● Soil & Wetland Studies
● Ecology ● Application Reviews
● Listed Species Surveys ● GPS
● Environmental Planning & Management
● Ecological Restoration & Habitat Mitigation
● Expert Testimony ● Permitting

February 23, 2021

VIA E-MAIL

Town of North Haven
Inland Wetlands Commission
Memorial Town Hall, 18 Church Street
North Haven, CT 06473

RE: **APPLICATION REVIEW - SUPPLEMENTAL**
The Slate Upper School, 5100 Ridge Road
IWC Application No.: 120-06
REMA Job #: 20-2352-NHA12

Dear Chairman Bumsted and Commissioners:

At the request of adjacent property owners, REMA ECOLOGICAL SERVICES ("REMA") has been asked to review the applicant's February 19th, 2021 submission for the above-referenced development proposal, which included revised plans and drainage report (i.e., revision dates: 2/17/22), as well as documents responding to comments made by REMA (1/25/21) and by Loureiro Engineering Associates, Inc. (LEA) (1/25/21).

1.0 Pollutant Loading

Loading of pollutants in stormwater runoff discharged from the above ground basin (Basin 110), and of airborne particulate pollutants will reflect the much higher frequency of trips (135/day)[1] for a school with 125 students plus staff, than would have been generated by the alternative of a small church, or by an alternative of several single family homes. Pollutants will include the entire suite of roadway pollutants, including toxic heavy metals, hydrocarbons

[1] Trip generation rates are from the 8th Edition of the ITE Trip Generation Guide, a standard reference for traffic studies.

including PAHs, phosphorus, and salt. If designed and built per customary engineering practices, pollutant removal efficiency will be that expected for these BMPs, in the range 30-80%, but no more than 30% – 40% for total nitrogen, as seen in the Table below.

Recommended pollutant removal efficiencies, in percent, for constructed ponds. Sources.
TSS=total suspended solids; TP=total phosphorus; PP=particulate phosphorus; DP=dissolved phosphorus; TN=total nitrogen

TSS	TP	PP	DP	TN	Metals	Bacteria	Hydrocarbons
85	50	91	0	30	70	60	80

Note: see "sources" in attached references[2]

The sensitivity of the receiving resource determines whether treatment by the stormwater basin will be sufficient to prevent significant adverse impacts, or whether additional polishing by passage through a wide vegetated buffer is warranted. The applicant failed to inventory, characterize, and assess the sensitivity of the receiving wetland and watercourse. Although constrained by the season, REMA has done so to the extent possible.

In fact, with the recent revision of the stormwater basin outlet and removal of the previous underdrain, this basin is still deficient in its design, and does not fully comply with the guidelines found in CT DEEP's 2004 Stormwater Quality Manual ("the Manual"). Therefore, its efficiency in treating stormwater runoff is diminished. We have attached Chapter 11 of the Manual, in its entirety. This chapter deals with "Stormwater Ponds" which is the closest fit based on the development plans. For instance, according to the "Design Criteria for Stormwater Ponds" (Table 1-P1-1) stormwater ponds should have a vegetated aquatic bench. Vegetation is necessary for the uptake and immobilization of pollutants, including nutrients from stormwater. Unfortunately, not only do the current plans not include an aquatic bench, the proposed seed mixture is incompatible with the expected hydrology of this basin.

Based on nearby soil test pits (i.e., TP-2-20 and TP-3-20) the basin will be excavated down into a "red sandy hardpan" by roughly 5 to 7 feet. With minimal infiltration being possible, a fact attest to by the applicant in his submitted narrative, this will be a wet bottom pond, with a fluctuating water level, depending on the season. Since the pond will not tap into a stable

[2] This table is from the State of Minnesota Stormwater Manual:
https://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs#References

water table, growth of vegetation will be quite challenging. Nevertheless, the applicant should have proposed an aquatic bench and emergent plants of wet meadows and shallow marshes.

We note that based on the poor design of the detention basin, which is the primary water quality renovation BMP (best management practice) for the site, it will discharge partially treated runoff to the level spreader which is just a few feet upgradient of the wetland boundary. With respect to nitrogen, for instance, this discharged runoff will combine with nitrogen that will reach the wetland from a poorly designed and inefficient septic system.

Based on computations by LEA, submitted separately, the concentration of nitrogen reaching the wetland boundary will be 33.3 mg/L, which is more than three times what is allowable by the CT Health Code, of 10 mg/L. As will be explained in the following section, this high concentration, augmented by the partially treated discharge from the detention basin, will have result in significant adverse physical impacts to the regulated resources, that is, the downgradient wetlands and watercourses.

2.0 Nitrogen Loading

Roughly 50-60% of nitrogen is not treated by a correctly designed and maintained septic system and exits the system as septic effluent. Given an adequate distance to the receiving wetland or watercourses, and an adequate upgradient watershed, the concentration of nitrogen from a septic system in groundwater, most of which is nitrate-nitrogen, can be brought down to a safe level both from the standpoint of a human health and wetland and watercourse health. This happens (1) by means of dilution, (2) by means of uptake by plants (conversion to foliage and biomass), and (3) by means of conversion to atmospheric nitrogen by denitrifying bacteria. Note that dilution alone is the mechanism required for septic system design. This is because mechanisms 2 and 3 are site specific, depending on local characteristics such as tree cover, and available organic matter as a microbial substrate.

However, multiple carefully designed studies have measured nitrogen uptake in vegetated buffers between septic systems or crop fields, and receiving wetlands or streams. A vegetated, preferably forested, buffer of 80 to 100 feet, has repeatedly been found to remove over 90% of the untreated nitrate in septic effluent, and also excess nitrate from lawns or farm operation. But this is only for septic systems that are property designed in the first place (Sabater et al. 2003, Mayer et al. 2005, Hill et al. 1996).

With larger inputs into a septic system, use of the more fine-tuned and accurate CT DEEP methodology for calculating dilution, used by LEA, is able to predict the concentration of nitrogen reaching the edge of the receiving wetland. This methodology takes into account factors such as soil properties and slopes. Although developed for use in large community septic systems, it can be used with any septic system, even an individual home; REMA confirmed this though discussions with CTDEEP personnel, over a decade ago.

The results of using this methodology for the septic system proposed for the Slate Middle School are of grave concern, both for the wetland resource and human health: a concentration of 33.3 mg/L of nitrogen is predicted at the wetland edge. The human health standard is 10 mg/L; infants suffer "blue baby syndrome" if the water in their formula has a nitrate-nitrogen concentration exceeding 10 mg/L.

The draft USEPA criterion for nitrate + nitrite nitrogen issued in 2000 is 0.31 mg/L; it is based on extensive data sets on streams in our ecoregion.[3] States were given the option of developing their own standards based on local in-state data, but Connecticut is still in the process. An USEPA workshop, with conference proceedings, addressed this issue in April 2013.[4] This USEPA criterion is consistent with more than 30 years of experience by REMA, with stream assessment, accompanied by water testing[5]. The assessed streams with nitrate-N levels less than 1 mg/L, and most often with less than 0.5 mg/L, were the ones without excessive periphyton, and a normal quota of stream macroinvertebrates including pollution sensitive taxa like mayflies (<u>E</u>phemoptera), stoneflies (<u>P</u>lecoptera), and caddisflies (<u>T</u>richoptera), termed EPT taxa. Stream bio-assessments of benthic macroinvertebrates, often conducted by volunteer stream monitors[6] are used as a snapshot of stream health; given diverse and plentiful benthic macroinvertebrates, it can be assumed that nitrate-N levels are low, in the neighborhood of the USEPA criterion of 0.31 mg/l. The calculated 33.3 mg/L by LEA, is a far higher level.

Over the past fifteen years, we (REMA) and many other volunteer stream monitors have been alarmed by the increasing scarcity of lower order streams (i.e., headwater) with diverse benthic

---

[3] USEPA Nutrient Criteria (draft) for EcoRegion 1V, Level 11 Ecoregion 59 (coastal New England)
[4] USEPA Expert Workshop: Nutrient Enrichment Indicators in Stream. September 2014. Office of Water EPA-822-R-14-004 www.epa.gov
[5] Much of this testing has been combined with testing by other wetland and environmental scientists and is accessible at the website of the Connecticut Association of Wetland Scientists (CAWS).
[6] Such a program is adiminstered by the CT DEEP: Riffle Bioassessment by Volunteers (RBV)

macroinvertebrates. Excessive nitrogen loading both from septic systems and from over fertilized lawns is a large part of the problem, though sedimentation and other toxins such as polycyclic hydrocarbons (PAHs) in road runoff also impair streams.

Carpenter et al. (1998) reviewed the effects on surface waters of non-point pollution with phosphorus and nitrogen. Eutrophication, including toxic algal blooms, oxygen stress, proliferation of aquatic invasives, may occur in downgradient ponds, lakes, and reservoirs. Excess nutrients in lakes, estuaries, or slow-moving streams and rivers can lead to an increase in primary productivity that degrades water quality.

An algal bloom, reduces dissolved oxygen (DO) in the water when the algae die and decompose and can cause fish and invertebrates to die. If this cycle happens repeatedly, species may be lost from the lake or waterway. Loss of habitat and eutrophication of the water can kill off plants and macrobenthos (i.e., aquatic organisms) that fish depend on for their habitat and alter the streambed habitat for invertebrate species. Increased turbidity and decreased water clarity, visibility, reduces recreational suitability and also reduces the ability of some fish to see prey or predators.

Elevated nitrate-N levels also impair in-stream watercourse habitats through the following processes. The surfaces of stones and woody debris and crevices between them are an important macroinvertebrate habitat, and multiple taxa graze on the thin coating of diatoms on these rocks. Elevated nitrate-N levels trigger heavy growth of other algae which smothers this habitat, and then depletes oxygen in the water as it decomposes. The rotting algae blacken the rocks. Note that phosphorus is also needed for algal growth, but is usually available in a shallow stream from the sediment on the stream bottom.

Excessive nitrogen also stimulates tall growth of cattails and *Phragmites*, often converting open water habitat into a marsh. Likewise, wetland plant diversity suffers as species that grow well in low-nutrient environments are outcompeted and overshaded by taller, denser reeds and other rank vegetation.

