Stormwater Issues

Burlington / South Burlington, VT

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With Contributions From:

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South Burlington Stormwater Utility

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Burlington Free Press

Table of Contents

Contacts for Stormwater iii

Potash Brook Watershed Boundary 1

Butler Farms / Oak Creek Village 2

Butler Farms / Oak Creek Village Sub-Watersheds 3

Treatment Option 1A 4

Treatment Option 2 5

Table of Treatment Options 6

Article: Pollution Bill Comes Due 7

Article: RAN: Working With Neighborhoods to Manage Stromwater 12

Stormwater Basics: Volume and Force 19

Article: Quantifying Increases in Stream Power and Energy 20

Hydraulic Geometry Curves 27

Stream Monitoring at Butler Farms / Oak Creek Village 28

Selected Results From the Tributary 7 Monitoring Initiative 31

An Introduction to Vermont's First Stormwater Utility 34

Stormwater Detention Ponds 38

Rain Garden Brochure 40

References 46

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Resources

Redesigning the American Neighborhood web site: http://www.uvm.edu/~ran

South Burlington Stormwater Utility: http://sburl.com/stormwater/

Vermont Agency of Natural Resources, Stormwater Program: http://www.anr.state.vt.us/dec/waterq/stormwater.htm

Potash Brook Watershed Boundary

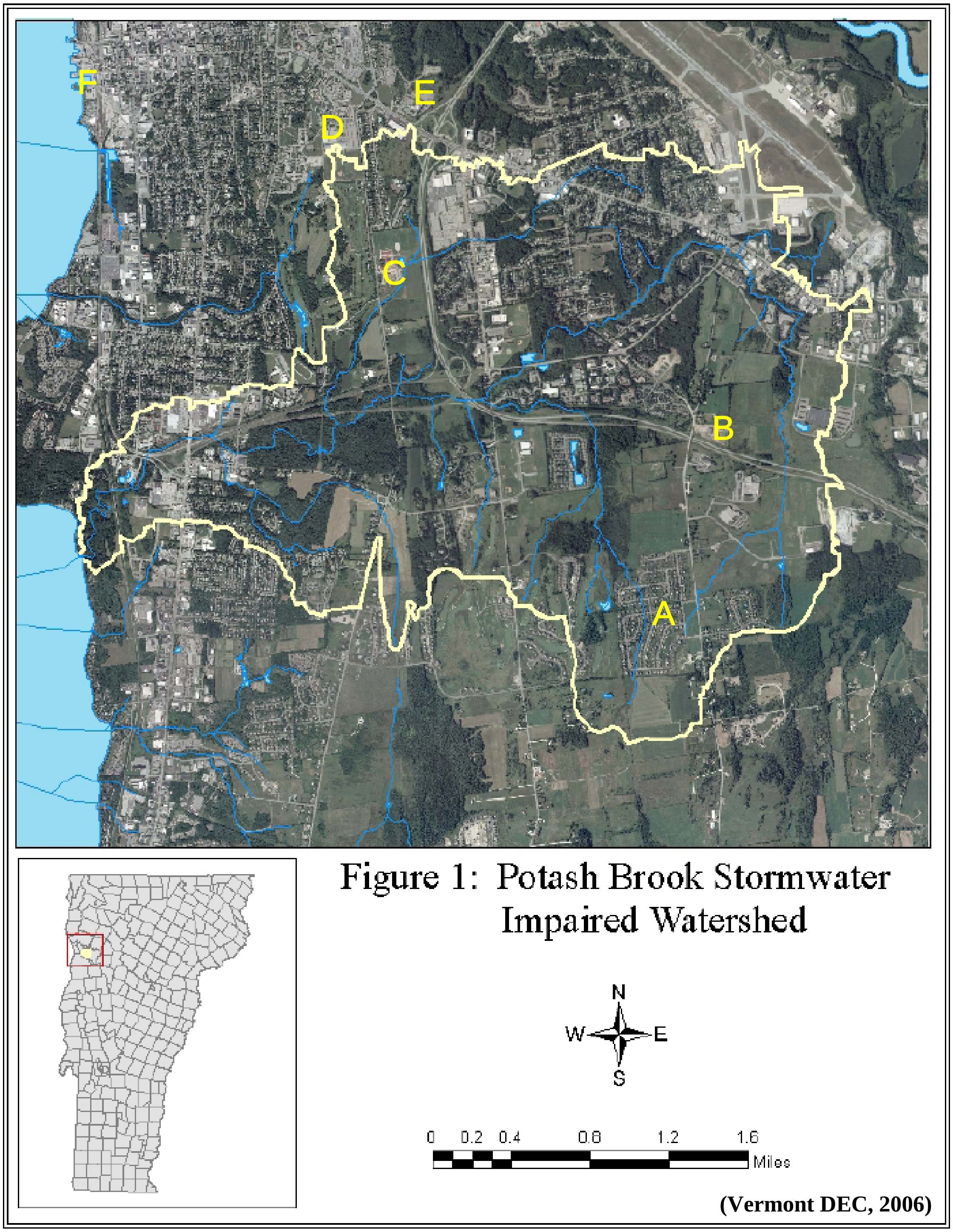


Figure 1: Potash Brook Stormwater Impaired Watershed

A) Butler Farms / Oak Creek Village
B) O'Brien Farm Condo BMPs
C) UVM Miller Farm- Incising Stream
D) UVM Redstone Campus Stormwater Pond
E) Centennial Field Stormwater Pond
F) Perkins Pier / Rubenstein Laboratory

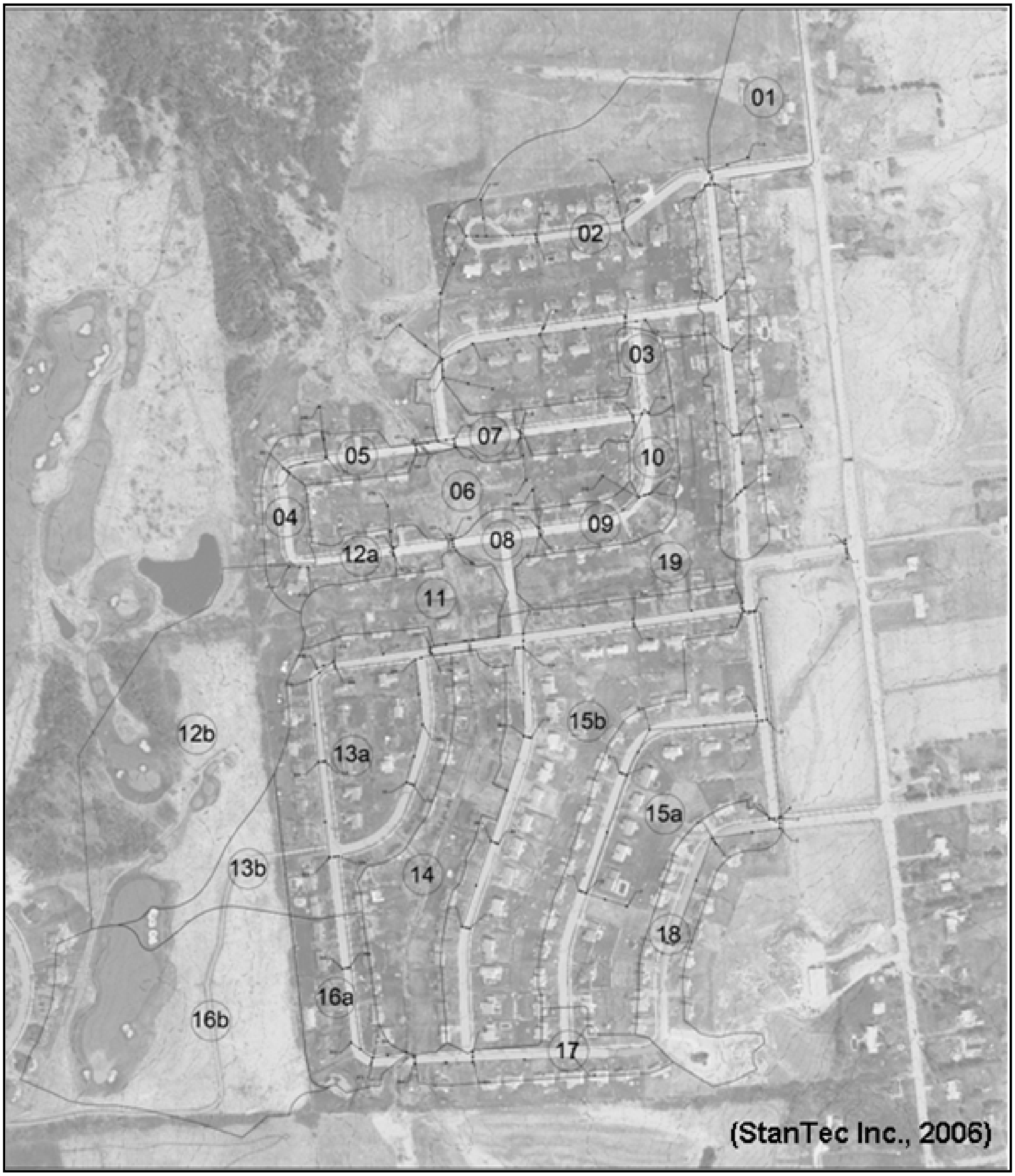
Butler Farms / Oak Creek Village

Figure 1. Aerial photograph of the Butler Farms / Oak Creek Village neighborhoods.

Butler Farms / Oak Creek Village reference information:

- Approximately 250 homes covering 60 hectares
- Tributary 7 of Potash Brook flows north through the neighborhood
- The neighborhood is bounded by:
  - Golf course to the west
  - Conservation lands to the north
  - Farmland that may be developed in the near future to the south
- The stormwater discharge permits for the neighborhood are expired
- The renewal deadline is September 2007
- There is no homeowners association, and thus no preexisting channels for internal communication among residents

Butler Farms / Oak Creek Village Sub-Watersheds



Treatment Option 1A

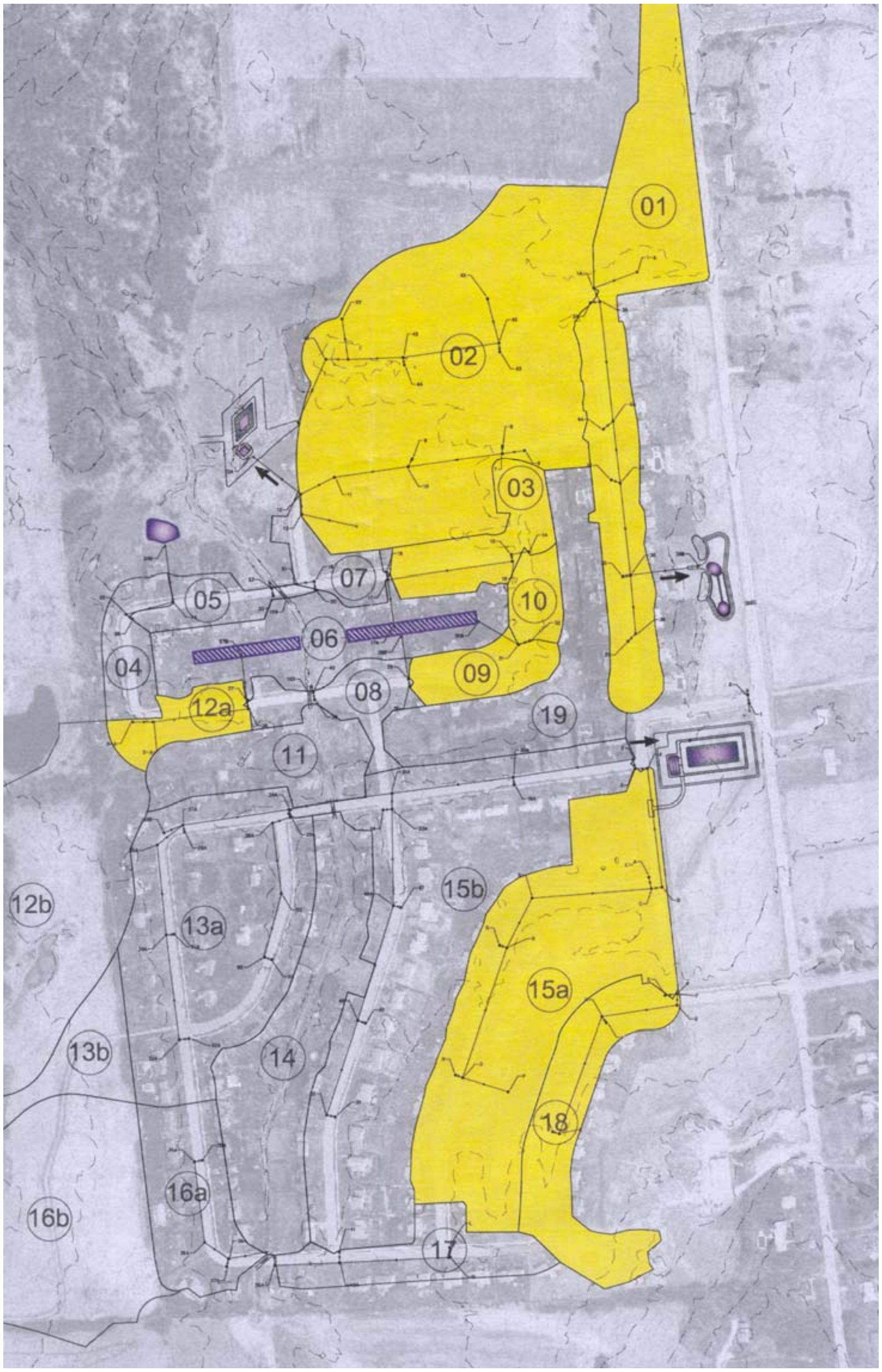


Figure 2. Sub-watersheds treated by option 1A with locations of required infrastructure (StanTec Inc., 2006).

