Citizen Volunteer Scientist Participation in Monitoring Stormwater Discharges in NH Seacoast Municipalities

Chapter 1

Report on
PILOT VOLUNTEER MONITORING PROGRAM-
Exeter and Greenland, New Hampshire

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EXECUTIVE SUMMARY

The project was a success, as volunteers demonstrated they were capable of monitoring storm drains and producing quality results. Local partners and state agencies helped with many aspects of the program, and demonstrate the availability of expertise and interest by volunteers in this type of effort. Significant levels of some key water pollutants were detected, like fecal-borne bacteria, chloride and nitrogen, showing how significant storm drains are as pollution sources and the need for continued monitoring. Some drains did not discharge any pollutants, or at least from among those included in this project. This is important as it can let towns know that not all drains will require pollution reduction measures. Future monitoring programs should emphasize training and QA/QC procedures because volunteer participation can provide quality data useful for more than just screening purposes. The project also showed what future similar efforts might cost. Volunteer participation clearly saves costs and allowed for significantly greater capacity to sample and take measurements at storm drains. Interest has been piqued, and it will be important to begin new monitoring efforts to provide opportunities for volunteers to continue in this type of project.

PROJECT OVERVIEW AND REPORT INTRODUCTION

The Great Bay Coast Watch program, a successful monitoring program featuring direct involvement of citizen volunteers, ended after 19 years with the retirement of the program director. During 2009-10 efforts were made by the NH Sea Grant Program (NHSG) and UNH Cooperative Extension to determine the best way to move forward. Meetings were held with representatives from local environmental groups and agencies and NHSG also solicited input from interested citizens. A decision was made to discontinue routine monitoring and instead focus citizen volunteer activities on funded research and monitoring projects. Direct participation in science projects that address critical issues in the NH Seacoast reflects the desires of the citizen volunteers to be involved in more meaningful activities and addresses the needs of researchers and local environmental agencies to enhance integrate public outreach and education into their projects with the involvement of citizen volunteers.

The new program, Citizen Research Volunteer (CRV) Program, is currently supported by the New Hampshire Sea Grant College Program (NHSG) to help with initial planning and implementation of the program. Dr. Jones is the NHSG Assistant Director for Research and is the current Program Coordinator for the CRV, with help from the NHSG Assistant Directors for Education and Extension. There were three initial meetings to present the new program plan and to get feedback and buy in from interested citizens. There have been four ensuing meetings with prospective volunteers that have featured presentations by four UNH researchers to discuss current projects that would benefit from volunteer participation. There are currently ~30 volunteers that will be trained by the project researchers to participate in four projects on oyster restoration, salt marsh adaptation to climate change, restoration of rare salt marsh plants and a musselwatch program for toxic chemical monitoring.

Stormwater discharges are generally considered to be the source of the bulk of water quality impairments in the NH Seacoast. Where there are a number of state, federal and local river coalition monitoring programs that track water quality at fixed sites in tributaries and the main estuarine waters, monitoring stormwater discharges poses a set of unique challenges and is thus not presently a focus of ongoing monitoring programs. To address this critical link for improving aquatic ecosystem health in urban surface waters, we propose to coordinate CRV and other local volunteer citizens in two Seacoast communities to sample and analyze runoff from prioritized stormwater discharges. We plan to work closely with local river protection groups to recruit local citizens for monitoring, harmonize sampling plans and share information. The primary goal of this study is to enhance education and outreach related to stormwater management for citizens in their own NH Seacoast communities. Identifying problem areas, getting citizens involved as advocates for treatment and promoting the use of effective LID treatment technologies are critical first steps in the process of implementing management strategies for eliminating these significant sources of pollution.

The specific objectives describing the work in this proposal are as follows:

1.) Develop plans for stormwater monitoring at priority discharges within two municipalities in the NH Seacoast;

2.) Organize and train teams of citizen volunteers for monitoring and outreach in both municipalities;

3.) Conduct monitoring of dry and wet weather stormwater discharges in the two watersheds;

4.) Develop a comprehensive plan based on the costs and logistics of the completed study for stormwater monitoring by citizen volunteers in any NH Seacoast town;

5.) Conduct public outreach sessions in both study towns and at a Seacoast-wide forum for presenting the results and implications of the study and to identify strategies to treat stormwater discharges.

Project deliverables include:

1.) A pilot plan for stormwater discharge monitoring in both pilot-study watersheds, including sampling design and strategy.

2.) A report on project-specific training procedures and a manual for field sampling, sample storage, sample processing and analytical methods.

3. A comprehensive monitoring plan for future citizen monitoring of stormwater discharges in the NH Seacoast.

4. Outreach materials -posters, slide presentations- and a summary of evaluations by audiences at public outreach and education meetings.

Items 1-3 are included in this report as Chapters 1, 2 and 3. Item 4 components are available from the Project PI, particularly large-sized PowerPoint presentations on the findings of this project given in numerous settings. The two towns involved in this project already had outreach materials they wanted to use to address certain specific problems discovered through this project. They were also not yet ready to begin new public outreach efforts on storm drain monitoring until they see what will be required by the yet to be published MS4 permit for New Hampshire.

Some of the volunteers! Exeter (top) and Greenland (bottom)

THANKS TO YOU ALL!!

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INTRODUCTION

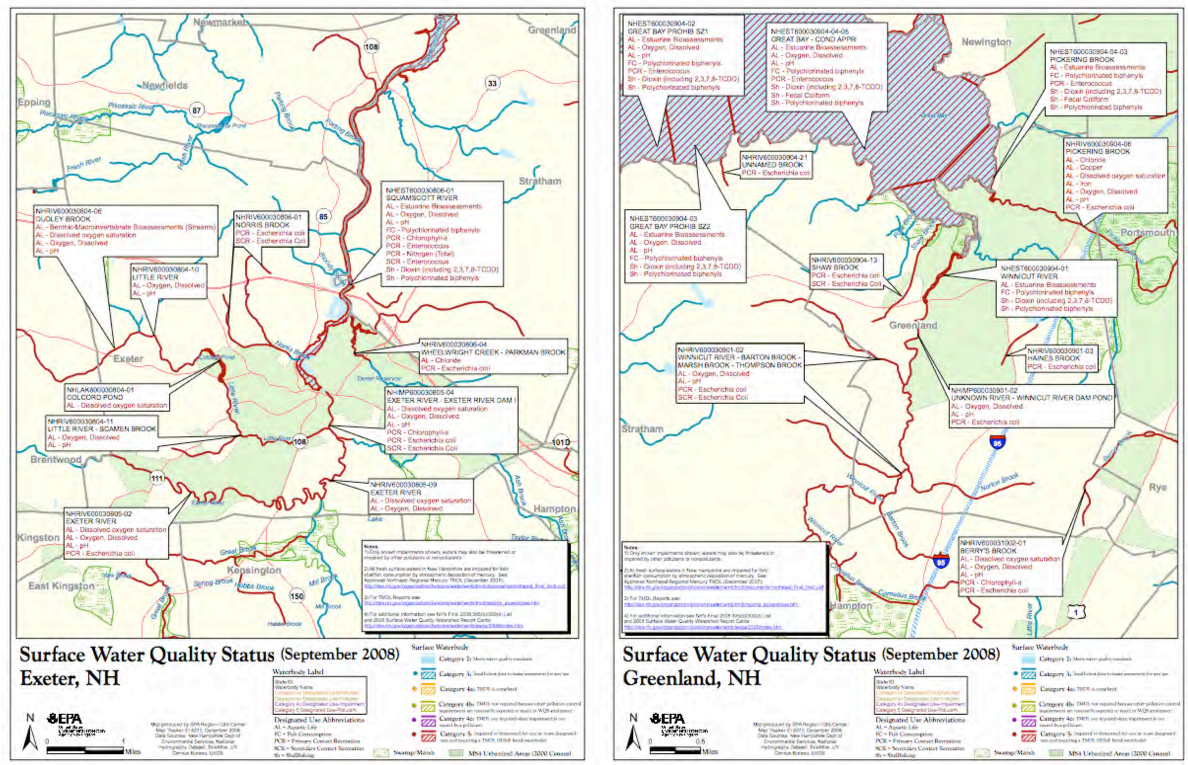
There is enormous interest by local citizens in understanding, identifying and eliminating the causes of water pollution that the affect surface waters of the NH Seacoast. In addition to being concerned about water quality and ecosystem health, people are concerned about what it will cost them and their communities to eliminate pollution. One of the costs is for identifying and assessing the significance of pollution sources. 80% of surface water impairments in New Hampshire are caused by stormwater runoff (NHDES 2008), so discharges from storm pipes are a significant and largely uncharacterized source of pollution to Seacoast waters.

As a result of ongoing discussions between the NH Sea Grant's Coastal Research Volunteer (CRV) Program coordinator and the NH Seacoast Stormwater Coalition (SSC), support was sought for a feasibility study to determine if local citizen volunteers could be engaged to effectively monitor storm drain discharges. The intent was to encourage this, if feasible, so that local towns could pursue this means for assessing the significance and identify sources of pollution from storm drains to save limited resources and nurture greater local stewardship for natural resources. Representatives from Greenland and Exeter at the SSC meeting volunteered their towns as pilot project sites for any future funded feasibility study.

This report outlines the approach taken, who was involved and in what capacity, the data generated and what it tells us about storm drains as pollution sources in the NH Seacoast.

PARTNERS, VOLUNTEERS, OTHER PARTICIPANTS AND PROJECT ROLES

Greenland and Exeter, NH were chosen as the study locations for this project as a result of interest expressed by key Town personnel who encouraged work in their communities. Both towns also had active groups that were coordinating the monitoring and protection of the rivers that coursed through urbanized areas. Rivers and streams in both towns had water quality impairments listed by the state 303(d) list (Figures 1a & b). Volunteers from the CRV would be trained and active participants along with locally recruited volunteers.



(a) (b)

Figures 1 a&b. Surface water quality and impairments for Exeter (a) and Greenland (b), NH.

In Greenland, the Town Administrator (Karen Anderson) was the main contact and initiator of all activities in her town. An early meeting was held with the coordinator of the local Winnicut River Watershed Coalition (WRWC), Jean Eno to determine how to recruit local volunteers and to identify high priority storm drains. A set of 11 storm drains was identified for possible monitoring, and Ms. Anderson provided maps of their locations. Ms. Eno helped to recruit a number of local volunteers, and remained in contact with the project PI as the monitoring program planning process evolved. Ongoing discussions with Ms. Anderson helped to identify which storm drains were of highest priority and suitable for monitoring. Ms. Anderson continued with logistical help throughout the project, approaching homeowners about identified pollution sources, setting up a final meeting with the Conservation Commission and citizens of Greenland, and other help to the project. Ms. Eno participated in the monitoring, helped with communication to the Conservation Commission and volunteers, and engaged home/land owners at or abutting study sites to explain our intentions, get their permission to access pipes and to educate them about the project and environmental problems it sought to address.

Phyllis Duffy, the Engineering Technician for the Stormwater Program, was the main contact and initiator of all activities in Exeter. A meeting was held early during the project with representatives from the Exeter Conservation Commission, the Exeter/Squamscott River Local Advisory Committee (ESRLAC) and the Planning Department to discuss prioritization of storm drains for monitoring and how best to recruit local volunteers. A short list of potential drainpipes was identified, and there were several mechanisms identified for recruiting local volunteers. Ms. Duffy remained the main Town representative and participant throughout the project, with help from all who attended the initial meeting. Ms. Duffy helped to gain permission from landowners for access to storm drains, and provided support for follow-up actions on identified pollution sources. She also helped with arranging a final meeting with the Conservation Commission. Others who helped out include Jill Robinson, the Environmental Stewardship manager for Phillips Exeter Academy, and Kristen Murphy, the Town Natural Resource Planner.

The CRV Program held a meeting in early 2011 where the project goals and tasks were described and interested volunteers could ask questions and sign up to participate. Volunteers signed up to work in either Greenland or Exeter. The Project PI is also the program coordinator for CRV and so continued to organize and contact volunteers from CRV and the two localities throughout the project. Dr. Jones also processed all samples, compiled and interpreted data, oversaw clean up and maintenance of meters, provided clean sampling bottles, prepared equipment and supplies for fieldwork, ordered supplies and made presentation of project findings.