3.0 Water Quality and Macrobenthos Sampling

On February 20th, 2021, REMA investigated the off-site downgradient wetlands and watercourses, located within the Town of Hamden, that would be receiving the excessive nitrogen and other pollutants from the stormwater discharge and from the proposed septic system. We sampled surface water at the downgradient stream (main stem), and conducted a qualitative macroinvertebrate biosurvey. Figure E, attached, shows the approximate stream sampling location (i.e., SS-1), as well as other important features of the downgradient resources.

Stream biosurveys are methods of assessing the quality and sensitivity of a stream, that have used for many decades. Macroinvertebrate biosurveys are conducted by CT DEEP on annual basis any many stream throughout Connecticut, and as mentioned above, CT DEEP also administers a volunteer program (RBV) that collects valuable data on stream health. REMA has been conducting biosurveys, including per CT DEEP requirements and protocols for several decades, and REMA staff have also been specifically trained in benthic biosurveys per USEPA standard methodologies. Attached is a simple, informative, fact sheet that REMA put together many years ago, to introduce stream biosurveys.

Since the surface water sampling at the stream station was conducted on a Saturday, the first opportunity following the submittal by the applicant, the analytical lab (Phoenix Environmental Laboratories) received the sample on Monday morning (2/22/21). Even with an "expedite" the results will not be available until after this review letter is submitted. We will supply the results as soon as they are made available, and further analyze them as deemed necessary.

We should note, however, that REMA observed an active seep within the downgradient wetland, which is likely to receive all or some of the discharge from the proposed stormwater management system (see Photos 3, 4 and 5, attached). This seep appears to be active for a prolonged period of time during a normal precipitation year, because a small stream channel has formed which feeds the main stream (see Figure E, attached; Photo 5). It is well understood that headwater seeps and streams are considerably more sensitive to water quality degradation, since, among many factors, they do not have a high dilution capacity as would a stream with a larger watershed.

A qualitative biosurvey at the main stem of the stream (see Figure E, attached), revealed an abundance of macroinvertebrates that are considered pollution sensitive and are typically only found in abundance in clean, unimpaired headwater streams, such as the one associated with the site. Two taxa, caddisflies and stoneflies were in abundance, represented by two families: Perlodidae (stoneflies) and Glossosomtidae (caddisflies) (see attached photos). Both of these taxa were found utilizing the hard substrate (i.e., rocks, cobbles) within the stream. These two families have very low pollution tolerance values.

Tolerance is a listing of tolerance values for each taxon used in the calculation of numerous well tested indices foremost among which are the Hilsenhoff species-level Biotic Index (HBI) and the Family Biotic Index. Tolerance values range from 0 for organisms very intolerant of organic wastes, including nutrients, to 10 for organisms very tolerant of organic wastes. Most of these values were taken from Hilsenhoff (1987) but were modified using latter data from Bode *et al* (1996 and 2002). For species not inluded in Hilsenhoff's listing, such as oligochaeta, values were assigned based on water quality data from the Stream Biomonitoring Unit surveys of New York and from other literature references. Values taken from survey data were assigned by taking the mean of the tolerance values of other species in the sample. According published values the tolerance values for both of the taxa that were abundant at the stream section that was sampled were: **1**. This indicates very good water quality an unimpaired stream.

In conclusion, it is our professional opinion that the excessive nitrogen released by an inadequately designed septic system, in combination with the release of excessive nitrogen and other pollutants from an ineffective stormwater management system, will result in pollution and impairment of the receiving wetlands and watercourses, through destruction of the stream habitat upon which aquatic biota rely, algal blooms, and the growth of rank vegetation in wetlands that will reduce the diversity of plants and the fauna that rely upon them.

4.0 Hydrologic Sizing Criteria

In their February 17th, 2021 response to our original review letter (1/25/21), MMI stated that since they were able to reduce the effective impervious surfaces to less than 1 acre, the Stream Channel Protection criterion was no longer applicable. We note the following: (1) there is no call outs for the "green roofs" that were included in the design, no details, and no discussion on how they work, (2) with the discovery of a wetland seep and a headwater feeder stream (see above section and annotated photographs), even less than an acre of impervious surfaces must comply with the channel protection criterion, and (3) while less than one acre is claimed, the impervious surfaces that are conveyed to the level spreader total 1.21 acres, based on the applicant's most recently revised drainage report. Therefore, without compliance with the Stream Channel Protection criterion as seen in the CT DEEP Manual, and as presented in our previous review report, there will be a significant and adverse impact upon the downgradient regulated resources, specifically through the erosion of stream banks, and sedimentation of aquatic habitat within the streams.

5.0 Conclusion

We stand by our previous stated primary categories of *significant, adverse, physical impacts to wetland and watercourses*, as stated in our previous review letter (1/25/2021). While the applicant, with the recent revisions, attempted to rectify some of the issues, it was not done successfully. With the recent baseline data collected by REMA, something that the applicant failed to do, and the calculations by LEA regarding the ineffectiveness of the septic system to treat nitrogen, we can even more confidently say that the impairment of the water quality of the downgradient regulated wetlands and watercourses is fully expected, and should be avoided by proposing alternatives that would generate much less pollution, and provide a generous permanent buffer to the regulated resources. As we have stated before this buffer should be a minimum 80-foot wide non-disturbance buffer.

We thank you for the opportunity to comment on the application before the Commission.

Respectfully submitted,

REMA ECOLOGICAL SERVICES, LLC

George T. Logan, MS, PWS, CSE
Professional Wetland Scientist, Registered Soil Scientist
Certified Senior Ecologist (ESA)

Attachments: Figure E, Photos 1 to 6, Stream Biosurveys, Chapter 11 (2004 Stormwater Quality Manual

cc: Joan F. Lakin, Chair, Hamden Inland Wetlands Commission (via email to Tom Vocelli)

REFERENCES:

Bode, R.W., Novak, M.A., and Abele, L.E. 1996. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. NYS Department of Environmental Conservation, Albany, NY. 89p.

Bode, R.W., Novak, M.A., Abele, L.E., Heitzman, D.L., and Smith, A.J. 2002. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. NYS Department of Environmental Conservation, Albany, NY. 115p.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications, 8*(3), 559-568. doi:10.2307/2641247

Hanson, G. C., Groffman, P. M., & Gold, A. J. (1994). Symptoms of nitrogen saturation in a riparian wetland. *Ecological Applications, 45*(4), 750-756.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomol. 20:31-39.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. J. N. Am. Benthol. Soc. 7(1):65-68.

Hill, A. R. (1996). Nitrate removal in stream riparian zones. *Journal of Environmental Quality, 25*, 743-755.

Lowrance, R., Altier, L. S., Newbold, J. D., Schnabel, R. R., Groffman, P., M., Denver, J. M.,…Todd, A. H. (1997). *Environmental Management, 21*(5), 687-712.

Mayer, P. M., Reynolds, S. K., Canfield, T. J., & McCutchen, M. D. (2005). *Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: A review of current science and regulations*. Washington, D. C.: U. S. Environmental Protection Agency. EPA/600/R-05/118

Mayer, P. M., Reynolds, S. K., McCutchen, M. D., & Canfield, T. J. (2007). Meta-analysis of nitrogen removal in riparian buffers. *Journal of Environmental Quality, 36*, 1172-1180. doi: 10.2134/jeq2006.0462

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M.. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. U.S. Environmental Protection Agency. EPA 440/4-89/001. 8 chapters, Appendices A-D.

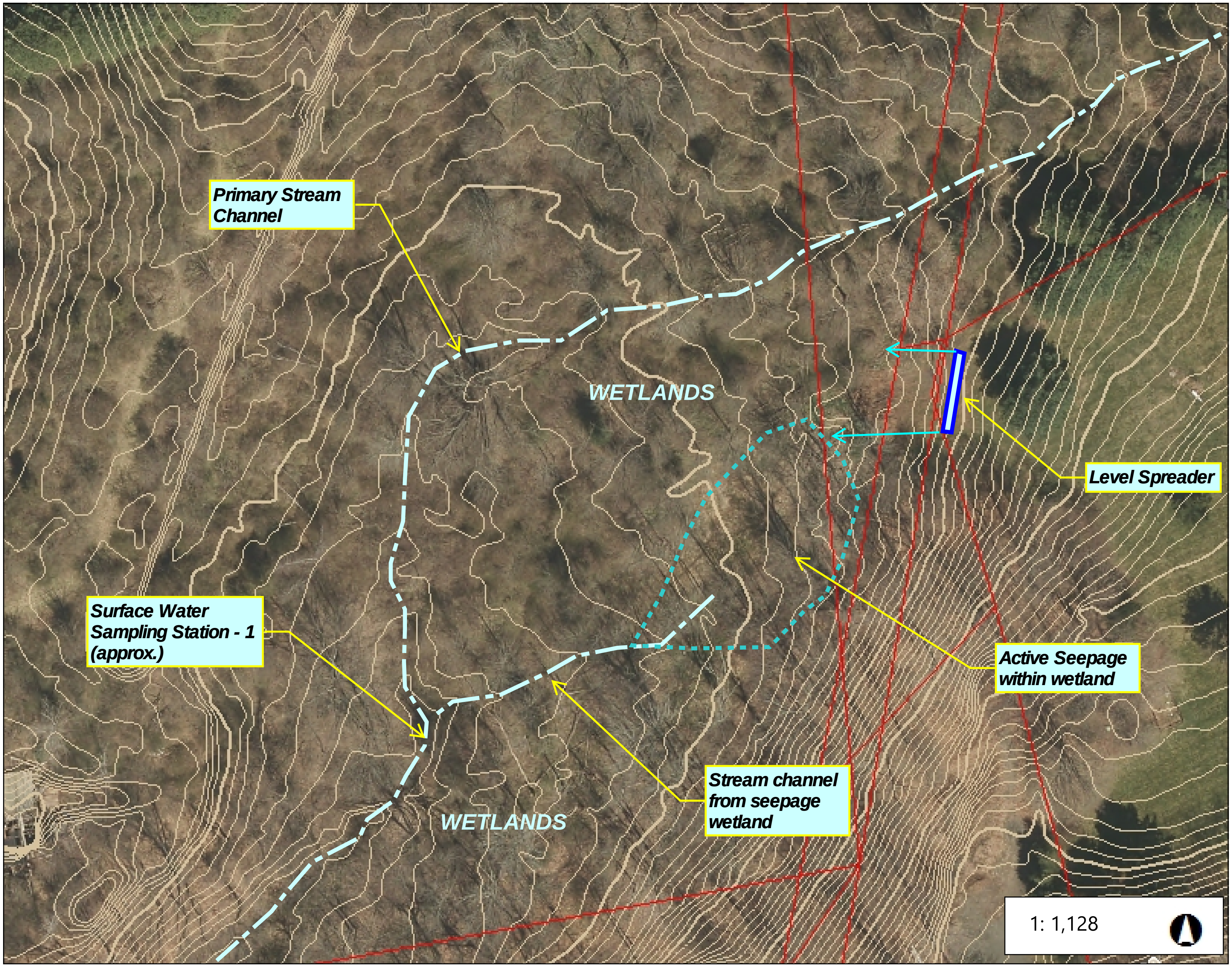
Sabater, S., Butturini, A., Clement, J., Burt, T, Dowrick, D, Hefting, M, Maître, V., Pinay, G.,…Sabater, F. (2003). Nitrogen removal by riparian buffers along a European climatic gradient: patterns and factors of variation. *Ecosystems, 6*, 20-30. doi: 10.1007/s10021-002-0183-8