Treatment Option 2

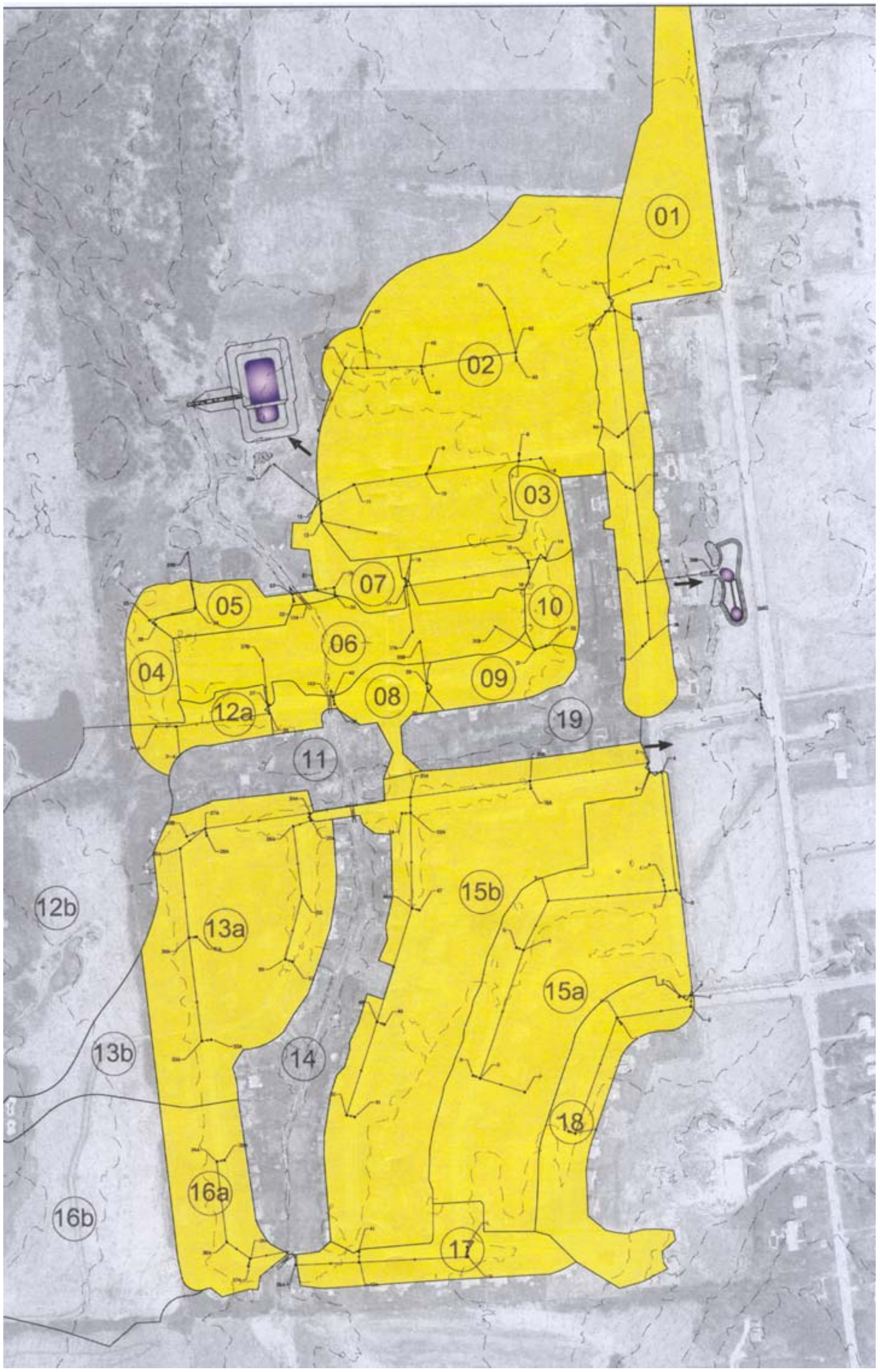


Figure 3. Sub-watersheds treated by option 2 with locations of required infrastructure (StanTec Inc., 2006).

Table of Treatment Options

Table 1. Treatment options with probable cost estimates, pollutant reduction estimations, and areas of land treated (StanTec Inc., 2006)

Treatment Options Presented at Meetings	Opinion of Probable Cost	Lbs of TSS Removed	Acres of Impervious Area Treated	$'s Per Acre Treated	Impervious Area that is Public (%)	Public Cost	Private Cost	Per Unit Cost
Option 1a **Butler Farms**								
Option 1a Areas 18 & 15a (Smaller Pond in Common Area)	$416,000	2059	6.1	$68,197	44%	$182,749	$233,251	**$1,609**
Oak Creek								
Area 1 (Micro Pool by Hinesburg Rd)	$231,000	1284	3.2	$72,188	57%	$131,670	$99,330	
Area 2 (Retrofit	$385,000	1760	4.1	$93,902	42%	$161,700	$223,300	
Areas 3,9,10, & 12a (Convert Swales to Treatment System)	$426,000	1184	3.1	$137,419	47%	$200,220	$225,780	
Subtotal Oak Creek	$1,042,000	4228	10.4	$100,192		$493,590	$548,410	**$4,941**
Total Option 1a	**$1,458,000**	**6287**	**17**	**$85,765**		**$676,339**	**$781,661**	
Option 2								
Treat all Areas both Developments (except Areas 1 and 19)	$2,098,000	12220	30.02	$69,887	44%	$923,120	$1,174,880	
Area 1	$231,000	1284	3.2	$72,188	57%	$131,670	$99,330	
Total	**$2,329,000**	**13504**	**33.22**	**$70,108**	**45%**	**$1,048,050**	**$1,280,950**	**$5,004**

Pollution Bill Comes Due

By Candace Page

SOUTH BURLINGTON — A light June rain fell on the bright green lawns and sloping driveways of the Butler Farms subdivision and began to collect some of the dirt it would carry to Lake Champlain.

Rainwater gurgled down a gutter on deserted Butler Drive. Lawn clippings swirled in the gritty stream. A rainbow slick of oil coated the surface.

The runoff poured into a storm drain in front of Greg and Carole Lothrop's house and into Tributary 7 of Potash Brook. The tributary, more ditch than stream, ran faster and faster, dirtier and dirtier, through Butler Farms and neighboring Oak Creek Village, then north to join the main brook.

Potash Brook rushed west through some of the most intensely developed land in Vermont. Polluted runoff from city streets, Interstate 89 and shopping mall parking lots plowed into the brook, ripping dirt from its banks. Just south of Queen City Park, the brook dumped the scourings from 7½ square miles of South Burlington into Shelburne Bay.

Cleaning up those scourings — and stormwater pollution across the Champlain Basin — will require enormous amounts of public and private money, more than $18 million in South Burlington alone. Statewide, the bill could mount into tens of millions, stormwater regulators say.

The job is important to the health of Lake Champlain because stormwater runoff is laced with phosphorus, a fertilizer that feeds algae blooms and has become a major water quality concern for the lake.

Stormwater carries traces of many pollutants — bacteria, oil, pesticides, heavy metals — but it delivers one-third of all the phosphorus reaching the lake.

Stormwater, the experts like to say, is everybody's fault.

Experts know it — but most of us do not. Most of us have no idea how we contribute to stormwater pollution. When we're told, we can be reluctant to change how we fertilize our lawns or pave our driveways.

We're even less thrilled about the cost of cleaning up.

Cost estimates make neighbors fume

At Butler Farms and Oak Creek Village, 258 homeowners learned this summer that controlling stormwater will cost each of them up to $5,000. Failure to act could create legal difficulties when residents want to sell their homes.

The neighborhood's reaction can be summed up like this: "Are you nuts?!"

"Vermont likes to go after neighborhoods like mine," fumed Bryan Hunt, a retired New York City firefighter who lives on Whiteface Street. "Excuse me, who is going to pay for all this?"

What would residents of Butler Farms and Oak Creek Village do if they were not required to install new stormwater treatment?

"They'd do nothing," said Chris Smith, a financial planner, City Council member and resident of Oak Creek Drive since 1994. "Doing nothing isn't the right answer, but I'm telling you, that's what people think."

While most Vermonters aren't required to install stormwater controls for existing homes, Butler Farms residents are not the only exception to the rule.

About 3,000 home or condominium owners in South Burlington and a smaller number in other Chittenden County communities might be required to improve stormwater controls by October 2007.

Breaking down the cleanup challenge

South Burlington's expensive cleanup illustrates the size of the challenge Vermont faces, in financing stormwater improvements and educating Vermonters about how each person can help:

-- Cost: Preventing future pollution adds costs to new development. For developments built without stormwater controls, the price of retrofits averages $30,000 an acre.

-- Cost-benefits: Because each stormwater source is relatively small, it is difficult or impossible to quantify the benefits to the lake obtained from an improvement project, even a costly one.

-- Many changes are voluntary: Although Vermont has taken important steps to reduce future pollution, retrofitting existing roads and developments is largely voluntary.

-- Changing behavior: Voluntary cleanup moves slowly. It requires homeowners and governments not just to spend money but to change the way they manage their property, from re-engineering roadside drainage to cleaning up after their dogs.

W. Breck Bowden, a University of Vermont professor of watershed science, said there is nothing unusual in the stormwater contribution — or the attitude — of Butler Farms residents. They stand for all of us.

"People don't make a connection between what happens in their back yard and what happens to the lake," he said. "They don't want to be told to do things differently, and that includes the way they fertilize their lawns and wash their cars."

Stormwater excavates with a bulldozer's power

Stormwater pollutes two ways.

First, it washes dirt and pollutants off lawns and paved surfaces.

Second — and worse, stormwater specialists say — pavement doesn't absorb or slow runoff. Stormwater channeled by culverts or roadside ditches can hit a stream literally with the force of a bulldozer, plowing tons of phosphorus-laced dirt from streambeds and banks.

As a result, developments like Butler Farms cause three times as much phosphorus pollution per acre as farmland they replace and 40 times as much as naturally forested land.

Vermont has cleaned up sewage treatment plants and worked to limit farm pollution. Still, the amount of phosphorus reaching Lake Champlain has increased.

"The likelihood is that urban development in the watershed has offset phosphorus reductions we've accomplished in agriculture," said Eric Smeltzer, state government's lead Lake Champlain researcher.

Without new controls, stormwater problems will only grow as land is converted to homes, highways and shopping malls.

Power of the law is brought to bear

South Burlington has so many streams damaged by stormwater that the city set up a new stormwater utility to help build, improve and maintain control systems. Every homeowner pays a $4.50 monthly stormwater fee.

The city doesn't pay for stormwater improvements at private commercial developments or residential subdivisions like Butler Farms, but will take over maintenance once they are built to state standards.

Those improvements are required by new state regulations to restore the health of Potash Brook and 16 other Vermont streams — 14 of them in the Lake Champlain basin — so damaged by stormwater that they are on a federal list of "stormwater-impaired" streams.