Sampling design

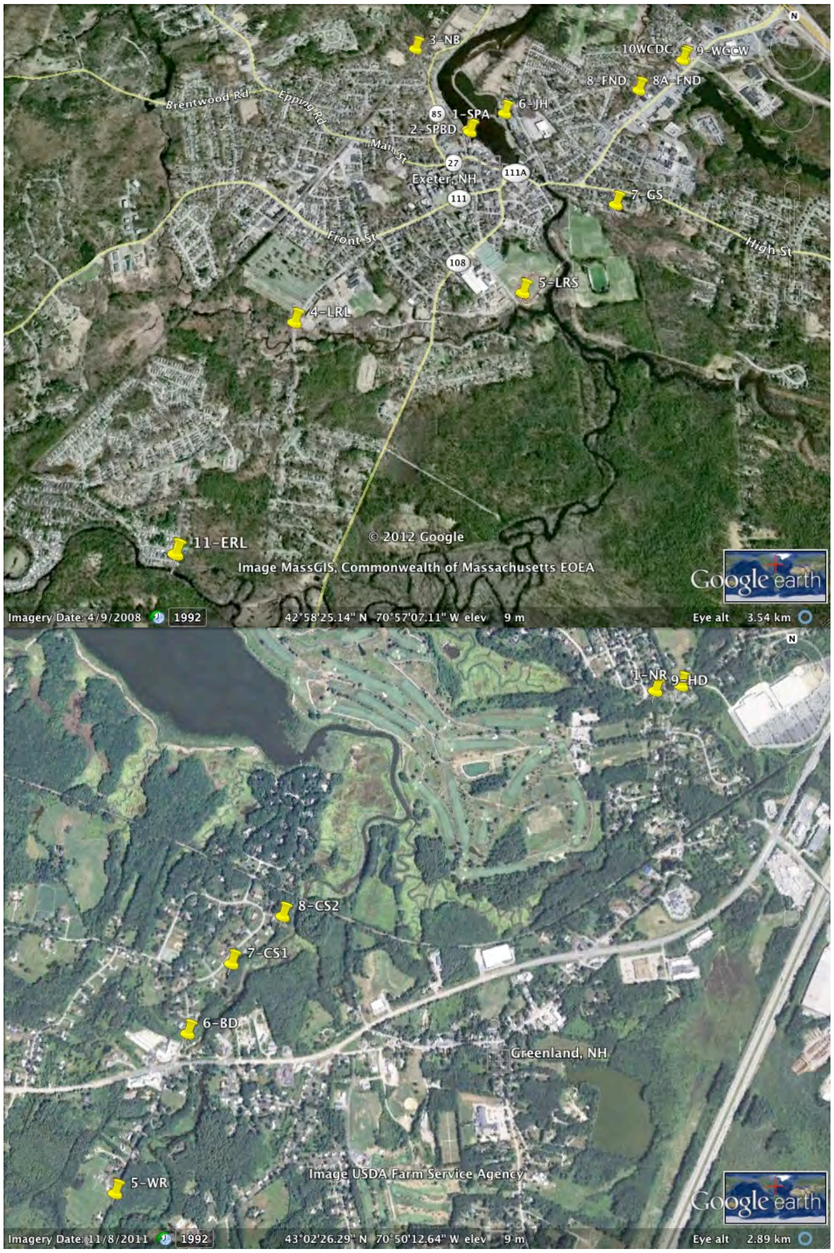
Several site inspection dates were scheduled for each town to identify sites suitable for inclusion in this study. The selection criteria included flow or evidence thereof, accessibility both for actual getting to the site and for taking samples from the discharge, and safety. A number of recommended sites were excluded due to a variety of conditions, including unsafe access, access that would require unreasonable effort or special equipment, pipe inundation by the receiving water and lack of flow. The final sites represented a variety of types of pipes in different settings in both towns (Table 1; Figures 2a & b). The pipe condition, pipe and site characteristics, and pictures of the pipes and sites were recorded during these initial site inspections and the information used as a reference during ensuing visits.

	LOCATION	Sampling frequency	Access road	Receiving water	Latitude	Longitude	Pipe Characteristics		
Station #	Station name						Shape & size	Condition	Material
	GREENLAND								
1-NR	Newington Road	2 weeks	Newington Road	Pickering Brook	43°02"57.51"	70°49"26.43"	Round- 12"	Good	Concrete
5-WR	Winnicut Road	2 weeks	Winnicut Road	Winnicut River	43°01"51.42"	70°51"06.93"	Round- 24"	Excellent	Cement
6-BD	Bayside Drive	2 weeks	Bayside Drive	Winnicut River	43°02"12.22"	70°50"54.11"	Round- 12"	Poor	Concrete
7-CS1	Caswell Street-1	2 weeks	Caswell Street	Winnicut River	43°02"21.37"	70°50"46.39"	Round- 14"	Poor	Galvanized steel
8-CS2	Caswell Street-2	2 weeks	Caswell Street	Winnicut River	43°02"27.35"	70°50"37.26"	Round- 22"	Good	Concrete
8-CSSP	Caswell St 2-small pipe	2 weeks (added)*	Caswell Street	Winnicut River	43°02"27.35"	70°50"37.26"	Round- 3"	Good	PVC
9-HD	Hillside Drive	2 weeks	Hillside Drive	Pickering Brook	43°02"56.84"	70°49"30.98"	Round- 9"	Poor	Iron
	EXETER								
1-SPA	Swazey Park	4 weeks	Swazey Park	Squamscott River	42°58"58.36"	70°56"57.90"	Round- 36-42"	Good	Concrete
2-SP BD	SwzyPk boatdock	4 weeks	Swazey Park	Squamscott River	42°58"58.83"	70°56"58.16"	Round- 48"	Fair	Concrete
3-NB	Norris Bk RR trks	4 weeks	Wadleigh Street	Norris Brook	42°59"15.25"	70°57"12.95"	Round- 48"	Good	Concrete
4-LRL	Little R-Linden St	4 weeks	Linden Street	Little River	42°58"20.42"	70°57"35.30"	Round- 24"	Good	Concrete
5-GS	Little R-Gilman St	4 weeks (dropped)	Gilman Street	Little River	42°58"28.14"	70°56"43.91"	Round- 12"	Excellent	Black plastic
6-JH	Jady Hill	4 weeks	Chestnut Street	Squamscott River	42°59"02.58"	70°56"49.54"	Round- 36"	Excellent	Corrugated steel
7-GS	Gardner Street	4 weeks	Gardner Street	Exeter River†	42°58"45.47"	70°56"22.35"	Round- 24"	Good	Concrete
8-FND	Friendly's big pipe	4 weeks	Portsmouth Avenue	Wheelwright Creek†	42°59"09.12"	70°56"16.04"	Round- 48"	Fair	Metal
8A-FND	Friendly's small pipe	4 weeks (added)*	Portsmouth Avenue	Wheelwright Creek†	42°59"09.14"	70°56"16.15"	Round- 12"	Good	Metal
9-WCCW	Wheelwright carwash	4 weeks	Portsmouth Avenue	Wheelwright Creek	42°59"16.35"	70°56"04.55"	Half oval-36"	Excellent	Cement
10-WCDC	Wheelwright dogcare	4 weeks	Portsmouth Avenue	Wheelwright Creek	42°59"16.78"	70°56"04.09"	Half oval-36"	Excellent	Cement
11-ERL	Exeter R-Linden St	4 weeks (added)*	Linden Street	Exeter River	42°58"58.83"	70°57"53.81"	Round- 18"	Good	Steel

*Some sites were added after the beginning of the study.

†The pipe discharges at these sites do not empty directly into suface waters; the surface waters listed are the closest to the pipe outfalls.

Table 1. Sampling site locations and descriptions.



Figures 2 a&b. Sampling site locations (yellow markers) in Exeter (a) and Greenland (b).

Scheduling of sampling is critical for volunteers. A 'random design' schedule was set up for sampling once every two weeks, so that weather would not be a pre-determining factor. To enable the Project PI to be present at each sample event, volunteers were assembled into two teams, one for each town. In Greenland, the team was able to sample from all sites on each sample date. In Exeter, sites were separated into two groups, one on the east and one on the west side of town, and the two groups were sampled every other sample date by the Exeter team (Table 1).

Training

A training session was scheduled prior to the beginning of the sampling schedule. The training was held at the UNH Jackson Estuarine Laboratory (JEL) where two 'outfalls', which are actually just estuarine water that runs through the lab, could be used to demonstrate sampling methods. A total of 22 volunteers were trained that day, and the Project PI was joined in supervising and training volunteers by Dari Ward, the UNH Marine Docents coordinator, Ted Walsh Manager of the NHDES VRAP program, Jean Eno from WRWC, and James Houle and Mindy Bubier from the UNH Stormwater Center. Volunteers were trained in sampling methods, site and weather condition characterization and documentation, meter calibration and measurements, and sample processing in the lab. Volunteers were also trained each time they went out into the field for sampling.

Parameters measured

Storm drains can be sources of many pollutants. An array of parameters were chosen for inclusion in this study to reflect local problems and to represent a variety of measurement methods and sampling techniques, to provide well-rounded training for the volunteers. A total of 11 parameters were measured to provide data for assessing the significance of the drainpipes studied as pollution sources (Table 2). Each parameter is either an indicator of a specific pollution source, or it helps in the interpretation of other parameters. A set of three different meters were used to measure parameters, while water samples were collected into bottles and transported to several labs for laboratory analysis for other parameters.

Parameter	Indicator	Lab/method	Container*	Preservation	Maximum holding time
E. coli	Sanitary wastewater	UNH-JEL	PA, G	<10°C, 0.008% Na_2S2O_3	6 hours
Total N	Sewage, animal waste, fertilizer	UNH-WQAL	P, FP, G	Freezing @ -20°C	28 days
Ammonia	Sanitary wastewater	UNH-WQAL	P, FP, G	Freezing @ -20°C	28 days
Chlorine, total residual	Potable water	Field kit	P, G	None required	15 minutes
Chloride	Road salt, sewage, estuarine water	NHDES lab	P, G	Refrigeration: 4°C	28 days
pH	Natural & polluted water	Meter	P, FP, G	Refrigeration: 4°C	14 days
Turbidity	Natural & runoff material	Meter	P, FP, G	Refrigeration: 4°C	48 hours
Dissolved oxygen	Oxygen demand	Meter	P, FP, G	None required	Immediate
Specific conductance	road salt, polluted water	Meter	P, FP, G	Refrigeration: 4°C	28 days
Salinity	Road salt, estuarine water	Meter	P, FP, G	Refrigeration: 4°C	28 days
Temperature	Many factors	Meter	P, FP, G	None required	Immediate

*P=polyethylene; G=glass; LDPE=low density polyethylene; FP=fluoropolymer (polytetrafluoroethylene (PTFE; Teflon®);
PA=polypropylene or other autoclavable plastic

Table 2. Water quality parameter characteristics and analytical labs.

The methods chosen for laboratory analysis were all included in the US Code of Federal Regulations list of acceptable detection methods for the EPA in the analysis of pollutants in water (eCFR 2012), and were chosen based on several criteria. Several labs in the area have been used for measuring water quality parameters as part of other research studies and monitoring programs. To better enable comparison of findings from this study with other studies, analyses were performed at two of these labs at UNH, the Water Quality Analysis Lab where Dr. Bill McDowell is the director, and the JEL Microbiology lab where the Project PI is the lab director. The NHDES lab conducted the chloride analysis as part of the VRAP program analyses. A field kit was used to detect total residual chlorine; other parameters can be detected using field detection kits, so this was a useful model approach for other future parameters. A YSI 85 meter was used to measure water temperature, salinity, and dissolved oxygen (DO) as % saturation and concentration. A LaMotte 2020e meter was used to measure turbidity and pH was measured in the field using an Oyster pH meter. We also used a new YSI ProODO meter with an optical DO probe along side the YSI 85 meter for future reference and for QA purposes. It was also used for water temperature measurements to check the YSI 85 meter measurements.

