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Final Report for the Portsmouth Peirce Island Snow Dump Project

University of New Hampshire Stormwater Center (UNHSC)

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Proposed Project Description: BMP Installation at Peirce Island Municipal Snow Dump

The Portsmouth Pierce Island Snow Dump project had two primary objectives: 1) to implement a Low Impact Development/Green Infrastructure (LID/GI) project to mitigate water quality impacts from a municipal snow dump site on Peirce Island, a known high load contribution site or pollution "hot spot", and 2) to quantify the pollutant load and future reductions associated with LID/GI implementation. The Pierce Island snow dump site is approximately 0.54 acres and serves as the dumping location for snow removed from the downtown area of the City.

Background Analysis:

Geosyntec Consultants (Geosyntec) conducted a preliminary analysis to estimate the total suspended sediment (TSS) loading from the typical snow stockpile present at the Pierce Island snow dump area (the Site) during winter months. Geosyntec first estimated the total area of streets, from which snow is plowed and transported to the Site, utilizing Geographic Information Systems (GIS) by:

1. Adding the NHDOT roads layer
2. Adding the NH town's layer
3. Using the buffer tool to draw a polygon with the pavement width feature around the road centerline
4. Creating a new shapefile and drawing a polygon around the City of Portsmouth boundary
5. Clipping the buffered road to the new shapefile created in step 4
6. Dissolving all the road features into one feature
7. Creating a new shapefile and drawing a polygon around the area of Portsmouth where plowed snow is transported to the Site. This area was obtained from the City of Portsmouth (http://www.cityofportsmouth.com/publicworks/snowbanparkinglots.htm).
8. Clipping the buffered road to the new shapefile created in step 7
9. Using the area tool to calculate the total street area from which plowed snow is sent to Peirce Island
10. Adding a base map to check the outline of the streets.

Geosyntec then accessed the National Climatic Data Center (NCDC) for annual average snowfall depth in the area of Portsmouth. Average annual data from 1981-2011 was available from a gage (GHCND: USC00273626) located in Greenland, New Hampshire. The average annual snowfall during these years was 59.9 inches. The average volume of snow per year disposed of at the Peirce Island site was estimated by multiplying the estimated area of plowed streets, from which plowed snow is sent to the Site, by this average snowfall depth. The estimation assumes that the entire volume of snow on the plowed streets is transferred to the Site and there is no loss of snow in the transportation process.

Original sediment load estimates were generated using data collected for the Alaska Department of Environmental Conservation in a report by CH2MHill titled “Evaluation of Snow Disposal into Near Shore Marine Environments”. The report was produced to provide permitting officials in Alaska with a background of information on the debris and pollutants that could potentially be disposed of in Alaska’s coastal waters from plowed snow. Sampling was conducted along five streets and five intersections in Anchorage as well as Juneau and receiving water pollutant levels were also measured. For receiving waters in Anchorage and Juneau, the report identified that the average Event Mean Concentration (EMC) of TSS was 1,398 mg/L and 30 mg/L, respectively. Table 1 presents the corresponding TSS loading in lbs /year from the Peirce Island snow stockpile using these two EMC values:

Table 1: Range of estimated annual total suspended sediment (TSS) load deposited at the Portsmouth, NH snow dump site.

	TSS EMC (mg/L)	**TSS (lb/year)**
Low Estimate	30 mg/L	13,400
High Estimate	1,398 mg/L	622,600

As the Table indicates, the resulting range of estimated TSS loading from the Site is 13,400 to 622,600 lbs /year. The results represent a preliminary planning estimate for the range of TSS loading that could potentially come from the snow stockpile at the Site.

Stormwater BMP Concepts

Three concept configurations were considered and included:

1. Installing porous asphalt on the entire area where snow is currently stockpiled at the Site; under this scenario, the snow would be dumped on top of the porous asphalt.

2. Installing standard asphalt on the entire area where snow is currently stockpiled at the Site and routing the runoff to a bioretention cell adjacent to the impervious asphalt; under this scenario, the snow would be dumped on top of the standard asphalt.

3. Installing standard asphalt on the entire area where snow is currently stockpiled at the Site and routing the runoff to a gravel wetland adjacent to the impervious asphalt; under this scenario, the snow would be dumped on top of the standard asphalt.

Cost Estimates

Cost estimates were completed for the three different stormwater BMP concepts. Most of the cost information was obtained from the "University of New Hampshire Stormwater Center 2012 Biennial Report". The cost information for installation of traditional asphalt was obtained from "RS Means 2011" and the CPI Inflation Calculator (U.S. Department of Labor) was used to attain 2013 estimates. Of the BMP construction costs, 66% were assumed to labor-related and 33% were assumed to be materials-related. Table 2 presents the preliminary cost estimates of the three different BMP concepts as well as a -10% and +30% contingency.

Table 2: Preliminary cost estimates of three stormwater BMP options for management of the pollutant loads from the Portsmouth, NH snow dump site.

