 .'



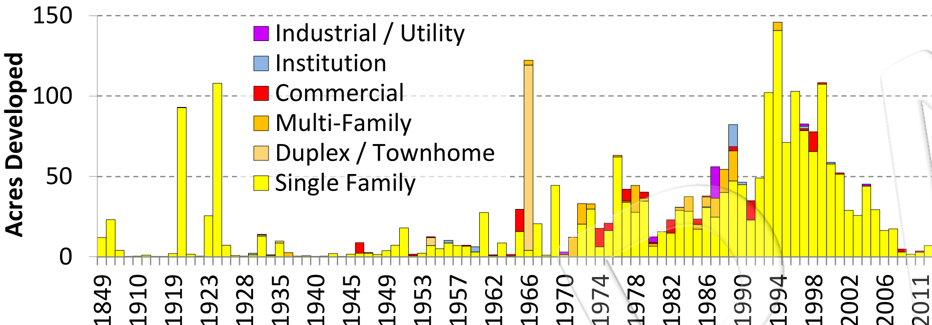


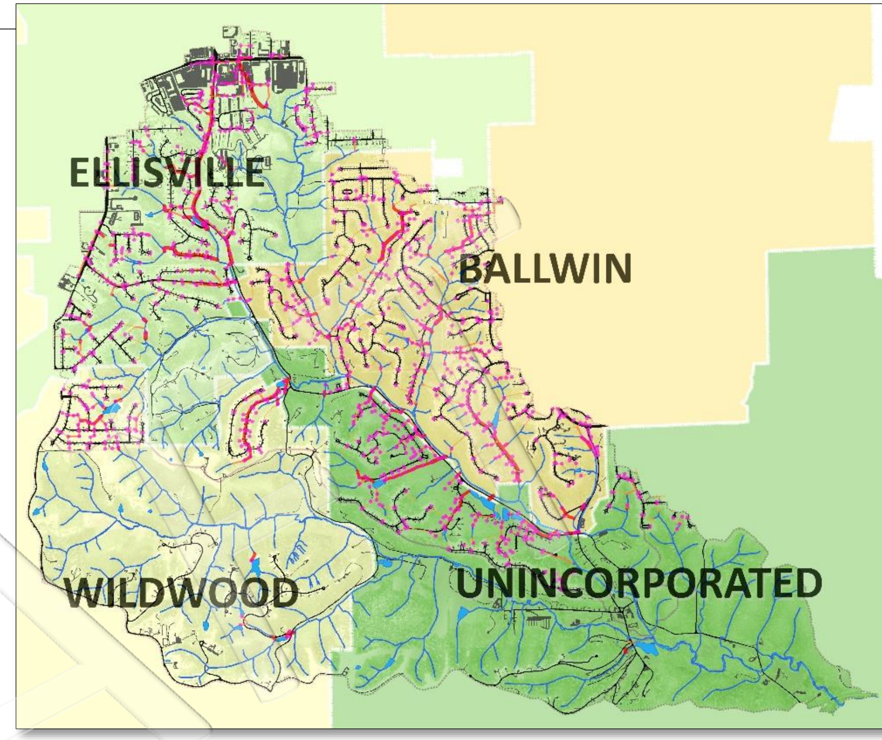


The Missouri Stream Team Watershed Coalition assessment of stream macroinvertebrate monitoring in the Meramec River Region helps us put the condition of Kiefer Creek into relative terms. Right now Kiefer Creek is in 'Fair' condition, while many other tributaries to the Meramec that are just upstream from Kiefer have 'Good' and 'Excellent' water quality ratings. If the chloride impairment in Kiefer Creek can be addressed through BMPs, Kiefer would likely become repopulated with more sensitive organisms from the Meramec and its nearby tributaries.

Chloride Assessment

In the Kiefer Creek Watershed driveways, roads and parking lots are the largest source of chloride in the watershed, comprising 90% of the paved surfaces that receive road salt in response to winter weather. The majority of snow removal and deicing of roads and parking lots in the watershed is managed by local municipalities and contractors, while homeowners are generally in charge of their driveways and sidewalks. We can surmise from the chart below that over time the rate of development has increased in the watershed, driving up the chloride levels and killing off sensitive aquatic species. In the table at the bottom of this page we have broken down the total impervious surfaces by municipality and type to estimate the allocation of chloride loading in terms that will be relevant to the adoption of BMPs.





