Cumulative nutrient and sediment load reduction estimates for street cleaning and other storm water control measures

September 4th, 2018

Project partners: CCRPC, VTDEC, City of South Burlington, and Vermont municipal coalition

UVM

southburlington
VERMONT

VERMONT
Agency of Natural Resources
Department of Environmental Conservation

CHITTENDEN COUNTY RPC
Communities Planning Together

Problem

- Reducing the eutrophication of receiving waters is a top priority

- Vermont municipalities in the Lake Champlain Basin, Lake Memphremagog Basin, and the Connecticut River Basin must meet phosphorus and nitrogen reduction targets as a result of recently completed and pending TMDL and MS4 requirements

Photo: Kathryn Morse

Photo: Bill Harding

Overall Objective

- Provide information to effectively target high phosphorus source areas and achieve load reductions in the most economical manner by enhancing common stormwater control measures

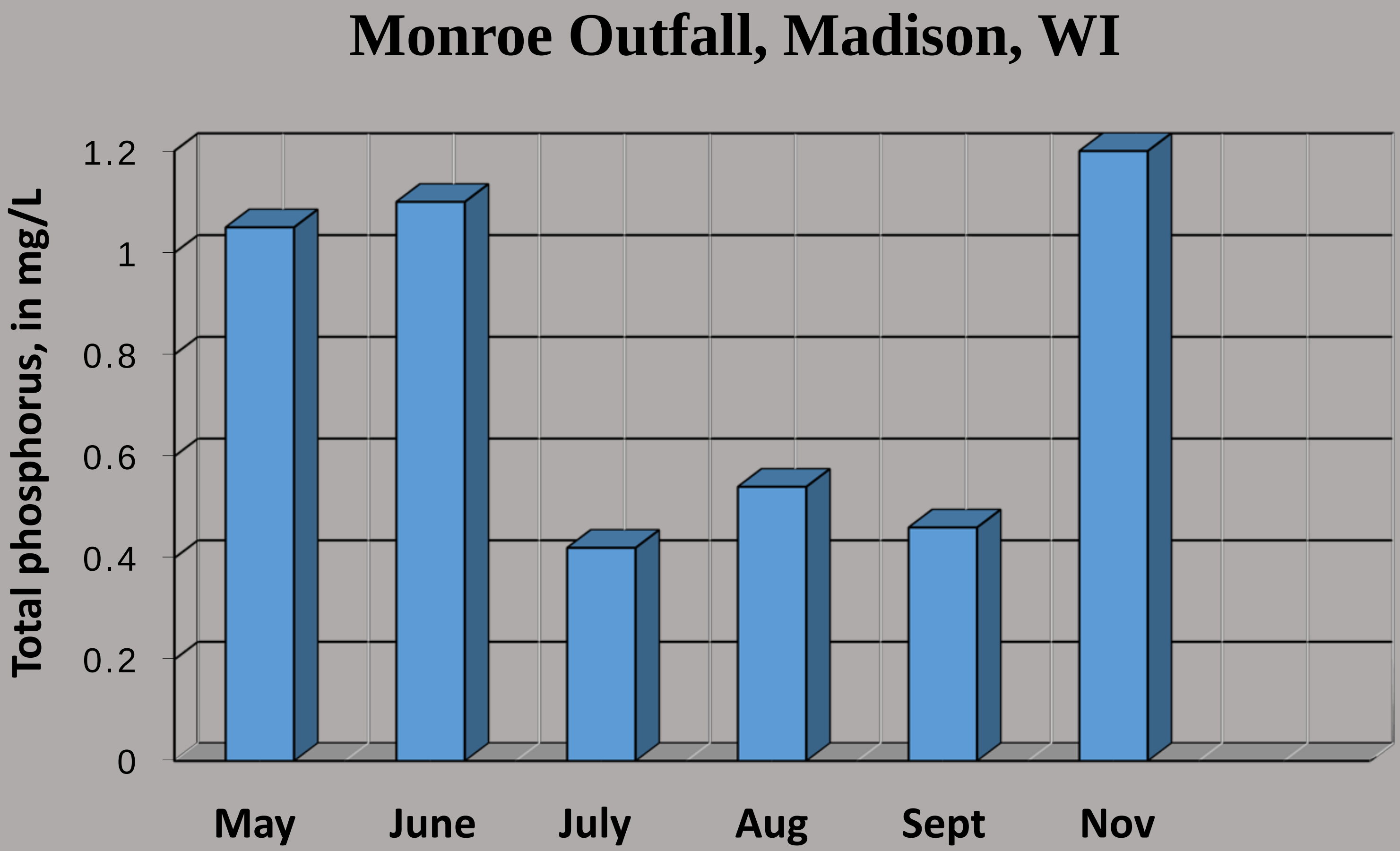
Previous work

- ❖As much as 9% of total leaf phosphorus is leached from leaves in water for 2 hours *(Dorney, 1986)*
- ❖Nearly 60% of annual phosphorus yields come from leaf litter in the fall *(winter excluded)* *(Selbig, 2016)*
- ❖Timely removal of leaf litter can reduce phosphorus concentrations by 80% *(Selbig, 2016)*

Previous work

- Resuspension in catch basins can occur at 25% sump capacity during flows >0.14 ft^3/sec *(Smith, 2002)*
- Estimated increases in winter EMCs of P, Fe, and Mn attributed to highway maintenance sand are about 94%, 38%, and 53%, respectively *(Smith, 2009)*
- Mobilization of soils onto surfaces subject to washoff can cause large increases in constituent concentrations

Previous work- Seasonal change in phosphorus



Waschbusch, R.J., Selbig, W.R., and Bannerman, R.T., 1999, Sources of phosphorus in stormwater and street dirt from two urban residential basins in Madison, Wisconsin, 1994–95: U.S. Geological Survey Water-Resources Investigations Report 99–4021, 47 p.

Previous work- Estimate of the Amount of Phosphorus Leached from Leaves in the Pilot Area During the Fall of 2015-Bannerman and Selbig, 2016

TABLE 1

Leachable P, total P and % of total P leachable (and standard deviation) from urban street tree leaves and seeds

Species name: Common name	Scientific name	Leachable P µg gm^{-1}	Total P %	% of total P leachable	Number of samples: Leachable P	Number of samples: Total P
Leaves						
Sugar Maple	Acer saccharum Marsh.	259.9(113.1)	0.20(0.032)	13.43(6.2)	6	3
Silver Maple	Acer saccharinum L.	232.7(117.6)	0.13(0.040)	17.7(6.3)	3	3
Green Ash	Fraxinus pensylvanica Fern.	188.4(75.1)	0.24(0.049)	7.0(0.43)	7	2
Honey Locust	Gleditsia tricanthos L.	176.0(101.1)	0.44(0.117)	4.5(2.3)	8	5
White Ash	Fraxinus americana L.	161.9(137.9)	0.14(0.042)	9.6(0.04)	4	2
American Elm	Ulmus americana L.	158.5(66.8)	n.d.[b]	n.d.	2	0
Basswood	Tilia americana L.	95.7(32.1)	0.15(0.045)	7.8(2.1)	5	3
Chinese Elm	Ulmus pumila L.	88.6(36.1)	n.d.	n.d.	2	0
Little Leaf Linden	Tilia cordata L.	86.5(22.5)	0.09 (n.d.)	6.7(n.d.)	3	1
Pin Oak	Quercus palustris Muenchh.	81.5(29.3)	n.d.	n.d.	2	0
Norway Maple	Acer platanoides L.	80.1(53.9)	0.08(0.035)	8.4(3.63)	5	2
Hessian Ash	Fraxinus excelsior L.	66.1(40.0)	n.d.	n.d.	3	0
Weeping Willow	Salix babylonica L.	38.1(1.1)	n.d.	n.d.	2	0
All Leaves		148.1(99.4)	0.22(0.147)	9.3(5.4)	52	21
LSD[a]		38.8	0.06	3.4		
Seeds						
Green Ash	Fraxinus pensylvania Fern.	77.6(n.d.)	0.26(n.d.)	3.0(n.d.)	1	1
Sugar Maple	Acer saccharum Marsh.	40.8(12.5)	0.35(n.d.)	1.4(n.d.)	2	1
Little Leaf Linden	Tilia cordata L.	39.2(11.6)	0.26(n.d.)	1.8(n.d.)	2	1
All Seeds		47.5(18.9)	0.29(0.052)	2.1(0.8)	5	3

[a] Least significant difference ($P \le 0.05$).
[b] n.d. = not determined.

Dorney, 1986

Used published values to estimate leachable P in leaves

Average = 167 µg/g   167 µg/g x 453.6 g/lb = 76,000 µg

Or

0.076 grams of P per lb of leaves

Leachable P normalized by curb length in g/ft

$$leaves\,\frac{\mathbf{lb}}{\mathbf{ft}} \times 0.076\,\frac{\mathbf{g}}{\mathbf{lb}} = P\,\frac{\mathbf{g}}{\mathbf{ft}}$$

Previous work- Preliminary credit using leaf surveys

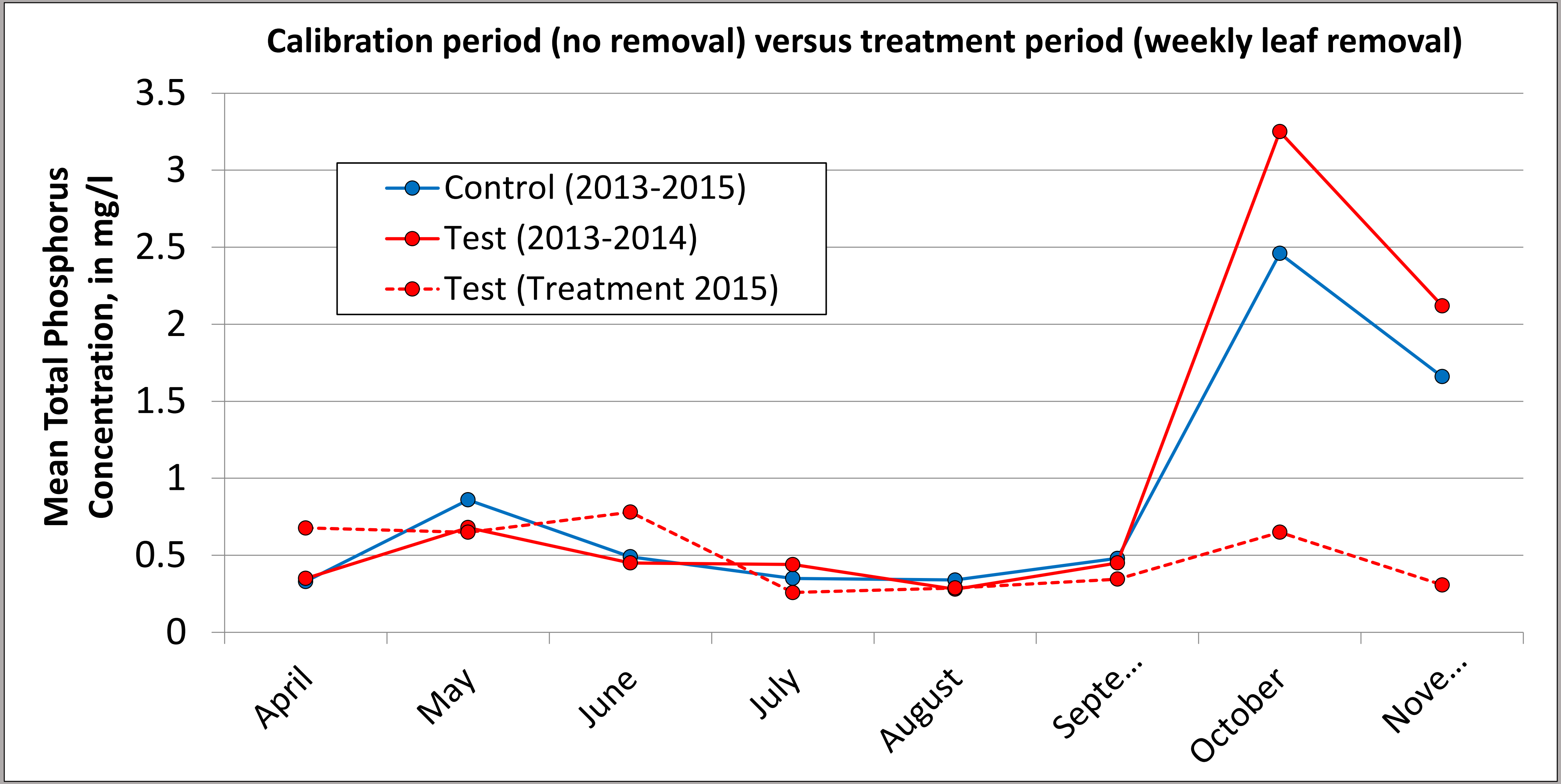
Estimate weight of leaves in front of each house