Gravel Wetland					
	Labor	**Materials**	**Asphalt Paving**	**Total: Labor & Materials**	**Total: Labor, Materials, & Paving**
Estimated Cost	$ 8,100	$ 4,000	$ 84,100	$ 12,100	$ 96,200
Estimated Cost -10%	$ 7,300	$ 3,600	$ 75,700	$ 10,900	$ 86,600
Estimated Cost +30%	$ 10,500	$ 5,200	$ 109,400	$ 15,700	$ 125,100
Bioretention Cell					
Estimated Cost	$ 9,000	$ 4,500	$ 84,100	$ 13,500	$ 97,600
Estimated Cost -10%	$ 8,100	$ 4,000	$ 75,700	$ 12,100	$ 87,800
Estimated Cost +30%	$ 11,600	$ 5,800	$ 109,400	$ 17,400	$ 126,800
Porous Asphalt					
Estimated Cost	$ 102,000	$ 51,000			$ 153,000
Estimated Cost -10%	$ 91,800	$ 45,900			$ 137,700
Estimated Cost +30%	$ 132,600	$ 66,300			$ 198,900

Consultations between Geosyntec, UNHSC and Portsmouth City officials concluded that the most cost effective means to move forward would be with the development of designs for a linear Bioretention cell. Considering the amount of potential pollutant load a pretreatment sediment bay was also designed to capture 50% of the overall sediment load originating from the snow dump site. A Bioretention system was chosen as it could be easily planted with native species of marsh grasses and long-term maintenance would be easier due to the fact that pollutant loads would accumulate on the surface of the Bioretention cell. Porous asphalt was not chosen due to the excessive potential for clogging and that maintenance would require use of equipment (vacuum sweepers) that is not readily available to city staff. Subsurface gravel wetlands, while top water quality performers for stormwater runoff also have the potential to accumulate sediments and pollutants in the subsurface gravel layers that would prove inaccessible to routine maintenance procedures over time. It was also decided to forgo paving and simply re-grade the snow dump site until the long-term status of the site was determined with respect to the prospective upgrades to the Pierce Island Waste Water Treatment Facility the City is planning for.

Final Design

Once the final design concept was determined Geosyntec with assistance from UNHSC worked to develop a set of final design plans included as an attachment to this report. Of note was the overall lack of any design standards for snow dump facility treatments. Traditional sizing strategies for stormwater management strategies do not seem entirely relevant to snow dump facilities that concentrate large volumes of snow, ice and pollutants in a relatively small drainage area. Results of this project therefore could provide additional details necessary to properly and effectively design treatment strategies for runoff from snow dump facilities.

Data Collection

To fulfil the second objective of the project UNHSC staff developed a sampling plan over the course of the 2013-2014 and 2014-2015 winter seasons in an effort to quantify the pollutant load potential from snow dump facilities. A series of grab samples were collected between December 2013 through April 2014 and January 2015 through April 2015 from the snow dump site. Grab samples were taken from snow that was recently delivered to the snow dump facility (i.e. new snow) and of the snow that had been stored for an extended period of time (i.e. old snow). Additional samples included newly fallen snow samples for background and various water samples from the snow pile meltwater and runoff. Samples were collected and sealed into 1L Whirl-Pak bags and immediately delivered to Absolute Resource Associates, Inc., in Portsmouth, NH for analysis. Laboratory analysis of pollutant concentrations included total suspended sediments (TSS), zinc (Zn), copper (Cu), ammonia (NH_3), nitrate (NO_3), nitrite (NO_2), total kjeldahl nitrogen (TKN), total nitrogen (TN), total phosphorus (TP), and chloride (Cl). Sample dates, descriptions, and individual pollutant concentrations are listed in Table 3.

Table 3: Pollutant concentrations of snow grab samples taken from the Portsmouth snow dump area over two winters. Italicized values are either below or above the detectable limits of the analytical method and inputted as half the lower detection limit or as the maximum detection limit accordingly.