Sampling task order and procedures

With a group of volunteers and many tasks, the approach to sampling was best performed with a logical order of procedures and tasks (Figure 3). The initial step was to meet at a designated location where people could meet, carpool, and consider the weather conditions for clothing needs and whether it was safe for sampling. One team of volunteers met every other Tuesday in the Greenland Town office parking lot at 1 PM. In Exeter, volunteers met every other Wednesday at 1 PM in the municipal parking lot behind the Town Hall. The timing of low tide was important for some sites in Exeter, as three storm drains were inundated at high tide, or even just after low tide. The order of sampling at the set of sites for the day was determined, sample bottles were labeled and the team traveled together to the first site.

Stormwater Monitoring Study-2012

<u>Meeting Place Instructions:</u>

Record Air temperature
Calibrate pH, DO (2) and turbidity meters
Plan sampling order and procedure

<u>On-site Instructions</u>:

*the crew will need to split **RESPONSIBILITIES***:

Site observation and characterization recorder
Sample collector
Instrument users
Analysis kit users
Data recording
Quality assurance/procedures 'cop'

*Order of **TASKS**:*

Determine if water is flowing and if sampling is possible; **If YES:**

-Characterize site description & take photo (first time only, or if significant change has occurred)

-Collect sample for chlorine, pH and turbidity
  -Conduct chlorine, pH and turbidity measurements

-Label lab analysis bottles (bacteria, nutrients and chloride)

-Collect samples for bacteria, nutrients and chloride into bottles
-Collect sample in bucket or cut-off sample bottle for DO meter
  -Measure DO, salinity, temperature & specific conductance
  -Measure standards if appropriate (1 site/sample date)
-Collect duplicate sample if appropriate

-Measure flow rate if possible
-Clean all probes with deionized water prior to proper storage

Figure 3. Field sampling order of tasks.

At each site, the first step was to inspect the pipe outfall and see if there was flowing discharge and whether the site was accessible for sampling. Safety hazards were noted, including poison ivy, slippery conditions, traffic, mosquitoes/ticks, and any other condition that would justify extra care. If any condition was not favorable, no sampling occurred. If all conditions were favorable, several individuals or groups would begin with different tasks. One individual would record time, weather conditions, site characteristics, and eventually would record measurement data. Other groups would calibrate meters while others would collect water samples.

The first set of samples collected were those for laboratory analyses. Sample bottles were filled directly from the pipe discharge or water was collected using another container where water was too shallow of otherwise not conducive to direct sample collection (Table 3). The lab analysis sample bottles were immediately put on ice in a cooler. The next sampling involved collection of a large volume (2-4 gallons) in plastic buckets to provide enough water for measurement of parameters by meters and for detection using field kits. By this time meters were calibrated and sample measurements were initiated. Meanwhile the sampling team measured flow rate when possible. The easiest sites allowed collection of all discharge into the sample bucket over a measured time period. The collected water volume was measured using a large graduated cylinder, and the flow rate was determined at least three times at each site. The flow was less accessible at some pipes, or too spread out for the bucket to capture the full flow. In the former instance, discharge was collected into a smaller container while time was recorded; the volume was again measured using the graduated cylinder. For laterally spread discharges, the collection container was placed to capture the most representative fraction of the flow, and the remaining flow was visually estimated based on amount of water discharged to determine the flow rate for the full volume of pipe discharge.

Water Measurements & Analysis Kits

Parameter	Unit of Measure	Instrument	Nature of sample
Turbidity	NTU	LaMotte 2020e turbidity meter	Subsample from bucket
pH	pH units	“The Oyster” pH meter	Subsample from bucket
Chlorine	mg/L	Hach chlorine test kit	Sample direct from pipe or subsample from bucket
Temperature	°Centigrade	YSI 85 or Pro ODO meter	In Sample bucket
Salinity	ppt	YSI 85 or Pro ODO meter	In Sample bucket
Specific conductivity	µS	YSI 85 or Pro ODO meter	In Sample bucket
Dissolved oxygen concentration	mg/L	YSI 85 or Pro ODO meter	
Dissolved oxygen saturation	% saturation	YSI 85 or Pro ODO meter	In Sample bucket

Water Sampling

Parameter	Sample Method	Storage
Dissolved & total nutrients	Direct sample from pipe flow or from sample bucket transferred to 1 L *acid-washed* Nalgene bottle	In cooler on ice
Bacteria	Direct sample from pipe flow or from sample bucket transferred to 1 L *sterile* Nalgene bottle	In cooler on ice
Chloride	Direct sample from pipe flow or from sample bucket transferred to 50 ml plastic bottle	In cooler on ice

Table 3. Water quality parameters and sample methods, measurements and storage.

When all sample measurements were completed, data sheets were inspected to make sure all data were recorded, and once verified, meter probes and sampling containers were rinsed with de-ionized water in preparation for the next site. Standards used in calibration re-sealed, instruments were cleaned with de-ionized water and Kimwipes, and all materials properly stored.

QA/QC

As previously mentioned, all meters were calibrated just prior to use each sampling date according to manufacturer specifications. A useful, comprehensive guide to many of these procedures is available through the NHDES VRAP (NHVRAP 2011). Another step was to include replicate analyses at one site per sample date. Midway through the sampling, standards were re-checked on all meters to detect meter drift. Meters were also re-calibrated at this time if necessary. At the end of the day, meters were again checked for readings of standards to again check for drift. For laboratory analyses, duplicate samples were collected for every ten samples collected. Field and lab blanks with de-ionized were also included in the analysis.

IMPLEMENTATION

Sampling success and conditions

Sampling occurred at all intended sites on all sampling dates, with a few exceptions and modification (Tables 4, 5a&b). There was never any flow at site 5-LRS in Exeter, and other sites, notably sites 7-CS1 and, to a lesser extent, site 1-NR in Greenland, had flow on only some sampling dates. In other instances, meters gave problems so some field measurements were not taken. There were several extra samples collected for bacterial analysis only (Table 4), either to see if a newly discovered pipe might be a pollution source, or to gain a deeper understanding about a pollution source. The number of samples collected provided a useful preliminary look at how clean or polluted pipe dischargers were, although the small number of samples for which there are data prohibits useful statistical analysis.

GREENLAND Date			SITES*						TOTAL
3/27/12	5	6	8	9					4
4/10/12	5	6	8	9					4
4/24/12	1	5	6	7		8	9		6
5/8/12	1	5	6	8		9	1-DS†	1-DF†	5
5/22/12	5	6	8-CS2	8-CSB		8-CSSP	9		6
6/5/12	1	5	6	8		9			5
							SUM =		30
EXETER Date			SITES*						TOTAL
3/28/12	6	7	8	8A	9	10			6
4/11/12	1	2	3	4					4
4/25/12	6	7	8	8A	9	10			6
5/9/12	1	2	3	4	11				5
5/23/12	6	7	8	8A	9	10			6
6/6/12	1	2	3	4	4-AS	8	9	11†	6
							SUM =		33

*Sites: see Table 1 for more details
Greenland sites: 1-NR, 5-WR, 6-BD, 7-CS1, 8-CS2, 8-CSSP, 9-HD
Exeter sites: 1-SPA, 2-SPBD, 3-NB, 4-LRL, 6-JH, 7-GS, 8-FND, 8A-FND, 9-WCCW, 10-WCDC, 11-ERL
†Bacterial sample only; 1-DS is 1-NR downstream; 1-DF is 1-NR dog feces sample; 4-AS is 4-LRL animal sprat

Table 4. Sampling summary for Greenland and Exeter.

EXETER DATE	SITE	Water flow rate ml/sec	Water Temperature °C	Salinity ppt	Specific conductance μS	Chloride mg/L	pH	Chlorine mg/L	Turbidity NTU	Dissolved saturation %	Oxygen concentration mg/L	Fecal coliform cfu/100 ml	*E. coli* cfu/100 ml	*E. coli* loading rate cfu/sec	Total nitrogen mg N/L	Total N loading rate μgN/sec	Ammonium mg N/L	NH4:TN %
3/28/12	6-JH	362	8.7	0.2	200	140	6.42	0	nd	96	11.2	480	480	1738	1.77	642	192	11%
	7-GS		11.7	0	0	140	6.4	0	0.65	73	7.3	360	240		2.33		46	2%
DRY	8-F	2630	9.2	0.6	500	1200	6.27	0	nd	82	9.4	<1	0	0	3.08	8110	134	4%
	8A-F		7.4	2	nd		6.65	0	nd	95	11.3	25	24		1.62		402	25%
	9-WCCW	1800	9	1.6	2104	980	7	0	nd	94	10.8	24	24	432	2.14	3847	77	4%
	10-WCDC		8.1	0.4	1000	520	7.6	0	nd	86	10.2	42,800	38,000		3.95		614	16%
4/11/12	1-SPA	1000	12.1	0.4	777	190	6.46	0	4.6	96	10.1	188	180	1800	2.79	2786	113	4%
	2-SPBD	6	14	0.9	1728	430	7.7	0	2.1	89	10.0	5200	5200	312	1.70	10	395	23%
DRY	3-NB	225	9.8	0.3	548	140	7.42	0	0.5	99	11.3	4	4	9	3.35	755	11	0.31%
	4-LRL	476	10.5	0.3	568	140	6.33	0	0	91	10.3	0	0	0	3.72	1771	7	0.18%
	5-LRS	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
4/25/12	6-JH		12.3	0.2	464	110	6.1	0	4.2	95	10.3	<10	<10		0.96		133	14%
	7-GS		12.3	0.2	362	120	5.75	0	0.35	87	9.7	260	260		1.53		17	1%
WET	8-F	610	14.8	0.7	1059	1200	6.52	0	0.23	88	8.9	<10	<10	0	2.58	1574	27	1%
	8A-F		11.3	1.9	2577	400	6.37	0	0.2	104	11.5	16	16		1.35		144	11%
	9-WCCW	420	12.9	1.2	2410	780	6.72	0	2.7	102	10.8	104	104	437	1.89	792	13	1%
	10-WCDC	133	11.6	0.7	1435	420	7.26	0	3.9	104	11.3	23,600	22,800	30324	1.40	186	5	0.37%
5/9/12	1-SPA		13.2	1.4	2020	200	7.43	0	1.5	96	10.0	520	520	0	2.47		110	4%
	2-SPBD	no data				780						2800	2800		1.32		198	15%
WET	3-NB	1357±101	12	0.2	477	110	7.2	0	2.5	97	10.5	<4	<4		2.59	3514	3	0.12%
	4-LRL	1600±48	12.1	0.2	359	160	6.97	0	0	98	10.5	8	8	128	3.53	5649	18	0.50%
	11-ERL		11.6	0.1	187	60	7.1	0	0.35	100	10.9	<4	<4		1.09		5	0.48%
5/23/12	6-JH	358±15	14.9	--	--	180	--	--	--	--	--	240	160	573	1.50	537	58	4%
	7-GS		15.3	0	7.8	150	5.9	0	3.19	79	7.9	420	230		1.86		18	1%
DRY	8-F	571	*	*	*	890	6.88	0	2.29	*	*	172	52	297	1.89	1080	38	2%
	8A-F	432±68	*	*	*	330	6.86	0	1.36	*	*	68	64	276	1.29	556	168	13%
	9-WCCW	833±138	18	0.6	1030	820	6.4	0	0.93	n/r	n/r	120	70	583	1.94	1612	11	1%
	10-WCDC	84±8	17.9	*	*	64	6.9	0	5.59	*	*	11200	9600	8064	0.89	74	152	17%
6/6/12	1-SPA	100	15.7	0.3	583	150	5.6	0	10.7	81	8.1	940	720	720	1.16	116	104	9%
	2-SPBD		15.7	0.4	742	190	6.1	0	2.67	92	9.1	6000	3200		lost sample		82	
WET	3-NB	1200	14	0.2	334	93	6.4	0	2.1	95	9.9	92	44	528	2.47	2964	6	0.24%
	4-LRL		13.6	0.3	578	150	6.4	0	0.16	94	9.8	152	136		3.54		11	0.31%
	4-LRL-animal sprat (#/g wet wt)												2,320,000		feces			
	9-WCCW	625	14.5	1.2	2363	780	6.5	0	1.55	92	9.4	80	80	500	2.01	1255	35	2%
	10-WCDC	83	15.6	0.4	767	200	6.9	0	4	86	8.6	24800	24,800	20584	4.09	340	899	22%
	11-ERL	no flow	no flow	no flow	no flow		no flow	no flow	no flow			<4	<4		no flow			

Table 5a. Data collected at Exeter sites for all measured and analyzed parameters.