Impervious Square Feet	WILDWOOD	% of Wildwood Imp.	% of Total NPS Chloride	UNINCORPORATED SLC	% of Uninc. SLC Imp.	% of Total NPS Chloride	ELLISVILLE	% of Ellisville Imp.	% of Total NPS Chloride	BALLWIN	% of Ballwin Imp.	% of Total NPS Chloride	Total	% of Total	% of Watershed	% of NPS Chloride
Main Buildings	1229367	33.0%	---	1771004	32.7%	---	3145319	29.5%	---	3522854	43.6%	---	9668544	36.0%	5.16%	---
Driveway	708220	19.0%	4.4%	1016219	18.8%	6.3%	1120674	10.5%	6.9%	843648	10.4%	5.2%	3688761	13.8%	1.97%	22.72%
Parking	59759	1.6%	0.4%	252081	4.7%	1.6%	2990808	28.0%	18.4%	133612	1.7%	0.8%	3436259	12.8%	1.84%	21.17%
Patio	231536	6.2%	---	254142	4.7%	---	369041	3.5%	---	531136	6.6%	---	1385855	5.2%	0.74%	---
Public Walks	125598	3.4%	0.8%	135841	2.5%	0.8%	388910	3.6%	2.4%	413781	5.1%	2.5%	1064129	4.0%	0.57%	6.55%
Sidewalk	63381	1.7%	0.4%	68945	1.3%	0.4%	146895	1.4%	0.9%	117097	1.4%	0.7%	396318	1.5%	0.21%	2.44%
Out Buildings	36458	1.0%	---	58891	1.1%	---	72498	0.7%	---	36437	0.5%	---	204284	0.8%	0.11%	---
Pool	31379	0.8%	---	23903	0.4%	---	50172	0.5%	---	24784	0.3%	---	130238	0.5%	0.07%	---
Recreation	---	---	---	4961	0.1%	---	54635	0.5%	---	15413	0.2%	---	75009	0.3%	0.04%	---
Bridge	457	0.0%	0.0%	17990	0.3%	0.1%	1547	0.0%	0.0%	9058	0.1%	0.1%	29051	0.1%	0.02%	0.18%
Tank	246	---	---	326	0.0%	---	50	0.0%	---	540	0.0%	---	1162	0.0%	0.00%	---
WaterTower	---	---	---	1064	0.0%	---	---	---	---	---	---	---	1064	0.0%	0.00%	---
Roads-Paved	1180799	31.7%	7.3%	1712143	31.6%	10.5%	2302950	21.6%	14.2%	2424063	30.0%	14.9%	7619955	28.4%	4.07%	46.94%
Roads-Unpaved	53423	1.4%	---	98646	1.8%	---	30371	0.3%	---	6393	0.1%	---	188833	0.7%	0.10%	---
Total Muni. Imp.	3720623			5416154			10673869			8078815			**27889462**	---	---	
% of Total Imp.	13.34%			19.42%			38.27%			28.97%			---	**100%**	---	
% of Watershed	1.99%			2.89%			5.70%			4.32%			---	---	**14.90%**	
Total NPS Chloride Surface	2138213		13.17%	3203218		19.73%	6951783		42.82%	3941258		24.28%	**16234473**	58.2%	**8.67%**	

Road safety is of the utmost importance so it is important to ensure that whatever solutions are implemented do not result in an increased risk to drivers.

Roads and Parking Lots

In the Kiefer Creek Watershed, roads and parking lots are likely the largest source of chloride in the watershed, comprising XX% of the paved surfaces that receive road salt in response to winter weather. Snow removal from roads and parking lots in the watershed is managed by a variety of entities:

Convert to Liquid Brine Solution - Applying a brine solution consisting of 50% water and 50% dissolved rock salt before snowfall, can prevent ice from bonding to road surfaces. When used properly this leads to a reduced need for salt to be applied to the roads, reducing both total salt used and the cost. This practice will also reduce run-off of sodium-chloride into waterways.

Homeowners can reference our website, kiefercreekwatershed.weebly.com, for homemade brine solution recipes and tips.