Event Date	Sample	TSS (mg/L)	Zn (mg/L)	Cu (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (mg/L)	TP (mg/L)	Cl (mg/L)
12/19/2013	New Snow Pile	1300	0.51	0.13	*0.25*	*2.5*	*0.05*	4.8	*2.5*	1.2	3200
1/6/2014	New Snow Pile	91	0.01	*0.025*	*0.25*	*0.5*	*0.05*	1.0	1.0	0.05	8.3
1/6/2014	Old Snow Pile	750	0.33	0.07	*0.25*	*0.5*	*0.05*	3.0	3.0	0.8	9.3
2/10/2014	New Snow Pile	4200	*0.005*	*0.025*	*0.25*	*1*		1.9	*1*	0.01	*3500*
2/10/2014	Old Snow Pile		0.03	*0.025*	*0.25*	*0.5*		9.7	9.7	0.18	9.8
2/20/2014	New Snow Pile	260	0.16	*0.025*	*0.25*	*0.25*	*0.05*	2.2	2.2	0.53	1600
2/20/2014	Old Snow Pile	180	0.16	*0.025*	*0.25*	*0.25*	*0.05*	1.4	1.4	0.29	320
3/14/2014	New Snow	900	0.18	*0.025*	0.6	*0.5*		1.3	1.3	0.59	11
3/14/2014	Old Snow	560	0.32	0.07	0.6	*0.5*		1.7	1.7	0.68	2.9
3/14/2014	Old Snow	810	0.64	0.11	*0.25*	*0.5*		2	2	1	41
4/2/2014	Old Snow	2200	1	0.23	*0.25*	*0.1*		5.2	5.2	1.8	*0.25*
4/2/2014	Old Snow	2200	0.91	0.17	*0.25*	*0.1*		3.2	3.2	1.1	*0.25*
1/28/2015	Snow Bank (State St.)	190	0.26	*0.025*	*0.25*	*0.05*	*0.05*	1.5	1.5	0.05	410
1/30/2015	New Snow	310	0.12	*0.025*	*0.25*	0.1	*0.05*	1.3	1.4	*0.005*	820
2/11/2015	New Snow	330	0.13	*0.025*	*0.25*	0.7	*0.05*	5	5.7	0.18	1400
2/11/2015	Old Snow	500	0.28	0.05	*0.25*	0.6	*0.05*	2.3	2.9	0.32	1200
3/4/2015	New Snow	250	*0.025*	*0.025*	*0.25*	0.3	*0.05*	0.9	1.2	0.12	620
3/4/2015	Old Snow	1100	0.46	0.1	*0.25*	*0.05*	*0.05*	2.3	2.3	0.85	110
3/20/2015	New Snow	360	0.05	*0.025*	0.6	*0.05*	*0.05*	0.8	0.8	0.13	3.3
3/20/2015	Old Snow	2200	2.6	0.53	0.7	*0.05*	*0.05*	11	11	1.9	2.5
4/15/2015	Old Snow	700	0.49	0.12	*0.25*	*0.05*	*0.05*	2.5	2.5	0.81	1.8
Count		20	21	21	21	21	21	21	21	21	21
Minimum		91	0.01	0.03	0.25	0.05	0.05	0.8	0.8	0.01	0.3
25th Quartile		298	0.12	0.03	0.25	0.10	0.05	1.4	1.4	0.13	3.3
Median		630	0.26	0.03	0.25	0.30	0.05	2.2	2.2	0.53	41
75th Quartile		1150	0.49	0.11	0.25	0.50	0.05	3.2	3.0	0.85	820
Maximum		4200	2.60	0.53	0.70	2.50	0.05	11.0	11.0	1.90	3500
Average		970	0.41	0.09	0.32	0.44	0.05	3.1	3.0	0.60	631.9
St. Deviation		997	0.56	0.11	0.15	0.53	0.00	2.7	2.7	0.55	1009.6

Additional data collected to calculate the pollutant load potential of snow removal operations were the size and density of the snow pile. During each sample event the snow pile was measured to provide an estimation of the total volume of snow. The density of the snow pile was calculated using the snow to water equivalency ratio (SWE), which is a percentage of the volume of water contained within the snow pile. SWE values were determined through collection of samples of various snow conditions including: new fallen snow, newly transported snow dump at the site and old compacted snow within the snow dump core. SWE were calculated by comparing the volume of the original samples to the melted or water equivalent volume. The ratio of the melted volume to the snow volume is the SWE. Following guidance from the USDA – NRCS website[1], which defines SWE as "the amount of water contained within the snowpack" or "the depth of water that would theoretically result if you melted the entire snowpack instantaneously"; the SWE values were generated throughout the sampling period, which are listed in Table 4. In comparison the NRCS website states that fresh fallen snow at 14°F and 32°F are 5% and 20% SWE, respectively. Factors such as plowing, trucking, settling, wind packing, melting, and recrystallization all play a role in increasing the density of the snow over time. Little actual data exists with respect to the concentration of SWE and pollutant loads in municipal snow processing activities.

Table 4: Snow to water equivalent values for referenced and collected snow samples.

Description	SWE
Fresh Fallen Snow at 14°F[1]	5%
Fresh Fallen Snow at 32°F[1]	20%
Fresh Fallen at the Site 2015	11%
Average of Newly Delivered Snow 2014	27%
Average of Newly Delivered Snow 2015	45%
Average of Old Resident Snow 2014	64%
Average of Old Resident Snow 2015	58%

Data Evaluation

Data evaluation covers a range of approaches including:

- Laboratory analyses of pollutant concentrations in samples, i.e. Total Suspended Sediments (TSS), Zinc (Zn), Copper (Cu), Ammonia (NH_3), Nitrate (NO_3), Nitrite (NO_2), Total Kjeldahl Nitrogen (TKN), Total Nitrogen (TN), Total Phosphorus (TP), and Chloride (Cl)
- Calculation of total pollutant load based on sample concentration, pile size, and SWE.
- Comparison of pollutant concentrations between new snow delivered to the snow dump area and old snow that has been sitting at the snow dump area.
- Comparison of pollutant concentrations from Portsmouth snow dump and stormwater runoff at the UNHSC field facility.

Laboratory analyses were conducted at Absolute Resource Associates, Inc. (ARA) in Portsmouth, NH. ARE is a third party analytical lab which follows specified SOPs and methodologies detailed in their Resource Laboratories Quality Assurance Manual. The lab methods and sample detection limits for each parameter are listed in Table 5.