The regulations were adopted after the Conservation Law Foundation, an environmental advocacy organization, successfully challenged permits for new development in the

Potash Brook watershed. The foundation argued that Vermont was failing to protect stormwater-damaged streams as required by law.

In response, lawmakers passed tough cleanup plans, not for the lake, but for damaged streams.

Lake Champlain will see phosphorus reductions as the brooks are restored, but scientists and regulators cannot quantify that benefit.

An initial estimate found a phosphorus reduction of just one-third ton from reducing pollution wash-off into all 14 streams. The savings should be greater than that if streambank erosion also is reduced.

Lack of evidence about the benefits of cleanup creates skeptics.

"Show me the benefit to the lake," Smith, the city councilor, said after learning the cost of stormwater control in his neighborhood.

Pete Laflamme, the state's stormwater chief, said persuading people to spend money or change their habits to clean up a stream like Potash Brook, as opposed to the lake, can be a tough sell.

"You go out and tell people, 'I want $5,000 from you to build a stormwater pond because there are no mayflies in the brook,'" he said. "People will say, 'I don't care about the mayflies; it's an urban stream. There are shopping carts and dead dogs in it.'"

Neighborhood asks, 'Why us?'

In the lottery of suburban life, Butler Farms and Oak Creek Village drew a terrible stormwater card.

The development is built on clay soils that don't soak up rainwater. A rudimentary stormwater system installed when the development was built in the 1980s does not work well.

And, although residents didn't know it, the developers' state stormwater permits expired years ago.

To obtain a new permit, the two subdivisions must rebuild stormwater controls to meet state standards, work that could cost $5,000 a household.

"Montpelier thinks we're all millionaires in this neighborhood," said Dr. Paul Newhouse, a psychiatrist at the UVM College of Medicine. "Their attitude is we are just whining when we should be prepared to cough up the money."

"Everybody benefits from a cleaner lake, not just me and my neighbor," said Mary Lou

Newhouse. Like others in the subdivision, she said the cost should be shared by a wider group of taxpayers in South Burlington or across Vermont.

People at Butler Farms say they care about the health of Lake Champlain. A request for volunteer homeowners to host two demonstration rain gardens, a stormwater control strategy, attracted 50 interested neighbors.

Carole Lothrop, who has lived on Butler Drive for 14 years, said she still fertilizes her lawn and garden, but has cut back since learning she could be contributing pollution.

"We're ecology-minded. We want to do our part," said Greg Lothrop, who installed a rain barrel to trap runoff from their roof.

Others, like Ray Forsell, a firefighter who lives on Moss Glen Lane, said they have not changed personal habits that might affect stormwater pollution. Forsell still fertilizes his lawn once a year and washes his car in the driveway.

"I'm unconvinced that anything our neighborhood does will improve Lake Champlain," he said. "To me, our best option is to go the Legislature and get them to change this crazy law."

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Stormwater
FEATURES

RAN: Working With Neighborhoods to Manage Stormwater

An innovative project works with suburban homeowners to design stormwater controls.

By Alan McIntosh, Breck Bowden, Evan Fitzgerald, Alex Hackman, Barton Kirk, John Todd, Helena Vladich, Alexey Voinov, and Joseph Bartlett

Imagine this scenario: The real estate agent shows the excited young family all the latest features in the new split-level—solar-powered appliances, the latest in high-security systems, and wireless access. Young Johnny spies some folks working in the backyard. Mom asks, "Is that Chem-green?" "No," the agent replies, "that's the city crew maintaining your rain garden."

Far-fetched? Not really. The urgent need facing many smaller communities to manage stormwater is bringing control practices down to the local level. Water pollution control, whether practiced at major point-source dischargers like sewage treatment plants or by municipalities using detention basins to trap nonpoint-source runoff, has typically been out-of-sight, out-of-mind, far removed from the average suburbanite. Phase II regulations of the National Pollutant Discharge Elimination System (NPDES) are changing all that. Suburban homeowners are, in some cases, learning a lot more about stormwater than they might like to.

A team of researchers at the University of Vermont and city officials from South Burlington, VT, are assisting suburban neighborhoods as they struggle to comply with today's stormwater regulations. Dubbed "Redesigning the American Neighborhood"(RAN), this USEPA-funded program helps homeowners evaluate environmental, economic, and social factors while designing the best approach for managing stormwater in their neighborhoods.

While involving homeowners in discussions about stormwater management may not be a typical approach, it makes sense, because many of the water pollution and excess water problems plaguing suburban developments result when rainfall picks up pollutants as it travels over homeowners' lawns, roofs, and driveways, and because many of the opportunities to treat and manage stormwater occur on homeowner properties in existing neighborhoods.

Rationale

The RAN project is not reinventing the wheel. We are building on an excellent base of recent work on low-impact approaches to managing stormwater. Researchers with the Jordan Cove (CT) National Urban Watershed Monitoring Project (Phillips et al. 2003) have been comparing the quality of stormwater leaving a traditional housing development to runoff from an experimental housing complex with stormwater control techniques such as permeable pavement and rain gardens. Initial results suggest that such low-impact approaches can substantially improve stormwater quality. The innovative SEA Streets project in Seattle (Taus 2002) used vegetated swales to reduce the amount of impervious surface along urban streets, and reduced by 90% the volume of a two-year storm event.

An article in the September/October 2004 issue of *Stormwater* gave an excellent overview of similar efforts under way in Anchorage, AK; Denver, CO; and elsewhere to include innovative stormwater management approaches in new housing developments (Baxter 2004). The article highlights landscape architect Bill Wenk and his team's approach in their project in Denver's Goldsmith Gulch. Wenk's team worked with the local neighborhood to develop design concepts and participated in site walks to help neighbors visualize property improvements related to stormwater management.

But what about stormwater management efforts in existing neighborhoods? Shouldn't these homeowners also be part of the stormwater brain trust? By including homeowners, developers, and other stakeholders in stormwater management efforts, we can create both economic and non-economic incentives to move in the right direction. This process of shared learning has been shown to be a critical element in the success of past watershed-level management efforts (Voinov and Costanza 1999, Van den Belt 2004).

The purpose of the RAN project is to develop and test the tools that will allow homeowners, developers, and city/state officials to optimize the mix of stormwater interventions at various spatial scales that will best balance environmental, social, and economic goals. Using a diverse palette of ideas, technologies, engineering approaches, and ecologies specifically tailored to a particular neighborhood should help achieve the dual goals of effective stormwater management and public acceptance.

The RAN project consists of four elements: assessment, evaluation, participation, and implementation.

Assessment
The Butler Farms and Oak Creek Village (BF/OCV) subdivisions in South Burlington, VT (Figure 1), provide an excellent opportunity to test our approach to stormwater management.

Figure 1. Butler Farm and Oak Creek Village in South Burlington, VT

These adjacent subdivisions of over 200 homes occupy about 65 hectares and are representative of so-called cookie-cutter neighborhoods that typify suburban sprawl. Tributary 7 of Potash Brook, a small impaired stream on Vermont's 303(d) list, arises in agricultural lands above BF/OCV, flows through the middle of the development, and then emerges onto conservation lands managed by the City of South Burlington (Figure 2).

Figure 2. Butler Farm and Oak Creek Village in South Burlington, VT

The condition of the stream within BF/OCV is highly degraded, and the channel is deeply incised. In addition, some residents complain about excess water, including flooded basements, during wet weather. Improved stormwater management within BF/OCV must address both water-quality and -quantity issues.

The goal of the assessment phase of the project, now well under way, is to collect background information that will help identify opportunities for stormwater intervention in BF/OCV at different spatial scales and levels of community involvement. Interventions being considered include both centralized approaches, such as detention ponds or created/enhanced wetlands, and distributed interventions, such as swales and rain gardens, which would modify the neighborhood's hydrology at a micro-scale level.

The first step in the assessment process was to collect specific data on the landscape of the neighborhood. These included historical GIS base soils data, a map of watershed boundaries, and site hydrology. When assembled and mapped, this information suggested stormwater management approaches most appropriate for BF/OCV. Surveys of BF/OCV homeowners informed us about their level of understanding about stormwater in general and how their daily lives might contribute to local water-quality and -quantity problems.

To help stakeholders visualize and evaluate their options for managing stormwater, we developed a framework that allows users to consider the costs and benefits of the range of possible interventions. This framework, posted on the project's Web site (www.uvm.edu/~ran), includes an introductory virtual tour of the BF/OCV neighborhood and the impaired stream; background information on stormwater and its environmental impacts; photos and case studies of many of the best management practices (BMPs) available; and a listing of local, state, and national stormwater resources. The framework can be used by homeowners and local officials anywhere to help manage stormwater at the local level.

Evaluation

In the evaluation phase, we will develop and use a variety of analysis tools to compare various BMP implementation scenarios. Our evaluation focuses on potential stormwater interventions identified during the assessment phase. This evaluation allows community members and local regulators to learn about potential approaches and compare the relative costs and benefits of each intervention using ecological, social, and economic criteria.

For example, an evaluation of options by residents of BF/OCV may find that construction of a large detention basin in the neighborhood is the cheapest option. However, more individualized approaches like onsite rain gardens are likely to enhance property values and may be worth the additional cost. Another possible option, the use of two vacant city-owned lots to develop ecotechnologies like a stormwater ecopark (Todd, Brown, and Wells 2003) may be more expensive than a traditional detention basin but may provide additional economic and ecological services like biofuel production or habitat enhancement that increase benefits.

Several tools are helping facilitate the evaluation. A stormwater BMP evaluation tool (RAN-55) based on an existing rainfall-runoff simulation model will bridge the gap in understanding the hydrology of stormwater between scientists and engineers and residents in affected neighborhoods.

Environmental life cycle assessment (LCA) will provide further insights into the various management options. Combined with life cycle cost analysis, LCA will enable us to evaluate the long-term direct, indirect, and cumulative costs and benefits of several candidate BMPs for BF/OCV.

Finally, we are developing a modeling framework to help stakeholders visualize and evaluate the costs and benefits associated with different stormwater management options. This integrated assessment tool will explicitly include both monetary and non-monetary costs that we pay for polluting the environment. The model will help stakeholders understand how the costs and benefits of stormwater management are distributed.

Defining specific outcomes (e.g., reduced nutrient loading to Potash Brook or dampened storm-flow peak volume) that can be achieved for different costs will help stakeholders better see what they are getting for their money. The RAN team, the stakeholders, and the regulators are working together to determine the costs and acceptability of potential management options. This collaborative effort will ensure that the proposed interventions will be politically feasible. Our goal, then, in the evaluation phase is to use a variety of analysis tools that can broadly compare various BMP implementation scenarios.

Participation
Involvement of the community stakeholders throughout the various phases of the RAN program is critical to our success. We are using various means to encourage participation. Several residents of BF/OCV act as informal liaisons to the broader community. Representatives from the City of South Burlington, relevant state and federal agencies, and local non-governmental organizations sit on our advisory committee. To promote outreach, we have created a Web site so that the community can learn more about the project and view up-to-date monitoring data and other project activities. Links to the cost-benefit analysis framework described above are also prominently displayed on our Web site.

Direct interaction with community members is the most important activity in this phase. At the outset, we met with a small group of interested BF/OCV residents who were concerned primarily with flooded basements during storm events. This was followed in the fall of 2004 with a Saturday field day in the neighborhood. Attended by more than 50 residents, this event introduced the RAN project team to the community. The RAN team discussed project goals and responded to questions and concerns of residents and demonstrated low-impact stormwater interventions, such as rain barrels.

In the spring of 2005, the City of South Burlington formed a utility to help manage stormwater communitywide. As a result, neighborhoods like BF/OCV became more aware of their roles in citywide efforts to better manage stormwater. The RAN project has taken advantage of this upswing in interest to organize several community meetings. A recent such meeting, reportedly the largest public meeting ever held in South Burlington, was devoted to discussing the implications of Phase II stormwater regulations for BF/OCV and the role RAN might play in working with residents to explore effective stormwater management.

As an outcome of the meeting, a neighborhood Stormwater Study Group has formed. RAN team members will work with the community through this group to evaluate the stormwater management alternatives available to BF/OCV residents. In the coming year, the Stormwater Study Group will use the information generated during the assessment and evaluation phases of our project to give BF/OCV residents an opportunity to develop their own comprehensive stormwater management plan.