Calibration of survey system

1. Survey test and control to measure benefit of leaf management
2. Determine leachable P by comparing weight of leaves in curb to P load in runoff
3. Determine accumulation rate of leaves in street

Bannerman and Selbig, 2016 in conjunction with: *Selbig,W.R., 2016, Evaluation of leaf removal as a means to reduce nutrient concentrations and loads to urban stormwater, Science of the Total Environment, vol 571, 124-133 p.*

Previous work- Paired basin study in WI



Selbig,W.R., 2016, Evaluation of leaf removal as a means to reduce nutrient concentrations and loads to urban stormwater, Science of the Total Environment, vol 571, 124-133 p.

What was learned from the Madison paired site projects?

No leaf control

Leaves on terrace but no cleaning - Baseline

Selbig, 2016

2015

Some leaf control

Leaves on terrace, transfer & street clean ~3-4x

40 Percent Total P Reduction

2016

No leaves

Leaves on terrace, weekly cleaning + Pickup + Pre rain removal

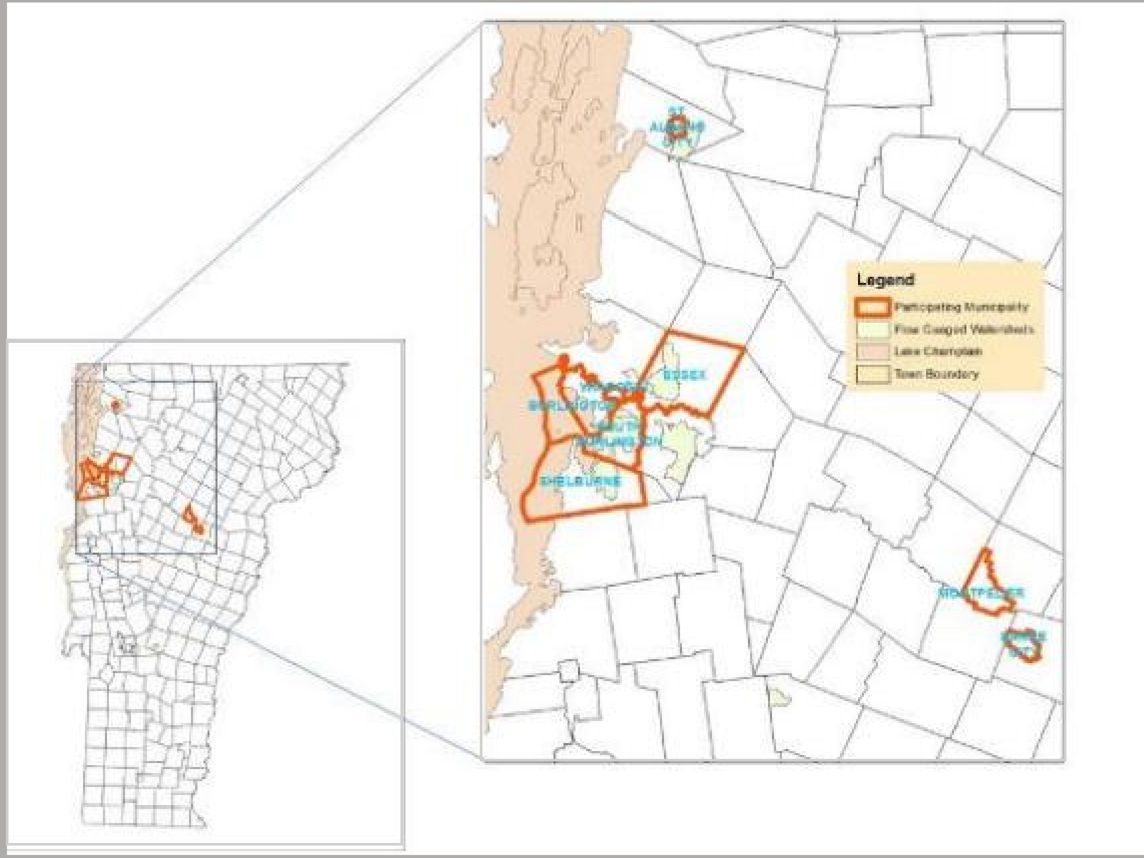
84 Percent Total P Reduction

Project Tasks

1. Create database of existing information: (i) physical and chemical data of municipal solids; (ii) current municipal SCMs and their operation and maintenance schedules; (iii) Geographic Information System (GIS) coverages of land-use types within the study area; and (iv) continuous records of precipitation, streamflow and water-quality.
2. Collect monthly samples of municipal solids from each SCM to create seasonal composite samples (as available).
3. *Conduct tree-cover analysis in Chittenden, Franklin, and Washington Counties (UVM-SAL).*
4. Source Loading and Management Model (SLAMM) of an urban subcatchment that best represents targeted land-use, tree cover, SCMs and SCM frequencies.
5. Document the methods, data, and findings in a peer-reviewed format.

Task 1

1. Working with towns to obtain existing information:
    - S.Burlington: SC metals
    - S.Burlington and Essex: CB organics (EPA 8260B)
    - SWAT model input and loading rates
2. Distributed operational questionnaire
3. GIS data available from each town
4. Tree cover analysis: UVM-SAL
5. USGS Englesby Brook flow and WQ data
    - Medalie (2007)



Task 2

- Characterize average physical and chemical properties of municipal solids in selected locations of Vermont

Monthly samples from 9 different municipal sources based on monthly/annual availability:

1. street cleaner hopper solids,
2. catch basin solids, and
3. leaf-litter programs

Techniques based on ASTM D 6009, ASTM D 4687, U.S.EPA SOP# 2017, and U.S.EPA 530-D-02-002

Task 2-Collection of samples

Barre, VT-September 2017 street cleaning pile

Montpelier, VT- October 2017 street cleaning pile

Task 2-Analytes

- Submit samples for analysis of total organic carbon, total Kjeldahl nitrogen, and total phosphorus.

Analyte	Method	Reporting level	Unit
Total organic carbon	EPA 415.1	0.5	mg/kg
Total Kjeldahl nitrogen	EPA 351.2	0.5	mg/kg
Total Phosphorus	SM_4500-P-F	0.1	mg/kg

This includes at least 10 percent quality assurance samples such as blanks and replicates.

Task 2-Processing of samples

1. Homogenize materials
2. Subsample for seasonal composites
3. Subsample for grain-size analysis
4. Process composite samples for lab analysis
5. Wet-sieve seasonal composite materials into four grain size fractions
6. Submit samples to USGS contract lab (RTI)
7. Graded silica sand blank material
8. Split and concurrent replicates

Task 2-Homogenizing samples

Task 2-Grain Size Fractions for Seasonal Composite Samples

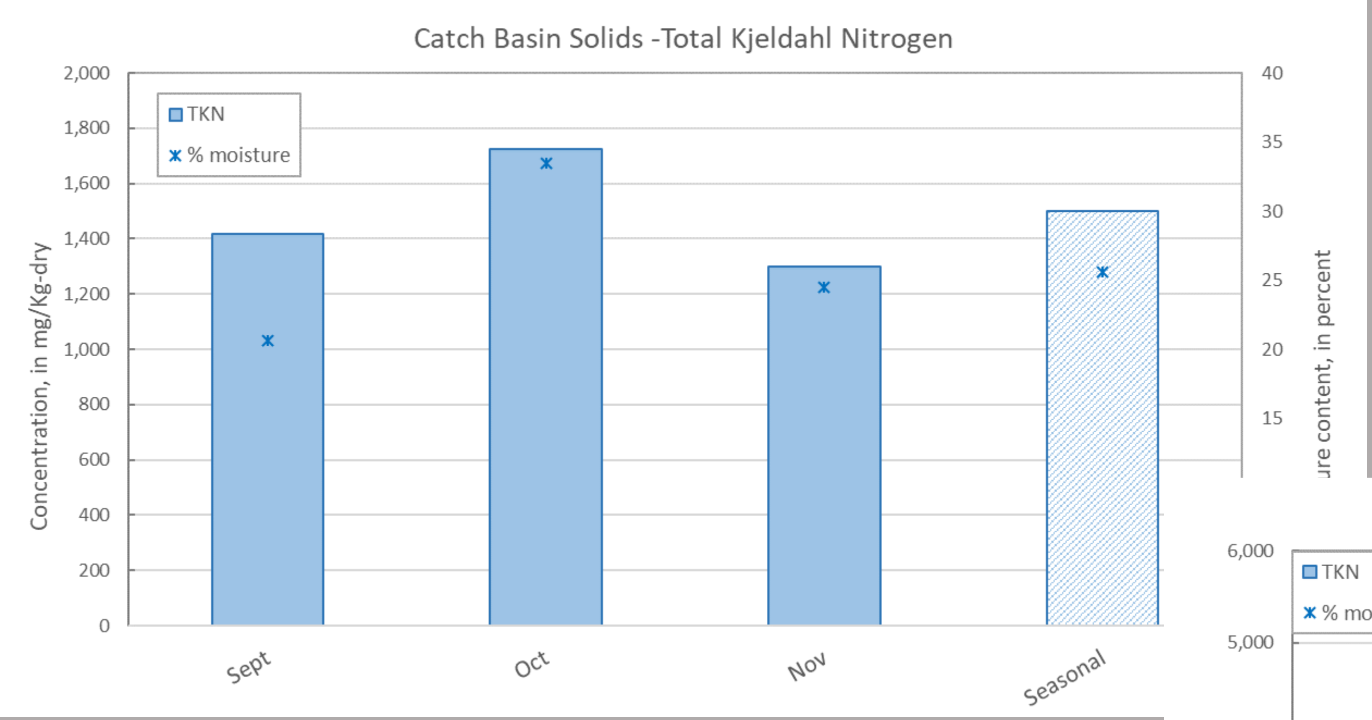
1. ≥ 2 mm
2. < 2 mm to ≥ 0.125 mm
3. < 0.125 mm to ≥ 0.063 mm
4. < 0.063 mm