"Sources" for pollutant removal efficiencies of stormwater management practices discussed in this report:

- ASCE/EPA Database. International Stormwater Best Management Practices (BMP) Database.
- ASCE/EPA 2000. Determining Urban Stormwater Best Management Practice Removal Efficiencies. EPA Assistance Agreement Number CX 824555-01-Task 3.4.
- Geosyntec Consultants and Wright Water Engineers. 2012. Urban Stormwater BMP Performance Monitoring. Prepared under Support from U.S. Environmental Protection Agency, Water Environment Research Foundation, Federal Highway Administration, Environmental and Water Resource Institute of the American Society of Civil Engineers.
- Langer, R. 1997. *1997 Twin Cities Water Quality Initiative Grant Report*. Ramsey-Washington Metro Watershed District.
- Schueler, T. 1996. Irreducible Pollutant Concentrations Discharged from Stormwater Practices. Article 65: Technical Note #75 from Watershed Protection Techniques 2(2):369-372. Center for Watershed Protection.
- Strecker, E, and M. Quigley. 1999. Development of Performance Measures, Task 3.a – Technical Memorandum: Determining Urban Stormwater Best Management Practice (BMP) Removal Efficiencies. Prepared by URS Greiner Woodward Clyde, Urban Drainage and Flood Control District, Urban Water Resources Research Council (UWRRC) of ASCE, and Office of Water, US Environmental Protection Agency.
- SWAMP (Stormwater Assessment Monitoring and Performance Program) 2005. Synthesis of Monitoring Studies Conducted Under the Stormwater Assessment Monitoring and Performance Program. Prepared for Great Lakes Sustainability Fund of the Government of Canada, Toronto and Region Conservation Authority, Municipal Engineers Association of Ontario, and Ontario Ministry of the Environment.
- Tornes, L. 2005. Effects of Rain Gardens on the Quality of Water in the Minneapolis-St. Paul Metropolitan Area of Minnesota, 2002-04. U.S. Geological Survey Scientific Investigations Report 2005-5189.
- Yetka, L. and K. Leuthold. 2005. *Burnsville Rainwater Garden Retrofit Project*. Presentation at 2005 Annual Minnesota Erosion Control Association Conference.
- Weiss, P.T., J.S. Gulliver, and A.J. Erickson. 2005. The Cost and Effectiveness of Stormwater Management Practices. Minnesota Department of Transportation, St. Paul, MN.
- Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, for EPA Office of Science and Technology

CT Environmental Conditions Online

FIGURE E: Proposed Slate Upper School, 5100 Ridge Road, N. Haven, CT
showing prop. stormwater discharge, streams, seepage wetland, and surface water sampling station



Legend

Parcels for Protected Open Sp

Light Gray Canvas Base

Notes

0.0 0 0.02 0.0 Miles

This map is intended for general planning, management, education, and research purposes only. Data shown on this map may not be complete or current. The data shown may have been compiled at different times and at different map scales, which may not match the scale at which the data is shown on this map.

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Chapter 7
Hydrologic Sizing Criteria for Stormwater Treatment Practices

Volume II: Design

Chapter 7

Hydrologic Sizing Criteria for Stormwater Treatment Practices

7.1 Introduction

This chapter presents a recommended approach for sizing stormwater treatment practices in the State of Connecticut. Although the primary focus of this Manual is on stormwater quality, the management of stormwater quantity is an important related concern. Therefore, the sizing criteria in this chapter are designed to achieve both water quality and quantity control objectives. The recommended sizing criteria have been adapted from the Center for Watershed Protection's Unified Sizing Criteria, which is one of the more comprehensive approaches for sizing stormwater treatment practices developed to date. This approach has been implemented in several other states including Maryland, New York, Vermont, and Georgia.

The sizing approach described in this chapter is intended to manage the full spectrum of storm flows and their associated water quality and quantity impacts. These range from small, frequent storms that are responsible for a majority of the annual runoff volume and pollutant loads to large, infrequent events which are responsible for nuisance and catastrophic flooding. Stormwater treatment practices should be designed to accomplish the following primary objectives:

- *Pollutant reduction*
- *Runoff volume reduction and groundwater recharge*
- *Stream channel protection and peak flow control*

The following sections of this chapter describe criteria and methods for sizing stormwater treatment practices to meet these objectives. These criteria are intended to be consistent with local subdivision and planning/zoning ordinances of most municipalities throughout the state, particularly regarding peak flow control requirements. Some differences may exist between the criteria presented in this chapter and local requirements. Local requirements should be consulted in addition to these criteria. However, the criteria presented in this chapter are recommended where local regulations are less stringent.

7.2 Criteria Applicability

The design criteria presented in this chapter are generally applicable to the following types of new development and redevelopment projects, including phased developments:

- *Any development resulting in the disturbance of greater than or equal to one acre of land*
- *Residential development consisting of 5 or more dwelling units*
- *Residential development consisting of fewer than 5 dwelling units involving construction of a new road or reconstruction of an existing road*
- *Residential development consisting of fewer than 5 dwelling units where imperviousness of the site after construction exceeds 30 percent*
- *Stormwater discharge to wetlands/watercourses*
- *New stormwater discharges located less than 500 feet from tidal wetlands*
- *Land uses or activities with potential for higher pollutant loadings (see **Table 7-5**), excluding the groundwater recharge criterion*
- *Industrial and commercial development projects which result in 10,000 sq. ft. or greater of impervious surface*
- *New highway, road, and street construction*
- *Modifications to existing storm drainage systems*

These and other types of projects not listed above, such as single family residential development, are encouraged to incorporate alternative site design, low impact development practices, and source controls to reduce imperviousness, runoff volumes, and stormwater pollutant sources.

Table 7-1 Summary of Stormwater Treatment Practice Sizing Criteria

Sizing Criteria	Description	Post-Development Storm Magnitude
Pollutant Reduction	***Water Quality Volume (WQV)*** Volume of runoff generated by one inch of rainfall on the site WQV = (1")(R)(A)/12 WQV = water quality volume (ac-ft) R = volumetric runoff coefficient = 0.05+0.009(I) I = percent impervious cover A = site area in acres	First one inch of rainfall
	Water Quality Flow (WQF) Peak flow associated with the water quality volume calculated using the NRCS Graphical Peak Discharge Method	
Groundwater Recharge and Runoff Volume Reduction	***Groundwater Recharge Volume (GRV)*** Maintain pre-development annual groundwater recharge volume to the maximum extent practicable through the use of infiltration measures	Not applicable
	Runoff Capture Volume (RCV) Retain on-site the volume of runoff generated by one inch of rainfall for new stormwater discharges located within 500 feet of tidal wetlands RCV = (1")(R)(A)/12 RCV = runoff capture volume (ac-ft) R = volumetric runoff coefficient = 0.05+0.009(I) A = site area in acres	First one inch of rainfall
Peak Flow Control	***Stream Channel Protection*** Control the 2-yr, 24-hour post-development peak flow rate to 50 percent of the 2-yr, 24-hr pre-development level or to the 1-yr, 24-hr pre-development level ("Two-Year Over-Control").	2-year, 24-hour rainfall
	Conveyance Protection Design the conveyance system leading to, from, and through stormwater management facilities based on the 10-year, 24-hour storm.	10-year, 24-hour rainfall
	Peak Runoff Attenuation Control the post-development peak discharge rates from the 10-, 25-, and 100-year storms to the corresponding pre-development peak discharge rates, as required by the local review authority.	10-, 25-, and 100-year 24-hour rainfall
	Emergency Outlet Sizing Size the emergency outlet to safely pass the post-development peak runoff from, at a minimum, the 100-year storm in a controlled manner without eroding the outlet works and downstream drainages.	100-year, 24-hour rainfall

Consult local regulations for additional criteria. The above criteria are recommended where local regulations are less stringent.

Some of the sizing criteria presented in this chapter may not be practical to meet due to space limitations, soil conditions, and other site constraints which are common in redevelopment or retrofit applications. Treatment practices sized for smaller treatment volumes/flows or exemptions from certain criteria may be appropriate in these situations, at the discretion of the review authority. Conditions where the recommended sizing criteria may not be applicable are identified in the following sections.

7.3 Criteria Summary

Table 7-1 summarizes the hydrologic sizing criteria for stormwater treatment practices in Connecticut. As indicated in **Table 7-1**, the sizing criteria are based on stormwater runoff generated by 24-hour duration storms of various return frequencies (i.e., design storms). **Table 7-2** lists 24-hour design rainfall depths for each county in Connecticut. The rationale for and application of these criteria are described in the following sections.