Table 5: Analytical methods and detection limits for pollutants measured from snow dump samples

Pollutant	Analytical Method	Sample Detection Limit (mg/L)
Total Suspended Sediments	SM 2540 D	Variable 1-50*
Zinc	EPA 200.7	0.01
Copper	EPA 200.7	0.05
Ammonia	SM 4500 NH3-D	0.5
Nitrate	EPA 300.0A	Variable 0.1-5.0*
Nitrite	SM 4500 NO2-B	0.1
Total Kjeldahl Nitrogen	ASTM D359002A	0.5
Total Nitrogen	SM 4500 NH3	Variable 0.1-5.0*
Total Phosphorus	EPA 365.3	Variable 0.01-0.1*
Chloride	EPA 300.0A	Variable 0.5-50*
*Variable detection limits are based on sample volume available for analyses		

The total pollutant load potential of the snow dump area was calculated using the sample concentrations listed in Table 3 above, the estimated size of the pile, and the SWE. The results from the grab samples provide discreet pollutant concentrations within the pile. In order to quantify total pollutant load potential these concentrations were assumed to be consistent throughout the snow pile. The SWE was applied to the estimated total pile volume to get the total volume of water in the pile. The water volume was multiplied by the sample concentrations to generate a total pollutant mass for both the old and new snow samples. Equation 1 defines the steps used to generate total pollutant mass.

Equation 1:

$$Total\ Mass\ (kg) = Sample\ Concentration\ \left(\frac{mg}{L}\right) \times Snow\ Pile\ Volume\ (gal) \times SWE\ (\%) \times Unit\ Conversions$$

New snow and old snow samples have different pollutant concentrations and different SWE values. Combining these different values is a dynamic process that changes as the new snow transitions over time to an older more concentrated sample by SWE and pollutant concentration. On a per event basis a total mass was calculated using equation 1 for both the old and new snow samples. The two total mass values were averaged together to generate a total mass for each event. Overall pile size was tracked over time to generate a cumulative total mass. Positive differences between sampling events were assumed to include new snow additions. Negative differences between sampling events were assumed to represent export events occurring either through melt and runoff and/or rainfall events. The exported pollutant mass was calculated using equation 1 by inputting the change in pile volume, the average old snow concentrations, and old snow SWE. The old snow values were used to represent the dynamic concentration and consolidation processes that occur over time. The export mass was subtracted from the cumulative pollutant mass for each export event.

The pollutant concentrations were further evaluated by comparing the snow dump sample concentrations to an 8 year data set from the UNHSC field facility in Durham, NH. The UNHSC field facility samples are direct stormwater runoff from a 7 acre commuter parking lot which is typically full and has routine bus traffic throughout the academic year. Pollutant loading from the UNH commuter lot is similar to loading from a commercial lot and has been provided in the Results section for comparison purposes.

Results

Using Equation 1 a cumulative pollutant mass was calculated for each sample event. These results are listed in Table 6. There were several samples that were below detection limit (BDL) and a couple that were over detection limit (ODL). The standard approach is to report half the detection limit when BDL and double the detection limit when ODL. Assignment of a value to BDL and ODL measurements carries a high risk of generating large estimates of tot al mass of pollutant due to the variability in pile size and SWE throughout the sampling period. This has the potential to falsely create mass from samples that did not have a laboratory analyzed value. Using a value of zero also is accompanied by the opposite risk and makes statistical analysis of results difficult. Thus a conservative approach of 0.5 x the standard lower detection limit and using the upper detection limit value was adopted.

Table 6: Cumulative snow pile volumes, water equivalent volumes and pollutant mass from Portsmouth snow dump over the sampling season.

Sample Date	Pile Volume (ft^3)	Water Equivalent (gal)	TSS Mass (kg)	Zn Mass (kg)	Cu Mass (kg)	TN Mass (kg)	TP Mass (kg)	Cl Mass (kg)
12/19/2013	392,040	791,870	3,897	1.53	0.39	7.49	3.60	9,592
1/6/2014	653,400	1,319,783	8,564	3.51	0.87	27.75	8.46	9,667
2/10/2014	561,924	2,690,402	25,027	3.02	0.91	72.61	8.22	23,101
2/20/2014	718,740	3,441,212	26,914	4.50	1.14	87.77	11.56	29,581
3/14/2014	588,060	2,815,537	30,329	6.54	1.48	91.01	15.68	27,361
4/2/2014	426,344	2,041,264	44,532	12.77	2.79	111.65	24.79	24,440
1/28/2015	212,125	403,940	291	0.40	0.04	2.29	0.08	627
1/30/2015	212,125	490,499	866	0.62	0.08	4.89	0.09	2,149
2/11/2015	334,525	1,306,904	2,910	1.63	0.27	26.31	1.32	8,591
3/4/2015	762,000	3,142,547	11,434	4.76	1.06	47.77	7.51	12,635
3/20/2015	776,000	3,739,688	29,064	22.84	4.85	128.57	21.41	12,677
4/15/2015	427,980	1,853,112	27,557	20.82	4.55	119.44	21.56	8,978

In addition to standard practices associated with snow dump activities an appropriately sized stormwater BMP could be installed to manage the exported mass from rain and melt events. To quantify this pollutant removal potential an assessment of the annual pile volume, the total pollutant mass delivered to the snow dump area, the exported pollutant mass, and the pollutant removal potential by a properly designed bioretention system was conducted for this study. The results of this assessment are in Table 7 and Figure 1.