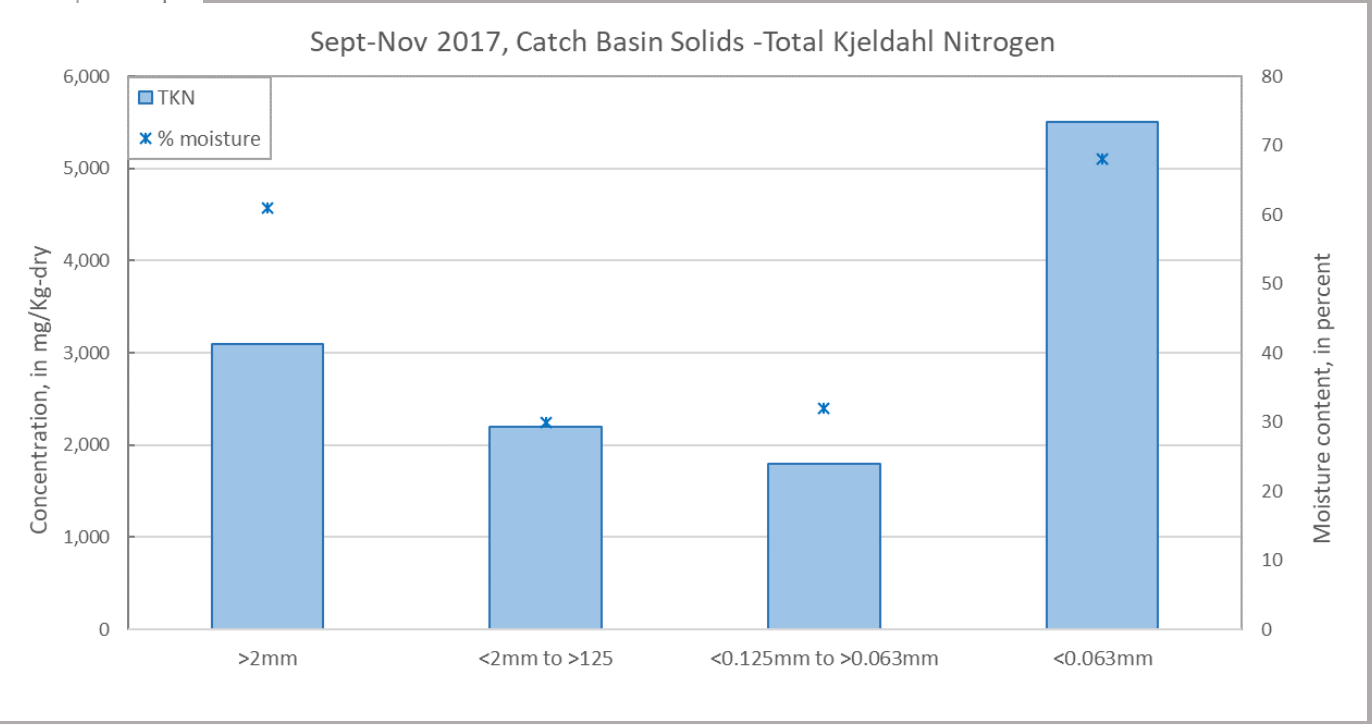
Raw sample

≥2mm

≥0.125 mm

Task 2-Preminary Sample Results-Catch Basins





Provisional data-subject to change

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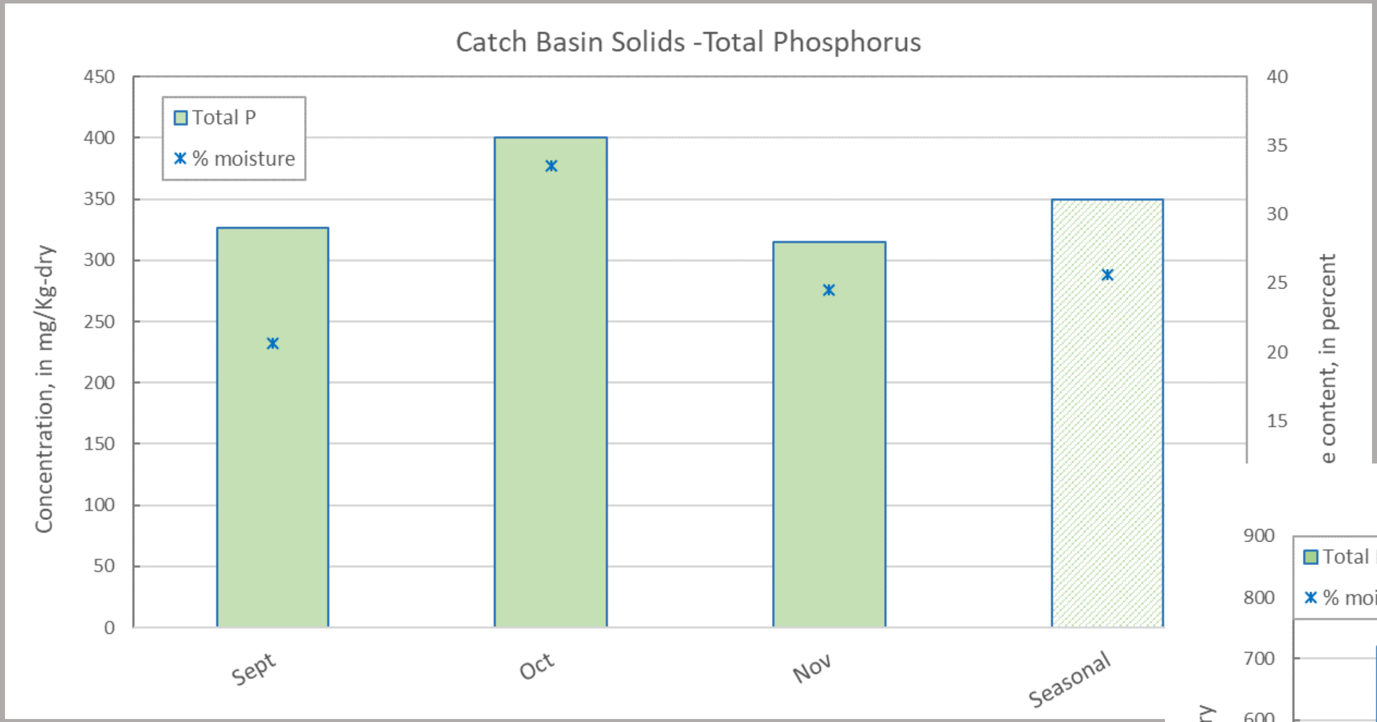

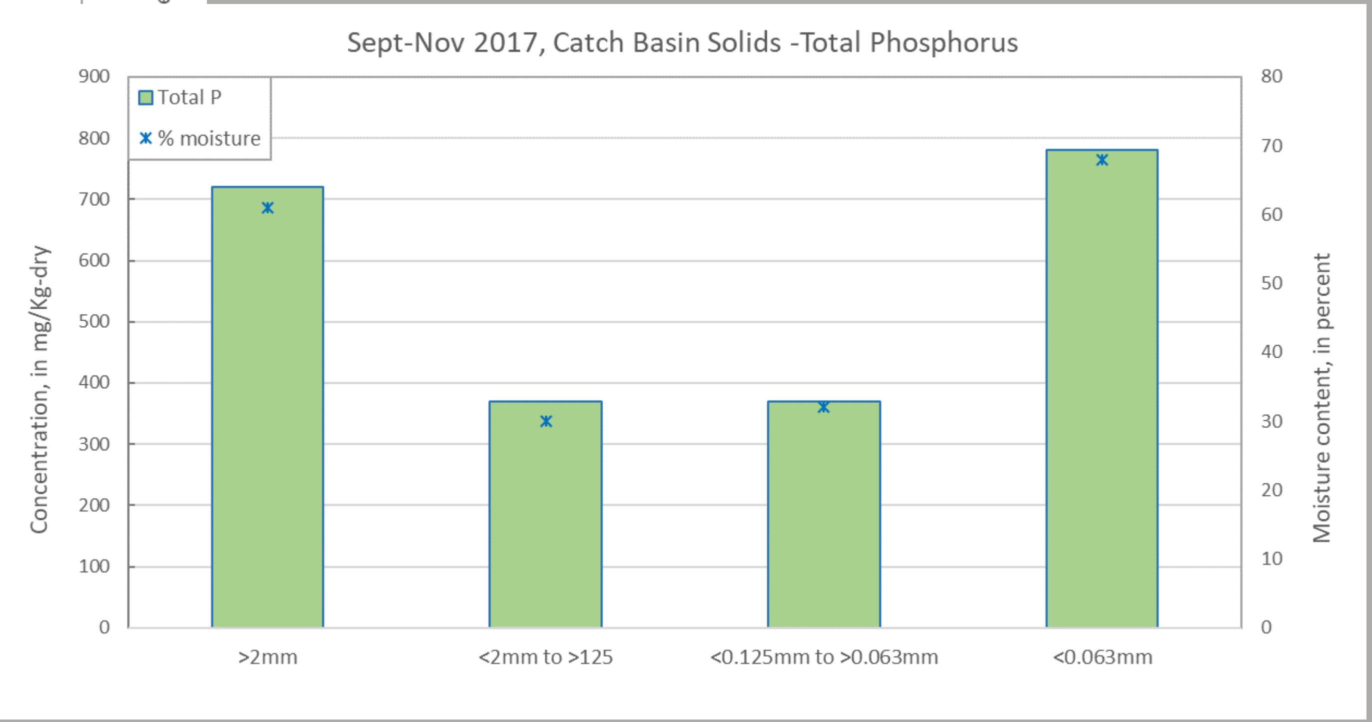

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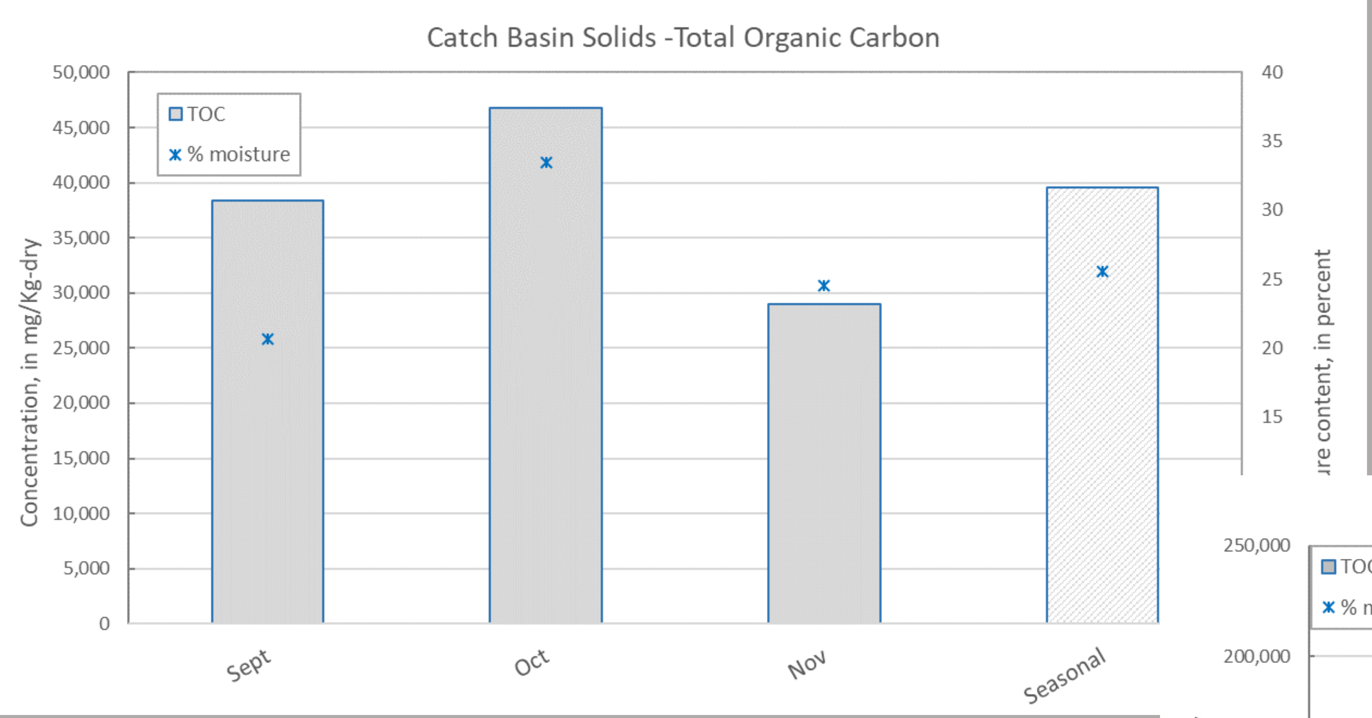