GREENLAND DATE	SITE	Water flow rate ml/sec	Water Temperature °C	Salinity ppt	Specific conductance μS	Chloride mg/L	pH	Chlorine mg/L	Turbidity NTU	Dissolved saturation %	Oxygen concentration mg/L	Fecal coliform cfu/100 ml	*E. coli* cfu/100 ml	*E. coli* loading rate cfu/sec	Total nitrogen mg N/L	Total N loading rate μgN/sec	Ammonium mg N/L	NH4:TN %
3/27/12	1-NR	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	5-WR		12.7	0	2.8	30	7.26	0	29	86	9.1	10	0		1.88		92	5%
	6-BD		11.5	0	7.1	500	5.00	0	10	64	7.1	0	0		0.44		343	78%
	7-CS1	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	8-CS2		10	0.2	490	300	7.00	0	0	96	10.8	0	0		1.88		37	2%
	9-HD	265±32	7.3	0	19.7	54	6.50	0	0	94	11.1	0	0	0	4.23	1120	11	0.25%
4/10/12	1-NR	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	5-WR		15.3	0	6.5	43	7.27	0	nd	84	9.8	0	0		1.36		176	13%
	6-BD		13.6	0	0	510	6.35	0	nd	64	7.1	0	0		0.59		531	90%
	7-CS1	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	8-CS2		10.2	0.4	9.2	490	7.07	0	nd	91	10.0	0	0		1.69		86	5%
	9-HD	129±18	10.3	0.1	200	64	6.95	0	nd	96	10.3	0	0	0	4.17	538	10	0.23%
4/24/12	1-NR	148±35	13.6	0.1	185	130	6.81	0	5.1	96	10.6	1200	1200	1776	0.75	111	49	7%
	5-WR		11.1	0.1	131	29	7.30	0	11	90	10.5	328	244		2.39		53	2%
	6-BD		13.5	0.7	1091	440	6.36	0	1	57	5.7	8	<4		0.43		331	77%
	7-CS1		11.7	0.4	575	210	7.09	0	15	94	10.2	160	152		1.93		64	3%
	8-CS2		11.4	0.3	510	180	7.40	0	3.7	88	10.2	32	28		1.61		29	2%
	9-HD	90±10	10.7	0.2	342	99	6.57	0	0	92	11.0	8	8	7	4.51	406	9	0.19%
5/8/12	1-NR		12	0.3	487	180	7.60	0	9.4	99	10.2	4000	4000		0.47		168	36%
	1-NR downstream		nd	nd	nd		nd	nd	nd	nd		124000	124000		no sample			
	1-NR dog feces (#g wet wt)		nd	nd	nd		nd	nd	nd	nd		45600000	43600000		feces			
	5-WR		10.5	0.1	252	44	7.02	0	7.7	92	9.5	30	20		1.84		76	4%
	6-BD		12.7	0.5	766	310	6.92	0	3.9	65	5.2	800	<4		0.45		147	33%
	7-CS1	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	8-CS2		11.7	0.5	735	290	6.97	0	2.6	89	9.2	260	252		1.72		63	4%
	9-HD	105±5	11	0.1	406	76	6.48	0	0	95	10.8	<4	<4		4.79	503	20	0.42%
5/22/12	1-NR	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	5-WR		14.8	0	3.2	36	6.88	0	3.28	89	9.2	60	60		0.87		47	5%
	6-BD		18.4	0	10	390	6.15	0	5.11	48	4.5	240	240		0.29		178	61%
	7-CS1	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	8-CS2		15.4	0	13.8	350	6.77	n/r	1.36	84	8.1	240	170		1.61		47	3%
	8-CS2	field duplicate				350						280	250		1.98		51	3%
	8-CSSP		16.8	0	4.5	170	6.47	0	7.01	57	5.7	<10	<10		2.82		1941	69%
	9-HD	198±23	12.4	0	285	60	6.41	0	0.32	95	10.3	<4	<4		4.56	904	7	0.15%
6/5/12	1-NR		13.1	0.2	255	90	6.8	0	4.6	93	9.8	1760	1760		0.87		92	11%
	5-WR		14.3	0	104	12	6.35	0	3.82	86	8.3	190	190		1.97		56	3%
	6-BD		15.6	0.2	292	250	6.39	0	12.9	56	4.6	80	80		0.57		139	24%
	7-CS1	no flow	no flow	no flow	no flow		no flow	no flow	no flow	no flow	no flow	no flow	no flow		no flow			
	8-CS2		15.1	0.3	530	130	6.35	0	2.92	86	8.1	270	210		1.50		42	3%
	9-HD	105±5	12.4	0.1	496	100	6.58	0	0.34	84	9.8	44	40	42	4.69	493	8	0.17%

Table 5b. Data collected at Greenland sites for all measured and analyzed parameters.

An obviously important condition that affects storm drain discharges is rainfall. Most of the drainage areas are relatively small for the drain pipes in this study, so the effect of runoff from rainfall on water quality or pollutant loading may not manifest in any discernable effect in this study because sample dates considered to be ‘wet’ are those with >0.5” of precipitation (at the UNH-Durham, NH weather station) in the previous 48 h (Table 6), and the immediate effects of runoff on the pipe discharges probably preceded any sampling in small drainage areas (Figure 4).

		Days prior to sampling/ Rainfall (inches)				
DATE	Condition	0	1	2	3	4
3/29/12	Dry	0.02	0.02	0	0.01	0.1
4/11/12	Dry	0	0	0	0	0
4/25/12	WET	0	0	1.75	0.78	0
5/9/12	WET	0.36	0.56	0	0	0
5/23/12	Dry	0.01	0.22	0	0	0
6/6/12	WET	0.1	0.21	0.47	0.21	2.25

Table 6. Rainfall amounts for four days preceding sample events (UNH weather statistics).

Figure 4. Exeter storm drains (circle/numbers) and drainage areas (in color).

The daily rainfall amounts showed the study period included an extended initial dry period through most of April followed by a relatively wet period through much of May, and again in early June (Figure 5). Water temperatures warmed early this late winter and spring, with a gradual warming from March to June (Tables 5a&b).

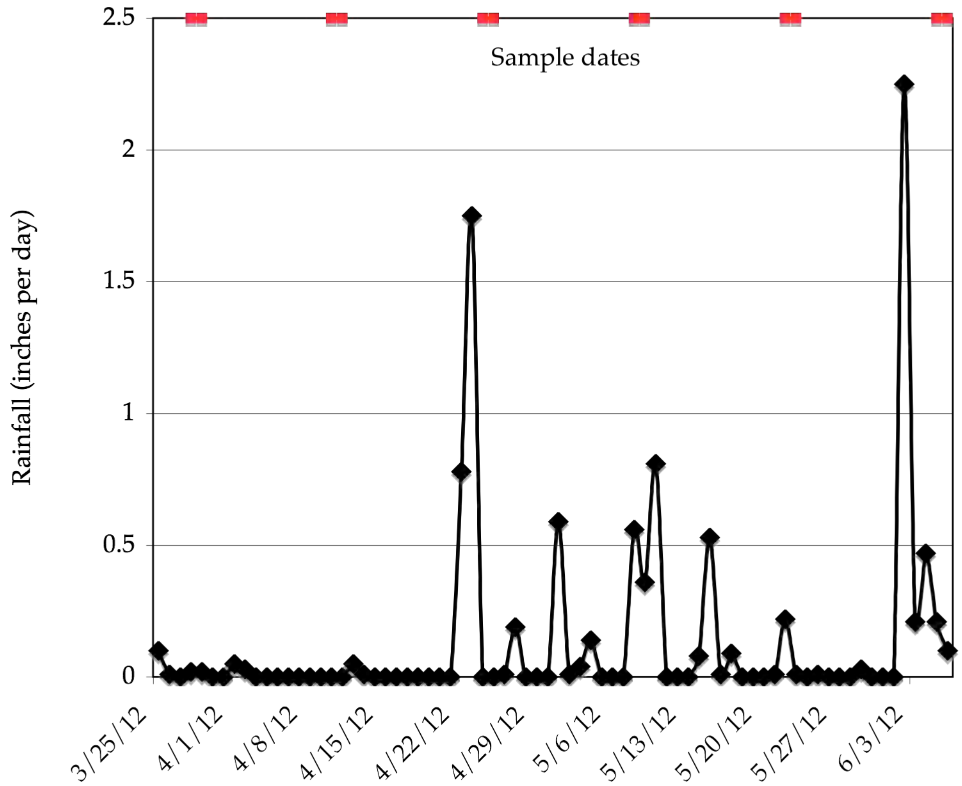


Figure 5. Daily rainfall amounts (inches per day) and sample dates (UNH weather statistics).

Data results & discussion

The resulting data from field measurements and laboratory analyses showed some pipes were relatively free of contaminants while some had potential water quality problems (Tables 5a&b). State and federal environmental protection agencies publish standards and guidance levels for parameters for classifying and managing water quality. Few standards have been established for storm pipe discharges, so standards for receiving waters were used for determining if discharges may cause water quality problems (Figure 6). The results of this study were compared with the standards in Figure 6, and data that violated standards or indicated potential problems were highlighted in Tables 7a&b. For Exeter, a number of sites on different sample dates showed levels of *E. coli*, total nitrogen, chloride and specific conductance readings in excess of state standards or were at levels that suggested problems (Table 7a). Sites in Greenland showed violations of state standards for the same parameters; pH and dissolved oxygen measurements also violated state standards or were at levels that suggested problems (Table 7b).

A Quick-Reference Guide to VRAP Water Quality Standards

<table>
<tr><th>Parameter</th><th>Class A Standard</th><th>Class B Standard</th></tr>
<tr><td>Chloride
(mg/L)</td><td colspan="2">Chronic standard is 230 mg/L
Acute standard is 860 mg/L</td></tr>
<tr><td>Chlorophyll-a
(mg/L)</td><td colspan="2">No Numeric Standard
<table>
<tr><th>Unit</th><th>Category</th></tr>
<tr><td>< 3</td><td>Excellent</td></tr>
<tr><td>3 – 7</td><td>Good</td></tr>
<tr><td>7 – 15</td><td>Less than desirable</td></tr>
<tr><td>> 15</td><td>Nuisance</td></tr>
</table></td></tr>
<tr><td>Conductivity/
Specific Conductance
(µS/cm as chloride surrogate)</td><td colspan="2">No Numeric Standard
Although in many fresh surface waters, specific conductance can be used as a surrogate to predict compliance with numeric water quality criteria for chloride.
<table>
<tr><th>Unit</th><th>Category</th></tr>
<tr><td>0 – 100</td><td>Normal</td></tr>
<tr><td>101 – 200</td><td>Low Impact</td></tr>
<tr><td>201 – 500</td><td>Moderate Impact</td></tr>
<tr><td>> 501</td><td>High Impact</td></tr>
<tr><td>Approximately 850</td><td>Likely exceeding the chronic chloride standard</td></tr>
</table></td></tr>
<tr><td>Dissolved Oxygen
(mg/L & %)</td><td>6 mg/L
75% Minimum Daily Average; Unless Naturally Occurring</td><td>5 mg/L
75% Minimum Daily Average; Unless Naturally Occurring</td></tr>
<tr><td>E. coli
(Counts/100mL)</td><td>Geometric mean of ≤47 E. coli cts/100 mL based on at least 3 samples obtained over a 60-day period
≤ 153 E. coli cts/100 mL in any 1 sample</td><td>Geometric mean of ≤126 E. coli cts/100 mL based on at least 3 samples obtained over a 60-day period
≤ 406 E. coli cts/100 mL in any 1 sample</td></tr>
<tr><td>pH (Units)</td><td colspan="2">6.5 – 8.0
Unless Naturally Occurring
<table>
<tr><th>pH (Units)</th><th>Category</th></tr>
<tr><td><5.0</td><td>High Impact</td></tr>
<tr><td>5.1 – 5.9</td><td>Moderate to High Impact</td></tr>
<tr><td>6.0 – 6.4</td><td>Normal; Low Impact</td></tr>
<tr><td>6.5 – 8.0</td><td>Normal;</td></tr>
<tr><td>6.1 – 8.0</td><td>Satisfactory</td></tr>
</table></td></tr>
<tr><td>Total Phosphorus
(mg/L)</td><td colspan="2">No Numeric Standard. As Naturally Occurs
<table>
<tr><th>Unit</th><th>Category</th></tr>
<tr><td>< 0.010</td><td>Ideal</td></tr>
<tr><td>0.011 – 0.025</td><td>Average</td></tr>
<tr><td>0.026 – 0.049</td><td>More than desirable</td></tr>
<tr><td>≥0.050</td><td>Excessive "NHDES Level of Concern"
(potential nuisance concentration)</td></tr>
</table></td></tr>
<tr><td>Total Kjeldahl Nitrogen
(mg/L)</td><td colspan="2">No Numeric Standard. As Naturally Occurs
<table>
<tr><th>Unit</th><th>Category</th></tr>
<tr><td>< 0.25</td><td>Ideal</td></tr>
<tr><td>0.26 – 0.40</td><td>Average</td></tr>
<tr><td>0.41 – 0.49</td><td>More than desirable</td></tr>
<tr><td>≥ 0.50</td><td>Excessive
(potential nuisance concentration)</td></tr>
</table></td></tr>
<tr><td>Turbidity
(NTU)</td><td>As Naturally Occurs</td><td>Shall not exceed naturally occurring conditions by more than 10 NTU</td></tr>
</table>

New Hampshire Volunteer River Assessment Program

29 Hazen Drive/PO Box 95 - Concord, NH 03302-0095
http://des.nh.gov/organization/divisions/water/wmb/vrap/index.htm

2006

Figure 6. Reference guide to NHDES water quality standards and categories (VRAP).