Table 7-2
Design Rainfall Amounts By County

	24-Hour Rainfall Amount (inches)				
County	1-yr	2-yr	10-yr	25-yr	100-yr
Fairfield	2.7	3.3	5.0	5.7	7.2
Hartford	2.6	3.2	4.7	5.5	6.9
Litchfield	2.6	3.2	4.7	5.5	7.0
Middlesex	2.7	3.3	5.0	5.6	7.1
New Haven	2.7	3.3	5.0	5.6	7.1
New London	2.7	3.4	5.0	5.7	7.1
Tolland	2.6	3.2	4.8	5.5	6.9
Windham	2.6	3.2	4.8	5.5	6.9

Source: TP-40, Department of Commerce, Weather Bureau, May 1961; NWS Hydro-35, Department of Commerce, National Weather Service, June 1977.

7.4 Pollutant Reduction

The pollutant reduction criterion is designed to improve the water quality of stormwater discharges by treating a prescribed water quality volume or associated peak flow, referred to as the water quality flow. Most treatment practices described in this Manual use a volume-based sizing criterion. The exceptions are grass drainage channels, proprietary stormwater treatment devices, and flow diversion structures, where a peak flow rate is utilized.

7.4.1 Water Quality Volume (WQV)

Description

The water quality volume (WQV) is the amount of stormwater runoff from any given storm that should be captured and treated in order to remove a majority of stormwater pollutants on an average annual basis. The recommended WQV, which results in the capture and treatment of the entire runoff volume for 90 percent of the average annual storm events, is equivalent to the runoff associated with the first one-inch of rainfall. The WQV is calculated using the following equation:

$$WQV = \frac{(1'')(R)(A)}{12}$$

where:
- WQV = water quality volume (ac-ft)
- R = volumetric runoff coefficient = 0.05+0.009(I)
- I = percent impervious cover
- A = site area in acres

- *The volumetric runoff coefficient R can also be determined from commonly available tabulated values for various land use, vegetative cover, soil, and ground slope conditions. However, the use of the above equation is recommended since it is directly related to the amount of impervious cover at a site, thereby providing incentive to reduce site imperviousness and the required runoff treatment volume. Reducing impervious cover using the site planning and design techniques described in Chapter Four can significantly reduce the WQV.*
- *Impervious cover should be measured from the site plan and includes all impermeable surfaces that are directly connected to the stormwater treatment practice such as paved and gravel roads, rooftops, driveways, parking lots, sidewalks, pools, patios and decks. In the absence of site-specific information or for large residential developments, impervious cover may be estimated based on average impervious coverage values for various parcel sizes listed in **Table 7-3**. The values shown in **Table 7-3** were derived from research by the University of Connecticut, Cooperative Extension System NEMO Project (Prisloe et al.,).*
- *The WQV should be treated by an acceptable stormwater treatment practice or group of practices described in this Manual. The WQV should be used for the design of the stormwater treatment practices described in this Manual, except grass drainage channels and proprietary stormwater treatment devices (e.g., hydrodynamic separators, catch basin inserts, and media filters), which should be designed based on the water quality flow (WQF).*

Table 7-3 Residential Land Use Impervious Cover	
Parcel Size (acres)	**Average Percent Impervious Cover**
<1/8	39
1/8 to 1/4	28
1/4 to 1/2	21
1/2 to 3/4	16
3/4 to 1	14
1 to 11/2	10
11/2 to 2	9
>2	8

Rationale

The above approach is similar to water quality sizing criteria that have been adopted elsewhere in the United States for the design of stormwater treatment practices. These criteria are intended to remove the majority of pollutants in stormwater runoff at a reasonable cost by capturing and treating runoff from small, frequent storm events that account for a majority of the annual pollutant load, while bypassing larger, infrequent storm events that account for a small percentage of the annual pollutant load. This approach is based on the "first flush" concept, which assumes that the majority of pollutants in urban stormwater runoff are contained in the first half-inch to one-inch of runoff primarily due to pollutant wash-off during the first portion of a storm event. Early studies in Florida determined that the first flush generally carries 90 percent of the pollution from a storm (Novotny, 1995). As a result, treatment of the first half-inch of runoff was adopted as a water quality volume sizing criterion requirement throughout much of the United States. More recent research has shown that pollutant removal achieved using the half-inch rule drops off considerably as site imperviousness increases.

A number of alternative water quality sizing methods were developed to achieve higher pollutant removals for a wider range of site imperviousness. One of the more common methods is known as the "90 Percent Rule", in which the water quality volume is equal to the storage required to capture and treat 90 percent of the annual runoff events (approximately 90 percent of the annual runoff pollutant load) based on analysis of historical precipitation records. The specific rainfall event captured is the storm event that is less than or equal to 90 percent of all 24-hour storms on an average annual basis. In the northeastern U.S., the 90 percent rainfall event is equal to approximately one inch, which is consistent with the recommended WQV sizing criteria for Connecticut.

7.4.2 Water Quality Flow (WQF)

Description

The water quality flow (WQF) is the peak flow rate associated with the water quality design storm or WQV. Although most of the stormwater treatment practices in this Manual should be sized based on WQV, some treatment practices such as grass drainage channels and proprietary treatment devices (designed to treat higher flow rates, thereby requiring less water quality storage volume) are more appropriately designed based on peak flow rate. In this approach, a stormwater treatment facility must have a flow rate capacity equal to or greater than the WQF in order to treat the entire water quality volume (Adams, 1998). In addition, flow diversion structures for off-line stormwater treatment practices can also be designed to bypass flows greater than the WQF.

The WQF should be calculated using the WQV described above and the NRCS, TR-55 Graphical Peak Discharge Method. The procedure is based on the approach described in Claytor and Schueler, 1996 and is summarized in **Appendix B**. Design guidance for flow diversion structures is also found in **Appendix B**.

Rationale

The use of the NRCS, TR-55 Graphical Peak Discharge Method in conjunction with the water quality volume for computing the peak flow associated with the water quality design storm is preferable to both traditional SCS Methods and the Rational Equation, both of which have been widely used for peak runoff calculations and drainage design. The traditional SCS TR-55 methods are valuable for estimating peak discharge rates for large storms (i.e., greater than 2 inches), but can significantly underestimate runoff from small storm events (Claytor and Schueler, 1996). Similarly, the Rational Equation may be appropriate for estimating peak flows for small urbanized drainage areas with short times of concentration, but does not estimate runoff volume and is based on many restrictive assumptions regarding the intensity, duration, and aerial coverage of precipitation. The Rational Equation is highly sensitive to the time of concentration and rainfall intensity, and therefore should only be used with reliable intensity, duration, frequency (IDF) tables or curves for the storm and region of interest (Claytor and Schueler, 1996).

7.5 Groundwater Recharge and Runoff Volume Reduction

This criterion is designed to reduce stormwater runoff volumes and maintain groundwater recharge rates to pre-development levels. The criterion includes two components: groundwater recharge and runoff capture, which are described below.

7.5.1 Groundwater Recharge Volume (GRV)

Description

The groundwater recharge criterion is intended to maintain pre-development annual groundwater recharge volumes by capturing and infiltrating stormwater runoff. The objective of the groundwater recharge criterion is to maintain water table levels, stream baseflow, and wetland moisture levels. Maintaining pre-development groundwater recharge conditions can also reduce the volume requirements dictated by the other sizing criteria (i.e., water quality, channel protection, and peak flow control) and the overall size and cost of stormwater treatment practices.

The groundwater recharge volume (GRV) is the post-development design recharge volume (i.e., on a storm event basis) required to minimize the loss of annual pre-development groundwater recharge. The GRV is determined as a function of annual pre-development recharge for site-specific soils or surficial materials, average annual rainfall volume, and amount of impervious cover on a site. Several approaches can be used to calculate the GRV:

- ***Hydrologic Soil Group Approach:*** *This method was first developed and adopted by the state of Massachusetts, and has since been implemented in several other states including Maryland and Vermont. This approach involves determining the average annual pre-development recharge volume at a site based on the existing site hydrologic soil groups (HSG) as defined by the United States Natural Resources Conservation Service (NRCS) County Soil Surveys (MADEP, 1997). Based on this approach, the GRV can be calculated as the depth of runoff to be recharged, multiplied by the area of impervious cover, as shown below:*

$$GRV = \frac{(D)(A)(I)}{12}$$

where: GRV = groundwater recharge volume (ac-ft)
D = depth of runoff to be recharged (inches), see **Table 7-4**
A = site area (acres)
I = post-development site imperviousness (decimal, not percent) for new development projects or the net increase in site imperviousness for re-development projects

Table 7-4
Groundwater Recharge Depth

NRCS Hydrologic Soil Group	Average Annual Recharge	Groundwater Recharge Depth (D)
A	18 inches/year	0.4 inches
B	12 inches/year	0.25 inches
C	6 inches/year	0.10 inches
D	3 inches/year	0 inches (waived)

Source: MADEP, 1997.
NRCS – Natural Resources Conservation Service

Where more than one hydrologic soil group is present on a site, a composite or weighted recharge value should be calculated based upon the relative area of each soil group. The GRV should be infiltrated in the most permeable soil group available on the site.

- ***USGS Surficial Materials Approach:*** *This approach is similar to the above hydrologic soil group method, except the pre-development average annual recharge quantities and recharge depths are based on the predominant surficial materials classifications on the site (coarse-grained stratified drift versus glacial till and bedrock) as determined from U.S. Geological Survey (USGS) mapping. In areas underlain by coarse-grained stratified drift, average annual recharge is approximately three times greater than from till and bedrock areas. Areas of coarse-grained stratified drift and till/bedrock can be obtained from USGS 7.5-minute topographic maps of 1:24,000 scale, available from the USGS and DEP. Estimates of average annual recharge values for these materials are available from the Connecticut Water Resources Inventory Bulletins prepared jointly by the USGS and DEP for the major drainage basins throughout the state.*

- ***Other Methods:*** *Pre-development recharge values and the required GRV can also be determined using the results of on-site soil evaluations or other geologic information provided that information sources and methods are clearly documented.*

Meeting the recharge requirement can be accomplished through the use of primary treatment practices (infiltration, bioretention, filtration, and swales), secondary treatment practices (drywells, permeable pavement, level spreaders), and non-structural site design techniques such as disconnection of rooftop runoff and grading. Stormwater ponds, wetlands, and sediment forebays generally are not suitable for groundwater recharge since they are either designed with impermeable bottoms or have significantly reduced permeability due to accumulation of fine sediment. When designing infiltration practices, a factor of safety should be used to account for potential compaction of soils by construction equipment, which can significantly reduce soil infiltration capacity and groundwater recharge. See the design sections of this Manual for guidance on the design and construction of infiltration practices to reduce this potential.