Implementation
A key component of the project’s implementation phase is water-quality and -quantity monitoring. We have already collected more than a year’s worth of baseline and stormwater-quality data on Tributary 7 of Potash Brook. Isco samplers have been installed above and below BF/OCV to collect flow-weighted proportional composite samples during storm events. Key parameters being measured include pH, total suspended solids, total phosphorus, nitrate, nitrite, total Kjeldahl nitrogen, and total metals.

The goal of the stream monitoring effort is to measure the total load of pollutants entering the stream during individual storm events. Monitoring results will allow us to evaluate the effectiveness of the BMPs employed in BF/OCV. In order to provide a snapshot in time of existing conditions, geomorphic and biological surveys have also been completed. Rainfall and discharge are also being continuously monitored.

The culmination of the project will be the approval and implementation of the stormwater management plan developed by BF/OCV residents. Key throughout the project has been the involvement of City of South Burlington officials. Juli Beth Hinds, the director of planning and zoning for South Burlington, has been an invaluable ally. In addition to acting as a liaison to the community and interpreting relevant city regulations, she has secured federal funding to help defray the costs of putting structural components of the plan into place. Once BF/OCV has implemented its stormwater management system, the city will assume responsibility for maintaining stormwater interventions on city land.

The “town gown” relationship has proved to be invaluable. As Hinds notes, “The university’s strong involvement as the ‘honest broker’ of sound scientific information, coupled with the faculty expertise in environmental consensus building, created an atmosphere of trust and cooperation that would not have been possible otherwise.”

The project team hopes that the approach being tested might be used elsewhere to help suburban landowners make wise decisions about stormwater management. As Project Manager Eric Perkins of EPA’s Region 1 notes, “The kinds of decision-making tools being developed through this project should have significant applicability in the other New England states and beyond. I think there will be a lot of interest, especially in the RAN-55 and cost analysis components—these are relatively simple but innovative tools that should help empower homeowners, businesses, and watershed associations to become much more proactive on stormwater issues.”

Lessons Learned

While the project is in its second year, we have learned several important lessons so far:

1. Despite a number of challenges, applied research can help address local environmental issues. With a community facing a real need to manage stormwater and a supportive city government, we have been able to make substantial progress in developing and testing an innovative approach to making decisions about the best way to manage stormwater in communities.
   There are and will remain obstacles. Federal funding runs in annual cycles. There is no guarantee that funding will continue until all project goals are met. In the RAN project, there is a considerable time lag between the initial discussion of BMP approaches and final implementation of the community-developed stormwater management plan. The challenge for us is to complete both the stormwater management effort and the post-implementation monitoring to evaluate effectiveness. The slow and sometimes arduous process of ensuring community involvement and leadership doesn’t lend itself well to a conventional funding schedule.
   It is crucial to maintain momentum. The research process needs to be continuous and gradually build up to project goals. With the many stops and starts typical of stormwater management, this can be a daunting challenge.
2. Meshing the goals of individual homeowners in BF/OCV with broader project goals is not always easy. For example, convincing a resident suffering from frequently flooded basements that he or she should be as concerned about reducing the movement of phosphorus into nearby Lake Champlain for the greater good is difficult. Our challenge is to meet local concerns while improving the broader environment.
   Of course, for overall project success, it is vital that the research team be able to set some part of the agenda and not constantly need approval from external parties. In this manner, project goals are more likely to be accomplished, an important outcome for any grant.
3. The role of stakeholder cooperation is critical. While there are many divergent opinions among BF/OCV homeowners about stormwater approaches, no action is not an option. When faced with the reality of having to spend money to control stormwater, many residents appear willing to work with the RAN team to develop solutions.
   Also key is the support of the city government. We have benefited from the help of city officials familiar with the neighborhood and its issues, and we hope the city will see an outcome based on both the best available science and the wishes of the community. If RAN is successful, we believe that the city could employ the approach in other affected neighborhoods as well.
   It is crucial to tailor such activities as data gathering and model generation to stakeholder needs. Nothing will turn off the stakeholders more quickly than an academic presentation that is not germane to the issues at hand. The challenge for the research team is to learn to package findings in a way that is appealing and responsive to stakeholder needs. The

art is learning how to weave in the facts and findings that the research team thinks important with stakeholder needs.

4. There are reasons that stormwater management has remained such a difficult issue to resolve. The wide variety of pollutants moving off the landscape in massive volumes during rainstorms presents a host of technical challenges. It is crucial that scientists adequately explain these challenges to all stakeholders. At every step, it is important to be open with residents about what's achievable and what isn't with any approach or set of approaches.
5. Luck plays an important role. There is no way to predict whether a particular stakeholder group will operate effectively. Sometimes a single individual can drive, and possibly derail, the whole process. Unforeseen external factors can also be important. In our case, the implementation of a stormwater utility in the city proved to be a stimulus for BF/OCV residents to become more involved with RAN.

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Alan McIntosh, Ph.D., is a professor at the Rubenstein School of Environment and Natural Resources at the University of Vermont (UVM). Breck Bowden, Ph.D., is the Patrick Professor for Watershed Science and Planning in the Rubenstein School. Evan P. Fitzgerald, Alex Hackman, and Barton Kirk are current or former graduate students at UVM. John Todd, Ph.D., is a Research Professor in the School of Natural Resources at UVM. Helena Vladich is a research associate at the Gund Institute for Ecological Economics at UVM.Alexey Voinov, Ph.D., is Research Associate Professor at the Gund Institute for Ecological Economics and Computer Science Department. Joseph Bartlett is a research technician at UVM.

http://www.forester.net/sw_0605_ran.html

Stormwater Basics: Volume and Force

Below are a series of example calculations showing the volume and force of rainfall runoff generated from a hypothetical storm.

Question: Can you guess the volume of stormwater generated by a five-year, two-hour long storm from the area in the photograph?

By consulting the NOAA historical data below, we can assume that a 5-year, two-hour long storm could produce 2" of rain.

Assume that there are 10 homes in the area, each on 1 acre lots. The individual components of the impervious area can then be calculated as:

- House footprint (roof): 30 ft by 60 ft = **1,800 ft^2**
- Driveway: 12 ft by 30 ft = **360 ft^2**
- Sidewalk: 5 ft by 200 ft = **1,000 ft^2**
- Roadway: 15 ft ($^1/_2$ of 30 ft road width) by 200 ft = **3,000 ft^2**
- Total Impervious Cover (IC) per lot = **6,160 ft^2**
- Total IC for all 10 lots = **1.4 acres** (14% of total)

Then, assuming 2" of rainfall (5 yr/2h rainfall NOAA)

- Total volume = (61,600 ft^2) x (2 in) x (1 ft/12 in) *[conversion]* = **10,266 ft^3**
- This is a cube of water measuring 23 feet on each side!
- This can be converted to weight:
  - $10{,}266\,ft^3 * \frac{7.5gal}{1\,ft^3} * \frac{8lbs}{1gal} * \frac{1ton}{2000lbs} =$

308 tons of water!

This explains the connection between stormwater and erosion: it is the force of the water moving through the watershed from a higher elevation to a lower elevation that is responsible for scouring the tributaries and streams en route to Lake Champlain. 308 tons of force can move a lot of sediment!

Figure 4. The Butler Farms / Oak Creek Village neighborhood (www.uvm.edu/~ran).

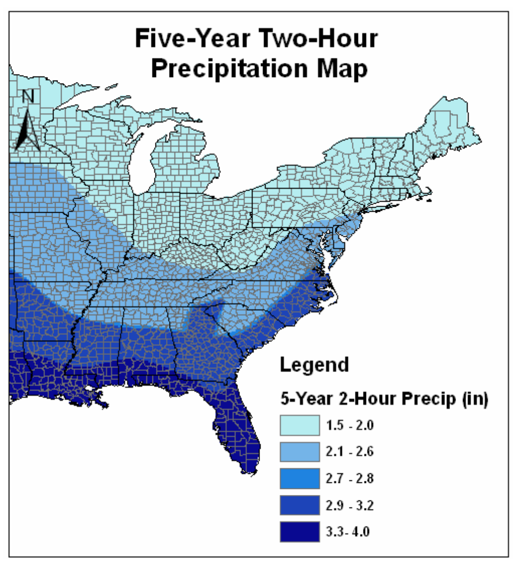
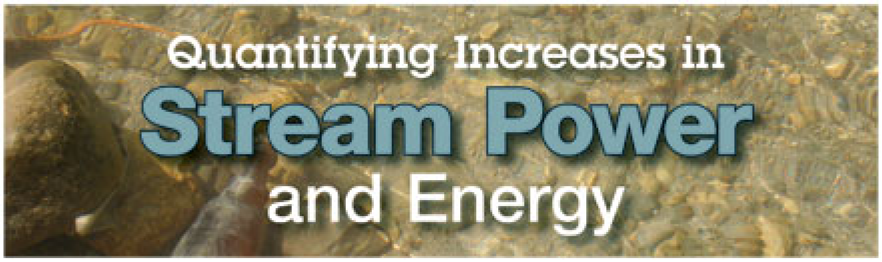


Figure 5. An NOAA precipitation frequency map showing the eastern U.S. (Data from www.tucson.ars.ag.gov).

The Journal for Surface Water Quality Professionals
Stormwater
FEATURES



Using flow duration curves to depict streamflow values

By Evan Fitzgerald and Breck Bowden

Watershed scientists use various methods to quantify urban impacts on stream channels. These methods, when focused specifically on the physical changes that occur in channels, include the following measurements: cross-section geometry change over time, bedload movement and sediment deposition at the reach scale, and shear stress and tractive force. One of the most remarkable changes in the urban stream environment, quantifiable with various equations used by hydrologists and engineers, is stream power. Stream power calculations are critical in understanding many of the scientific measurements listed above, as the available water power in the stream channel is the principal driver of physical change (Booth 1990).

Although traditional calculations of stream power are scientifically sound and adequate for discussion within the scientific community, they fall short of capturing, in layman’s terms, the raw and dramatic changes that occur in urban streams because of human impacts. In this article we propose an alternative, scientifically defensible method of interpreting stream power increases, albeit outside the realm of traditional scientific analysis of stream power, to help other watershed professionals convey the message of stream power increases to their nontechnical audiences.

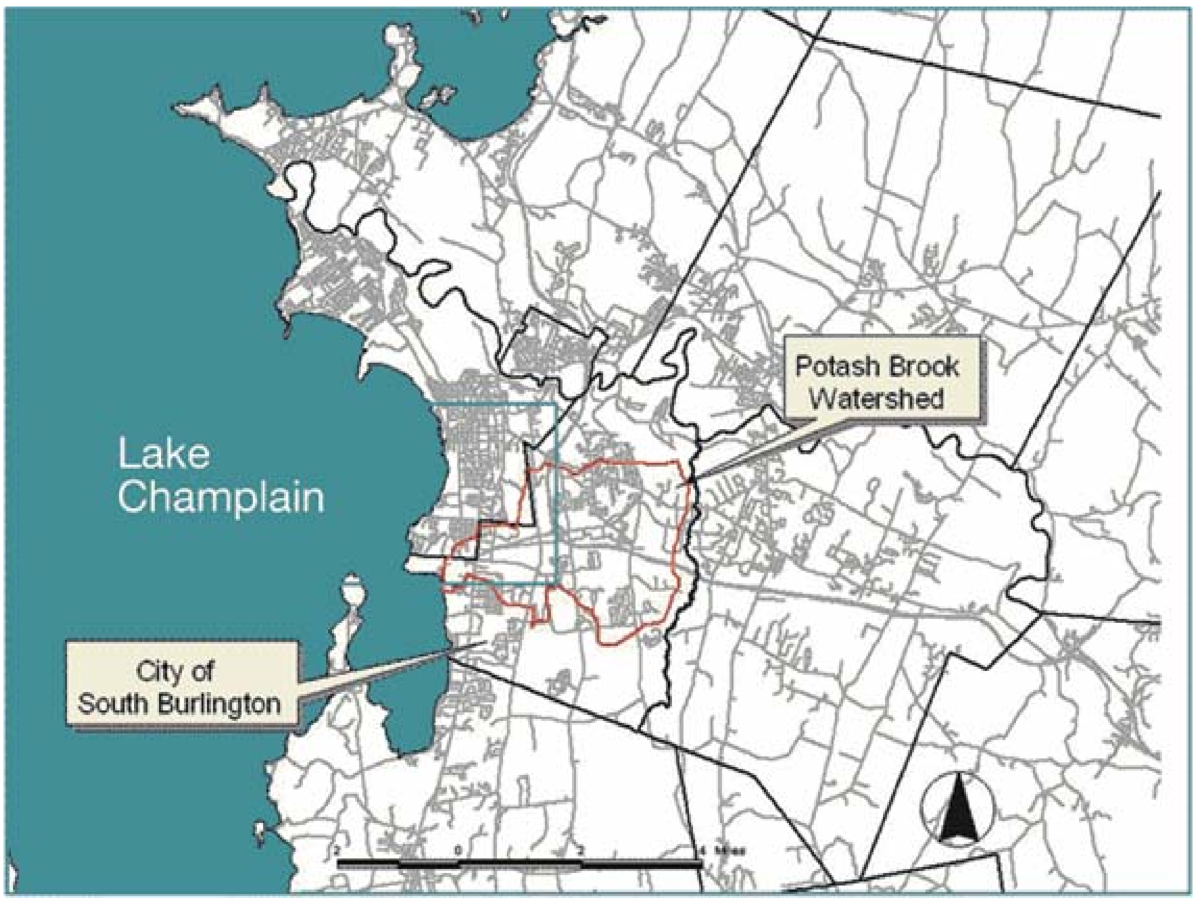
Flow duration curves (FDCs) are a graphical depiction of streamflow values arranged from highest to lowest (*y* axis) and percent exceedence (*x* axis) at each interval. The source of the data can be actual gauged data or simulated data from a model output. FDCs are used throughout the watershed science community to predict return intervals for different streamflow events, often those large-magnitude events associated with flooding. FDCs provide one of the important pieces of data needed to calculate stream power: streamflow values. FDC data are also convenient for stream power calculations, because the time component allows for a quantification of stream power for specific flow durations (e.g., one-day return flow). The comparison of FDC data for a watershed under both forested and urbanized conditions provides the data needed to quantify stream power increases due to the effects of urbanization. When the effects of urbanization on stream power are considered for the infrequent streamflow events characterized by the upper end of a flow duration curve, being those high-flow events most effective in channel formation, increases are significantly large(Wissmar, Timm, and Logsdon 2004). Furthermore, when quantified increases in stream power and energy for these infrequent events are displayed in units commonly understood outside the scientific community (e.g., kilowatt-hours of energy, horsepower of machinery), results are impressive and have the potential to change the public’s perception about the magnitude of stormwater impacts in their own backyards.

