Second Annual Report
Of the Nutrient Scientific Advisory Board

To the Secretary
Of the NC Department of Environment and Natural Resources

As Required by SL 2009-216

July 2, 2012

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To the Secretary of the Department of Environment and Natural Resources

Summary

In July 2010, the Secretary established a Nutrient Scientific Advisory Board as called for in Session Law 2009-216 regarding existing development requirements of the Jordan Nutrient Strategy. The Board provided a first annual status report in July 2011 as called for in the legislation. In this second report, the Board provides certain products called for by the session law. This report was assembled by Nonpoint Source Planning staff with the Division of Water Quality with guidance from and review by the Board.

The Board recognizes the precedent-setting nature of existing development stormwater requirements in this state and our role in providing direction for local governments and state and federal entities in Jordan and Falls Lake watersheds and potentially beyond. Thus, the primary product provided herein is attached in the form of guidance to local governments and other affected parties. This guidance identifies the set of practices currently available in the state for reducing nutrient loads from developed lands, the nutrient accounting methods associated with these practices, and a discussion of costs, benefits and feasibility. As keen interest exists in expanding the range of management options, we also include discussion of priorities being pursued by the Board for additional load-reducing measures.

Regarding the use of this guidance, formal implementation of local existing development programs begins June 2015 for all Falls communities and the Upper New Hope communities in Jordan. Haw and Lower New Hope communities in Jordan commence implementation three years later in June 2018. Falls local governments are to begin implementing nutrient load-reducing measures in January 2014 as they simultaneously submit programs for Environmental Management Commission approval. Under both Jordan and Falls rules, the Division of Water Quality is tasked with providing a model local program for existing development nutrient control to the Commission in July 2013. In part, that model program will identify the set of load-reducing measures available at that point along with associated credit accounting methods. Staff will be working with the Board over the coming year to add to the measures identified herein to fashion a program of greatest utility to affected parties. Beyond July 2013, staff and the Board will continue development of creditable measures for addition to the toolbox as local programs are formulated and launched.

The other product called for by the session law is offered primarily for the Department's consideration. It is a set of recommendations regarding improvements to modeling and other analytical tools that may better enable effective implementation of nutrient strategies.

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Background

Session Laws 2009-216 and 2009-484 established staged implementation requirements for local governments and state and federal entities in the Jordan Lake watershed, aimed at reducing nutrient loading from existing developed lands. In addition, given the precedent-setting nature of the requirements in this evolving area of technology, the drafters of the session law felt it was important to include a process for evaluating current practice and providing guidance to local governments in Jordan and other watersheds that may face similar requirements in the future. Therefore, SL 2009-216 also established a Scientific Advisory Board for nutrient-impaired waters. As specified in the legislation, six of the Board's ten members are representatives of local governments in the Jordan Lake watershed, while the remainder represent DOT, the conservation community, water quality science and stormwater engineering expertise (see Attachment A for Board composition and membership).

The Board is charged with completing certain tasks by July 2012 that will facilitate stormwater management on existing development in the state:

(1) Identify management strategies that can be used by local governments to reduce nutrient loading from existing development.
(2) Evaluate the feasibility, costs, and benefits of implementing the identified management strategies.
(3) Develop an accounting system for assignment of nutrient reduction credits for the identified management strategies.
(4) Identify the need for any improvements or refinements to modeling and other analytical tools used to evaluate water quality in nutrient-impaired waters and nutrient management strategies.

In addition to these four duties, the Session Law provides for one elective, Jordan-specific action. It states that the NSAB may recommend an alternative method to the Department to calculate baseline nutrient loads from the existing developed lands of jurisdictions in the Jordan watershed. These loads are the basis for assigning load reduction goals to the jurisdictions.

In both the Jordan and Falls watersheds, the products of these tasks will be used by the Department to develop a model program for EMC approval by July 2013. In the Falls watershed, local governments will use the model program to prepare and submit programs for Division review in January 2014, while the communities simultaneously begin implementing measures. Formal implementation of Falls local programs is to occur in June 2015 following review, EMC approval and local adoption. In the Jordan watershed, the model program will be used by local governments in the Upper New Hope subwatershed to develop and implement their programs as early as June 2015, contingent upon results of monitoring in the corresponding arm of Jordan Lake to be reported by the Division in March 2014. Haw and Lower New Hope subwatershed communities in the Jordan watershed face corresponding requirements to implement by June 2018 based on March 2017 monitoring results.