The GRV is considered as part of the total water quality volume (WQV) and therefore can be subtracted from the WQV, provided that the proposed infiltration measures are capable of infiltrating the required recharge volume. Reducing the WQV (and consequently the size and cost of stormwater treatment) is an additional incentive for meeting the groundwater recharge criterion. Additionally, both WQV and GRV are a function of site imperviousness, providing further incentive to minimize site impervious cover.

There are several instances where the groundwater recharge criterion should be waived to protect against contamination of drinking water supplies and mobilization of existing subsurface contamination. Infiltration of stormwater is not recommended under the following site conditions:

- ***Land Uses or Activities with Potential for Higher Pollutant Loads:*** *Infiltration of stormwater from these land uses or activities (**Table 7-5**), also referred to as stormwater "hotspots," can contaminate public and private groundwater supplies. Infiltration of stormwater from these land uses or activities may be allowed by the review authority with appropriate pretreatment. Pretreatment could consist of one or a combination of the primary or secondary treatment practices described in this Manual provided that the treatment practice is designed to remove the stormwater contaminants of concern.*
- ***Subsurface Contamination:*** *Infiltration of stormwater in areas with soil or groundwater contamination such as brownfield sites and urban redevelopment areas can mobilize contaminants.*
- ***Groundwater Supply Areas:*** *Infiltration of stormwater can potentially contaminate groundwater drinking water supplies in public drinking water aquifer recharge areas and wellhead protection areas.*

Rationale

The objective of the groundwater recharge criterion is to mimic the average annual recharge rate for pre-development site conditions. The recommended approach for calculating the GRV (i.e., the required stormwater infiltration volume) is a function of post-development site imperviousness and the prevailing surface permeability and infiltration capacity. The hydrologic soil group approach uses the widely available NRCS Soil Survey maps and estimates of average annual infiltration rates for each hydrologic soil group. This method has been adopted in Massachusetts and other northeastern states, which have humid climates and receive approximately 44 inches of average annual rainfall. The recharge factors developed for this approach are also valid for Connecticut, which has similar rainfall, soils, and climate.

The alternative surficial materials approach may be less accurate than other soil-specific methods for estimating site-specific infiltration rates. The annual recharge values for surficial material categories are based on basin-wide analyses of stratified drift and till, which may not be applicable to specific sites. However, the approach is believed to be suitable for estimating the required recharge volume and utilizes readily available, published information from the USGS and DEP.

7.5.2 Runoff Capture Volume (RCV)

Description

The objective of the runoff capture criterion is to capture stormwater runoff to prevent the discharge of pollutants, including "unpolluted" fresh water, to sensitive coastal receiving waters and wetlands. The runoff capture criterion applies to new stormwater discharges located less than 500 feet from tidal wetlands, which are not fresh-tidal wetlands. The stormwater runoff volume generated by the first inch of rainfall must be retained on-site for such discharges. The runoff capture volume is equivalent to the WQV and can be calculated using the following equation:

Table 7-5 Land Uses or Activities with Potential for Higher Pollutant Loads

Land Use/Activities	
○ Industrial facilities subject to the DEP Industrial Stormwater General Permit or the U.S. EPA National Pollution Discharge Elimination System (NPDES) Stormwater Permit Program[1]	○ Road salt storage facilities (if exposed to rainfall)
○ Vehicle salvage yards and recycling facilities	○ Commercial nurseries
○ Vehicle fueling facilities (gas stations and other facilities with on-site vehicle fueling)	○ Flat metal rooftops of industrial facilities
○ Vehicle service, maintenance, and equipment cleaning facilities	○ Facilities with outdoor storage and loading/unloading of hazardous substances or materials, regardless of the primary land use of the facility or development
○ Fleet storage areas (cars, buses, trucks, public works)	○ Facilities subject to chemical inventory reporting under Section 312 of the Superfund Amendments and Reauthorization Act of 1986 (SARA), if materials or containers are exposed to rainfall
○ Commercial parking lots with high intensity use (shopping malls, fast food restaurants, convenience stores, supermarkets, etc.)	○ Marinas (service and maintenance)
○ Public works storage areas	○ Other land uses and activities as designated by the review authority

[1]Stormwater pollution prevention plans are required for these facilities. Pollution prevention and source controls are recommended for the other land uses and activities listed above.

$$RCV = \frac{(1'')(R)(A)}{(12)}$$

where: RCV = runoff capture volume (acre-feet)
R = volumetric runoff coefficient
I = percent impervious cover
A = site area in acres

Wet ponds designed with adequate storage volume to capture and retain the RCV or infiltration practices described in this Manual can be used to satisfy the runoff capture volume criterion.

Rationale

The runoff capture volume criterion is consistent with DEP coastal management policy and stormwater general permit requirements. Discharge of the "first-flush" of stormwater runoff into brackish and tidal wetlands is prohibited due to the resultant dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species such as Phragmites.

7.6 Peak Flow Control

Peak flow control criteria are intended to address increases in the frequency and magnitude of a range of potential flood conditions resulting from development. These include relatively frequent events that cause channel erosion, larger events that result in bankfull and overbank flooding, and extreme floods. The following sections describe sizing criteria for controlling peak flows, as well as for designing stormwater conveyance and emergency outlet structures. Natural Resource Conservation Service (NRCS) peak flow calculation methods such as TR-55 or TR-20 should be used to compute the required peak flow rates for each of the criteria described below.

7.6.1 Stream Channel Protection

Description

The stream channel protection criterion is intended to protect stream channels from erosion and associated sedimentation in downstream receiving waters and wetlands as a result of urbanization within a watershed. By restricting peak flows from storm events that result in bankfull flow conditions (typically the 2-year storm, which controls the form of the stream channel), damaging effects to the channel from increased runoff due to urbanization can be reduced.

Either of the following two methods can be used to satisfy the stream channel protection criterion. Both rely on "over-control" of the two-year frequency design storm:

- *Control the 2-year, 24-hour post-development peak flow rate to 50 percent of the 2-year, 24-hour pre-development level or*
- *Control the 2-year, 24-hour post-development peak flow rate to the 1-year, 24-hour pre-development level*

There are several practical limitations on the application of the stream channel protection criterion. For sites having less than one acre of impervious cover, the size of the orifice or weir required for extended detention becomes too small (approximately 1 inch in diameter) to effectively operate without clogging. In addition, channel protection is generally not required where sites discharge to a large receiving water body (Brown and Caraco, 2001). Therefore, the channel protection criterion does not apply under the following conditions:

- *The entire channel protection volume is recharged to groundwater*
- *Sites less than or equal to one acre of impervious cover*
- *The site discharges to a large river (fourth order or greater), lake, estuary, or tidal water where the development area is less than 5 percent of the watershed area upstream of the development site unless known water quality problems exist in the receiving waters. Stream order indicates the relative size of a stream based on Strahler's (1957) method. Streams with no tributaries are first order streams, represented as the start of a solid line on a 1:24,000 USGS Quadrangle Sheet. A second order stream is formed at the confluence of two first order streams, and so on.*

Rationale

A number of design criteria have been developed for the purpose of stream channel protection. The earliest and most common method relied on control of post-development peak flows associated with the 2-year, 24-hour storm event to pre-development levels based on the assumption that bankfull discharge for most streams has a recurrence interval of between 1 and 2 years (Leopold, et al., 1964 and Leopold, 1994). More recent research indicates that this method does not adequately protect stream channels from downstream erosion and may actually contribute to erosion since banks are exposed to a longer duration of erosive bankfull and sub-bankfull events (MacRae, 1993 and 1996, McCuen and Moglen, 1988).

The two-year "over-control" methods recommended above were developed as a modification of the original two-year control approach to provide additional protection. These methods require larger detention volumes than the traditional two-year approach, but reduce the duration of bankfull flows. More recent research has shown that extended detention of the 1-year, 24-hour storm event and a method referred to as Distributed Runoff Control (DRC) potentially provide the highest level of stream channel protection. In the extended detention method, the runoff volume generated by the 1-year, 24-hour rainfall (2.6 to 2.7 inches in Connecticut) is captured and gradually released over a 24-hour period to control erosive velocities in downstream channels. However, this method results in extremely large detention storage requirements (comparable to the storage volume required for 10-year peak discharge control), and the incremental benefits of this approach over the two-year over-control approach are undocumented. The DRC method involves detailed field assessments and hydraulic/hydrologic modeling to determine hydraulic stress and erosion potential of stream banks. This level of detailed, site-specific analysis is not warranted for use as a general stream channel protection criterion.

7.6.2 Conveyance Protection

Description

The conveyance systems to, from, and through stormwater management facilities should be designed based on the peak discharge rate for the 10-year, 24-hour storm. This criterion is designed to prevent erosive flows within internal and external conveyance systems associated with stormwater treatment practices such as channels, ditches, berms, overflow channels, and outfalls. The local review authority may require the use of larger magnitude design storms for conveyance systems associated with stormwater treatment practices.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.3 Peak Runoff Attenuation

Description

The peak runoff attenuation criterion is designed to address increases in the frequency and magnitude of flooding caused by development. This criterion is intended to control a range of flood conditions, from events that just exceed the bankfull capacity of the stream channel to catastrophic flooding associated with extremely large events. Other objectives include maintaining the boundaries of the pre-development 100-year floodplain and protecting the physical integrity of stormwater management facilities.