Methods

Flow Duration Curves

FDCs were developed by Tetra Tech Inc. for the Vermont Agency of Natural Resources as a means of identifying hydrologic targets for total maximum daily load implementation in stormwater-impacted watersheds in Vermont. FDC data have been developed and calibrated for current conditions using gauged streamflow data and simulated for forested (pre-development) conditions using the P8 model (Saravanapavan and Parker 2004). Potash Brook, which has been the focal point in the discussion on stormwater in Vermont, was chosen as the study watershed because of the overall familiarity with the basin by the scientific and regulatory communities and the public alike. Potash Brook, which drains directly to Lake Champlain, has a watershed area of 7.5 square miles and is located predominately in the city of South Burlington (Figure 1). There is a mix of residential, commercial, and agricultural land uses within the watershed, with approximately 22% total impervious cover. Potash Brook is a low-gradient riffle-pool stream (average channel slope approximately 1.0%) with a width of 35 feet at its outlet.

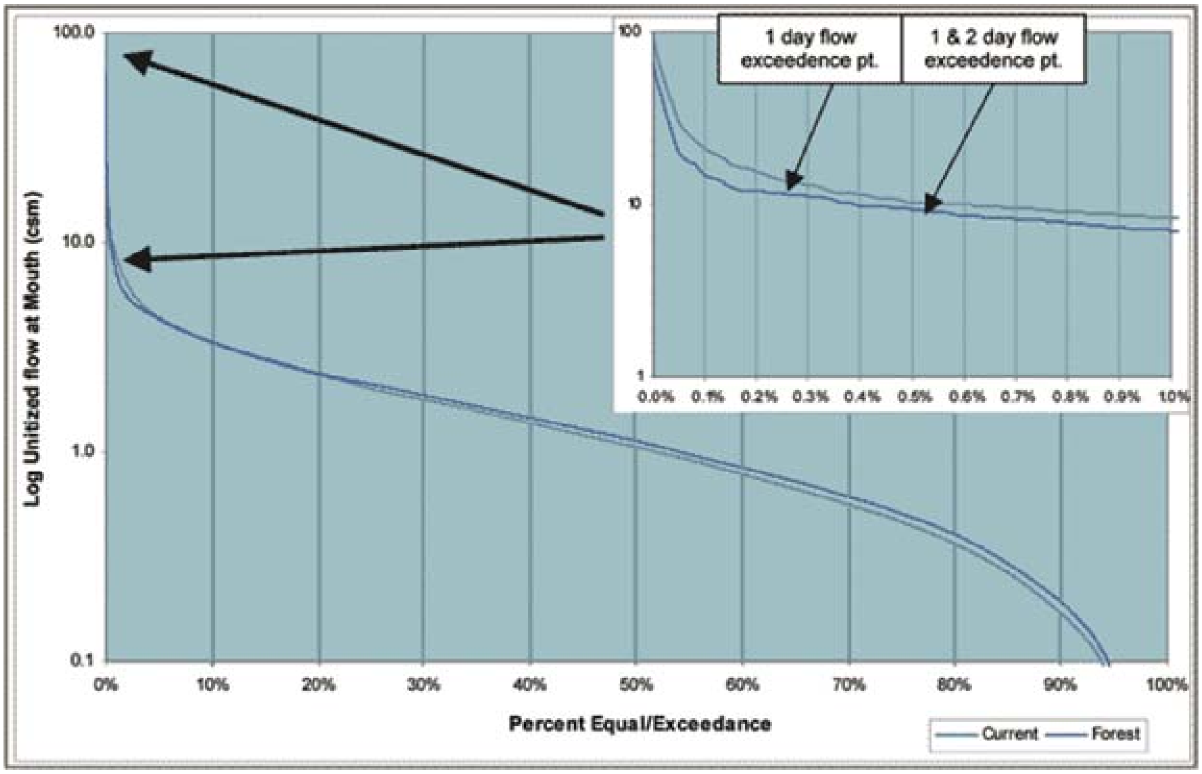
Figure 1. Location of the Potash Brook watershed



The P8 model was configured to produce unitized streamflow (cubic feet per second per square mile) values at the outlet to Lake Champlain with an individual time step of 0.07 day, or approximately 1.8 hours (Figure 2).Model results used in FDC development include current watershed conditions and forested conditions with no impervious cover. Using the FDC data for analysis of annual return frequency of streamflow discharges and durations, we find that the 0.27% exceedence flow values represent the one-day flow for any given year (100% divided by 365 days), and the 0.55% exceedence flow values represent the one- and two-day flows combined for any given year. Bankfull flow events have return intervals of one-and-a-half to two days per year and are known to have the greatest impact on the formation of the stream channel

(Leopold, Wolman, and Miller 1964). Thus, flow durations using the one- and two-day values were considered most important in quantifying increases in stream power and its ability to do work and actively form the channel.

Figure 2. Flow duration curves for Potash Brook for current and forested watershed conditions



Stream Power

Two equations are commonly used in the fields of hydrology and engineering for calculating stream power, yet their applications and resulting units are slightly different. Hydrologists typically calculate stream power using Equation 1 (Bagnold 1966; Ward and Trimble 2004).

Equation 1. $Sp = \gamma v d S$

Sp = stream power per unit measure of bed (kg/m/s)
γ = unit weight of water (kg/m^3)
v = streamflow velocity (m/s)
d = depth of streamflow (m)
S = slope (dimensionless)

In this equation the units, kilograms per meter per second, are describing the force exerted by a mass of water moving over and across a single cross-section per unit time. This equation is typically applied to studies of bedload movement to determine whether a stream reach is aggrading (sediment accumulation) or degrading (incision). On the other hand, general physics equations used for calculating mechanical power (horsepower, kilowatts) traditionally describe force per unit area. Although Equation 1 can be manipulated to calculate force per unit area by considering the longitudinal stream length with respect to slope, we have found another stream power equation to be more user-friendly and intuitive for our purposes. Equation 2 is the hydroelectric power calculation most commonly used by the engineering community to calculate potential power at a dam site (McKinney 1983).

Equation 2. $P = QHe/C$

P = power (kW)
Q = discharge (m^3/s)
H = head (m)
e = efficiency (80%–85%)
C = coefficient for units conversion and gravity (9.81 for SI)

Equation 2 describes the force exerted by a known volume of water descending a known vertical distance per unit time. Because this equation incorporates both the vertical and the force-per-unit-area components we were trying to capture, we have used it to quantify stream power using the FDC data for the flow periods of interest. We assumed a stream-reach length of 0.5 mile, and we calculated head using the average channel slope (2%) near the outlet of Potash Brook and the reach length. The efficiency coefficient is typically applied for thermal and mechanical losses of energy during the conversion of water energy to mechanical shaft energy in the turbine. Our calculations assumed 100% efficiency because in our case the stream's energy is confined and absorbed within the channel during bankfull flow events.

Stream Power and Energy
Hydroelectric stream power was calculated using predicted streamflows from FDC data for the flow durations of interest (one-day and combined one- and two-day duration flow events). Using the time interval associated with each event (24 and 48 hours), total hydroelectric energy, or the cumulative energy available during each time period, was calculated using the following conversion: Kilowatts multiplied by duration (hours) = kilowatt-hours.

Using the cumulative hydroelectric energy calculated for current and forested conditions for the two flow durations, energy increases due to effects of urbanization were quantified using the following equation: Energy increase = current conditions cumulative energy – forested conditions cumulative energy.

Stream Energy Versus Machine Energy
Values for energy increases were converted to British thermal units (Btus) and used to calculate the duration of time the resulting energy would power a bulldozer, given the known energy usage of the machine. The bulldozer chosen for this calculation was a Caterpillar 824H, which is a typical medium-sized bulldozer that consumes approximately 10 gallons of diesel fuel per hour (Caterpillar 2005). Diesel fuel contains approximately 130,000 Btus per gallon, with a large percentage of this energy lost to heat in the internal combustion process (a great amount of

mechanical work is lost). Given the known fuel usage of this machine, the quantity of bulldozer operation hours associated with each stream energy increase was calculated using the following equation: Number of bulldozer hours = energy increase (Btu)/1,300,000 (Btus per hour).

Figure 3. Streambank erosion in the lower reaches of Potash Brook

Results

Table 1 displays the results of cumulative stream energy increases calculated for Potash Brook for the two flow-duration periods considered in this analysis. For the one-day return flow, a total increase of 5,233 kilowatt-hours or 17,842,953 Btus were calculated from forested to current watershed conditions. For the one- and two-day return flow, a total increase of 6,235 kilowatt-hours or 21,261,550 Btus were calculated between the two watershed conditions.

Table 1. Comparison of stream energy for different watershed conditions

Flow Duration		Cumulative Stream Energy* (kWh) for Different Watershed Conditions		Increase in Cumulative Stream Energy (kWh)	Increase in Cumulative Stream Energy (Btu)
% Exceed.	Time Equivalency	Forest	Current	Forest to Current	Forest to Current
0.27%	1 day	14,000	19,232	5,233	17,842,953
0.55%	1 & 2 day	21,822	28,057	6,235	21,261,550

***Assumptions**
1) 0.5-mile reach with slope = 2.0%
2) 100% efficiency assumed (no thermal losses)
3) Cumulative power summed for each respective flow duration

Cumulative stream energy increases for two locations on Potash Brook have been translated into bulldozer operation hours and are displayed in Table 2. At the outlet of Potash Brook, energy increases are equivalent to 14 hours of bulldozer operation for the one-day return flow, and 16 hours of bulldozer operation for the one- and two-day return flow. Values prorated for Tributary 7, a smaller and highly impacted tributary of concern in the upper watershed, indicate that the energy increases for both flow durations are equivalent to three hours of bulldozer operation.