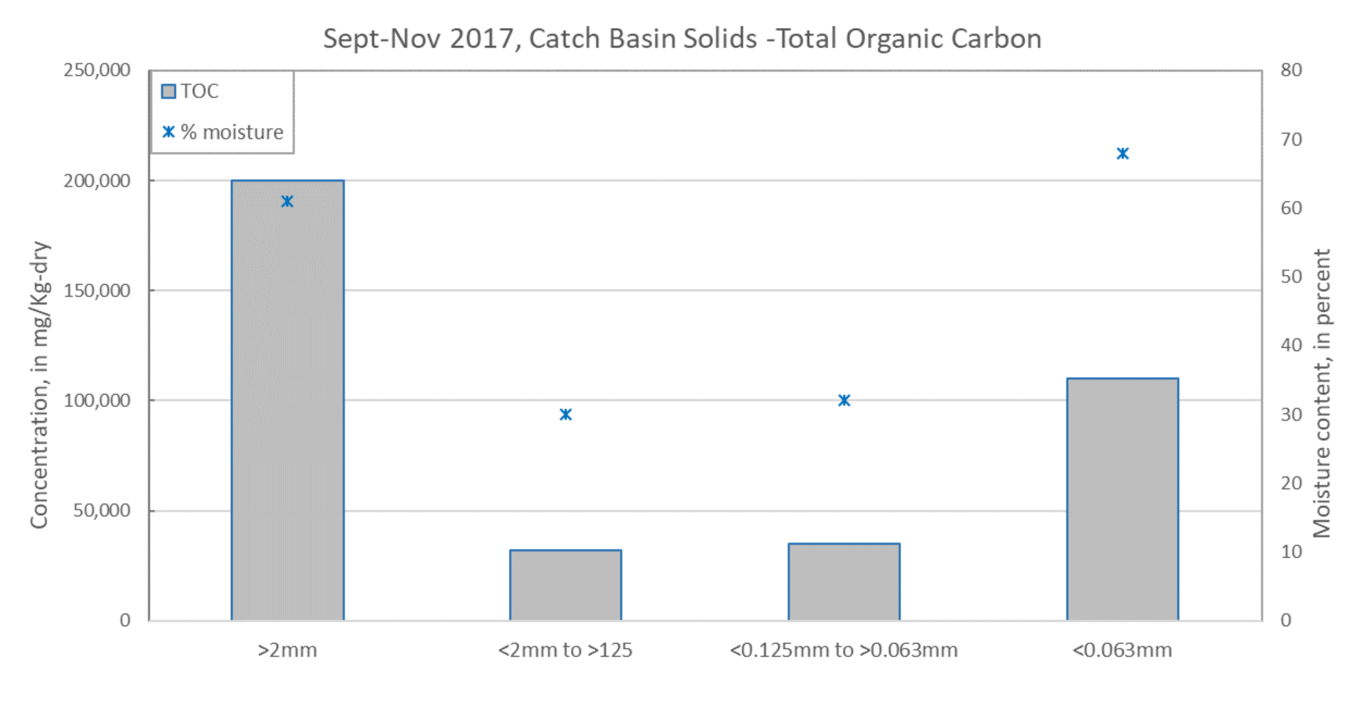

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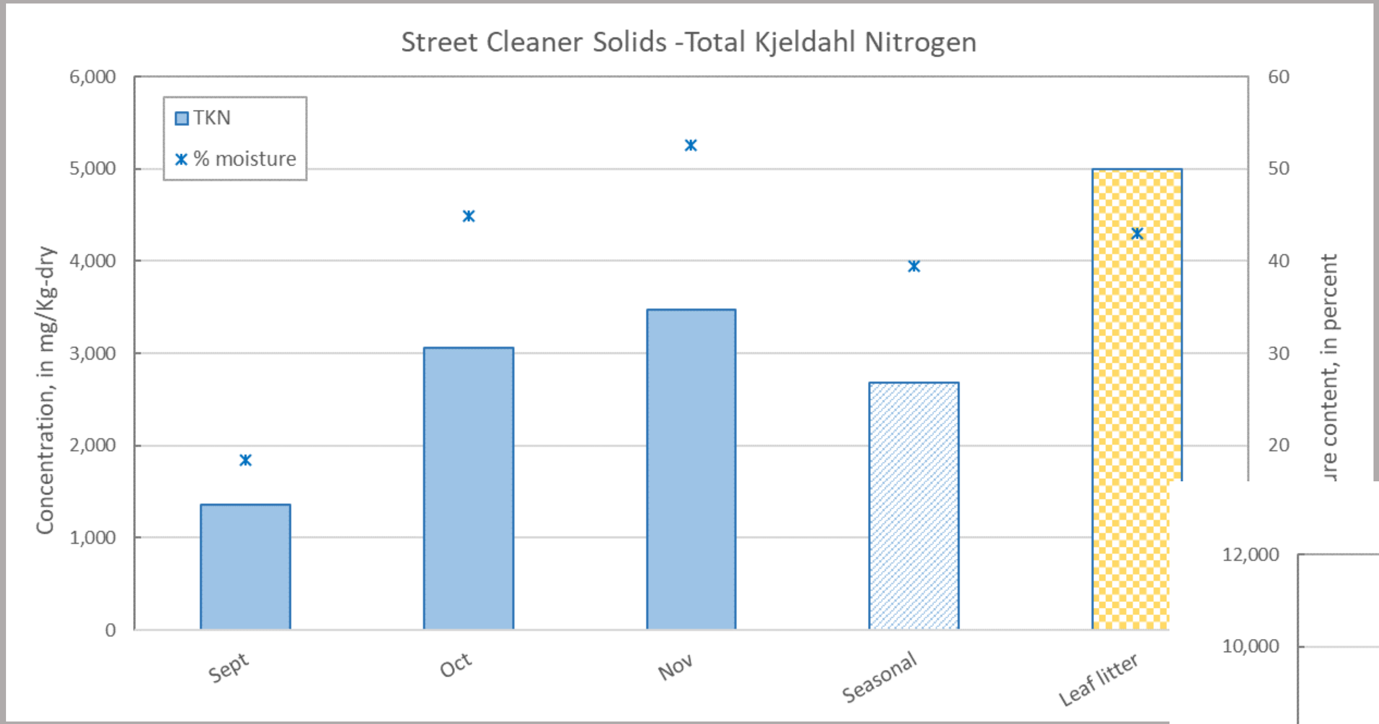
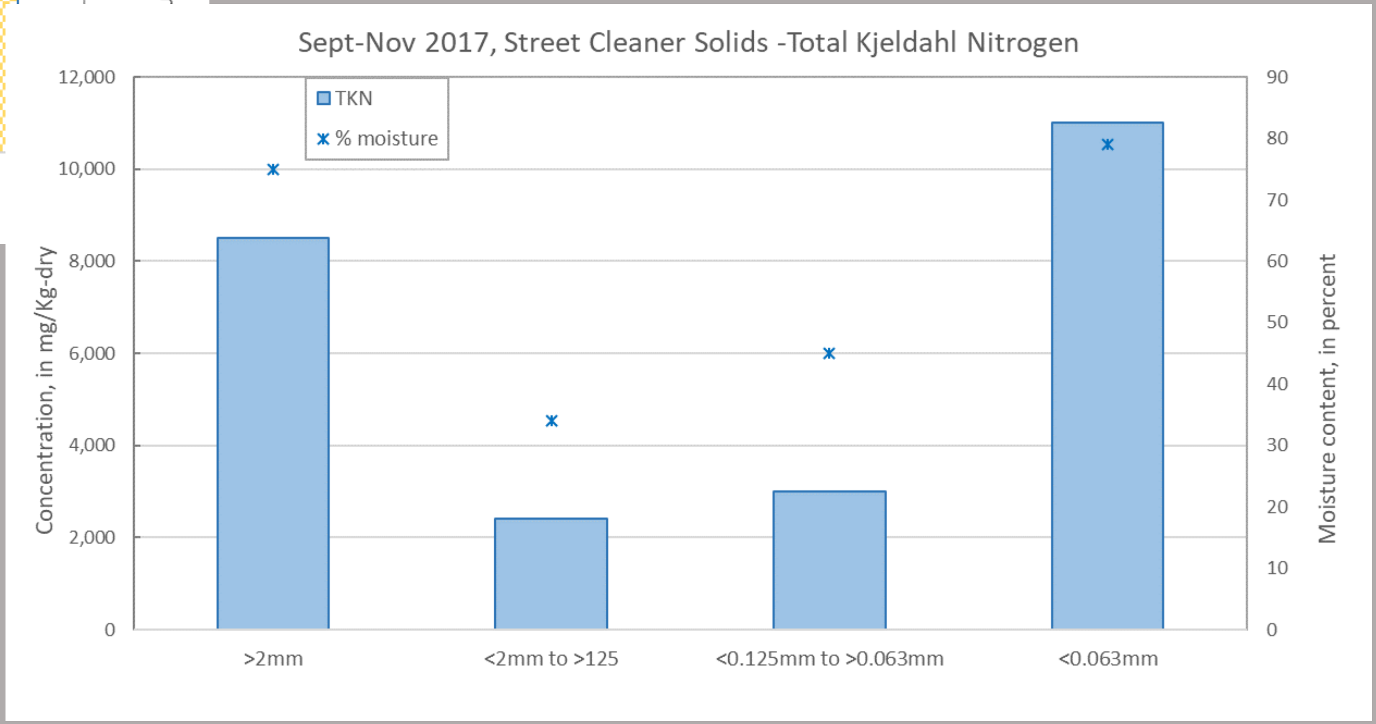
Task 2-Preminary Sample Results-Street Cleaning





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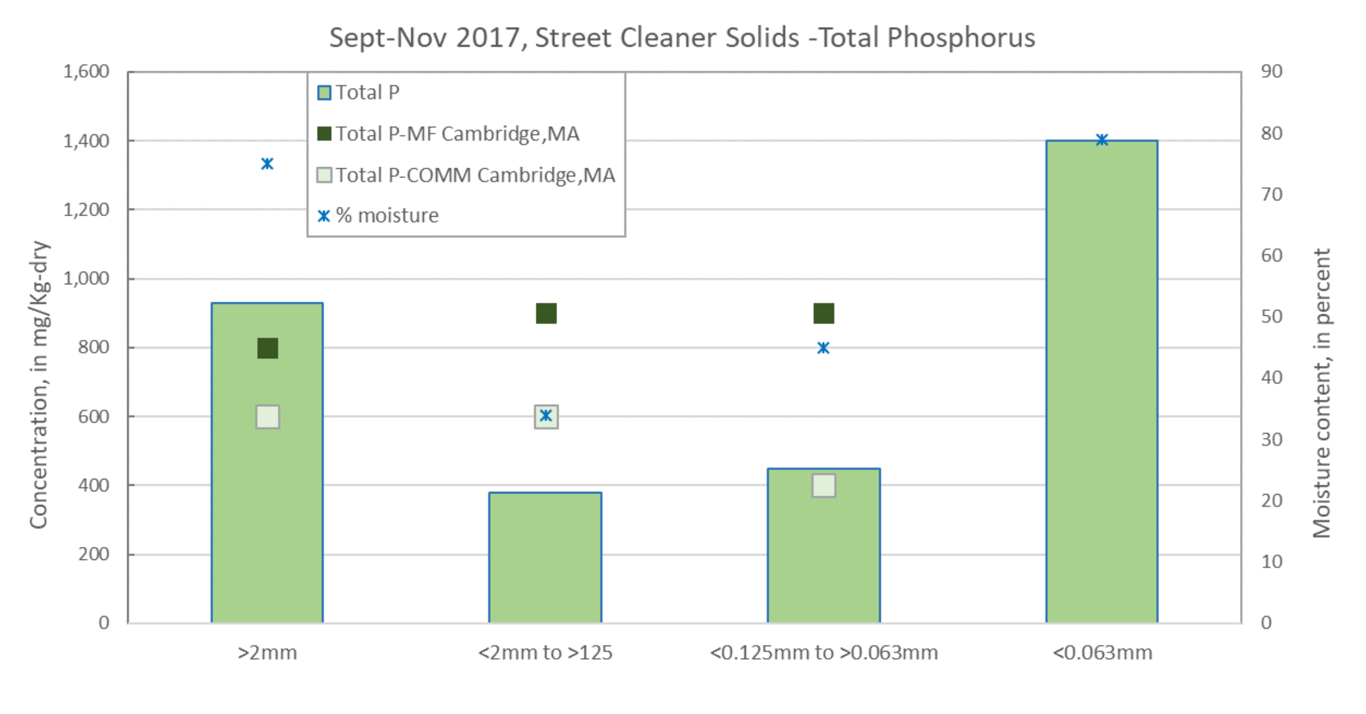
Task 2-Preminary Sample Results-Street Cleaning