Table 7: Pollutant removal potential through standard operating snow removal practices and through the addition of a properly sized bioretention system for managing runoff. Note the snow dump facility itself accounts for a mass reduction greater than 79% for all pollutants with the exception of chloride.

2014 - Pollutant Load Assessment			Kg					
	Pile Volume (ft3)	Water Equiv (gal)	TSS	Zn	Cu	TN	TP	Cl
Total	810,216	3,879,185	51,167	15.5	3.4	139.7	29.7	31,378
Total Remaining	0	0	44,532	12.8	2.8	111.7	24.8	24,440
Total Exported	810,216	3,879,184	6,635	2.7	0.6	28.0	5.0	24,440
Total Export w/ BMP	810,216	3,879,184	863	0.4	0.1	11.2	2.2	24,440
Total Removed w/ BMP	0	0	5,773	2.4	0.5	16.8	2.7	0
Total Removed			50,304	15.1	3.3	128.5	27.5	6,938
%RE Snow Dump only	NA	NA	87%	82%	83%	80%	83%	22%
%RE Snow Dump w/ BMP	NA	NA	98%	98%	98%	92%	93%	22%
% Export Rate			13%	18%	17%	20%	17%	78%
2015 - Pollutant Load Assessment			Kg					
	Pile Volume (ft3)	Water Equiv (gal)	TSS	Zn	Cu	TN	TP	Cl
Total	776,000	3,616,470	33,974	26.3	5.7	146.1	27.1	12,689
Total Remaining	0	0	27,557	20.8	4.6	119.4	21.6	8,978
Total Exported	776,000	3,616,470	6,417	5.5	1.1	26.7	5.5	8,978
Total Export w/ BMP	776,000	3,616,470	834	0.7	0.1	10.7	2.5	8,978
Total Removed w/ BMP	0	0	5,583	4.8	1.0	16.0	3.0	0
Total Removed			33,140	25.6	5.5	135.4	24.6	3,711
%RE Snow Dump only	NA	NA	81%	79%	80%	82%	80%	29%
%RE Snow Dump w/ BMP	NA	NA	98%	97%	97%	93%	91%	29%
% Export Rate			19%	21%	20%	18%	20%	71%
Project Totals			Kg					
	Pile Volume (ft3)	Water Equiv (gal)	TSS	Zn	Cu	TN	TP	Cl
Total	1,586,216	7,495,654	85,141	41.8	9.1	285.8	56.8	44,067
Total Remaining	0	0	72,089	33.6	7.3	231.1	46.3	33,418
Total Exported	1,586,216	7,495,654	13,052	8.2	1.7	54.7	10.5	33,418
Total Exported w/ BMP			1,697	1.1	0.2	21.9	4.7	33,418
Total Removed w/ BMP			11,355	7.1	1.5	32.8	5.8	0
Total Removed			83,444	40.7	8.8	263.9	52.1	10,649
%RE Snow Dump only	NA	NA	85%	80%	81%	81%	82%	24%
%RE Snow Dump w/ BMP	NA	NA	98%	97%	98%	92%	92%	24%
% Export Rate			15%	20%	19%	19%	18%	76%