Water Quality Parameter	Water Quality Standard	Site # 1	2	3	4	6	7	8	8A	9	10
Dissolved oxygen (% saturation)	75% saturation						x				
pH: Moderate impact	5.0 to 5.9	x					x				
Specific conductivity											
High impact	>500 μS/cm	x	x	x	x			x	x	x	x
Exceeds State chloride standard	850 μS/cm		X					X	X	X	X
Escherichia coli											
Single sample maximum	406/100 ml%	X	X			X					X
Geometric mean	126/100 ml	X	X				X				X
Chloride											
Exceeds chronic standard	230 mg/L		X					X	X	X	X
Exceeds acute standard	860 mg/L							X		X	
Ammonium	15 mgN/L										
Total Nitrogen											
Exceeds State (DO) standard	0.45 mg N/L	X	X	X	X	X	X	X	X	X	X

GREENLAND STORM DRAIN FINDINGS

Water Quality Parameter	Water Quality Standard	Site # 1	5	6	7	8	8A	9
Dissolved oxygen (% saturation)	75% saturation			X				
pH: Moderate impact	5.0 to 5.9			x				
Specific conductivity								
High impact	>500 μS/cm			x	x	x		
Exceeds State chloride standard	850 μS/cm			X				
Escherichia coli								
Single sample maximum	406/100 ml%	X						
Geometric mean	126/100 ml	X			x			
Chloride								
Exceeds chronic standard	230 mg/L			x		x		
Exceeds acute standard	860 mg/L							
Ammonium	15 mgN/L							
Total Nitrogen								
Exceeds State (DO) standard	0.45 mg N/L	X	X	X	X	X	X	X

Table 7. Summary of storm drain parameter results relative to water quality standards.

Some parameters were always present at levels that were not of concern. Salinity is only pertinent for estuarine waters, and so it was only relevant for sites 1&2 in Exeter. Turbidity appeared to not be a problem for this study; readings were relatively low and where it was somewhat higher there appeared to be natural causes. Chlorine was non-detectable in all samples tested using the kit detection assay.

The average total N concentrations (Table 8) at each site in both towns exceeded the state standard of 0.45 mg N/L, established to prevent problems with DO in receiving waters (Trowbridge 2009), reflecting the finding that all but 4 samples (all from Greenland site 6-BD) from all sites and sample dates also exceeded the state standard. The site averages ranged from 0.46 to 4.49 mg N/L at sites 6-HD and 9-HD, respectively. For comparison, average annual total nitrogen concentrations in the Exeter (9-EXT-Wood & Trowbridge 2012; Site 1 Jones & Gregory 2011) and Squamscott (Site 2-Jones & Gregory 2011) rivers are lower than all average storm drain discharge concentrations (Table 8). In Greenland, all storm drain discharge average total N concentrations also exceeded the concentration in the Winnicut River during 2011 (Wood and Trowbridge 2012).

Location & Site #	Number of samples	Average	Standard deviation
GREENLAND			
1-NR	3	0.69	0.21
5-WR	6	1.72	0.53
6-BD	6	0.46	0.11
7-CS1	1	1.93	
8-CS2	6	1.67	0.13
8A	1	2.82	
9-HD	6	4.49	0.25
2011 NHDES 02-WNC	*11*	*0.44*	*0.09*
EXETER			
1-SPA	3	2.14	0.86
2-SPBD	2	1.51	0.27
3-NB	3	2.80	0.48
4-LRL	3	3.60	0.11
6-JH	3	1.41	0.41
7-GS	3	1.90	0.40
8-FND	3	2.52	0.60
8A-FND	3	1.42	0.17
9-WCCW	4	1.99	0.11
10-WCDC	4	2.58	1.68
11-ERL	1	1.09	
2011 NHDES 09-EXT	*11*	*0.34*	*0.08*
**2011 Jones&Gregory Site#1*	*2*	*0.65*	*0.18*
**2011 Jones&Gregory Site#2*	*2*	*0.92*	*0.02*

*Jones & Gregory (2011) Site#1 is the same as NHDES 09-EXT.
Site #2 is downstream of downtown Exeter in the tidal Squamscott R.

Table 8. Average total nitrogen concentrations for all Greenland and Exeter storm drains.

Several sites in each town had specific conductance readings that suggested "high impact", *E. coli* readings that exceeded the geometric mean of single sample maximum standards, chloride concentrations above the state standard, and pH readings low enough to suggest moderate negative impacts. Single sites in both towns also had low % DO saturation readings that were below state standards.

The findings of this study showed some water quality parameters varied between sample dates while others remained relatively steady. No consistent temporal trend was observed for chloride (Figures 7a&b), total N (Figures 8a&b), ammonium (Figures 9a&b), *E. coli* (Figures 10a&b), specific conductance (Figures 11a&b) or dissolved oxygen (Figures 12a&b), although some sites did show upward or downward trends with time. ***NOTE: Figures 7 through 12 are presented at the end of this report.*** The graphs also illustrate the vast differences between sites. Many sites had parameters at levels that did not violate state standards, while others clearly violated standard levels or were present at levels much greater than found at other sites. The latter include site 8-FND and 9-WCCW for chloride, sites 4-LRL and 9-HD for total N, sites 2-SPBD 10-WCDC, 6-BD and 8A-CS2 for ammonium, sites 2-SPBD, 10-WCDC and 1-NR for *E. coli*, and sites 1-SPA, 2-SPBD, 8A-FND, 9-WCCW, 10-WCDC and 6-BD for specific conductance. Site 6-BD also had % DO saturation levels consistently below the state standard.

Pollution source identification

A look at both single parameters and all the water quality data can help deepen understanding about potential sources of detected contaminants. The elevated levels of *E. coli* all suggest fecal pollution sources, and probably human sewage for the sites with the highest concentrations. This is even more apparent given the elevated levels of ammonium at some of the same sites like 2-SPBD and 10-WCDC (Table 5b). Sites like 8A-CS1 and 6-BD with elevated ammonium but low *E. coli* levels suggests anaerobic conditions may exist at these sites, where septic system leachate or other nitrogen sources may remain present as ammonium instead of being transformed into nitrate by aerobic bacteria. The low DO levels at site 6-BD supports this conclusion.

High *E. coli* levels at a site in each town triggered further action to identify the sources of the bacteria. In Exeter, the *E. coli* levels at site 10-WCDC ranged from 9,600 to 38,000 cells/100 ml, well above the single sample maximum standard of 406 cells/100 ml (Figure 10a). The Town of Exeter responded to these findings by sending town personnel to begin exploration of the pollution source by collecting samples for testing at catch basins up into the drainage area for this pipe. That investigation continues.

A substantial pile of dog feces was observed next to the drainage ditch at 1-NR in Greenland early on during the initial site investigation. Soon thereafter the pile was pushed into the ditch, and more dog feces was dumped into the ditch during the study period. As part of the sampling on May 8, two extra samples were collected to help document the impact of this waste disposal issue to the downstream receiving water. The sampling occurred downstream from the pipe, and was not coming directly from stormwater runoff even though runoff was the means by which the contaminants were transported to Pickering Brook. A sample of the feces and a sample of the water flowing past the feces were analyzed for *E. coli* in addition to the regular sample of water discharged from the pipe. The dog feces contained 44,000,000 *E. coli* cells per gram of wet weight feces (Figure 13), thus representing a powerful source of bacterial pollution, given the pile probably weighed several kilograms. The water sample from downstream of the feces contained 124,000 *E. coli*/100 ml, a 31-fold increase over the level found coming out of the pipe (4,000 *E. coli*/100 ml). Both the WRWC and the Town Administrator undertook efforts to educate the adjacent landowner and neighbors about proper disposal of dog waste and the potential harm improper disposal can have on water quality and public health. The practice of disposal of feces into the ditch ceased as a result of the findings of this study and the outreach by the two local groups. Even though this site, 1-NR, had relatively low levels of total N discharged from the pipe, the downstream feces contains high levels of N, ~0.7%N by weight that translates to 7 mg N/g feces, and thus was also probably a significant source of N pollution to Pickering Brook.

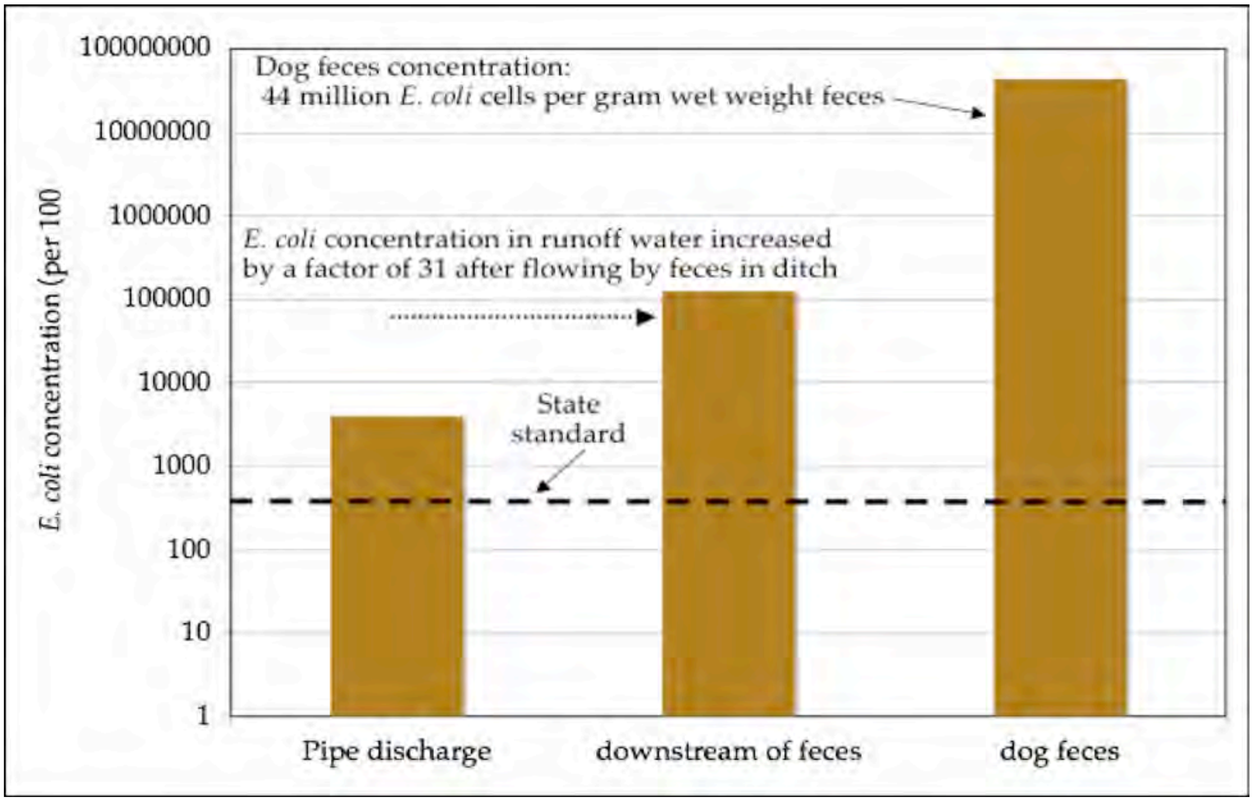


Figure 13. *E. coli* concentrations at Site 1-NR in Greenland: pipe discharge, dog feces and downstream of dog feces.