Multifamily and Commercial street solid data from Sorenson, 2012
https://pubs.usgs.gov/sir/2012/5292/



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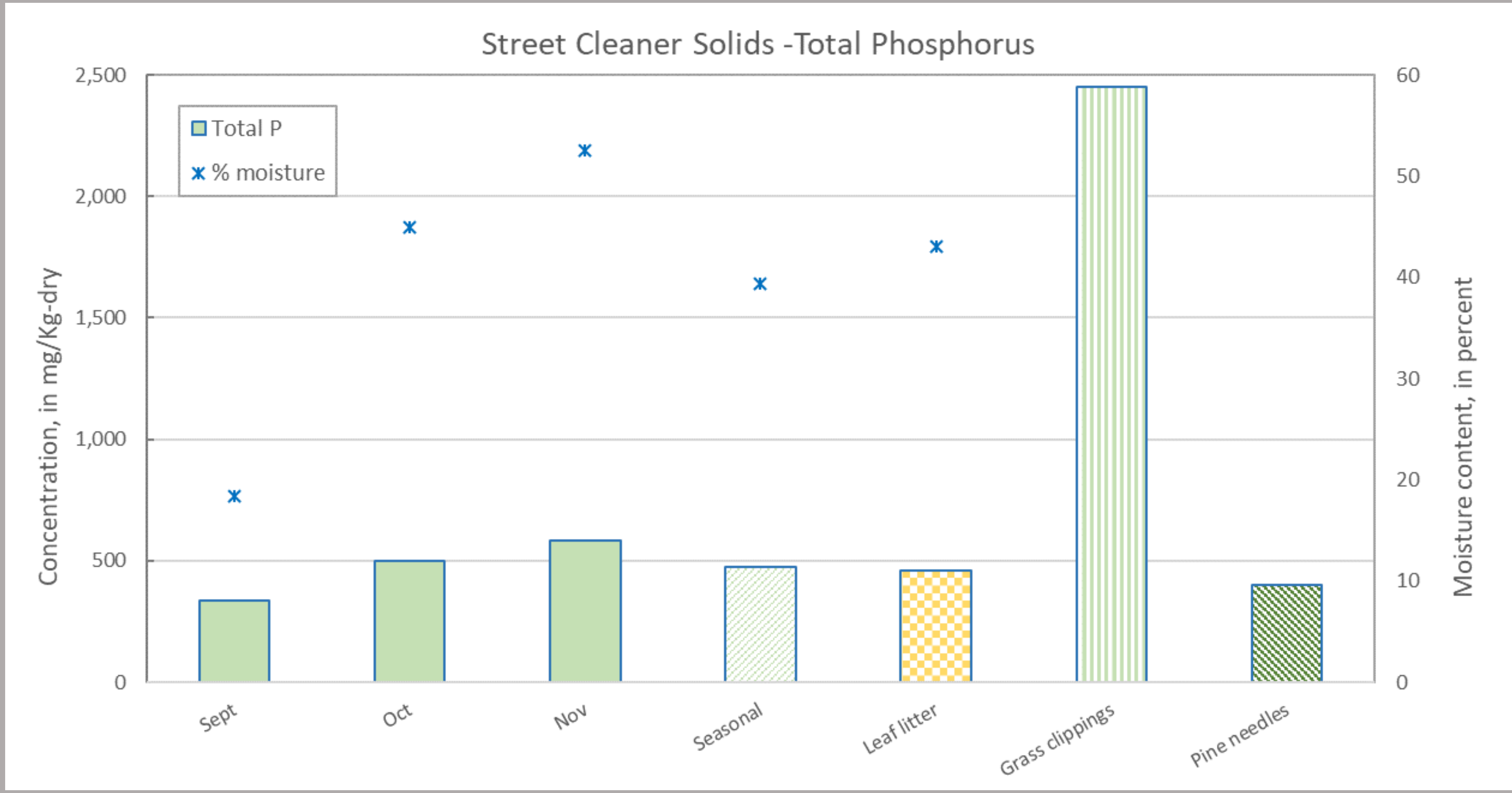

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Grass clippings and pine needles data from Smith, 2009
https://pubs.usgs.gov/sir/2009/5269/

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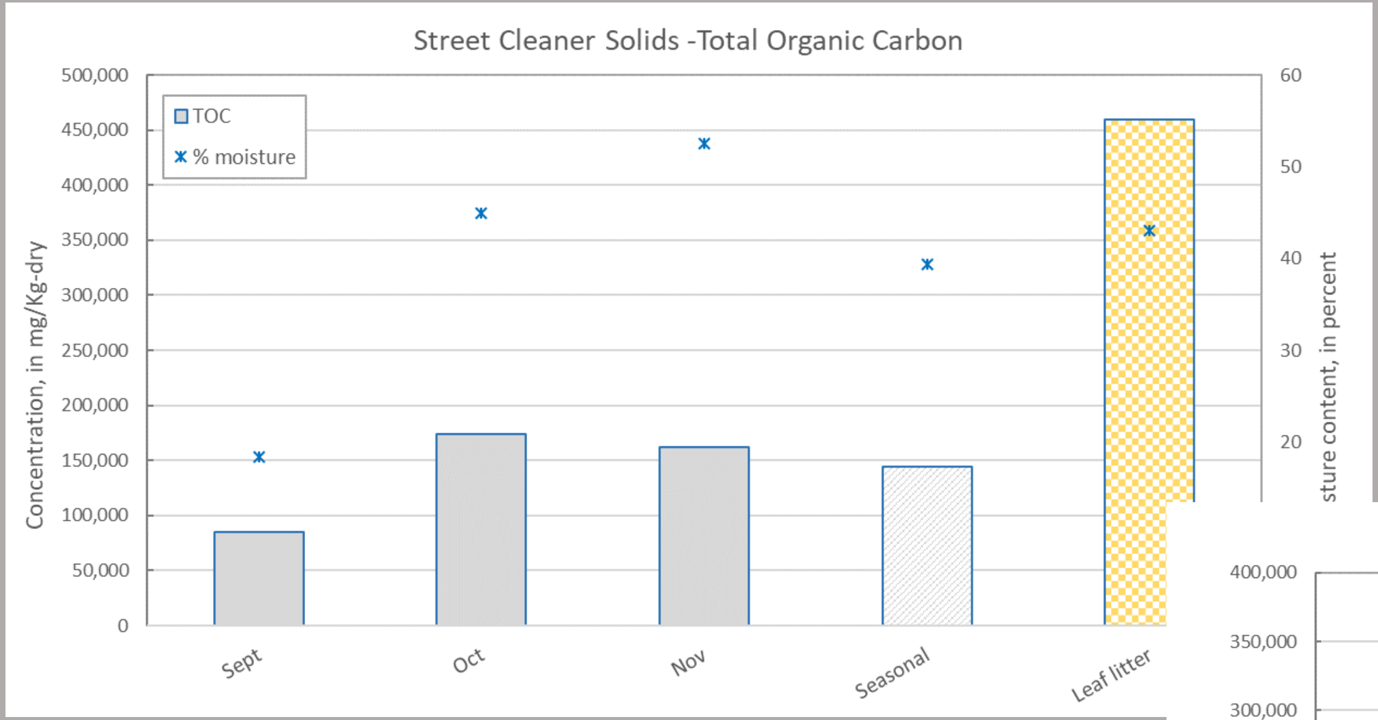

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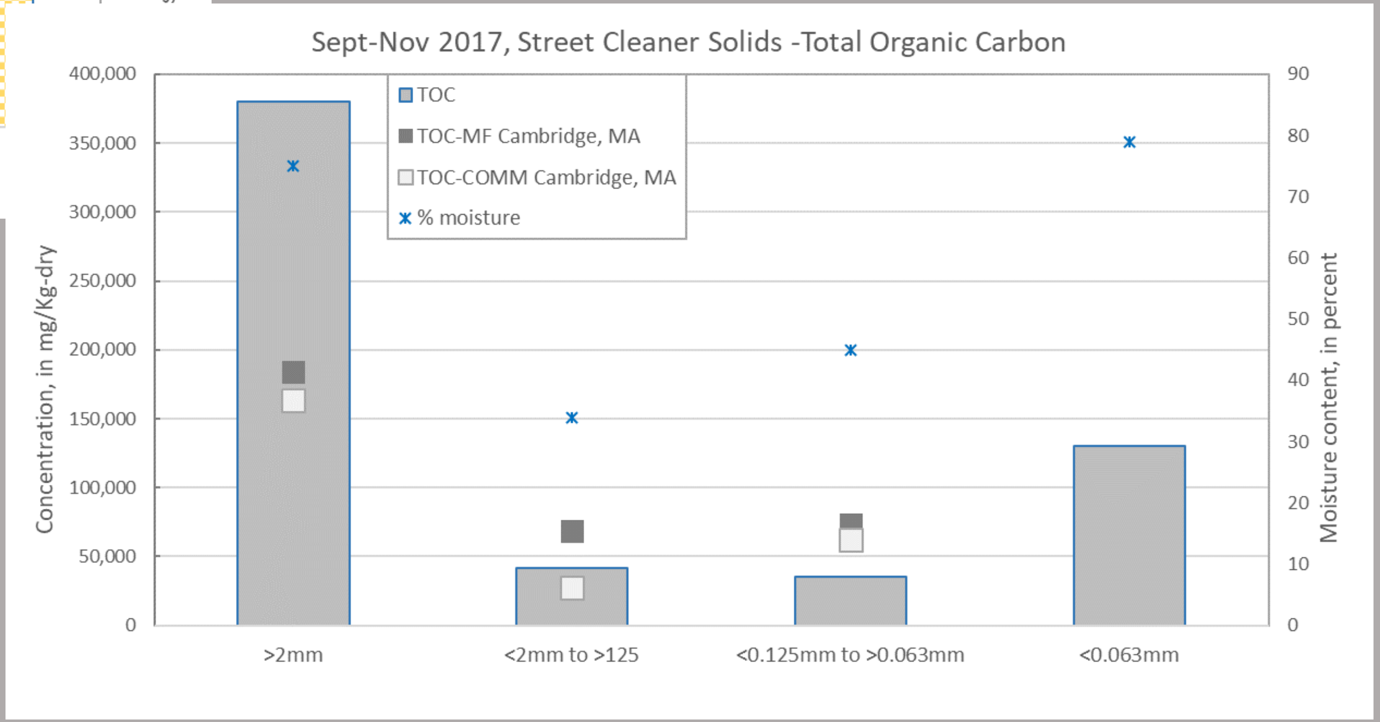