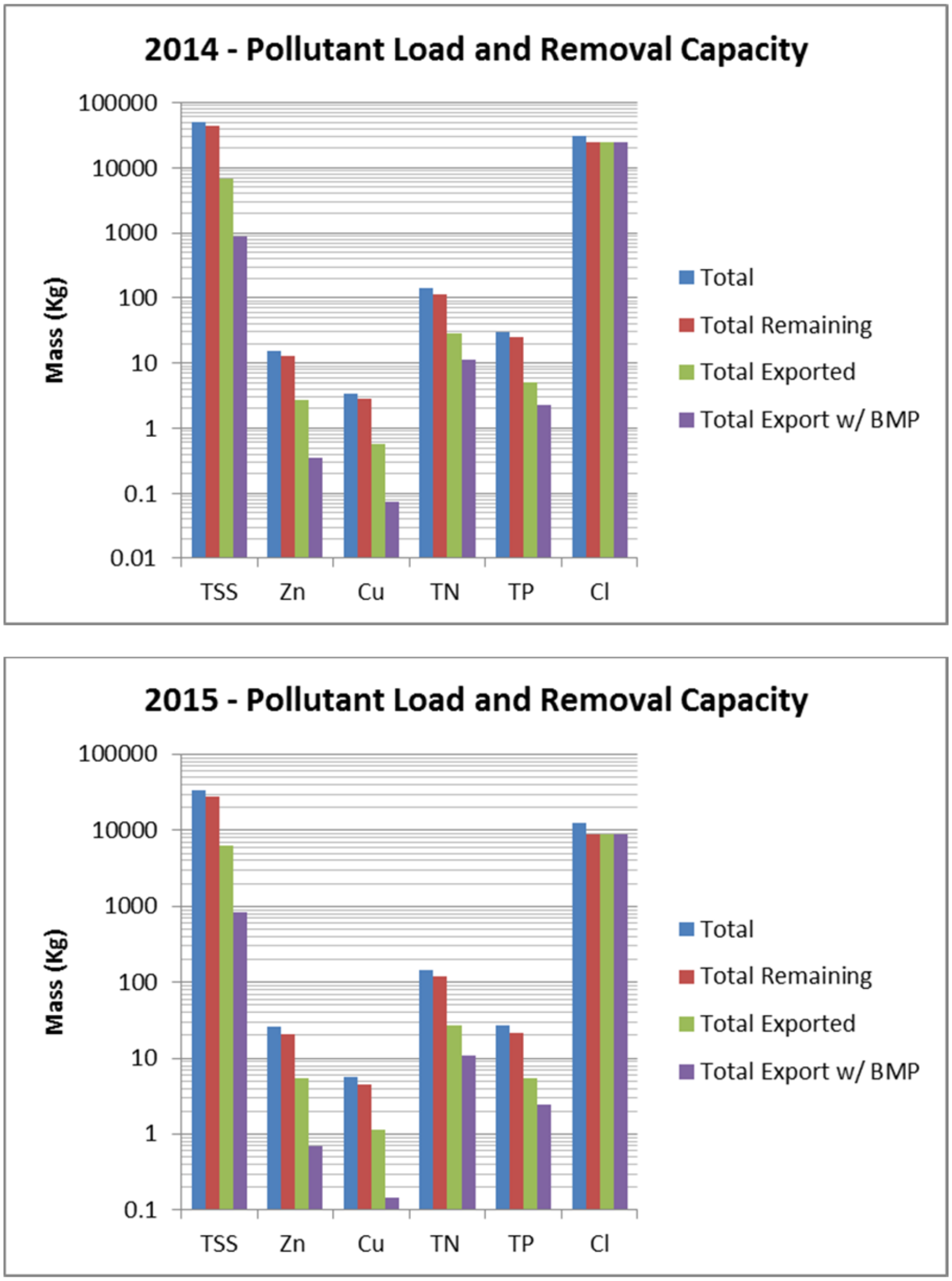

Figure 1: Snow dump pollutant load assessment comparing pollutant load deposited onsite (total), pollutant mass retained onsite (total remaining), pollutant load generally exported to the environment (total exported) and additional load reduction when export is through an innovative bioretention system (total export w/BMP).

Data Comparison

The snow dump sample concentrations were also compared to the Portsmouth snow dump meltwater samples as well as parking lot runoff samples from the UNHSC field facility. In this analysis all samples that were found to be below or above detection limits were given a value of half or double the detection limit, respectively. The individual snow sample results from the Portsmouth snow dump area are listed in Table 3 above and meltwater samples in Table 8. Samples of fresh snow and from a plowed pile in Durham, NH are provided as reference and for comparison in Table 9. The UNHSC has been collecting data for over 8 years of direct runoff from West Edge parking lot; the individual results are not included in this report. The parameters with measurable results that were monitored at both sites are TSS, Zn, TN, and TP and are included as box and whisker plots in Figure 2 through Figure 5. The median values of the West Edge runoff data is lower for each of the reported pollutants while the Portsmouth snow dump meltwater has the highest median values. This is likely due to the concentration of pollutants in one location such as the snow dump area as well as the continuous delivery of more pollutants over a longer time period. Runoff at the UNHSC facility effectively washes the parking lot during each storm event.

Table 8: Pollutant concentrations of water or slush samples from Portsmouth snow dump. Results that are BDL or ODL are italicized and replaced with either half or double the detection limit, respectively.

Event Date	Sample	Sample Type	TSS (mg/L)	Zn (mg/L)	Cu (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (mg/L)	TP (mg/L)	Cl (mg/L)
12/19/2013	Roadway Mix	Slush	2800	0.59	0.12	0.5	*2*	0.1	6.4	6.5	1.4	*11600*
1/6/2014	Outfall	Water	600	0.24	0.07	0.9	*1*	*0.05*	4.5	4.5	1.0	3000
1/6/2014	CB Influent	Water	1600	0.44	0.13	0.8	*1*	0.1	6.0	6.1	2.0	2600
2/20/2014	Snow Dump Puddle	Water	96	*0.025*	*0.025*	0.7	*0.25*	*0.05*	3.2	3.2	0.05	820
Count			4	4	4	4	4	4	4	4	4	4
Minimum			96	0.025	0.025	0.5	0.25	0.05	3.2	3.2	0.05	820
25th Quartile			474	0.18625	0.05875	0.65	0.8125	0.05	4.175	4.175	0.7625	2155
Median			1100	0.34	0.095	0.75	1	0.075	5.25	5.3	1.2	2800
75th Quartile			1900	0.4775	0.1225	0.825	1.25	0.1	6.1	6.2	1.55	5150
Maximum			2800	0.59	0.13	0.9	2	0.1	6.4	6.5	2	11600
Average			1274	0	0	1	1	0	5	5	1	4505
St. Deviation			1034	0	0	0	1	0	1	1	1	4178

Table 9: Pollutant concentrations of fresh snow and a plowed snow pile from Durham, NH. Results that are BDL are italicized and replaced with half the detection limit.