Pollutant loading estimates

Measurement of instantaneous flow rate was attempted at each site on each sample date. Not all discharges were amenable to flow rate measurement, while others provided an opportunity to make rough but consistent estimates of flow rate (Tables 5a&b), including seven sites in Exeter and two in Greenland. Given the delayed time of sampling relative to rainfall and runoff, there was evidence of increased flow during wet weather at only a few sites, while at others the dry weather flow rates were higher, yet variable (Figure 14). Using the rough flow rate estimates and the measured concentrations of *E. coli* and total N, we estimated loading rates to help frame the significance of storm drain discharge as pollution sources (Table 9). Instantaneous flow rates are not necessarily good estimates of daily or annual loading rates, especially because for this study data were only collected during a 3-month period in spring. Nonetheless, the estimates are useful to gain insight into the potential significant of these pipes as pollution sources.

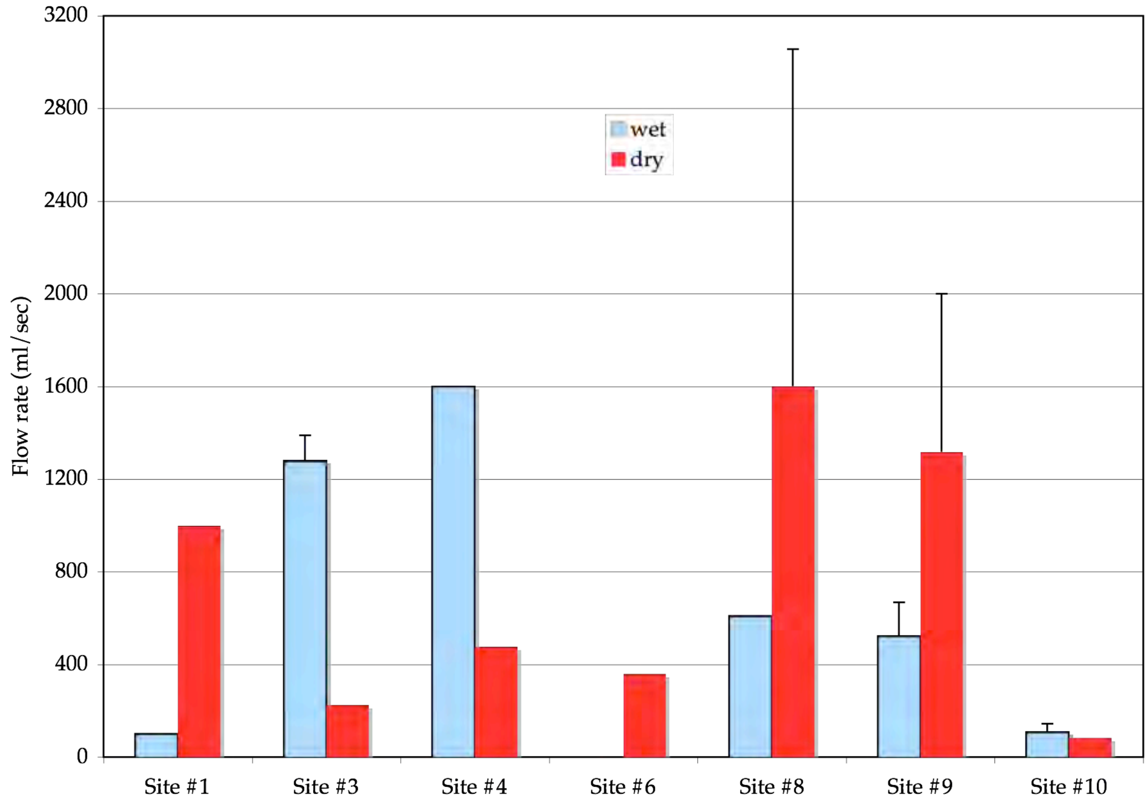


Figure 14. Effect of weather conditions (wet or dry) on flow rates of discharge from storm pipes in Exeter.

This Study		
Site	**10^6 *E. coli*/d**	**kg TN/y**
EXETER		
1	109	46
3	23	76
4	11	117
6	100	19
8	26	113
8A	24	18
9	42	59
10	1698	6
Total	**2033**	**454**
GREENLAND		
1	153	4
9	2	21
Total	**155**	**25**
Sum total	**2188**	**479**
Previous Studies		
	10^6 *E. coli*/d	**kg DIN/y**
PORTSMOUTH (Jones 2000)		
8020	11,253	121
DOVER (Jones 1998)		
CRT 950	0.77	16
CRT 1015	972	34
CRT 8000	99,360	713
Total	**100,333**	**763**
All total	**113,774**	**1363**

Table 9. Estimated loading rates for *E. coli* and nitrogen from storm drains in this and previous studies.

The overall daily loading of *E. coli* cells from the 9 drains in Exeter and Greenland for which flow rate measurement was possible, was 2,188,000,000 cells per day, with most of the loading (77.6%) from site 10-WCDC, and 94.1% from the top four sites, 1-SPA, 6-JH, 10-WCDC and 1-NR (Table 9). Thus, elimination of the sources from these 4 pipes would eliminate 94% of the bacterial loading from the drains for which we could estimate flow rates.

The annual loading rate of nitrogen (as total N) from all nine measurable pipes was 479 kg N per year, with two sites, 4-LRL and 8-FND contributing 48% of the load (Table 9). Thus, eliminating the nitrogen sources from these two pipes could decrease annual loading by 230 kg N, again acknowledging the rough estimation these numbers represent.

The annual loading rate for the nine measurable pipes in this study translates to 0.53 tons of N/year, which is the same order of magnitude as some small WWTFs in the Seacoast region (PREP 2009). This amount only represents an estimated loading from the 9 pipes analyzed in this study, and is an admittedly rough estimate. Other studies in the Seacoast, however, show there are many other pipes discharging significant levels of fecal-borne bacteria and nitrogen to coastal receiving waters (Jones 1998, Jones 2000). Thus, there are data supporting the fact that a few storm drains are significant sources of different types of pollution in the area. On the other hand, a number of the drainpipes either do not contain pollutants or contribute small pollutant loads to receiving waters. Through the process of monitoring water quality of storm drainpipes discharges, the effort needed to mitigate pollution sources becomes more clear and effort and resources can be focused on the pipes with the most significant pollutant loading.

The estimated loading rates for *E. coli* and total nitrogen in this study were determined in a similar fashion to the procedures of two previous studies. Jones (1998) measured flow rates and concentrations of *E. coli* and dissolved inorganic nitrogen (DIN) at three stormwater pipes in Dover during 1997-98, and Jones (2000) did the same at one stormwater pipe in Portsmouth. The *E. coli* loading rates ranged widely and bracketed the rates from this study, ranging from 770,000 to 11,253,000,000 cells per day, and the DIN loading rates ranged from 16 to 713 kg N/y. The total amount of nitrogen loaded into the estuary from the combined 9 pipes in this study and the four from the previous two studies was 1.5 tons N/y. This further illustrates the significance of stormwater pipes as pollution sources.

<u>QA/QC: Field and laboratory</u>

The accuracy of the field meters was checked during each sample date in a variety of ways (Table 10). The pH, turbidity and DO-salinity-specific conductance-temperature (YSI 85) meters were calibrated just before use at the first sampling site with standards and according to manufacturer recommended protocols. At a site in the middle of the sampling time readings were made with each meter to determine drift. The meters remained relatively well calibrated, with minimal drift; the pH values were 0.02 to 0.19 units greater than the standards used for calibration, the turbidity readings were, except for one reading, within 7% of standard values, and the % DO saturation values were within 4% of the standard (air=100%) value. The meters were re-calibrated as needed at this point. At the end of the day, readings of standards was repeated to re-check drift, with similarly favorable readings. We also used a separate DO meter (YSI ProODO) for water temperature and DO readings, and there was close agreement between values of both parameters for the two different YSI meters.

	pH						Turbidity						D O				
	Initial	Mid	4.0 pH	Std	7.0 pH	Std	Blank		1.0 Std		10.0 Std		% Sat		Conc (mg/L)		Midsample
Date	slope	slope	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	site
EXETER																	
3/28/12	98.0%												97				
4/11/12	104.0%				7.02		0		1.00				96		10.5		Site 4-LRL
4/25/12	103.6%	103.5%			7.04	7.04	0	0	1.00	1.00			97.5	99	10.1		Site 6-JD
5/9/12	98.1%				7.19		0		1.00		9.90		103.1		10.13		Site 3-NB
5/23/12	104.5%	n/r	4.03	4.02	7.13	7.03	-0.19	n/r	0.93	1.00	9.65	9.89	100	n/r	8.7	n/r	Site 8A
6/6/12	96.3%	96.5	4.16		7.14			-0.06		1.05		10.19					
GREENLAND					pH												
3/27/12	98.9%												98				
4/10/12																	
4/24/12	99.0%				7.07	7.08	0	0	1.00	0.75			99	100	9.8	9.8	site 6-BD
5/8/12	100.2%	101.0%		4.07	7.15		0		0.95		9.70						
5/22/12																	
6/5/12	103.0%		4.07		7.04	7.03	0.05	0	1.00	1.01	9.94	9.97	99.6	99.5			site 6-BD

FIELD DUPLICATES					
Date/site#		FC	*E. coli*	TN	NH4
5-22/ 8-CS2		240	170	1.61	47
		280	250	1.98	51
	RPD	15%	38%	21%	8%

Table 10. Field QA/QC and field duplicate sample analysis data.

Field duplicates and blanks were used for QA/QC in the laboratory. All blank analyses for the fecal coliforms, *E. coli*, ammonium and total nitrogen were negative/zero. The agreement between the single set of field duplicates for the bacteria and nitrogen analyses were within acceptable limits (Table 10).

Cost analysis

Engaging volunteers to conduct storm drain monitoring is a way to both cultivate stewardship for natural resources in the community and to save on costs. There are costs involved with such an approach, and this project was in part conducted to determine these costs. There are two major categories of cost: 1- taking measurements and analyzing samples to generate data, and, 2- the coordination of volunteers and the monitoring program (Table 11). The cost estimates summarized in Table 11 assume the cost of buying meters, and that the coordination is for one municipality; both of these costs for one municipality would be less if meters are already available and if the coordinator was to be working with more than one municipality. The analytical costs are for the identified labs: the UNH WQAL and JEL labs, and the NHDES lab. These labs were chosen for several reasons, including they are intimately involved in local monitoring and research projects and thus already generate much of the data on local water quality; this is desirable because of the ability to share and compare data between programs and projects. The chloride analysis can be conducted with no cost if the program is associated with the NHDES VRAP program (T. Walsh, personal communication).