The recommended peak runoff attenuation criterion in Connecticut includes control of post-development peak discharge rates from the 10-year, 25-year, and 100-year storms to the corresponding pre-development peak discharge rates, as required by the local review authority. Attention must be given to timing of peak flows. The local review authority may require peak runoff attenuation for additional design storms such as the 1-year, 2-year, 5-year and 50-year, 24-hour events. The local review authority may waive the peak runoff attenuation criterion for sites that discharge to a large river (fourth order or greater), lake, estuary, or tidal waters where the development area is less than 5 percent of the watershed area upstream of the development site.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.4 Emergency Outlet Sizing

Description

The emergency outlets of stormwater management facilities should be designed to safely pass the peak discharge rate associated with the 100-year storm or larger. The emergency outlet should be able to pass the 100-year peak runoff rate, at a minimum, in a controlled manner, without eroding outfalls or downstream conveyances. Emergency outlets constructed in natural ground are generally preferable to constructed embankments. This criterion is applicable to all stormwater management facilities that employ an emergency outlet.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.5 Downstream Analysis

Peak runoff control criteria are typically applied at the immediate downstream boundary of a project area. However, since stormwater management facilities may change the timing of the post-development hydrograph, multiple stormwater treatment practices or detention facilities in a watershed may result in unexpected increases in peak flows at critical downstream locations such as road culverts and areas prone to flooding. This effect is most pronounced for detention structures in the middle to lower third of a watershed. The local review authority may require a downstream analysis to identify potential detrimental effects of proposed stormwater treatment practices and detention facilities on downstream areas.

The downstream analysis should include the following elements:

- *Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule")*
- *Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations (stream confluences, culverts, other channel constrictions, and flood-prone areas) to the confluence point where the 10 percent rule applies*
- *The analysis should use an appropriate hydrograph routing method, such as TR-20, to route the pre- and post-development runoff hydrographs from the project site to the downstream critical locations*

The ultimate objective of this analysis is to ensure that proposed projects do not increase post-development peak flows and velocities at critical downstream locations in the watershed. Increases in flow rates and velocities at these locations should be limited to less than 5 percent of the pre-developed condition (NYDEC, 2001) and should not exceed freeboard clearances or allowable velocities.

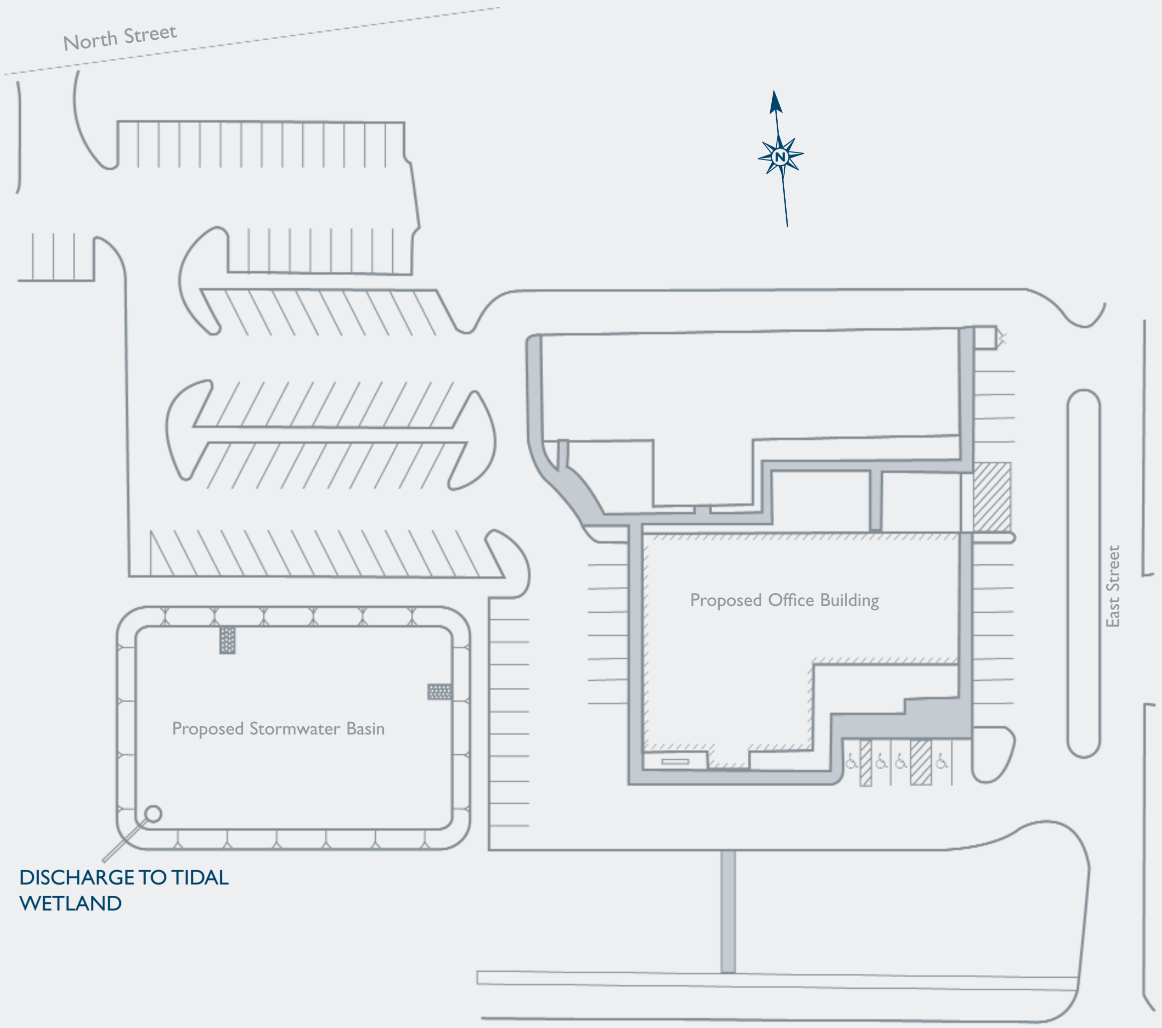
7.7 Sizing Example

The following example illustrates how the various sizing criteria described in this chapter are applied to determine stormwater treatment requirements (required storage volume and hydraulic capacity) for a hypothetical development project.

Old Town Office Building, New London, Connecticut

An office building is proposed on a commercial property in New London, Connecticut. The approximately 2-acre site is characterized by Type B soils. The proposed development consists of approximately 80 percent impervious area (parking lots and buildings), with approximately 20 percent as lawn or undisturbed area. Runoff from the impervious areas is collected and conveyed to a hypothetical stormwater treatment basin located on the southwest portion of the site. Stormwater is discharged from the basin to an adjacent tidal wetland. **Figure 7-1** shows a schematic layout of the proposed development.

Figure 7-1 Sizing Example – Proposed Old Town Office Building



Project Data

Location: New London, CT
Total Drainage Area (A)
Existing = 1.98 Ac; Proposed = 2.40
Impervious Area = 1.92 Ac; or I = 1.92/2.40= 80.0 %
Site Soil Type: "B"
Zoning: Business
Discharge to tidal wetlands

Hydrologic Data

	Pre-Development	Post-Development
CN	82	92
Tc (hr)	0.25	0.17

Source: Fuss & O'Neill, Inc.

1. Water Quality Volume

a. Compute volumetric runoff coefficient, R

R = 0.05+0.009(I)
= 0.05+0.009(80)
= 0.77

b. Compute water quality volume, WQV

WQV = (1")(R)(A)/12
= (1")(0.77)(2.40)/12
= 0.15 ac-ft

2. Water Quality Flow

Compute the water quality flow (WQF) for off-line stormwater treatment.

a. Compute the runoff depth, Q

$$Q = \frac{[WQV(acre-feet)] \text{ x } [12(inches/foot)]}{Drainage\ Area\ (acres)}$$

$$= \frac{(0.15)\text{x}[12(inches/foot)]}{2.40}$$

= 0.77 in

b. Compute the NRCS Runoff Curve Number (CN)

$$CN = \frac{1000}{\left[10 + 5P + 10Q - 10\left(Q^2 + 1.25QP\right)^{1/2}\right]}$$

$$= \frac{1000}{\left[10 + 5(1) + 10(0.77) - 10\left((0.77)^2 + 1.25\ (0.77)(1)\right)^{1/2}\right]}$$

= 98

c. Read initial abstraction, I_a (Table 4-1 in Chapter 4, TR-55)
I_a = 0.041

d. Compute I_a/P
= 0.041/1
= 0.041

e. Read initial abstraction, q_u (Exhibit 4-11 in Chapter 4, TR-55)
q_u = 580 csm/in (Type III storm)

f. Compute water quality flow (WQF)
WQF = (q_u)(A)(Q)
= (580)(0.004)(0.77)
= 1.8 cfs

3. Groundwater Recharge Volume

Compute the groundwater recharge volume (*GRV*) using the hydrologic soil group approach.

a. Read runoff depth to be recharged, *D* (Table 7-4)
   D = 0.25 in

b. Compute net increase in site imperviousness, *I* (proposed) – *I* (existing)
   I = 0.80-0.44
   = 0.36

c. Compute groundwater recharge volume, *GRV*

$$GRV = \frac{(D)(A)(I)}{12}$$

$$= \frac{(0.25)(2.40)(0.36)}{12}$$

$$= \underline{0.018\text{ ac-ft}}$$

4. Runoff Capture Volume

Compute the runoff capture volume (*RCV*) since the site discharges stormwater within 500 feet of tidal wetlands.

$$RCV = \frac{(1")(R)(A)}{(12)}$$

$$= \frac{(1")(0.77)(2.40)}{(12)}$$

$$= \underline{0.15\text{ ac-ft}}$$

5. Stream Channel Protection

Compute the required stream channel protection discharge using both "Two-Year Over-Control" methods recommended in Section 7.6.1.

a. Method-1, control the 2-year, 24-hour post-development flow to 50% of the 2-year, 24-hour pre-development flow

$Q_{2(control)}$ = (0.5) $Q_{2(exist)}$
= (0.5)(2.2)
= 1.1 cfs
$Q_{2(proposed)}$ = 0.9 cfs
$Q_{2(proposed)} < Q_{2(control)}$, meets method-1 criteria

b. Method-2, control the 2-year, 24-hour post-development flow to the 1-year, 24-hour pre-development flow

$Q_{1(exist)}$ = 1.8 cfs
$Q_{1(exist)} > Q_{2(proposed)}$, meets method-2 criteria

6. Conveyance Protection

Site storm drainage conveyance system designed for a 10-yr, 24-hour post-development peak flow, Q10.