Milestones

- Municipalities incorporating brine into winter weather strategy
- # of Trucks equipped with brine tanks and applicators
- Lane Miles of brine vs. lane miles of rock salt by weather event

Improve Application Efficiency - **M** - When rock salt is applied, efficient application can help reduce the amount of salt used and thus lower cost. Retrofitting municipal trucks with applicator regulators and not overfilling trucks are cost effective methods for reducing the amount of rock salt applied to roads. Lastly, training salt truck drivers regularly can also help improve application efficiency.

Milestones

- Municipal Road Salt Efficiency Strategies Developed
- # of Road Salt Efficiency BMPs implemented
- *More Plowing, Less Salt* - **M** - Switching to exclusively brine solutions will save municipalities a lot of money which can then be used to fund an increase in plowing frequency, further reducing the need for additional salt applications.

Reduce Salt Usage

Convert to Liquid Brine Solution - **MHB** - Applying a brine solution consisting of 50% water and 50% dissolved rock salt before snowfall can prevent ice from bonding to road surfaces. When used properly this leads to a reduced need for salt to be applied to the roads, reducing both total salt used and the cost. This practice will also reduce run-off of sodium-chloride into waterways.

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Milestones

Municipalities incorporating brine into winter weather strategy

# of Trucks equipped with brine tanks and applicators

Lane Miles of brine vs. lane miles of rock salt by weather event

Improve Application Efficiency - **M** - When rock salt is applied, efficient application can help reduce the amount of salt used and thus lower cost. Retrofitting municipal trucks with applicator regulators and not overfilling trucks are cost effective methods for reducing the amount of rock salt applied to roads. Lastly, training salt truck drivers regularly can also help improve application efficiency.

Milestones

Municipal Road Salt Efficiency Strategies Developed

# of Road Salt Efficiency BMPs implemented

More Plowing, Less Salt - **M** - Switching to exclusively brine solutions will save municipalities a lot of money which can then be used to fund an increase in plowing frequency, further reducing the need for additional salt applications.

Milestones

Increase in lane miles plowed per inch of snow

Beet Juice Additives - **MHB** - When the use of rock salt is necessary, mixing it with beet juice will improve the salt's effectiveness and help it adhere to the road. The beet juice will also lower the operating temperature of the rock salt from -20 degrees centigrade to -35 degree centigrade.

Milestones

Gallons of beet juice used as a salt additive

Measurable decrease in salt usage after implementation of beet juice approach

Reduce Salt Runoff

Salt Storage - **M** - Storing the salt in an enclosed or covered facility can help municipalities and businesses from losing salt in a rain event or with snowmelt runoff. Allowing the salt to be directly exposed to rain can cause large amounts of the salt to be washed away directly into near by water bodies.

Milestones

Tons of salt with improved storage (we haven't located salt piles in the watershed at this point)

Improved Stormwater Infiltration - **MHB** - Any infiltrative stormwater BMP with a driving or walking surface catchment is likely to reduce the amount of salt reaching the stream channel via surface runoff and storm sewers. For natural BMPs it is important to select salt tolerant plants where the BMP is likely to receive a substantial chloride load from snow removal practices such as a large commercial parking lot or a large road surface.

Milestones

Acres of stormwater features installed to collect runoff from paved driving and walking surfaces

% of stormwater features with salt tolerant plant selections

Estimated reduction in direct runoff of chloride

Cleanup and Reuse Excess Rock Salt - **MHB** - Once chloride has been applied to the driving surfaces of a watershed, it will eventuallly run off into the stream. By cleaning up excess road salt and reusing the salt that has already been applied in the watershed, we can reduce the total amount of salt used in the watershed, which is critical to reducing the chloride load that impairs aquatic life in Kiefer Creek. This is applicable to both homeowners and municipalities. Safety should be an important aspect of this procedure as any salt that has accumulated will have done so near a roadway.

Milestones

Estimated pounds/tons of salt collected and reused

Chloride Runoff Recycling - **M** - The chloride runoff from large parking lots is one of the more substantial sources of chloride in the watershed. In theory you could build settling ponds designed to allow trucks with brine systems to refill with the already chloride rich runoff, thereby reusing a portion of the chloride and reducing the total amount applied in the watershed.

Milestones

Gallons of brine collected from stormwater features and reapplied to driving/walking surfaces