DATA GENERATION COSTS

Parameter	Lab/method	Quantity	Cost*†	Per sample cost††
Fecal coliform & *E. coli*	UNH-JEL	each	$15	$15.00
Total N	UNH-WQAL	100	$1,120	$11.20
Ammonia	UNH-WQAL	100	$680	$6.80
Chlorine, total residual	Field kit	100	$218	$2.18
Chloride	NHDES lab	each	$12	$12.00
pH	Meter: Oakton pH 11	each	$337	
Turbidity	Meter: LaMotte 2020e	each	$798	
Dissolved oxygen	Meter: YSI ProPlus**	each	$1,410	
Specific conductance	Meter: YSI ProPlus	each	"	
Salinity	Meter: YSI ProPlus	each	"	
Temperature	Meter: YSI ProPlus	each	"	

*Costs are based either on per sample analysis or the cost for a meter.
For meter measurements, ongoing costs would be small and maintenance related
†Cost for Total N = $24/sample 1-20, $8/samples >20;
Ammonium cost = $10/samples 1-20, $6/samples >20
**One meter for dissolved oxygen, specific conductance, temperature, salinity
††Based on costs for 100 samples

PROGRAM & VOLUNTEER COORDINATION COSTS

Analysis and meter costs			Total Cost
Total analysis cost			$2,045
Total cost for 3 meters			$2,545
		Total	**$4,590**
Other costs	Amount	Rate	
Personnel-coordinator	6 months, 50% time	$40k/y*	$14,500
Transportation	500 miles	$0.55/mi	$275
Supplies & maintenance			$1,000
Overhead (26%)			$4,102
		Total	**$19,877**

*Salary = $40,000/y, Benefits = 45% salary **TOTAL $24,467**

Table 11. Estimated costs for conducting a storm drain monitoring project.

The data generation and coordination costs are based on a model for monitoring where 100 samples are collected. For example, a town might want to sample from ten pipes five times in one season and five times in another season (every other week for 2-3 months in both seasons), all within a year's time. Costs for nutrient analyses at WQAL are more expensive for the first 20 samples and costs are decreased for all subsequent samples (Table 11). The coordinator would probably need to work half time for two three-month periods to be able to plan, conduct training, supervise all sampling events, maintain meters, store and deliver samples to analytical labs, compile and interpret data, coordinate with volunteers and town personnel, and report on results.

These model assumptions are first estimates based on the PI's experience with this project. Thus, an overall cost per year of $25,000 is in the ballpark of what it would cost to monitor ten sites ten times, and generate reports and interpretations of results. As mentioned, there may be ways to cut some costs, but there were also built-in benefits for this project realized through the PI's connections to NH Sea Grant, JEL and graduate student volunteers at UNH. Each future situation will be unique…

Presentation of project findings

The storm drain monitoring occurred from March 28 to June 6, 2012. Many informal meetings and discussions occurred during that time with the volunteers, town personnel and other interested individuals. High school teachers, neighborhood representatives, homeowners, conservation commission members, public works employees, and others were interested in different aspects of the project, or wanted to join in or coordinate their activities with the monitoring program. Preliminary findings were presented at several meetings and to different audiences, including a UNH undergraduate class, a Portsmouth High School ecology class, and the NEWIPCC annual nonpoint source meeting.

Presentation of the project findings occurred in three venues, and all presentations are available from the Project PI as electronic PowerPoint and/or PDF files. The first was in Greenland, where a summary of the results (data available at that time) was presented to the Conservation Commission and other town officials. The meeting was attended by volunteers from the project and from the WRWC, and homeowners and other interested citizens were also there. The findings and next steps were discussed. It appears that the WRWC will probably be involved in future monitoring needs and the Town was willing to invest in needed equipment to be managed by the WRWC.

The next meeting was in Exeter as an agenda item before the Conservation Commission. The findings and next steps were discussed. The final presentation was with the NH Seacoast Stormwater Coalition at their June 2012 monthly meeting. Representatives from a number of Seacoast towns were present, along with some consultants and several people with the NH Coastal Program. Project findings were discussed, followed by a lively discussion of next steps, the potential for continuing involvement the CRV Program volunteers, and the upcoming issuing of the MS4 permit for New Hampshire.

Lessons learned, insights, modifications and trouble-shooting

The project was, overall, a surprising success. Few problems were encountered, to a great extent due to the high reliability, enthusiasm and capabilities of the volunteers. The project locations afforded different types of storm drains and conditions, and so posed some challenges that were useful for this pilot project to consider. One key aspect of this project was the presence of the Project PI at each sample event. The volunteers felt that was a plus because they were able to always ask questions, discuss observations, and have an experienced researcher present to make decisions and modifications. Meters failed, pipes had no flow, weather conditions changed, and modifications and adjustments were made to respond to these changing circumstances.

Because this project was a pilot project, the PI in some cases let things happen to see how volunteers would respond, and to see what people remembered to do. Even though the volunteers were great at carefully conducting measurements and collecting samples after the first few sample events, the field QA/QC procedures were not always followed. One way to ensure this would happen in the future is to make sure the group/team reviews their checklists of tasks; another would be to have one person be the ‘QA/QC cop’.

RECOMMENDATIONS

This pilot project was an overall success, demonstrating that volunteers can readily conduct storm drain monitoring and produce quality data. Certain recommendations are useful for future consideration of this approach:

-Have an experienced program coordinator present at all sample events to ensure procedures are followed, problems can be addressed, and volunteers can continue to learn and gain expertise.

-Volunteers work well together; the sampling design should involve small groups of volunteers.

-Design monitoring programs where sampling events are 2-3 hours long; not too long, not too short.

-Recruit volunteers with a wide range of capabilities and interests so all monitoring tasks can be conducted by volunteers. Get them involved in all aspects of the study!

-Communicate results back to volunteers as soon and as often as possible.

-Be meticulous about QA/QC procedures in the field.

-Write up simple instructions for conducting water quality measurements in the field, and laminate the 'one pagers' for reference at sampling sites.

-Include nitrogen and fecal-borne bacteria as target parameters because storm drains can be significant sources of these pollutants.

-Problem sites with high levels of pollutants can be useful educational opportunities for the volunteers and the community.

-Monitoring programs that involve volunteers are not free of costs, but significant savings can be realized.

Other considerations include:

-The CRV Program has a large contingency of interested volunteers, some of whom are now trained in storm drain monitoring. The program can be a useful partner in future programs to help seed local volunteer efforts and help with training of new volunteers.

-An integrated support program composed of town personnel, volunteers, experienced scientists and analytical labs is a potential mechanism to help towns meet anticipated mandates for monitoring. Formation of such a program for all regional communities to use would save significant local resources, provide consistency in sampling and analysis procedures, and provide comparable results to inform efforts to gauge how well management actions lead to improvements in water quality.

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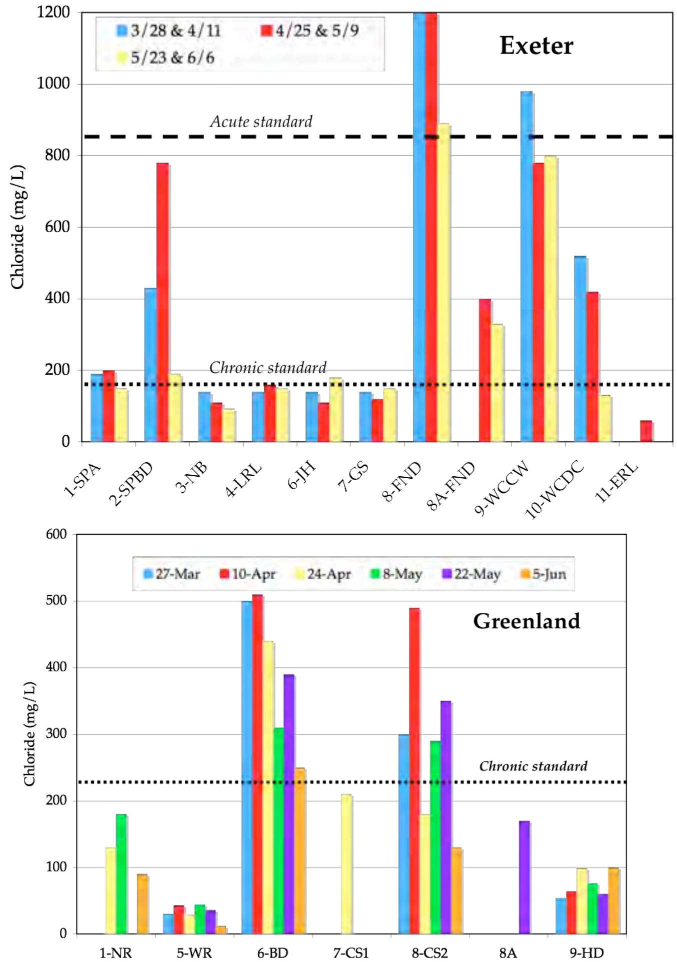
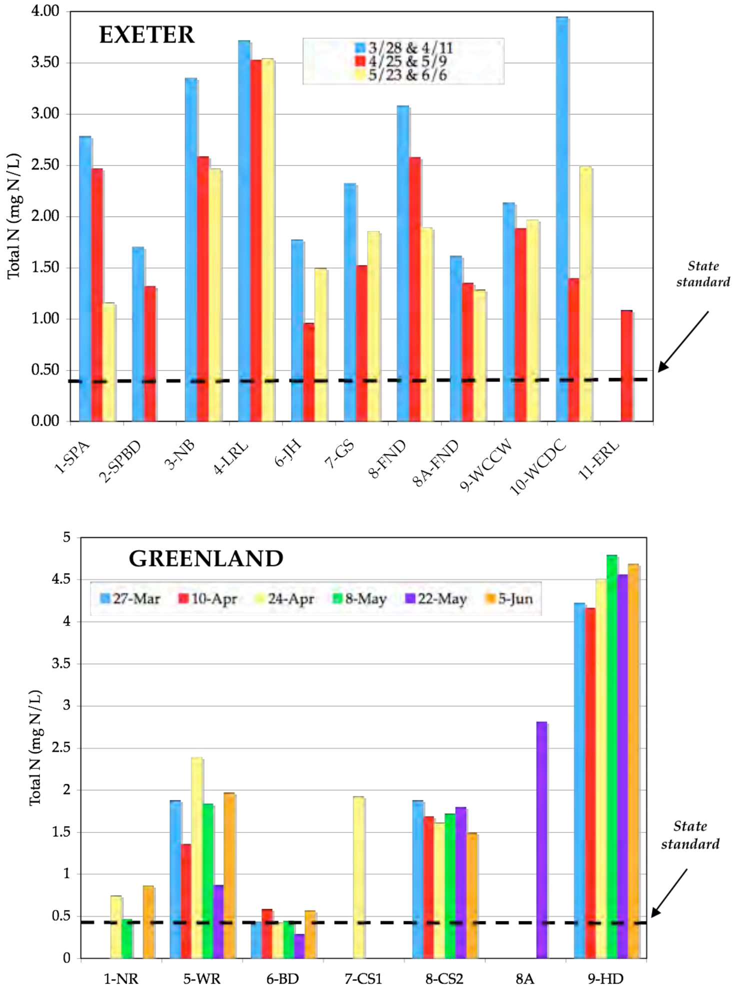
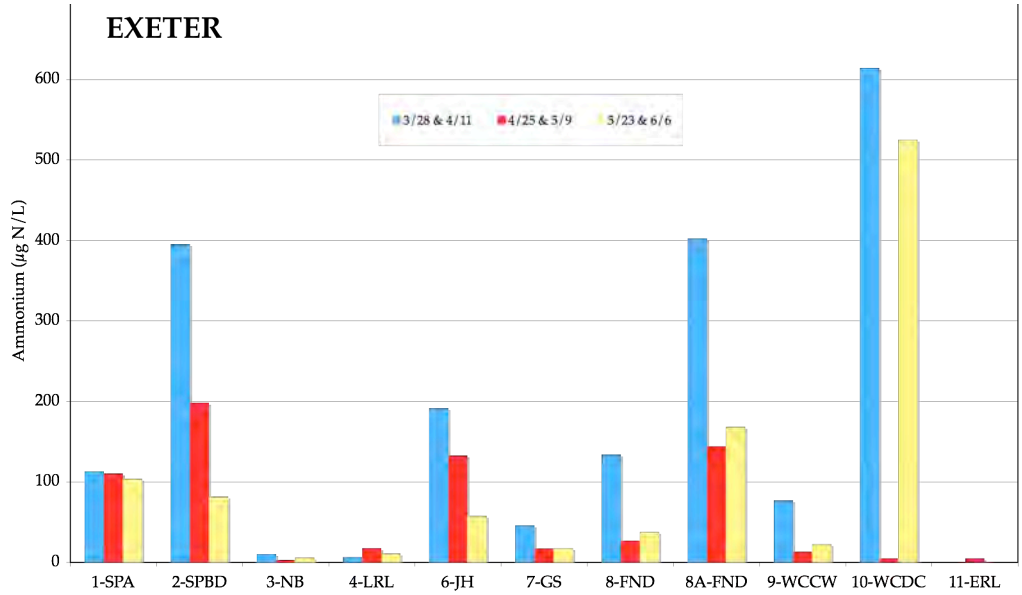
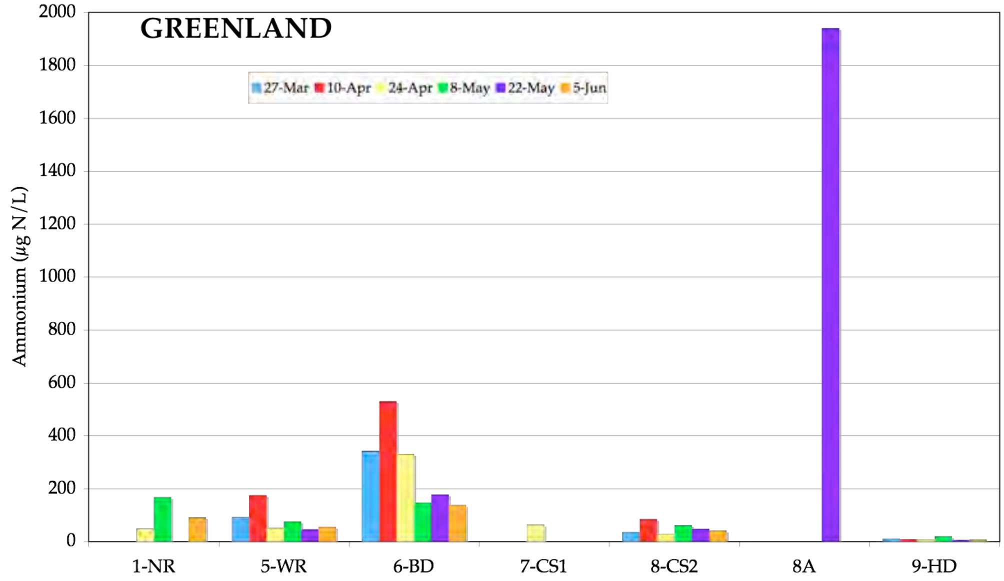