Q_{10} = 4.3 cfs

7. *Peak Runoff Attenuation*

From TR-55 peak discharge summary worksheets:

Storm Event	Pre-Development (cfs)	Post Development (cfs)
10-year	4.3	4.0
25-year	5.3	5.2
100-year	6.8	9.8

8. *Emergency Outlet Sizing*

Safe passage of the 100-year storm event under proposed conditions requires passing Q_{100} of 9.8 cfs through the proposed stormwater basin emergency spillway. The spillway is designed to safely convey 9.8 cfs without causing a breach of the stormwater basin that would otherwise damage downstream areas or present a safety risk.

Summary of Sizing Requirements

Criterion	Requirement
Water Quality Volume	0.15 ac-ft
Water Quality Flow	1.8 cfs
Groundwater Recharge Volume	0.018 ac-ft
Runoff Capture Volume	0.15 ac-ft
Stream Channel Protection	0.9 cfs (2-year "over-control")
Conveyance Protection	4.3 cfs (10-year)
Peak Runoff Attenuation	5.3 cfs (25-year)
Emergency Outlet Sizing	9.8 cfs (100-year)

References

Adams, T. 1998. Stormwater Facility Design: Calculating the First Flush. *Pollution Engineering*.

Brown, T. and D. Caraco. 2001. "Channel Protection" *Water Resources IMPACT*.

Chang, G., Parish, J., and C. Sober. 1990. *The First Flush of Runoff and Its Effect on Control Structure Design*. Environmental Resource Management Division. City of Austin, Texas.

Claytor, R.A. and T. R. Schueler. 1996. *Design of Stormwater Filtering Systems*. Center for Watershed Protection. Silver Spring, Maryland.

Department of Commerce. 1961.Weather Bureau, *TP-40*.

Leopold, L.B. 1994. *A View of A River*. Harvard University Press. Cambridge, MA.

Leopold, L.B., Wolman, M.G., and J.P. Miller. 1964. *Fluvial Processes in Geomorphology*. W.H. Freeman and Company. San Francisco, CA.

MacRae, C. 1993. "An Alternative Design Approach for the Control of Instream Erosion Potential in Urbanizing Watersheds." In Proceedings of *Sixth International Conference on Urban Storm Drainage*. Niagara Falls, Ontario.

MacRae, C. 1996. "Experience from Morphological Research on Canadian Streams: Is Control of the Two-Year Frequency Runoff Event the Best Basis for Stream Channel Protection?" In Effects of Watershed Development and Management on Aquatic Systems. L. Roesner editor. Proceedings of *Engineering Foundation Conference*. Snowbird, UT, August 4-9, 1996.

McCuen, R. and G. Moglen. 1988. "Multicriterion Stormwater Management Methods." *Journal of Water Resources Planning and Management*. Vol. 114, No. 4.

New York State Department of Environmental Conservation (NYDEC). 2001. *New York State Stormwater Management Design Manual*. Prepared by Center for Watershed Protection. Albany, New York.

Novotny, V. 1995. *Nonpoint Pollution and Urban Stormwater Management*. Technomic Publishing Company, Inc. Lancaster, Pennsylvania.

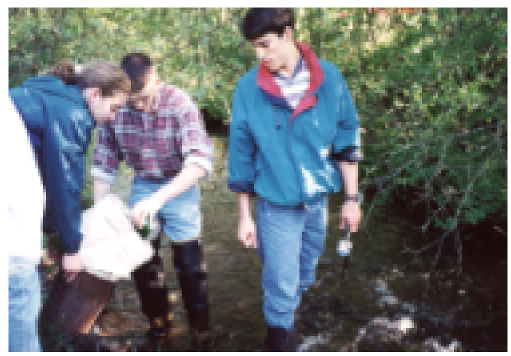
Prisloe, M., Giannotti, L., and W. Sleavin, No date. "Determining Impervious Surfaces for Watershed Modeling Applications." University of Connecticut, Cooperative Extension System. Nonpoint Education for Municipal Officials (NEMO) Project. Haddam, CT.

STREAM BIOSURVEYS

Introduction

Organic pollution in streams can result in the loss of many desirable aquatic species including fish and mussels

As human populations have grown, more and more pollution of our waters has occurred, both from point source discharges and as nonpoint or "diffuse" pollution. There are several categories of pollution associated with the aquatic environment (e.g. toxic pollution), but one of the most common categories is *organic pollution*. This is caused by oxygen-demanding wastes such as domestic sewage, leachate from landfills, and agricultural and urban runoff.



The natural processes of chemical oxidation and biological decomposition that occur within water-courses, consume dissolved oxygen. Decomposition of materials is a normal process in all aquatic ecosystems and is a function of decomposers such as bacteria and fungi. These organisms play an important role by metabolizing organic matter as an energy and nutrient source and use dissolved oxygen in the process.

However, serious consequences to aquatic organisms can result if the natural mechanisms that clean the water are overloaded by large influxes of organic pollution. Severe oxygen depletion can result in the loss of many desirable aquatic species including fish (e.g. trout) and mussels, and aquatic organisms such as stoneflies and mayflies.

Water Quality Testing

Traditional Methods

The long-term effects of nonpoint source pollution, such as from urban runoff, have often been determined through chemical monitoring. In recent years, however, a growing body of literature has emerged that points to the importance of biological monitoring. Many states are now selecting biological and physical monitoring over traditional chemical monitoring in their efforts to determine the health of aquatic ecosystems and of general watershed quality.

A single sampling of stream chemical constituents only provides a "snapshot" of water quality

Traditional water quality sampling methods have emphasized analyses of physical and chemical parameters such as dissolved oxygen, pH, temperature, nitrates, phosphates, and others. Although useful, this approach has several limitations. There are many chemical constituents that could theoretically result in water quality degradation. Not only are some of these very expensive to analyze, but their sheer number increases the likelihood that a pollutant will not be identified. A single sample can only provide a "snapshot" of water quality on the day of sampling, and may provide no information on recent degraded conditions which have since cleared up, but whose effect upon aquatic biota may be more lasting.

Benthic Organism Sampling

Biosurvey Methods

The technique of stream benthic organism or macroinvertebrate sampling was developed more than 50 years ago to complement traditional chemical water quality approaches, as well as to provide new information not available through other methodologies. This includes information about effects from multiple stressors (e.g. chemicals, sedimentation, exotic species, etc.) arising from point sources, nonpoint sources, habitat alteration, and hydrological modification. For example, ecological responses to such disturbances can be observed at the community level of organization of benthic macroinvertebrates, offering dependable and readily observable indicators that integrate the impacts of multiple, and often subtle, stressors.

What Are Benthic Macroinvertebrates?

Benthic organisms can serve as biological indictors of water pollution

The term "benthic" means bottom-dwelling. Benthic macroinvertebrates are organisms without backbones that live in, crawl upon, or attach themselves to bottom substrates (e.g. sediments, debris, logs, plants, filamentous algae, etc.). The term "macroinvertebrate" refers to those organisms that are large enough to be viewed without the aid of a microscope and that are retained by a sieve with mesh sizes greater or equal to 200 to 500 micrometers. Benthic macroinvertebrates include immature insects (larvae and nymphs), worms, crustaceans, mollusks, (clams and mussels), leeches, mites and snails. Insect larvae tend to be the most abundant macroinvertebrates in freshwater aquatic systems.

The majority of benthic macroinvertebrates are found in the riffles (i.e. erosional areas) of streams. Riffles range from uneven bedrock to cobbles to boulders. The optimum riffle area contains gravel-sized (1-inch diameter) to cobble-sized (10-inch diameter) substrate. The flow of water over these areas provides plentiful oxygen and food particles. Riffle-dwelling communities are made up of macroinvertebrates that generally require high dissolved oxygen levels and clean water. Most of these organisms are intolerant to pollution. In slow flow areas such as runs and pools (depositional areas), decomposer communities, which tolerate lower dissolved oxygen levels and higher organic matter and sedimentation, are typically more abundant. Riffle-dwelling communities are more sensitive to increasing pollution than communities in the pools or slow flowing areas of the same stream.

There are four primary feeding groups of benthic macroinvertebrates: shredders, filter collectors, grazers, and predators. Shredders such as stoneflies (*Plecoptera*) feed on plant material and some animal material, which is generally dead, and break it down into smaller particles through their feeding and digestive process. Collectors, such as caddisflies (*Trichoptera*) and blackflies (*Diptera*), feed on fine particulate matter that they filter from the water. Grazers, such as snails and beetles (*Coleoptera*), feed on algae and other plant material living on rocks and on plant surfaces. Predators such as dobsonflies (*Megaloptera*) or dragonflies (*Odonata*) feed on other macroinvertebrates. Individual species may be generalists, and fit into more than one of these groups (as opposed to specialists).

Benthic macroinvertebrates, as a group, exhibit a relatively wide range of response to chemical and physical water quality stressors (pH, temperature, dissolved oxygen, organic pollutants, heavy metals, sedimentation, etc.) and thus can serve as ***biological indicators*** of water pollution. Some organisms are tolerant of degraded water quality conditions, while others are pollution-sensitive. Many snails, worms and midge larvae belong to the former group, while the most widely recognized members of the latter group are the *Plecoptera* (Stoneflies), *Ephemenoptera* (Mayflies) and *Trichoptera* (Caddisflies).

In most cases, unpolluted streams will support a diverse population of macroinvertebrates

Some pristine streams have a low diversity of macroinvertebrate fauna because of the cold temperature and/or relatively low nutrient levels. Headwater streams may have only two or three dominant species. In most cases, however, an unpolluted stream will support a diverse population of macroinvertebrates, with pollution-sensitive species well represented. However, species diversity declines as water quality deteriorates and pollution-tolerant organisms become increasingly dominant.