Table 2. Stream energy and bulldozer hours

Location on Potash Bk	Drainage Area on Potash (mi^2)	Flow Duration	Increase in Energy (Btu)	Number of Bulldozer Hours	Number of Bulldozer Days*
Mouth	7.2	1 day	17,842,953	14	1.7
		1 & 2 day	21,261,550	16	2.0
Tributary 7	1.4	1 day	3,531,262	3	0.3
		1 & 2 day	4,207,830	3	0.4

***8-hour workday**

Discussion

Our results indicate that, given the energy increase from the one-day streamflow alone, a bulldozer could be operated in a 0.5-mile reach of Potash Brook near its outlet for 14 hours. Is this an accurate account of excess energy produced in a stream channel due to urbanization? Is the damage that could be caused by letting a bulldozer loose on a 0.5-mile reach of a small stream comparable to the physical changes occurring in the stream channel? Given the amount of active streambank erosion observed in the lower reaches of Potash Brook (Figure 3) and the channel adjustments occurring to accommodate this excess flow, it is plausible to relate the magnitude of bulldozer energy to that energy being expended in the channel during infrequent flow events. Note that for a smaller tributary of interest in the watershed, the prorated number of bulldozer hours was much reduced yet significant given the size of the drainage area and stream channel. Observations of bank failure in this tributary also suggest that our energy calculations are within the realm of possibility for this smaller channel.

We acknowledge that there are perhaps some “unscientific” assumptions that have been made in our calculations aimed at comparing stream and mechanical power and energy. It is difficult and perhaps impossible to make a true comparison between the mechanical work expended using a fuel-powered machine and the physical work expended by water in a stream channel. Geomorphologists understand that stream channels will adapt to changes in hydrologic regimes and become more or less efficient at transferring energy. Natural channel changes such as these make it difficult to understand expenditure of water energy in a watershed over time. With machines, great amounts of energy are lost to heat during the internal combustion process, further complicating this comparison.

Despite these difficulties, stream channel changes in response to urbanization are clearly dramatic and detrimental, and yet many scientific techniques used in assessing these changes fail to convey the magnitude of the impacts in familiar terms. In this analysis we have gone to the extreme of choosing the example of a bulldozer operating in the stream channel to impress upon the reader how powerful these changes can be. Bank erosion in urbanizing watersheds often produces an effect that is not unlike a bulldozer scouring down through a channel. The intent of our analysis is not to make a true scientific comparison between these two forces, but to stimulate a discussion in the watershed science community of how to bring attention to the problems we work on solving. Perhaps by using more familiar examples such as these, watershed scientists and land-use planners can get these important messages across to their nontechnical audiences more effectively.

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http://www.forester.net/sw_0603_quantifying.html

Hydraulic Geometry Curves

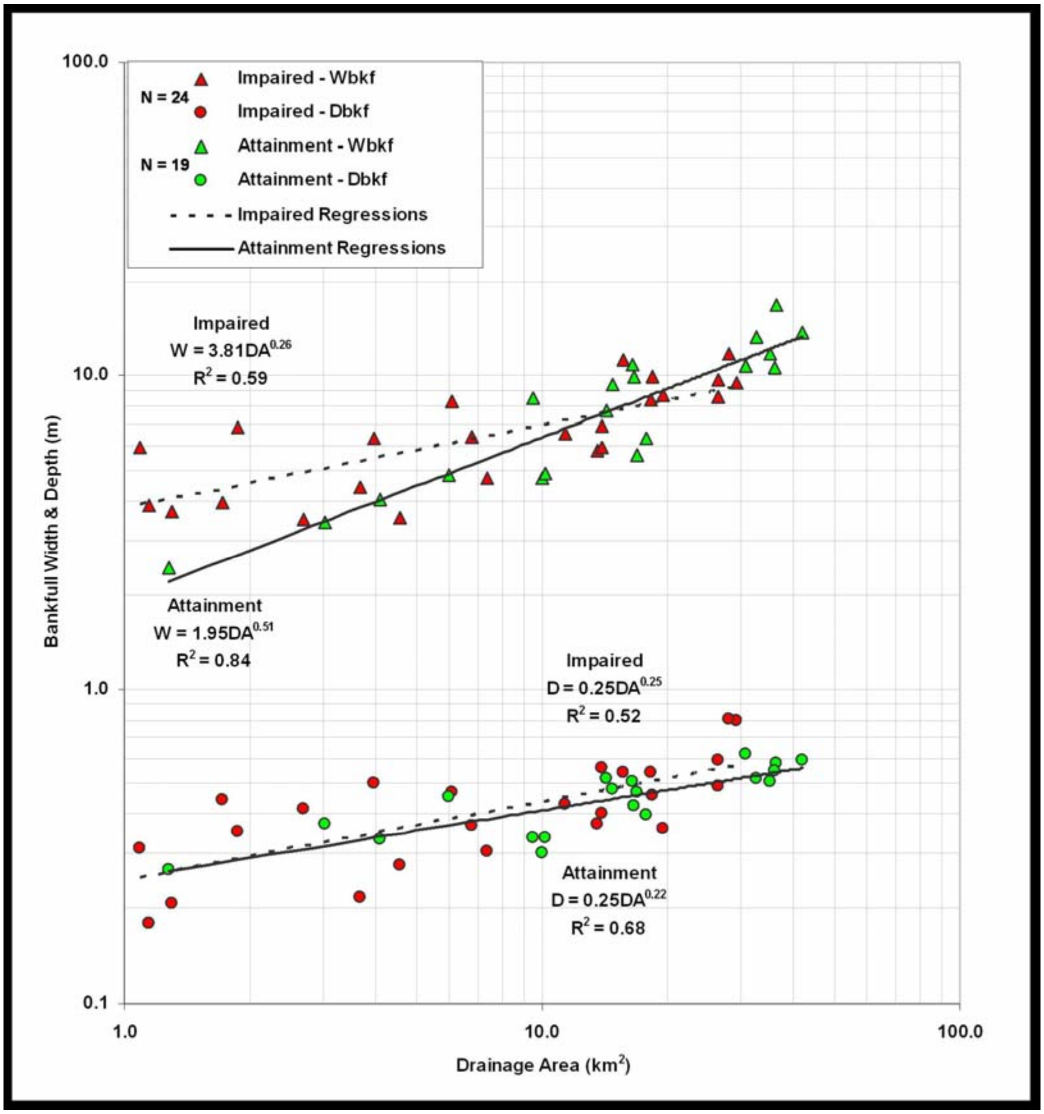


Figure 6. Hydraulic Geometry Curves of Channel Width and Depth for Small Urban and Non-Urban streams in Chittenden County, Vermont (Fitzgerald and Bowden, 2006).

Hydraulic geometry curves are useful in depicting changes in stream channel dimensions in response to urbanization. This plot compares urban (impaired) and non-urban (attainment) stream channel dimensions using an extensive dataset from 16 small watersheds in Chittenden County. Results show that impaired streams are wider in smaller drainage areas, a likely response to excess stormwater runoff from impervious surfaces. However, the difference in channel width is not significant in drainage areas larger than 15 km^2, and channel depth is not different between impaired and attainment streams. Similar studies across the country also show that stream channels in urbanizing watersheds tend to enlarge in response to greater stormflows. These results will be useful in determining the relative amount of excess sediment generated in Chittenden County impaired watersheds due to channel bank erosion.

Stream Monitoring at Butler Farms / Oak Creek Village

The stream running through Butler Farms / Oak Creek Village (BF/OCV), Tributary 7 of Potash Brook, is monitored before entering BF/OCV and after flowing out of BF/OCV. These data provide a picture of the change in stream characteristics as a result of inputs from the BF/OCV neighborhood.

To measure the flow of water at two stream cross sections (upstream or before, and downstream or after) an ISCO automatic sampling device was installed. This device measures the weight of water over a point along the stream bottom every 5 minutes and then relates it to the total flow of water using pre-established relationships. The device is also equipped to take periodic water samples and store them for subsequent physical and chemical analysis. A stream bed sampling location is shown in Figure 1.

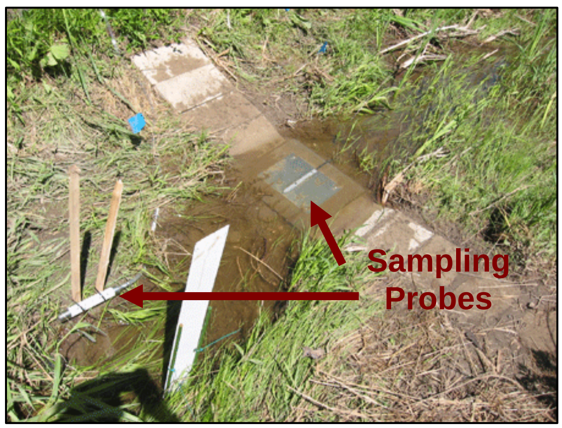


Figure 7. A constructed channel cross section of known geometry, with sampling probes (www.uvm.edu/~ran).

In Figure 2, the ISCO Automatic Sampler is shown next to the stream. Samples can be stored within the unit for a period of weeks between collections by RAN Field Technicians.

Figure 8. A picture of an ISCO automatic sampler in the field. Cables and tubing towards the bottom of the picture collects data and water samples from the stream which are then stored inside the sampling device (www.uvm.edu/~ran).

While some of the analyses require processing in the laboratory, others can be measured in the field. An electronic probe, or DataSonde, can be used for these measurements (Figure 3). Measurements taken in this way include water temperature, dissolved oxygen content, pH, and electrical conductance.

Figure 9. A DataSonde in position, used to collect physical and chemical stream water data (www.uvm.edu/~ran).

Hydrologic measurements are taken from the stream every 5 minutes. A hydrograph, or plot of streamflow versus time, is shown below for a 15 day period in 2004 (Figure 1). Also shown are the depths of daily precipitation over this period of time.

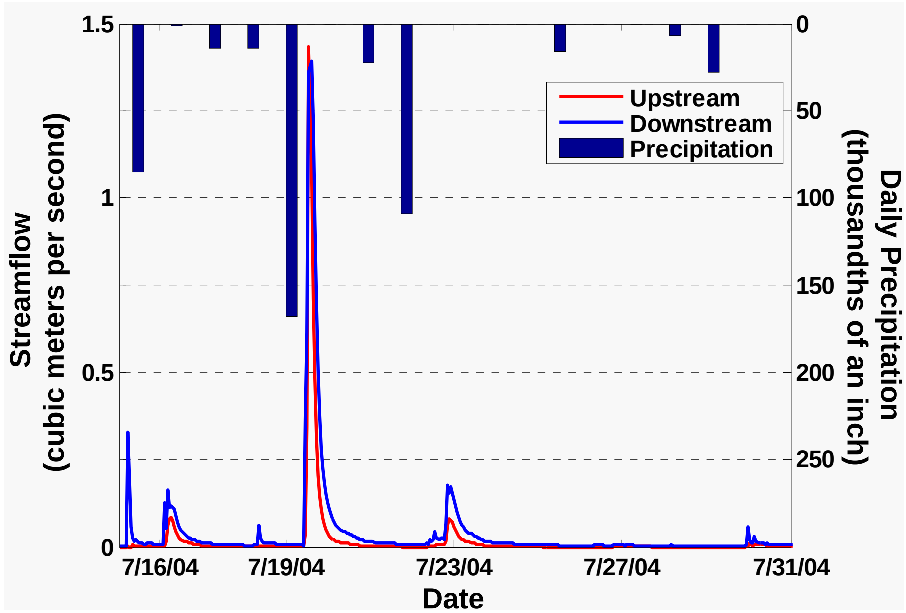


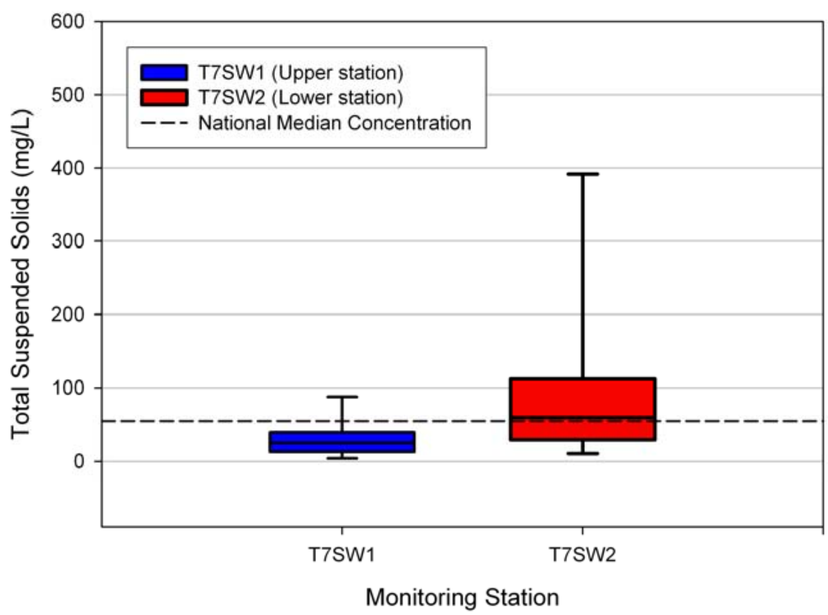
Figure 10. Upstream and downstream hydrographs showing the increase in streamflow following precipitation events.