Products of the Board's efforts to address items (1) through (3) above are provided in Attachment B as guidance to local governments. The Board's recommendations regarding item (4) are provided below.

Recommendations Regarding Modeling and Other Analytical Tools

To address Item (4) above, the Board has identified several areas of interest for the Department's consideration. We offer recommendations to guide future watershed modeling for existing development regulatory purposes, and recommendations in several other areas that range from more complete measurement of nutrients in the aquatic environment to revisiting the regulatory barriers against use of certain cost-effective measures.

Watershed Modeling

For much of the last year, the Board has focused most of its energy on developing recommendations to the Division of Water Quality on the design of watershed modeling of Jordan watershed to best support establishment of nutrient load allocations and load reduction needs to local governments and state/federal entities as called for under Jordan session law requirements. The Board has found that reconciling the complex, uncertain and large-scale nature of watershed modeling with the need for regulatory compliance assignments and credit accounting tools that provide predictability and small-scale accuracy is a great challenge. Nevertheless, through subcommittees and facilitated full Board discussions, we articulated a set of interests and potential future model uses, defined key desired model elements, outlined a model development process and a set of consultant tasks, obtained Section 319 grant funds from the Division for the modeling project, entered into a contract with the Triangle J Council of Governments to administer the project grant, and crafted a request for qualifications that included a suggested scope of services. Candidates were solicited in May and evaluated and interviewed in June. A consultant will be chosen in early July and will draft a scope of services for negotiation with the Board. Peer-reviewed modeling and allocations are to be finalized by early 2014.

The Board prioritized this watershed modeling effort in recognition of the implementation timeframes for the Jordan existing development requirements and the time required to develop such modeling. The regulatory compliance uses of the product, including parsing catchment-based load estimates among political jurisdictions, necessitate more rigorous design than watershed modeling typically employs. Board members felt compelled to seek the most accurate modeling that could reasonably be obtained within the available timeframe and budget. Board members also seek model features that will better inform effective management choices regarding load-reducing measures.

Based on our Jordan model discussions, we offer recommendations here on certain larger issues that may be of universal interest in building watershed models to meet similar regulatory needs. We believe that to some extent these recommendations may be actionable in a given watershed with sufficient planning and funding, but most of them also involve larger challenges to the field of watershed-scale estimation of nutrient loading from developed lands.

Unbiased Instream Water Quality Data: While it is rarely disputed that "more data is better" for the quality of modeling, we believe that watershed modeling efforts in this state can be challenged to overcome a certain bias that tends to exist in predominantly available instream data. We believe the record supports that station locations at which ambient water quality data is routinely sampled by the Division of Water Quality tend to be situated on larger streams downstream of major wastewater treatment facilities. We do not question the Division's logic or interests in this sampling pattern. We recognize this pattern, however, as potentially limiting or challenging for the interests of watershed modeling. Lacking other, upstream stations in a watershed of interest, calibration of a model based on Division ambient stations may lead to overestimation of nonpoint source loads to the watershed as well as total loads due to the influence of wastewater composition on stream concentrations. Thus we offer the general recommendation to all parties who may support monitoring that thought be given to the potential for diversifying monitoring efforts to capture a fuller range of ambient conditions by including various nonpoint source-dominated locations as well. We believe this should lead to improved nonpoint source and total load estimates.

Explicit Modeling, Better Understanding of Septic System Contributions: Given that septic systems serve a sizable portion of wastewater disposal needs in any watershed, the fate of their nutrient discharges is important. Watershed models vary in their ability to represent septic processes, and are constrained by limited scientific data on their loading effects. Recognizing nutrient management interests surrounding this waste disposal process, we highlight the importance of selecting a watershed model that explicitly and adequately represents septic processes separately from the host land use. Given the limited science on the delivery of nitrogen to surface waters from functioning and malfunctioning septic systems, we encourage the Department to seek better science to support better modeling of and accounting for this source and for the nutrient impacts of management actions.

Modeling Effects of Flow and Season on Nutrient Loads: Stormwater management measures are designed to capture and treat the "first flush" of runoff from rainfall events. This approach is rooted in foundational research on pollutant concentrations in runoff dating back to the National Urban Runoff Program in the 1970's, and it has generally been reinforced by more recent studies. We believe less attention has been given to cumulative watershed-scale estimates of the proportions of total loads delivered to watershed outlets by different watershed flow stages, and to attributions of predominant source types associated with those contributions. Given the substantial long-term commitments local governments are called upon to make regarding existing development, we believe it makes sense to seek to quantify the fraction of nutrient loads delivered under all flow regimes and to evaluate associated prevailing sources in order to assess the extent to which current nonpoint source management practices place attention where it should be focused. Watershed modeling projects typically do not but can be made to estimate the relative proportions of nutrients delivered to receiving waters at different flow stages. We would encourage the pursuit of such modeling to better inform the state's need for adapting current management tools.