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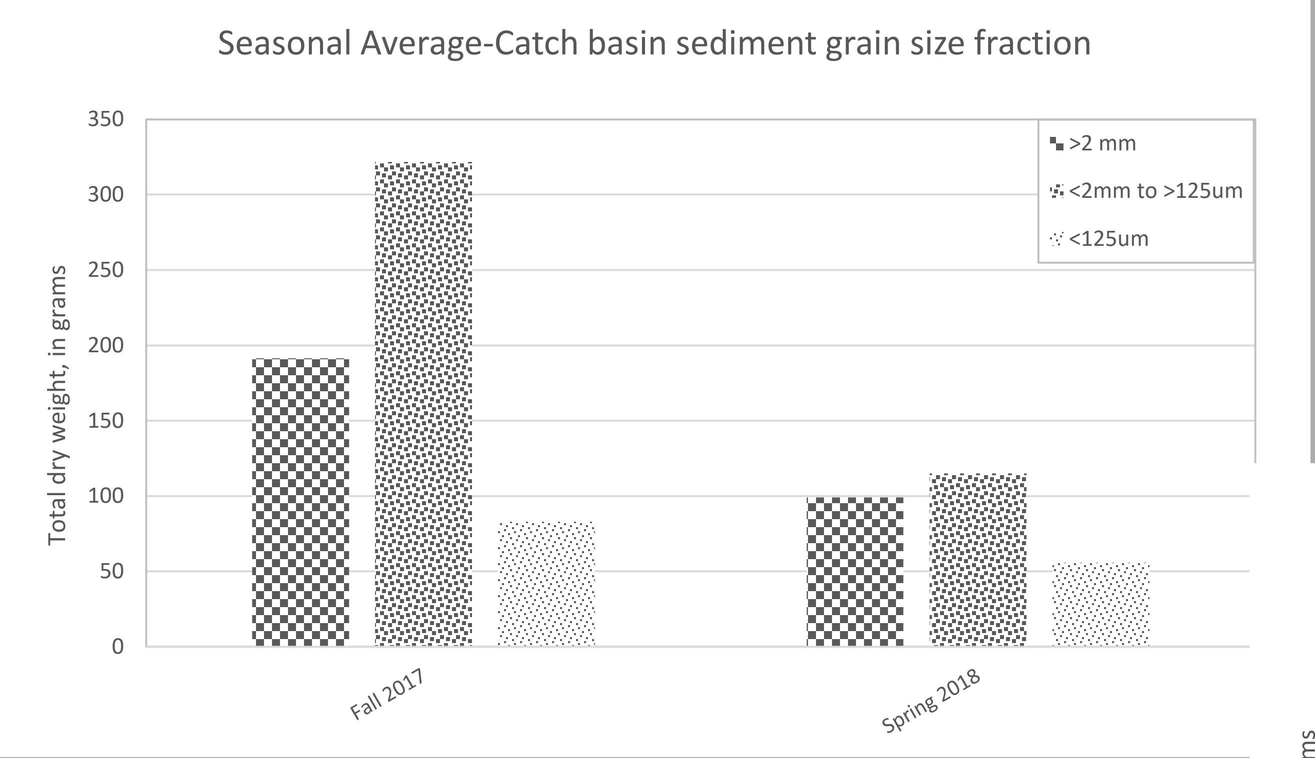
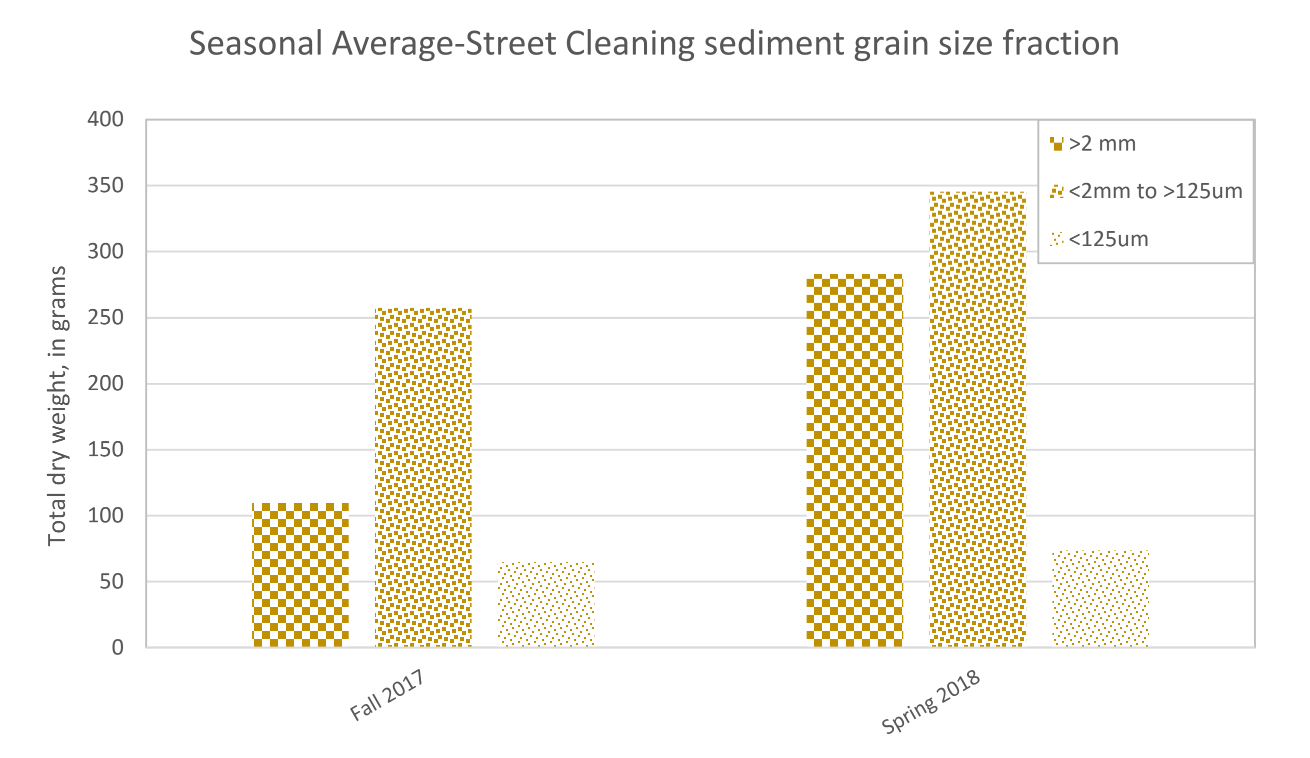
Task 2-Preminary Sample Results





Provisional data-subject to change

Task 3-Street Tree Buffer Analysis in Selected Towns in Chittenden, Franklin and Washington County

1. UVM developed: a tree canopy coverage raster dataset for the study area
2. Tree canopy height model
3. An estimate of Tree canopy volume
4. An analysis of #1-3 within the road buffer area extending from the center line of the road out 20 feet.
5. Tree canopy density within buffered area

Interim Load Reduction Credits-UVM and VTDEC

- Compiled by the UVM NSC202 Analysis and Assessment Project with Dr. Clay Williams and Jim Pease (DEC). GIS analysis by Hank Ainley (DEC).
- Draft street sweeping credits for participating MS4s in the USGS study who are currently or would be willing to increase sweeping frequency and manage fall leaf drop cleanup according to the Wisconsin Interim Municipal Phosphorus Reduction Credit for Leaf Management
- Tables show what credit(s) a municipality could get based on current sweeping catch basin cleaning practices, and if a town were to increase sweeping in Medium Density Residential zoning districts
- Need to decide on what amount of this credit is allowable during the TMDL monitoring period of 2000-2010. These numbers are provisional, and will be rerun and quality assured before considered final

Catch Basin-Interim Load Reduction Credit

MS4	SWAT Drainage Area	Assumed Current Catchbasin Cleaning Frequency	Current P Load Credit (kg/yr)	Total Phosphorus Load from Paved Roads (kg/yr)	SWAT Segment Reduction Target (%)	SWAT Target Load Reduction (kg/yr)	Current CB Cleaning Credit % of Target	Max P Load Credit (kg/yr) Assuming cleaning is 2x/year	Max Credit % of Target. Assuming cleaning is 2x/year	Approximate Year Current Practice Implemented	Current Cleaning Credit % of Target Prorated (-10%/yr) to TMDL Monitoring Period (2000-2009)
Burlington	Burlington Bay - DD	1 every 5 years	0.295	147.70	24.2	35.74	0.83	2.95	8.26	2009	0.7
Burlington	LaPlatte River	1 every 5 years	0.017	8.27	20.2	1.67	0.99	0.17	9.88		0.9
Burlington	Main Lake - DD	1 every 5 years	0.008	4.11	20.2	0.83	0.99	0.08	9.90		0.9
Burlington	Winooski River	1 every 5 years	0.199	99.59	20.2	20.12	0.99	1.99	9.90		0.9
Essex	Lamoille River	1 every 4 years	0.029	18.63	20.5	3.82	0.76	0.23	6.06	2008	0.6
Essex	Malletts Bay - DD	1 every 4 years	0.055	32.39	20.5	6.64	0.82	0.55	8.21		0.7
Essex	Winooski River	1 every 4 years	0.254	131.31	20.2	26.52	0.96	2.54	9.56		0.8
Essex Junction	Malletts Bay - DD	1 every 2 years	0.188	37.65	20.5	7.72	2.44	0.75	9.76	2008	2.0
Essex Junction	Winooski River	1 every 2 years	0.380	76.03	20.2	15.36	2.48	1.52	9.90		2.0
Shelburne	LaPlatte River	1 every 5 years	0.110	131.71	20.2	26.60	0.41	1.10	4.15	2008	0.3
Shelburne	Main Lake - DD	1 every 5 years	0.001	5.97	20.2	1.20	0.09	0.01	0.89		0.1
South Burlington	Burlington Bay - DD	1 every 5 years	0.009	4.72	24.2	1.14	0.77	0.09	7.69	2008	0.6
South Burlington	LaPlatte River	1 every 5 years	0.342	190.99	20.2	38.58	0.89	3.42	8.87		0.7
South Burlington	Winooski River	1 every 5 years	0.182	108.31	20.2	21.88	0.83	1.82	8.34		0.7
St. Albans	St. Albans Bay - DD	1 every year	0.678	95.79	21.7	20.79	3.26	1.36	6.52	2000	0.0
Winooski	Winooski River	1 every 4 years	0.199	79.61	20.2	16.08	1.24	1.59	9.90	2008	1.0

Provisional data-subject to change

Street Cleaning-Interim Load Reduction Credit-

MS4	SWAT Drainage Area	Mech P Load reduced (kg/yr)	Current Vacuum P Load Credit (kg/yr)	Current Regenerative Air P Load Credit (kg/yr)	Total Phosphorus Load from Paved Roads (kg/yr)	SWAT Target Load Reduction (kg/yr)	Current Vacuum Credit % of Target	Current Regenerative Air Credit % of Target	Approximate Year Current Practice Implemented	Current Sweeping Credit Prorated (-10%/yr) to TMDL Monitoring Period (2000-2009)
Burlington	Burlington Bay - DD	9.6846	16.11		147.70	33.74	45.1		2008	36.1
Burlington	LaPlatte River	0.4023	0.68		8.27	1.67	40.7			32.6
Burlington	Main Lake - DD	0.0445	0.09		4.11	0.83	10.7			8.6
Burlington	Winooski River	4.6333	6.49		99.59	20.12	32.3			25.8
Essex	Lamoille River		0.27		18.63	3.82	7.1		2003	2.1
Essex	Malletts Bay - DD		0.38		32.39	6.64	5.7			1.7
Essex	Winooski River		1.89		131.31	26.52	7.1			2.1
Essex Junction	Malletts Bay - DD		0.53		37.65	7.72	6.8		2000/2013	3.4
Essex Junction	Winooski River		0.79		76.03	15.36	5.2			2.6
Shelburne	LaPlatte River		0.70		131.71	26.60	2.6		2016	2.4
Shelburne	Main Lake - DD		0.00		5.97	1.20	0.0			0.0
South Burlington	Burlington Bay - DD		0.04		4.72	1.14	3.5		2006/2008	2.5
South Burlington	LaPlatte River		2.06		190.99	38.58	5.3			3.7
South Burlington	Winooski River		1.13		108.31	21.88	5.2			3.6
St. Albans	St. Albans Bay - DD		2.51		95.79	20.79	12.1		2017	12.1
Winooski	Winooski River			5.086	79.61	16.08		31.6	2006	19.0
			*Burlington uses a broom sweeper occasionally when primary sweeper is broken. This column may need to be adjusted down to account for the percent time vacuum sweeper is not operating.							