Selected Results From the Tributary 7 Monitoring Initiative

Alex Hackman and Breck Bowden
Rubenstein School of Environment and Natural Resources
University of Vermont

The following figures summarize total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) values measured in Tributary 7 above and below the Butler Farms and Oak Creek Village neighborhoods in 2004 and 2005. The Vermont Department of Environmental Conservation's Stormwater Manual (VT DEC, 2002) provides a list of national median concentrations for common constituents found in stormwater. Comparisons between the median storm-event concentrations found at Tributary 7 and these values are provided in Figs. 1-3 below. In these figures the median values (the value for which half the observations are higher and half are lower) are shown as a line within the box, the box shows the 25^{th} and 75^{th} percentiles and the whiskers show the 5^{th} / 95^{th} percentiles.

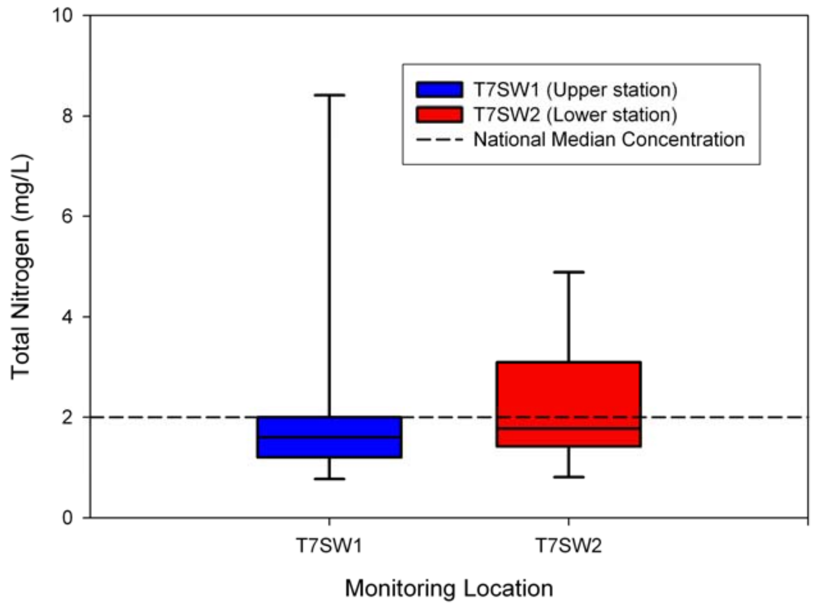
Figure 1. Storm-event TSS concentrations vs. the national median value



The median value for our TSS sampling at the upper station is below the national median concentration. At the lower station, the median TSS value is just above the national value. It is noteworthy that many storm events resulted in TSS concentrations above the national median value, particularly at the lower monitoring station located below the study neighborhoods. Efforts to reduce downstream sediment transport should be a focal point of any new stormwater management activities in this area.

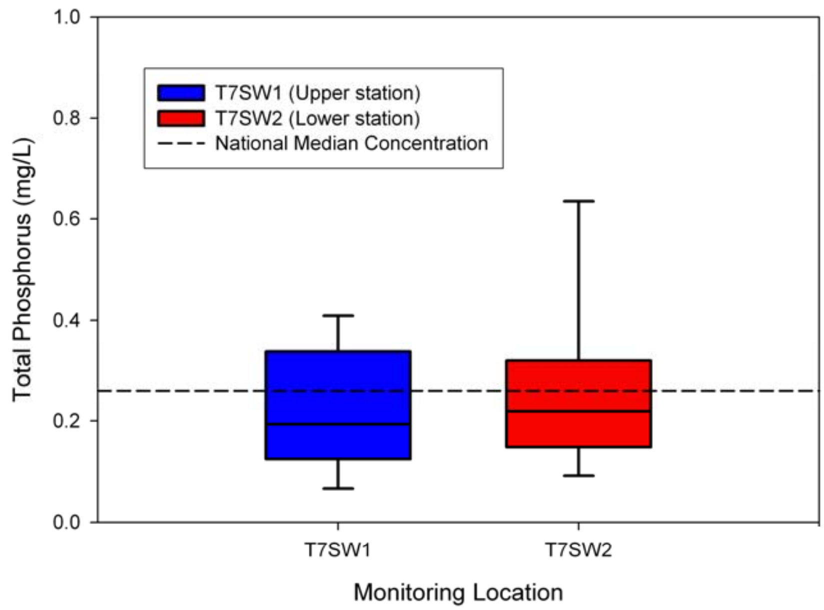
Median total nitrogen values at both stations were below the national median concentration (Fig. 2). The length of the whiskers for the T7SW1 (Upper station) plot reflects the considerable variability in the sampling results. In addition, total nitrogen concentrations at the lower station were above the national median value during many storms, but were also quite variable, as indicated by the relative size of the box. This variability indicates why it is so hard to document statistically significant development impacts from “ephemeral” data such as water quality parameters, which change rapidly among and with storm events.

Figure 2. Storm-event TN concentrations vs. the national median value



Median total phosphorus concentrations during storm events at both Tributary 7 monitoring sites were below the national median value (Fig. 3). This is an encouraging result. However, several storm events produced concentrations well above this national value, with elevated levels closely linked to total suspended solids. As noted above, efforts to reduce sediment transport may also have the dual-benefit of reducing total phosphorus export.

Figure 3. Storm-event TP concentrations vs. the national median value



South Burlington
Stormwater Utility
www.sburl.com/stormwater

An Introduction to Vermont's First Stormwater Utility

Stormwater drain

What is Stormwater?

Stormwater is water that runs off impervious surfaces such as rooftops, paved roads, driveways, and packed gravel roads.

Construction runoff

Stormwater carries sediment and surface pollutants such as petroleum products, trash, phosphorus, and nitrogen. Stormwater is washed down storm drains. Most stormwater is not treated before it empties into our waterways and Lake Champlain.

South Burlington
Stormwater Utility
www.sburl.com/stormwater

Stormwater and South Burlington

South Burlington contains all or a portion of six streams impaired by stormwater runoff, the highest number of any community in Vermont. Unmanaged stormwater is causing water pollution, erosion, flooding, and unstable streambanks in areas of South Burlington.
Private stormwater systems that are not maintained have become a public problem. Expired permits and difficulty obtaining a valid stormwater permit are hindering property transfers in South Burlington.

A Stormwater Utility

The City of South Burlington is proud of its history of providing valuable public services for residents and is recognized nationally for its natural resources. Unmanaged stormwater runoff jeopardizes these assets.

There are positive steps the City can and should take at this time to address stormwater and its related problems. Establishing a utility will help the City clean up streams and improve water quality.

The Utility is an efficient way to identify and manage stormwater problems, projects, and infrastructure upgrades. The Utility will provide a stable and adequate source of revenue to complete required maintenance and manage stormwater-related activities.

The entire area of the City of South Burlington, including City-owned and state-owned and maintained roads, culverts, and parking lots, will share the cost and receive services from the Stormwater Utility.

Stormwater is everyone’s responsibility. All properties with impervious surface generate stormwater runoff.

South Burlington
Stormwater Utility
www.sburl.com/stormwater

Benefits of a Utility

The Stormwater Utility will:
• Manage and upgrade the City's stormwater infrastructure, such as culverts and storm drains, so that systems continue to meet current regulations and would receive permits.
• Manage, maintain, and handle permitting for residential stormwater systems in the City, after the systems are brought up to current Vermont (2002) standards by residents or homeowners associations.
• Provide technical assistance to South Burlington property owners who need to bring their stormwater system up to current Vermont (2002) standards. Avalid stormwater permit is part of the value of your home and property.

Vermont Youth Conservation Corps volunteers plant the Bartlett Brook stormwater treatment wetland.

Stormwater Utility Fee

The Stormwater Utility user fee will be listed on existing sewer and water bills. Just like a water bill, the fee is based on service use.

A scientific process was used to calculate impervious surface area. The rate of $4.50 per equivalent residential unit (ERU) per month is based on the typical single-family South Burlington home having 2,700 square feet of impervious surface (rooftops, driveways, walkways).

User Fees

Every single-family home in South Burlington will be assessed a flat fee of $4.50 per month for services provided by the Utility.

Duplexes with fee simple ownership will be assessed $2.25 each per month. Triplexes with fee simple ownership will be assessed $1.50 each per month.

The fee will be billed quarterly. The annual cost is $54 for single-family homes, $27 for duplexes, and $18 for triplexes.

All other property owners (includes condominium ownership properties, businesses, institutions, and government) will be assessed a fee based on the amount of impervious surface.

Your Job, My Job

The City is responsible for parts of the stormwater system that are in the public right of way and located on public property. This includes storm drains, culverts, conveyance piping, catch basins and stormwater outfalls.

Property owners are responsible for everything on their property. This includes cleaning leaves out of your rain gutters and removing gravel from your driveway.

For more information visit our Web site, www.sburl.com/stormwater to learn more and view an interactive map which shows stormwater problem areas and improvement projects.

City of South Burlington
575 Dorset Street
South Burlington, VT 05403
(802) 846-4106
www.sburl.com/stormwater

Stormwater Detention Ponds

When land development and conversion of pervious lands to impervious lands increase the runoff from an area, detention ponds offer a means storing the excess runoff and thereby protecting the stream channel from the force of the excess water.

The Vermont Agency of Natural Resources (2002) defines detention as:

> ‘The temporary storage of storm runoff in a STP (stormwater treatment practice) with the goals of controlling peak discharge rates and providing gravity settling of pollutants.”

A detention pond of appropriate size and characteristics can be designed provided that some information about the area to be treated is available. In general, these structures will include a sediment forebay, followed by a larger constructed pond or series of constructed ponds (Figure 1).

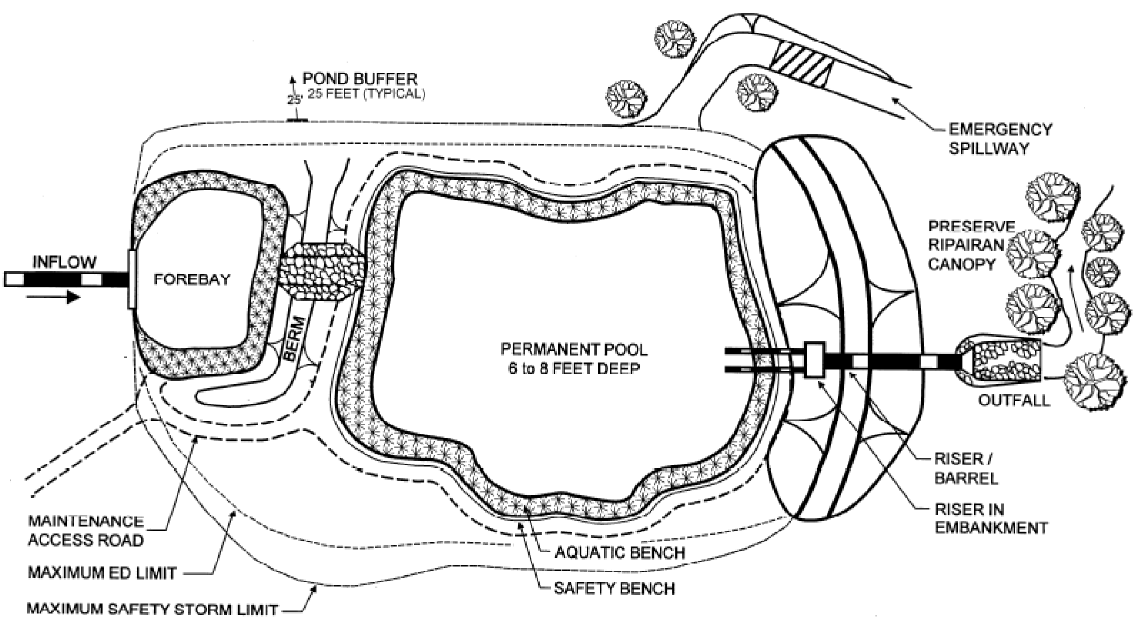


Figure 11. A typical detention pond setup with a sediment forebay and permanent pool (VT ANR, 2002).