Event Date	Sample	Sample Type	TSS (mg/L)	Zn (mg/L)	Cu (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (mg/L)	TP (mg/L)	Cl (mg/L)
2/20/2014	Fresh Snow	Snow	*6*	*0.025*	*0.025*	*0.25*	*0.25*	*0.05*	0.7	0.7	*0.005*	1.4
2/20/2014	Durham Snow Pile	Plowed Snow	670	0.48	0.07	*0.25*	*0.25*	*0.05*	1.9	1.9	0.96	7400

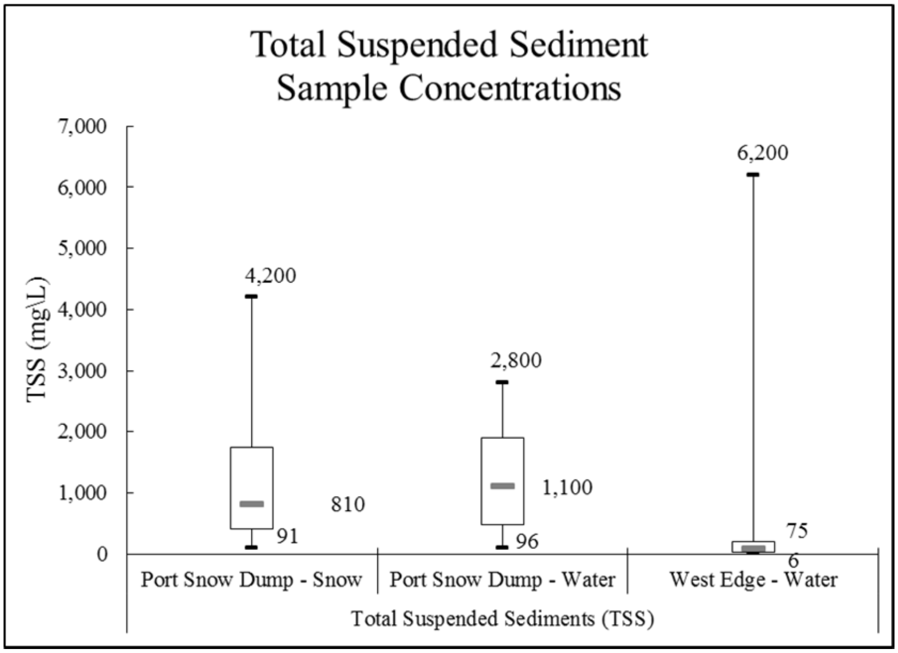

Figure 2: Sample concentrations of Total Suspended Sediment from Portsmouth snow dump area and West Edge parking lot.

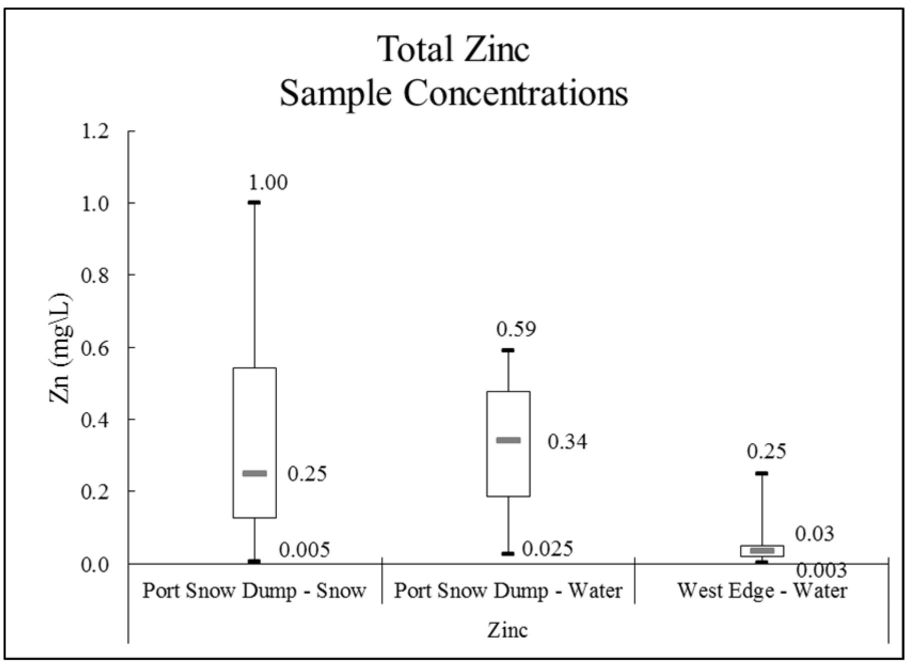

Figure 3: Sample concentrations of Total Zinc from Portsmouth snow dump area and West Edge parking lot.