Advantages of Macroinverterbrate Sampling

Plafkin et al. (1989) list several advantages of sampling stream macroinvertebrates in order to make inferences about water quality:

1. Since most stream macroinvertebrates have limited migration patterns or are sessile and spend much time clinging to rocks or the stream substrate, and do not move long distances, they are good indicators of localized water conditions.

2. Aquatic organisms integrate the effects of chemical, physical and biological parameters. Conducting an aquatic biosurvey will thus increase the likelihood that a degraded condition will be detected, if present.

3. Since most of these species have a relatively short life cycle (approximately one year), they will respond to stressors more rapidly than other longer-lived components of the community (e.g. fish).

4. Sampling techniques are rapid and inexpensive. An experienced biologist can detect degraded water conditions with only a cursory, or qualitative, examination of the macroinvertebrate community.

5. Benthic macroinvertebrates are a primary food source for fish, and as such can provide valuable information on the relative health of the fish community.

6. Benthic macroinvertebrates are common to abundant in most streams.

Sampling Methods

The simplest method of collecting stream macroinvertebrates is to inspect in-stream rocks for attached organisms, or disturb the stream substrate while placing a net downstream to gather dislodged biota. Depending upon the nature of the study, the organisms are identified to either the family, genus or species level. Family-level identification is most expeditious, and is the technique most commonly used. However, it is less precise since members of some stream macroinvertebrate families show a range of pollution tolerances, and the sensitivity of these families can only be expressed as an average (Hilsenhoff 1988).

Measuring Biological Health

The Biotic Index

A variety of useful indices or measurements (metrics) have been developed for assessing the health of streams through benthic macroinvertebrate sampling. These include: taxa richness, EPT Index or richness, percent abundance of EPT, percent dominance, percent dominance of scrapers, Hilsenhoff's Biotic Index (HBI), EPT:chironomid ratio, Pinkham and Pearson community similarity index, and many others.

Of these, and there are many, Hilsenhoff's (1988) "biotic index" (HBI) is one of most commonly used. Hilsenhoff developed a rapid stream biosurvey methodology that requires identification of macroinvertebrates to family-level. This method assigns a numerical score (biotic index) ranging from 0 to 10 to the most common stream macroinvertebrate taxa. The biotic index is directly related to the degree of pollution-tolerance and is based on field and laboratory responses of organisms toward organic pollution.

Approximately 100 organisms are collected and randomly sampled from a variety of habitats within the stream, including erosional and depositional areas (e.g. riffles and runs). The organisms are identified to family-level and the total number (**n**i) of each is recorded. The following formula is then used for the estimation of the Family-level Biotic Index (FBI):

$$FBI = \frac{\sum n_i a_i}{N}$$

where:

n_i = the number of specimens in each taxonomic group
a_i = the pollution tolerance score for the taxonomic group (see Table 1)
N = the total number of organisms in the sample (usually 100).

Ideally, the Family-level Biotic Index should be calculated during several different times of a year (e.g spring, summer and fall) and compared with reference sites within the particular watershed or in the region for more accurate conclusions to be drawn.

Who Can Take This Pollution?

Introduction

It is well documented that pollution of streams reduces the number of species of the aquatic ecosystem, (i.e. species diversity), while frequently creating an environment that is favorable to only a few species (i.e. pollution-tolerant forms). Thus, in a polluted stream, there are usually large numbers of a few species, while in a clean stream there are moderate numbers of many species.

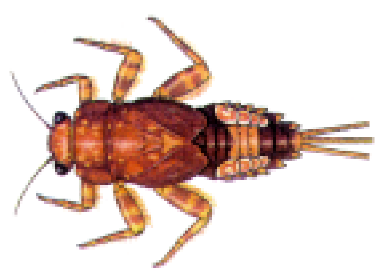
For instance, turbidity reduces light penetration and submerged aquatic plant productivity. Thus turbidity will affect those macroinvertebrates depending on plant matter for food and those that rely heavily on visual location of prey (predators). Filter feeders' filtering mechanisms may also be blocked by sediment particles associated with turbid waters. Turbidity also tends to increase temperature in waters and is often associated with higher organic decomposition. These are conditions that reduce oxygen levels and may result in impacts to many gill-breathing mayfly, stonefly, and caddisfly larvae that thrive only where there is abundant oxygen in the water. As turbidity increases - and turbidity is often associated with other pollutants such as nutrients and heavy metals - rock dwelling or attaching macroinvertebrates such as mayflies, stoneflies, and caddisflies, will be replaced by silt-tolerant and pollution tolerant macroinvertebrates that can tolerate low oxygen levels in the water or that can breath atmospheric oxygen. For example, rat-tailed maggots have snorkel-like breathing tubes, some snails have lungs (e.g. *Physa* spp.), and midges (chironomids) and worms (oligochaetes) have respiratory pigments which enable them to more efficiently obtain oxygen that is in low concentrations.

Pollution *Intolerant* Macroinvertebrates

The following are some typical macroinvertebrate groups (taxa) commonly encountered in streams and that usually indicate ***good water quality***.

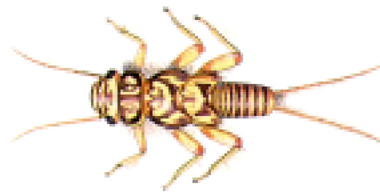
Mayflies

Mayfly nymphs are often the most numerous organisms found in clean streams. They are sensitive to most types of pollution, including low dissolved oxygen (less than 5 ppm), chlorine, ammonia, metals, pesticides and acidity. Most mayflies are found clinging to the undersides of rocks.



Stoneflies

Stonefly nymphs are most limited to cool, well-oxygenated streams. They are sensitive to most of the same pollutants as mayflies except acidity. They are usually much less numerous than mayflies. The presence of even a few stoneflies in a steam usually suggests that good water quality has been maintained for several months prior.



Caddisflies

Caddisfly larvae often build a portable case of sand, stones, sticks, or other debris. Many caddisfly larvae are sensitive to pollution, although a few are moderately tolerant. One family spins nets to catch drifting plankton, and is often numerous in recovery zones below sewage discharges.

Beetles

The most common beetles in streams are riffle beetles and water pennies. Most of these require swift current and an adequate supply of oxygen, and are generally considered to be clean water indicators.

Pollution *Tolerant* Macroinvertebrates

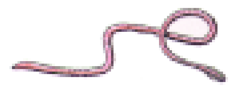
The following are some typical macroinvertebrate groups that are commonly encountered in streams and which usually indicate ***poor water quality***.

Midges

Midges are the most common aquatic flies. The larvae occur in almost any aquatic situation. Many species are very tolerant to pollution; most of these are red and are called "bloodworms". Other species filter suspended food particles, and are numerous in
sewage outfall recovery zones.

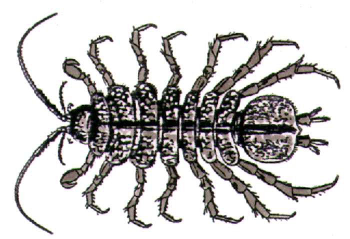
Worms

The segmented worms include the leeches and the small aquatic earthworms. The latter are more common, though usually unnoticed. They burrow in the substrate and feed on bacteria in the sediment. They can thrive under conditions of severe pollution and very low oxygen levels.



Sowbugs

Aquatic sowbugs are crustaceans that are often numerous in situations of high organic content and low oxygen levels. When abundant they can indicate a stream segment in the recovery stage of organic pollution.



Black Flies

Black fly larvae have specialized antennae for filtering plankton and bacteria from the water, and require a strong current. Most species are numerous in the decomposition and recovery zones of sewage outfalls and are generally indicative of at least moderate levels of organic pollution.

What Can We Do for You?

Benthic Macroinvertebrate Studies

Rema Ecological Services, LLC (RES) performs instream macroinvertebrate studies to assess existing water quality conditions. Instream biomonitoring can be used to assess baseline water quality conditions prior to development or alteration within the contributing watershed. These studies can also be used as part of a National Pollution Discharge System (NPDES) permit modification.

Our basic services include:

- Benthic faunal sampling and analysis
- Water quality assessments of streams and rivers
- Macroinvertebrate identification to genus or species
- Historical data comparisons

- Quantitative studies using multi-plate samplers

Depending on the level of analysis required, any combination of the following analyses can be incorporated to provide comprehensive assessments:

- Rapid Bioassessment (US EPA Rapid Bioassessment Protocol III)
- EPA Pollution Tolerance Index
- Invertebrate Community Index (ICI)
- Functional Feeding Group Analysis
- Diversity Analysis
- Modified Hilsenhoff Biotic Index

Fisheries Studies

In addition, RES can perform a variety of fisheries studies to determine the effects of point and nonpoint pollution on aquatic communities. Quantitative studies of fish communities can be used to assess general water quality and stream health. Because fish are large, highly visible organisms, they are useful when relating water quality issues to the general public and to the regulated community.

References:

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. J. N. Am. Benthol. Soc. 7(1):65-68.

Plafkin, J. L, M. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid Bioassessment Protocols for use in streams and rivers. US EPA. EPA/440/4-89/001

Slate Upper School, 5100 Ridge Road, North Haven, CT
Photos taken on 2/20/2021, by REMA Ecological Services, LLC

Photo 1: Primary stream channel below subject site, and water quality sampling station; note eroded bank; facing southerly.

Photo 2: Stream roughly 50 feet downgradient of water quality sampling station; facing southwesterly.

Photo 3: Active seepage within wetland; in the path of proposed stormwater discharge from subject site; facing easterly.

Photo 4: Wetland below proposed discharge, including area of active seepage (groundwater); facing westerly.

Slate Upper School, 5100 Ridge Road, North Haven, CT
Photos taken on 2/20/2021, by REMA Ecological Services, LLC

Photo 5: Secondary stream channel from active wetland seepage; subject site in background; facing easterly.

Photo 6: Example of caddisfly larva (Glossosomatidae) on hard substrate from stream at water quality sampling station

Photo 7: Examples of Glossosomatidae (family) caddisflies from subject stream

Photo 8: Examples of stonefly larva (Perlodidae) from stream at water quality sampling station