Figures 7 a&b. Chloride concentrations in Exeter (a) and Greenland (b) storm drain water.

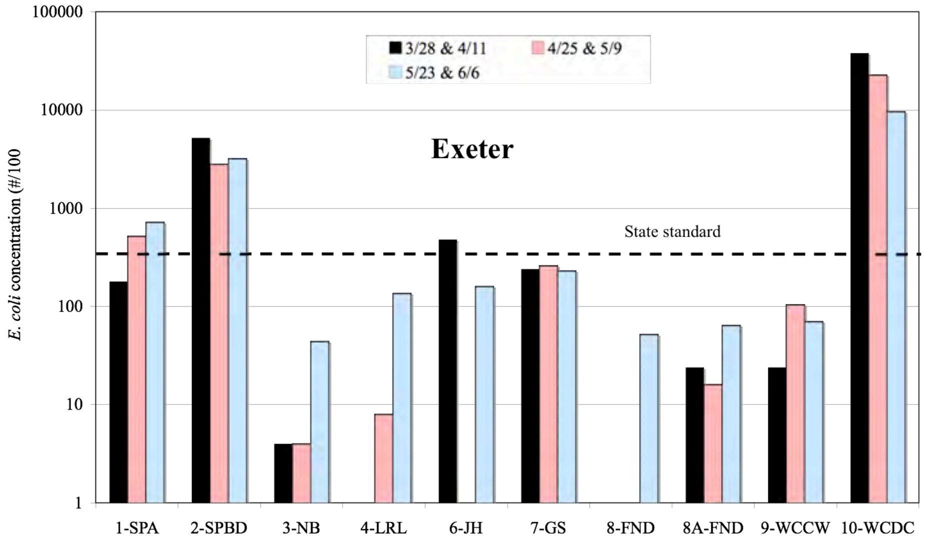


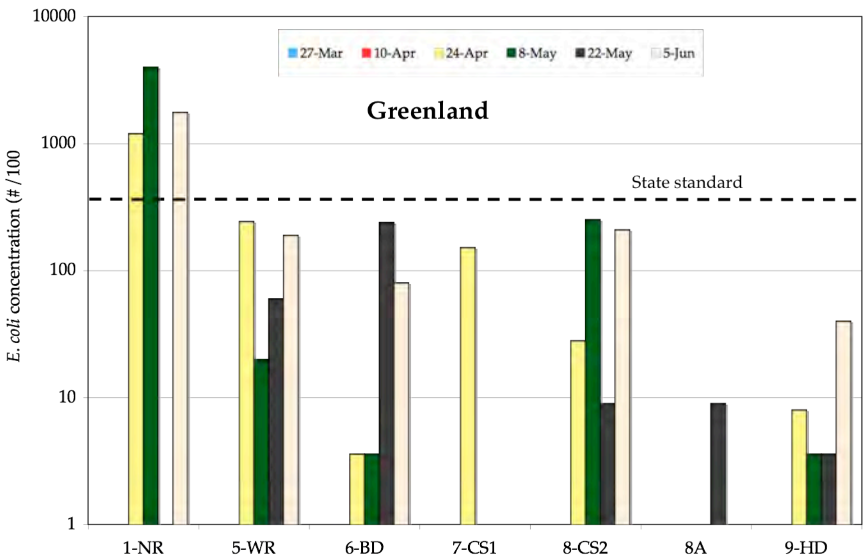
Figures 8 a&b. Total nitrogen concentrations in Exeter (a) and Greenland (b) storm drain water.



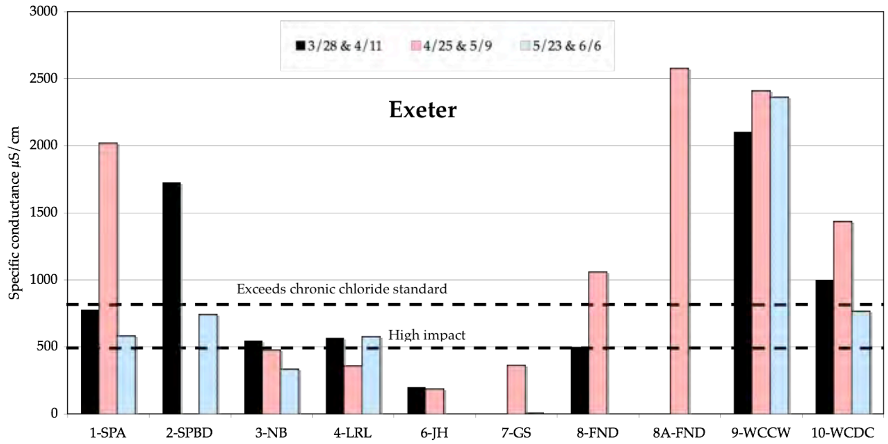


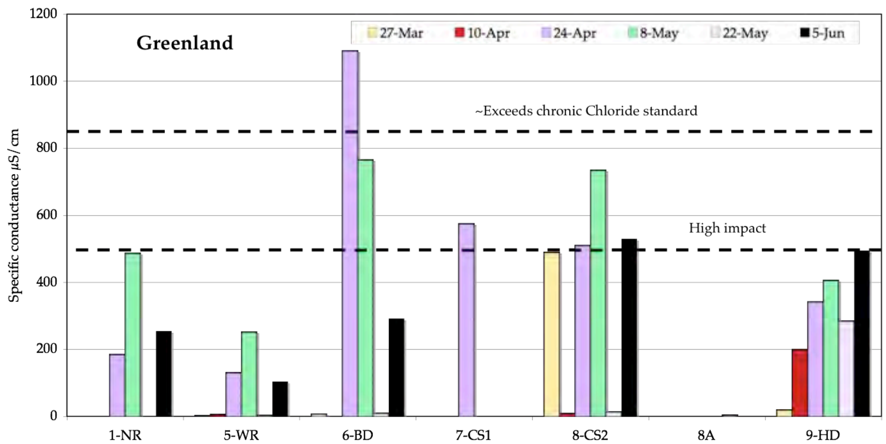
Figures 9 a&b. Ammonium concentrations in Exeter (a) and Greenland (b) storm drain water.



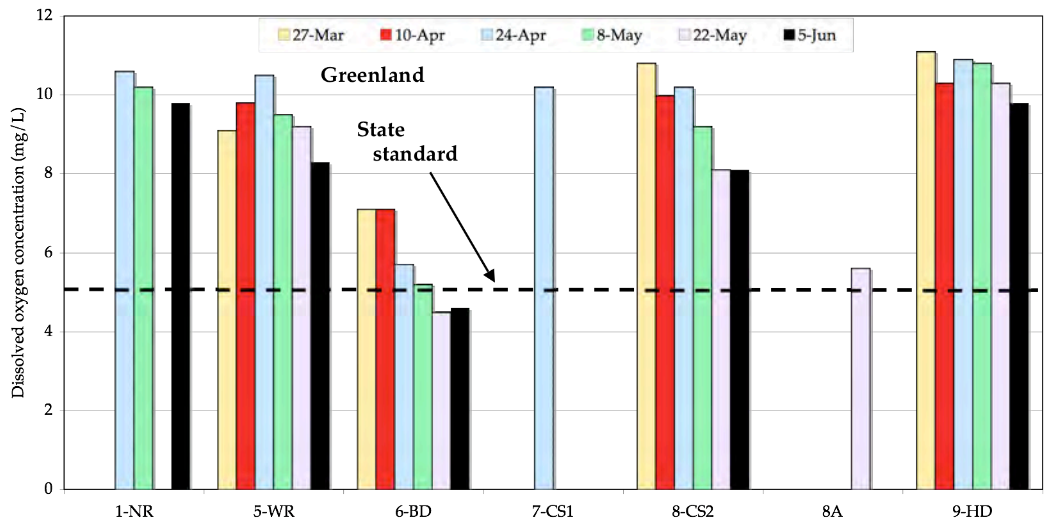


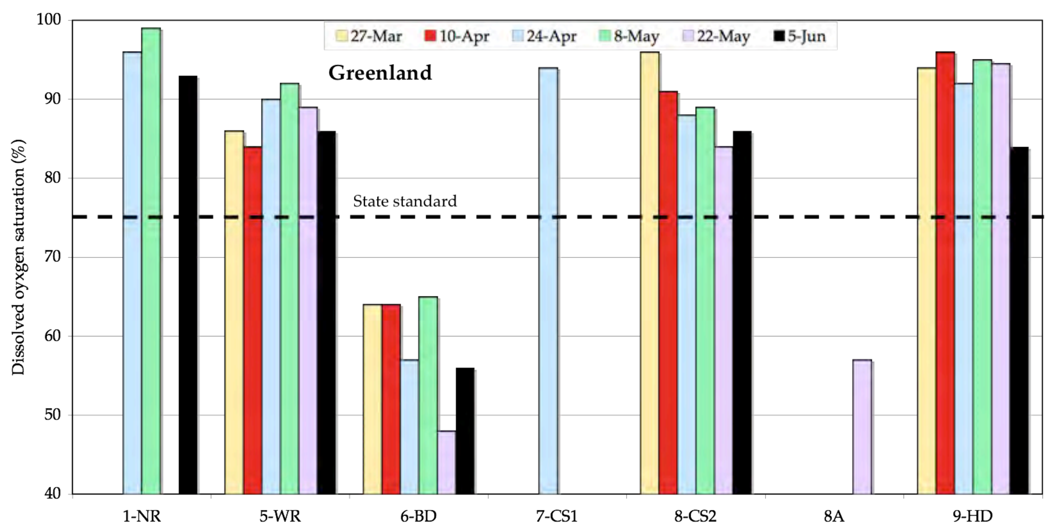
Figures 10 a&b. *E. coli* concentrations in Exeter (a) and Greenland (b) storm drain water.





Figures 11 a&b. Specific conductance in Exeter (a) and Greenland (b) storm drain water.





Figures 12 a&b. Dissolved oxygen concentration (a) and % saturation (b) in Greenland. storm drain water.