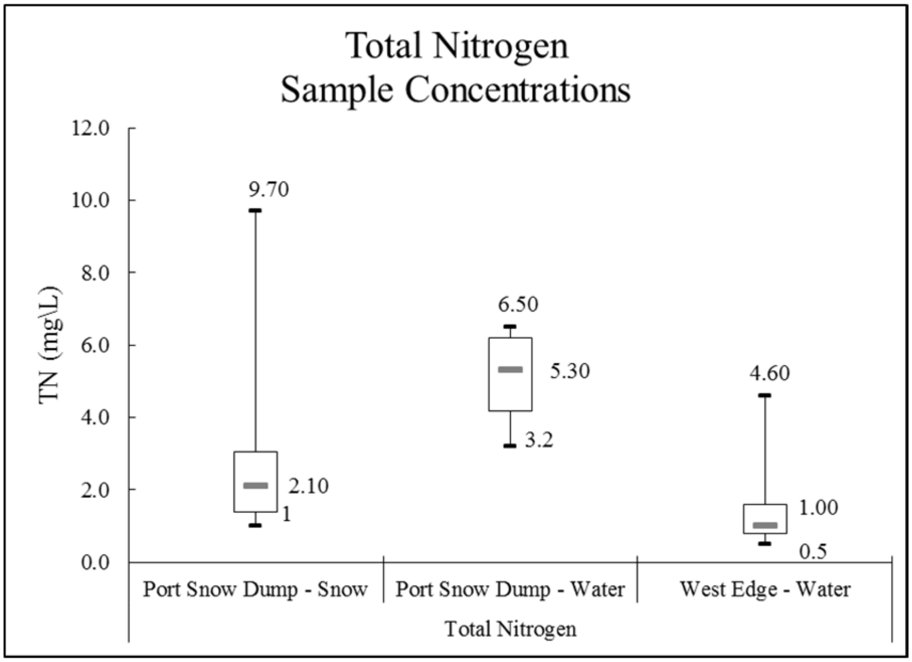

Figure 4: Sample concentrations of Total Nitrogen from Portsmouth snow dump area and West Edge parking lot.

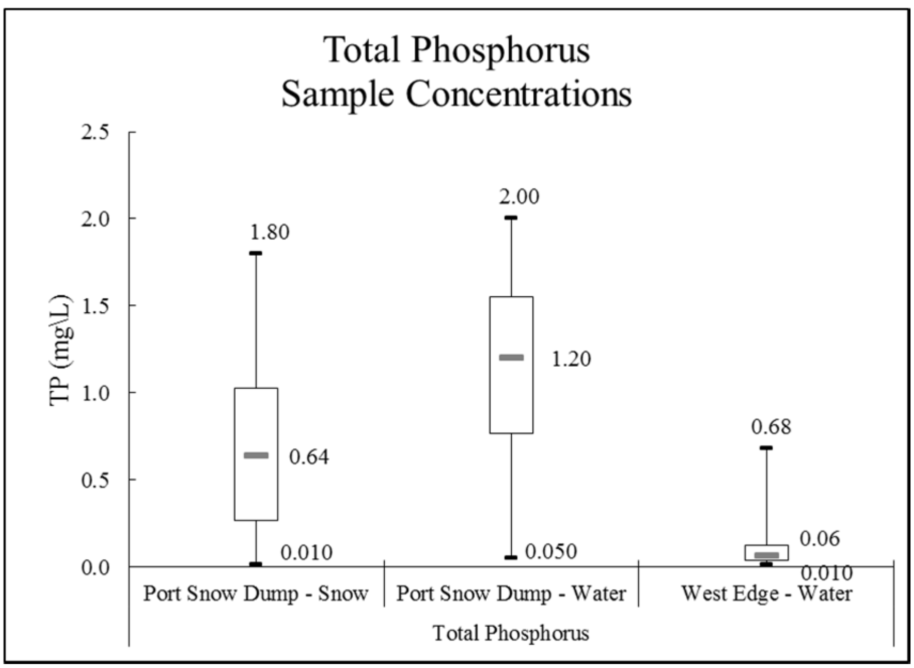

Figure 5: Sample concentrations of Total Phosphorus from Portsmouth snow dump area and West Edge parking lot.

Conclusions

This study demonstrated that standard snow dump facilities remove a large mass of pollutants from the urban core. The process of collecting, trucking, and dumping snow into a dedicated location dramatically reduces export of pollutants to receiving waters by up to 87% and itself should be considered a best management practice (BMP) for urban stormwater pollution. The practice of the cleaning up and landfilling pollutants and bulk debris in the spring furthers the pollutant removal potential. These pollutant removal potentials can be increased further by up to 98% through the design and installation of an appropriately sized Bioretention system. The lone exception is with respect to chloride loads which may be an issue if discharging to fresh water areas.

References

1. Snow Water Equivalent (SWE) summary on USDA – NRCS website: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/snow/?cid=nrcs142p2_046155