The sediment forebay is the first stop for the storm flows coming into a detention pond. It allows suspended materials, such as sediment, branches, and garbage to settle out. This allows the periodic removal of accumulated materials to be limited to a relatively small area, the sediment forebay, greatly reducing maintenance costs. The sediment forebay is typically sized to hold 10% of the total water quality volume (WQ_v). This volume, WQ_v, is calculated from the total area contributing runoff to the structure, the percent imperiousness of that area, and a number accounting for rainfall, which is the same for all of Vermont (VT ANR, 2002).

The permanent pool shown in Figure 1 would detain the remaining 90% of the predetermined WQ_v. Through a constructed device the flow rate out of the pool can be regulated, so that the flow rate into the stream remains below harmful or destructive levels despite increased flow into the detention pond (VT ANR, 2002).

There are numerous variations on the design shown above which may provide equal or better performance while also meeting other site specific considerations. For example, ponds can be constructed to intersect the water table, or natural level of groundwater below the surface, ensuring that the pool has water despite long periods with no precipitation. Another design variation is a multiple pond system, as shown in Figure 2.

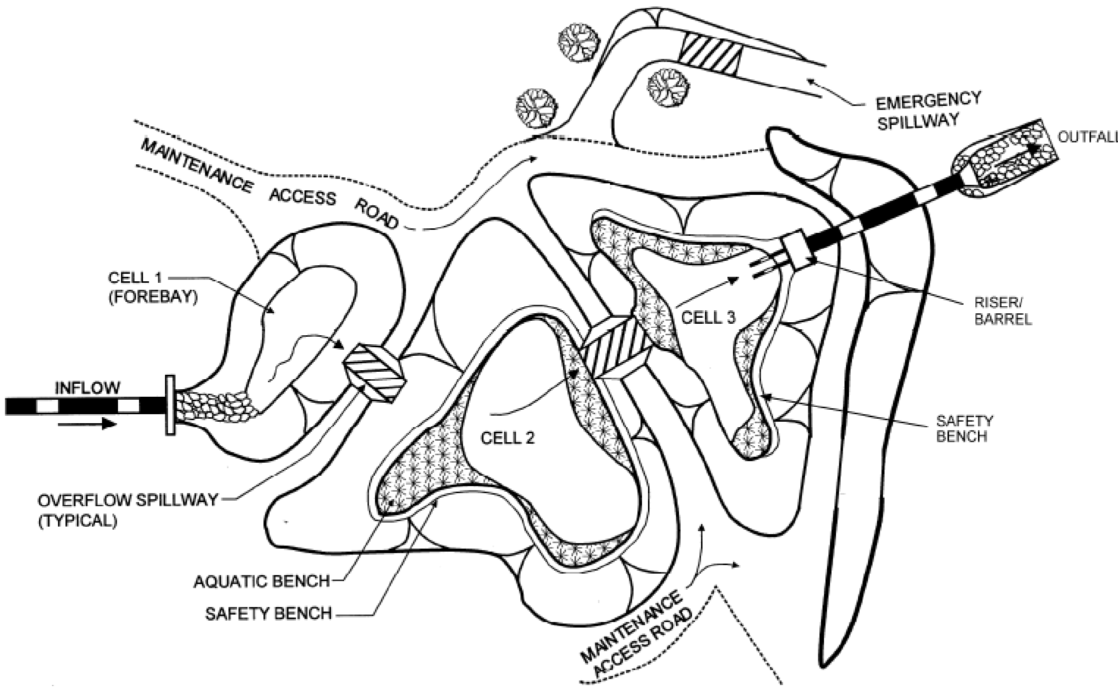


Figure 12. A multiple cell detention pond with a sediment forebay, providing enhanced temperature regulation and longer flow paths (VT ANR, 2002).

A multiple pond layout may be selected for several reasons. The division of the WQ_v into several smaller volumes will better regulated temperature, protecting cold water fish habitat downstream of the pond. This design type may result in a longer travel time for water and pollutants through the pond, resulting in greater reductions (VT ANR, 2002).

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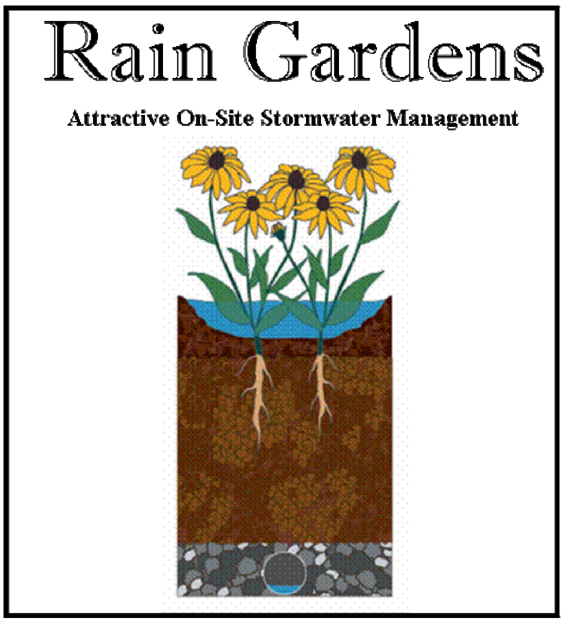
Rain Garden Brochure
1193 South Brownell Road, Williston, VT 05495



What is a Rain Garden?

Rain gardens are perennial gardens designed to capture stormwater runoff from a roof, parking lot or other impervious surface.

A recently completed neighborhood rain garden in Vermont.

Rain gardens reduce the amount of stormwater discharging to stormdrains, streams and lakes. The result is less sediment, nutrients, bacteria and other contaminants in our waterways. Plus, when precipitation infiltrates on-site, groundwater sources are recharged.

Common Questions

Does a rain garden form a pond?

No. Rain water will infiltrate the soil and the garden will be dry between rain events.

Will mosquitos breed in the rain garden?

No. Mosquitos require 7 to 12 days to lay and hatch eggs. Precipitation will infiltrate within a few days in a rain garden. Rain gardens attract dragonflies, which eat mosquitoes.

Is a rain garden expensive?

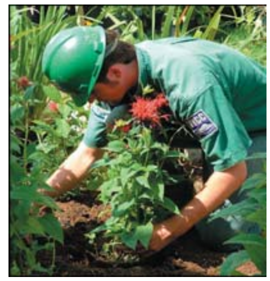
With the help of family and friends for labor, costs can be minimal. The greatest cost is the plants. Ask those you know if they have any perrenials ready to divide and you will minimize your expenses. Just be sure to confirm with your local Conservation District or Extension Service that the plants are non-invasive and appropriate for a rain garden.

Do rain gardens require a lot of maintenance?

In the first two years, some weeding, watering, and remulching will be necessary. Once plants are mature, they may require thinning.

Rain Garden Resources

For more detailed information on rain gardens, their benefits, and how to construct them, please consult the following resources:



A Vermont Youth Conservation Corps member plants Bee Balm in a South Burlington rain garden.

Vermont Organizations:

Winooski Natural Resources Conservation District
802-828-4493
Abbey.Willard@vt.nacdnet.net

VT Agency of Natural Resources
802-879-2339
http://www.raingardens.org/Create_A_Garden.php
Karen.Bates@vt.state.us

UVM Extension Master Gardener Hotline
800-639-2230
Master.Gardener@uvm.edu

Web Based Organizations:

University of Wisconson Extension
http://clean-water.uwex.edu/pubs/raingarden/

Rain Gardens of West Michigan

City of Maplewood, Minnesota, Rain Garden Site
http://www.maplewoodmn.govoffice.com/index.asp
(*Click on "Maplewood Stormwater Management" on the right side of the page, then click on Rainwater Gardens"*)

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How to Build a Rain Garden

Step 1. Site & Size

In selecting a site for your rain garden, choose a fully or partially sunny spot that is at least 10 ft. from any building foundation and not over a septic system. Locate it so the garden will intercept runoff, uphill from any current ponding area. It is easiest to locate your rain garden so it will collect roof runoff from one or more downspouts. Also, keep in mind that gentle slopes are easier to dig since they require less depth.

The size of your rain garden will depend on the slope, soil and drainage area of your site. To determine the size, first calculate the drainage area for your rain garden. The rain garden will be approximately 20-30% of your drainage area. Follow the steps below to determine the area and depth of your rain garden.

1. Calculate roof portion/impervious drainage area:

(Length) x (Width) = ______ft^2

2. Calculate the slope of your site:

- Pound two stakes, about 15 feet apart, at the uphill and downhill ends of your site.
- Use a carpenter's level and string to create a horizontal line between the two stakes.
- Measure the total length of the string and the height of the string at the downhill stake, in inches.
- Divide the height by the length and multiply the result by 100. This number is your slope.
- Use the table to the right to determine the depth of your rain garden.

Slope	Depth
< 4%	3"- 5"
5-7%	6"- 7"
8-12%	8"

3. Determine your soil type:

- Roll a clump of moist soil into a ball.
- Using your thumb, roll the ball along your forefinger to try to make a ribbon of uniform thickness and width.
- If no or only a weak ribbon can be formed, the soil is sandy.
- If a 1-2" ribbon is formed, the soil is silty.
- If the ribbon is greater than 2" the soils is high in clay and will likely need amendments to increase infiltration.

4. Calculate the size of your rain garden:

From your above calculations on depth and soil type, use the table below to determine your size factor. Then multiply the size factor by your drainage area. This is your recommended rain garden area.

Soil Type	3"- 5"	6"- 7"	8"
Sandy	0.19	0.15	0.08
Silty	0.34	0.25	0.16
Clay	0.43	0.32	0.20

________ X ________ = ________

Size Factor Drainage Area Rain Garden Area

Step 2. Dig/Excavate

For safety, call your local utility company or Dig Safe before you begin.

Loosen the soil to a depth of at least two feet. Adding amendments if necessary (sand and/or compost), create a level bed at the depth determined in Step 1. Excavated soil can be used to create a berm on the downhill sides of the rain garden. The berm will help retain the water during a rain event. Manufactured or natural edging can be used to create a defined look and help keep out weeds and grass.

Winooski Conservation District staff works on a rain garden at the Williston Town Library.

A downspout extension or plastic HDPE pipe buried below the grass can direct rain water to your garden. Also, a perforated drainage pipe in a bed of gravel at the floor of your rain garden will help with drainage. If you choose to insert one, the pipe should be laid perforated side down, at a 2% slope. The outlet end of the pipe needs to be protected from clogging and drain to an area that can accept the water.

Step 3. Plant & Mulch

Before you plant your garden, create a planting plan that shows the layout of your garden. The most important criteria in choosing plants for a rain garden is that they should be able to withstand some brief inundation of water, but also are tolerant of drier conditions. Native plants are often an excellent choice, since they are well adapted to our climate and are easy to care for. Many attractive native plants can be found at local nurseries and garden centers. Consider using a combination of different types of plants in your garden, including flowering perennials, grasses, sedges, ferns, and small shrubs. Be careful that you do not plant any invasive species.

Examples of attractive plants native to Vermont include:

Joe Pye Weed is a native Vermont plant that will thrive in rain gardens.

Joe Pye Weed (*Eupatorium maculatum*)
Blue Lobelia (*Lobelia siphilitica*)
Bee Balm (*Moarda didyma*)
New England Aster (*Aster novae-angiliae*)
Cinnamon Fern (*Osmunda cinnamomea*)
Blue Vervain (*Verbena hastata*)
Red-Osier Dogwood (*Cornus sericea*)
Winterberry (*Ilex verticillata*)
White Turtlehead (*Chelone glabra*)
Pussy Willow (*Salix discolor*)
Black-Eyed Susan (*Rudbeckia hirta*)
Blue Flag Iris (*Iris versicolor*)

For each plant, dig a hole twice as wide as the plant root mass and deep enough so the soil level of the potted plant will be at the rain garden soil level. Tamp the soil around the roots and water thoroughly. Top off your rain garden with a couple inches of shredded hardwood mulch.

Step 4. Water, Weed & Enjoy!

As the plants are establishing themselves, they will need about an inch of water per week. After the first season, the garden should get most of the water it needs from rain events. Weeding the garden at least once a year will help your plants flourish. Rain garden plants should not need fertilizing and in fact, fertilizing can be harmful to streams and lakes. Your completed rain garden will offer beauty, habitat and stormwater storage for years to come !

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