Provisional data-subject to change

Load Reduction Credit Using WISC. Method

MS4	SWAT Drainage Area	Acres of Roadway in Residential Areas Eligible for Wisconsin Credit	SWAT Target Load Reduction (kg/yr)	Current Sweeping Practice Meets Wisconsin P Load Credit (kg/yr)*	% of Target Met Currently	If Wisconsin Sweeping Practices Fully Implemented in Eligible Residential Areas - P Load Credit (kg/yr)	If Wisconsin Sweeping Practices Implemented - % of Target Met
Burlington	Burlington Bay DD -	57.80	35.74	2.24	6.3	13.45	37.6
Burlington	LaPlatte River	0.88	1.67	0.10	5.8	0.14	8.5
Burlington	Main Lake - DD	2.22	0.83	0.00	0.0	0.35	42.6
Burlington	Winooski River	29.30	20.12	0.15	0.8	5.57	27.7
Essex	Lamoille River	0.00	3.82	0.00	0.0	0.00	0.0
Essex	Malletts Bay - DD	0.19	6.64	0.00	0.0	2.85	6.7
Essex	Winooski River	71.29	26.52	0.00	0.0	13.54	51.1
Essex Junction	Malletts Bay - DD	6.26	7.72	0.28	3.6	0.88	11.4
Essex Junction	Winooski River	31.77	15.36	0.00	0.0	6.03	39.3
Shelburne	LaPlatte River	36.98	26.60	0.00	0.0	7.94	29.8
Shelburne	Main Lake	0.00	1.21	0.00	0.0	0.00	0.0
South Burlington	Burlington Bay - DD	1.50	1.14	0.00	0.0	0.35	30.6
South Burlington	LaPlatte River	58.60	38.58	0.00	0.0	9.49	24.6
South Burlington	Winooski River	21.90	21.88	0.00	0.0	4.15	19.0
St. Albans	St. Albans Bay - DD	22.12	20.79	0.00	0.0	4.66	22.4
Winooski	Winooski River	17.88	16.08	0.52	3.2	8.02	49.8

*This column shows the current credit only based on the required street sweeping frequency (criteria #5 below). The Wisconsin credit requires all of the following practices be adopted:

Provisional data-subject to change

Load Reduction Credit Using WISC. Method

MS4	SWAT Drainage Area	Acres of Roadway in Residential Areas Eligible for Wisconsin Credit	SWAT Target Load Reduction (kg/yr)	Current Sweeping Practice Meets Wisconsin P Load Credit (kg/yr)*	% of Target Met Currently	If Wisconsin Sweeping Practices Fully Implemented in Eligible Residential Areas - P Load Credit (kg/yr)	If Wisconsin Sweeping Practices Implemented - % of Target Met
Burlington	Burlington Bay DD -	57.80	35.74	2.24	6.3	13.45	37.6
Burlington	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5
Burlington							42.6
Burlington							27.7
Essex							0.0
Essex							6.7
Essex							51.1
Essex Junction							11.4
Essex Junction							39.3
Shelburne							29.8
Shelburne							0.0
South Burlington							30.6
South Burlington							24.6
South Burlington							19.0
St. Albans							22.4
Winooski							49.8

*This [illegible]

(1) Credit applies only to Medium Density (2-6 units/acre) Residential (Single-family) land use without alleys. Medium Density Residential with alleys land use may be included if the alleys receive the same level of leaf collection and street cleaning as the streets.

(2) Curb and gutter with storm sewer drainage systems.

(3) A tree cover defined as an average of one or more mature trees between the sidewalk and the curb for every 80 linear feet of curb. Where sidewalk is not present, trees within 10 feet of the curb may be counted toward tree cover. Generally, this equates to a tree canopy over the street of 17% or greater. Field investigations or aerial photography may be used to document the tree cover.

(4) The municipality has an ordinance prohibiting residents from placement of leaves. in the street and a policy stating that residents may place leaves on the terrace in bags or piles for collection.

(5) Municipal leaf collection provided at least 4 times spaced throughout the months of October and November. Leaves may be pushed, vacuumed, or manually loaded into a garbage vehicles. No leaf piles are left in the street overnight.

(6) Within 24 hours of leaf collection, remaining leaf litter in the street must be collected using street cleaning machines, such as a mechanical broom or vacuum assisted street cleaner. A brush attachment on a skid steer is not an acceptable equivalent.

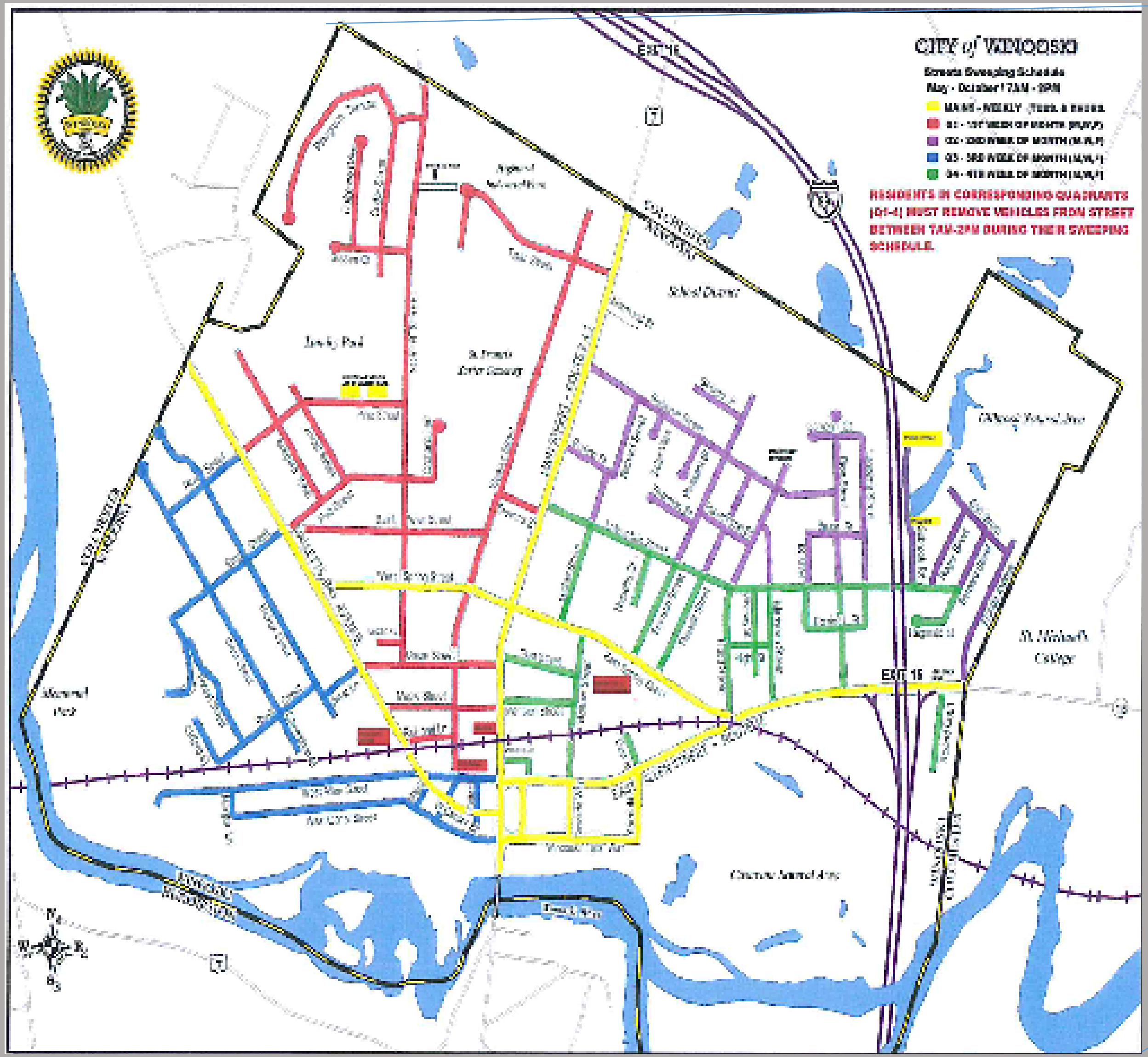
Provisional data-subject to change

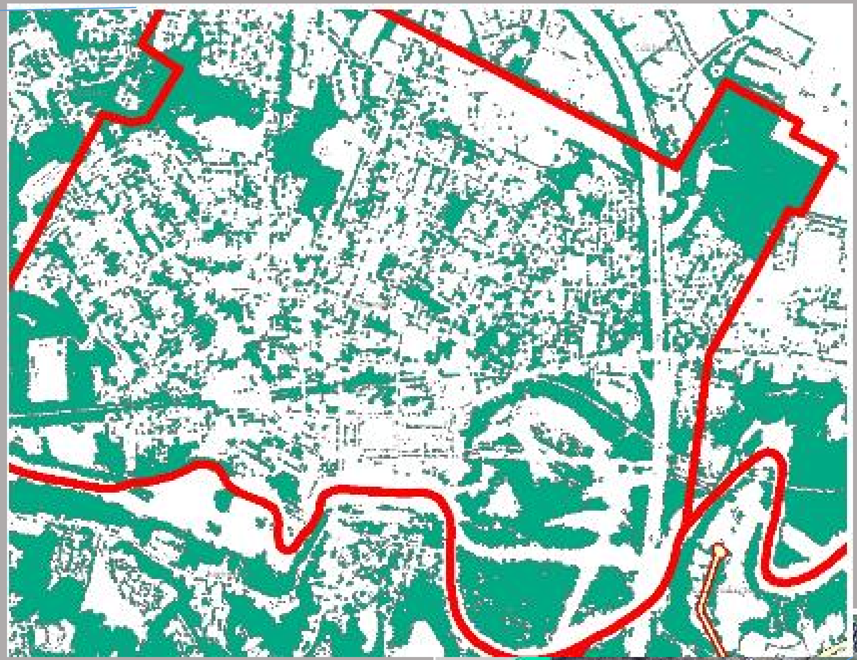
Summary of Current Credits

MS4	SWAT Drainage Area	SWAT Target Load Reduction (kg/yr)	Current CB Cleaning Credit % of Target Prorated (-10%/yr) to TMDL Monitoring Period (2000-2009)	Current Sweeping Credit % of Target Prorated (-10%/yr) to TMDL Monitoring Period (2000-2009)	Sum of Current Prorated Credits as % of SWAT Load Target	If Wisconsin Sweeping Practices Implemented in Medium Density Residential Areas - % of Target Met (NOT ADDITIVE TO YELLOW COLUMN EXISTING CREDIT MUST BE REMOVED)	High Potential for P Leaf Removal Credit
Burlington	Burlington Bay - DD	35.74	0.74	36.1	36.8	37.6	YES
Burlington	LaPlatte River	1.67	0.89	32.6	33.5	8.5	NO
Burlington	Main Lake - DD	0.83	0.89	8.6	9.5	42.6	YES
Burlington	Winooski River	20.12	0.89	25.8	26.7	27.7	YES
Essex	Lamoille River	3.82	0.61	2.1	2.7	0.0	NO
Essex	Malletts Bay - DD	6.64	0.66	1.7	2.4	6.7	NO
Essex	Winooski River	26.52	0.76	2.1	2.9	51.1	YES
Essex Junction	Malletts Bay - DD	7.72	1.95	3.4	5.4	11.4	NO
Essex Junction	Winooski River	15.36	1.98	2.6	4.6	39.3	YES
Shelburne	LaPlatte River	26.60	0.33	2.4	2.7	29.8	YES
Shelburne	Main Lake	1.21	0.07	0.0	0.1	0.0	NO
South Burlington	Burlington Bay - DD	1.14	0.61	2.5	3.1	30.6	YES
South Burlington	LaPlatte River	38.58	0.71	3.7	4.4	24.6	YES
South Burlington	Winooski River	21.88	0.67	3.6	4.3	19.0	YES
St. Albans	St. Albans Bay - DD	20.79	0.00	10.9	10.9	22.4	YES
Winooski	Winooski River	16.08	0.99	19.0	20.0	49.8	YES

Provisional data-subject to change

Tree Cover and Current Street Cleaning Routes





Madison Area Municipal Stormwater Partnership (MAMSWaP) Community outreach website:

http://www.ripple-effects.com/Leaf-free-Streets

1. Keep your leaves out of the street.
2. Read the helpful tips on this flyer.
3. Post the sign on the opposite side to show your love for our lakes.

SPRING

- ☐ If you don't already have one, set up a compost bin.
- ☐ Install a rain barrel or two.
- ☐ Only apply fertlizer if a soil test shows you need it and only after Memorial Day.
- ☐ If you use pre-emergent weed control, use one without fertilizer.
- ☐ Use finished leaf compost on your gardens and flower beds.

SUMMER

- ☐ Appreciate that keeping leaves out of the street last fall helps keep your lakes and streams healthy this summer. Nice work!
- ☐ Keep grass clippings out of the street gutter.
- ☐ Avoid pesticides and get a workout by removing weeds by hand.

FALL

- ☐ Skip municipal leaf pick-up and compost leaves for next year.
- ☐ If you opt for municipal collection, be sure to keep your leaves out of the street.
- ☐ Consider leaves an asset and not waste—chop them up when you mow and leave them as fertilizer on your turf or put them around trees & shrubs.
- ☐ Put leaves from your roof gutters in your compost bin.
- ☐ If a soil test shows you need fertilizer, this is the best time to apply it.

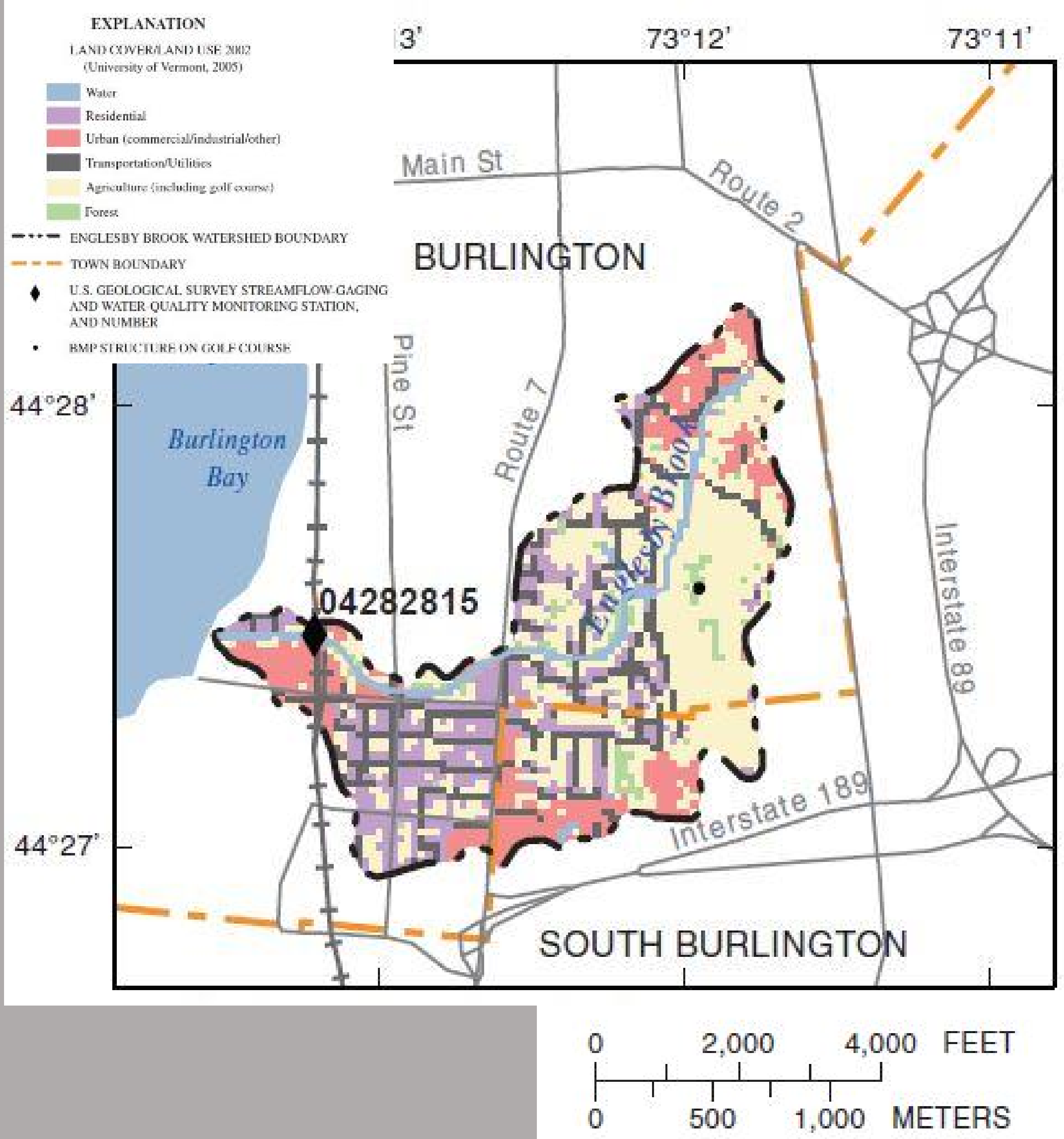
WINTER

- ☐ Limit use of de-icers. These chemicals are hard on your lawns, concrete, and lakes.
- ☐ Start planning your gardens and the steps you'll take to protect the lakes.
- ☐ Visit the myfairlakes booth at Garden Expo for more ideas and tips.

Go to **myfairlakes.com** for more ideas to help the lakes and order a full-size *Love Your Lakes Don't Leaf Them* yard sign!

Task 4-Modeling

- WinSLAMM ver 10.3.4
- Mass balance of land-use specific particulate and dissolved constituents
- Evaluation of source area control measures (street cleaning, etc…)
- Englesby Brook (USGS ID: 04282815) flow and WQ data from 1999-2010 (Medalie, SIRs 2007-5074 and 2012-5103)
- Precipitation data from Burlington Airport (National Weather Service)

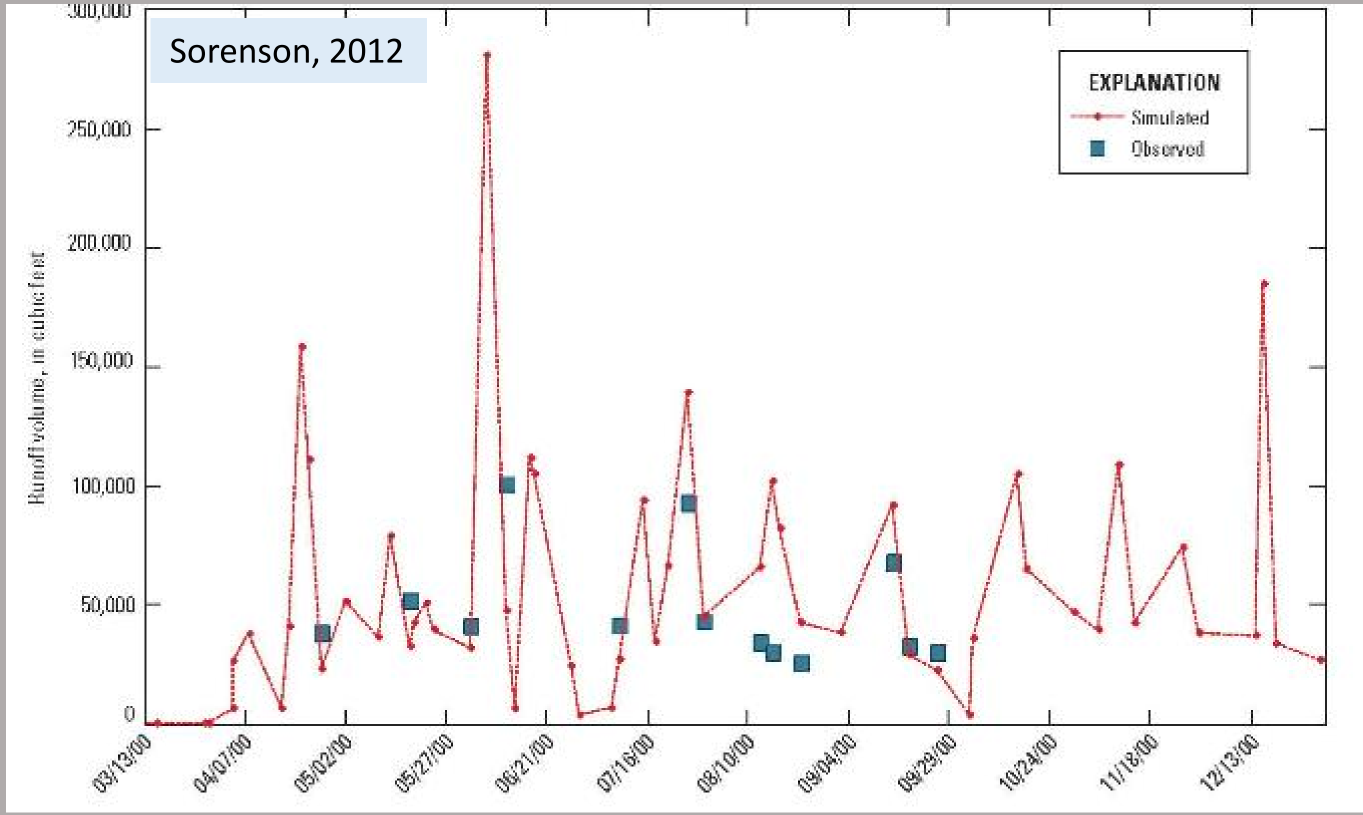


Task 4-Model scenarios

1. Base model validated with Englesby Brook data (runoff depth/time series)
2. Base scenario-current SCMs and frequency
3. Enhanced scenario-adjusted SCMs (adjusted SC, CB, LL programs)

Model should be sensitive to:

- Cleaning frequency
- Tree canopy
- P in leaves
- Leaf accumulation rate
- Species of tree



Task 5-Deliverables

- USGS National Water Information System (NWIS)
- USGS model archive and data release
- Peer reviewed journal or USGS Scientific Investigations Report (SIR)

Questions?