Improved understanding of seasonal patterns in loading is also likely to yield insights on potential management adaptations to better address nutrient over-enrichment. Watershed models typically produce seasonally aggregated loading estimates. We encourage the state to seek better understanding from modelers of the watershed sources and processes that drive these loading patterns.

Higher Resolution Land Cover Data: A key data element in modeling for these purposes is land cover. Various sources of land cover data exist, however the universally available, inexpensive sources are also coarse relative to the regulatory needs of the Jordan and Falls existing development requirements. Regulations need to provide adequate time, and the agency should seek sufficient funding to support the use of uniformly higher-resolution land cover data capturing appropriate time periods to facilitate more accurate attribution of jurisdiction nutrient loads. Thought should also be given to planning for periodic updates to such land cover data to enable periodic remodeling of watersheds to inform adaptive evaluations of progress.

Other Needs Related to Modeling and Analytical Tools for Nutrient Control

Perhaps the most pressing needs for regulated parties are those involved in developing credit accounting methods for nonpoint source measures other than conventional stormwater best management practices. The Board sees addressing those needs as an important part of its charge and will continue to work with Division staff to make gains on developing those tools as expeditiously as the requisite data and knowledge bases and resources allow. We discuss those needs in the attached guidance to affected parties. The recommendations here below raise larger issues that we believe the Department may have a role in addressing.

Recognizing Gross Solids: Research is revealing that larger-size constituents of stormwater runoff, termed gross solids or bulk solids, can comprise a significant portion of stormwater nutrient loads, yet largely elude conventional water quality monitoring methods. Gross solids include not only trash but leaf litter, grass clippings and other large organic debris and sediments that typically travel as either floatables or bedload and that escape detection by automated monitoring equipment and grab sampling. A substantial portion of the nutrients in gross solids is likely delivered in available form to the water body of concern, making this constituent a significant and unquantified contributor to the over-enrichment of our nutrient sensitive waters. Early studies indicate that urban areas contribute more nutrients in the form of gross solids than in the dissolved and fine particulate forms that are normally monitored. While gross solids are largely a hidden load, they are also amenable to management and thus present a potentially meaningful improvement opportunity. Management practices can include improved street sweeping, clean-up campaigns, end-of-pipe devices, catch basin inserts and vortex separators. Quantification of this constituent will be an important first step toward including its loads and load reductions in the nutrient regulatory framework.

Coordinated Watershed-Based Data Collection: The inclusion of requirements for nutrient control from existing development in Jordan and Falls nutrient strategies has placed highly quantitative expectations on the field of watershed modeling. While the technology and science of this field continue to expand in very productive ways, it remains true that the accuracy and robustness of modeling results are limited in good part by the scope and quality of available data. Beyond the "more data is always better" notion, we believe that it would make sense to explore the potential for state, federal and local water quality sampling entities to pool resources in support of coordinated, watershed-based data collection to support watershed modeling for nutrient strategies. This is not to suggest that participating partners would be asked to compromise existing monitoring program objectives. But based on this Board's discussions over the last year regarding watershed modeling to support Jordan existing development requirements, local governments, in addition to the state, have a clear interest in obtaining the best estimates of their loading contributions and the most insights into effective management approaches as modeling can afford them. Coordinated sampling efforts using uniform protocols and organized around watersheds would facilitate higher quality load estimates. Local governments may see value in directing new resources toward such efforts, but better coordination of existing resources with state and federal programs and potentially universities would itself likely be a valuable improvement. Thus we raise the question of whether this emerging priority of large watershed nutrient strategies should merit exploration of this type of coordination. To minimize planning resource demands, this coordination could be carried out over time as a watershed-scale geographically sequenced process based on forecasts of future nutrient management needs.

Project Feasibility Assessment Tools: Local governments in North Carolina are beginning to recognize multiple benefits from 'retrofitting' of developed landscapes for water quality purposes, and have begun implementing a range of these projects. Not surprisingly, early experience is revealing some of the challenges associated with these endeavors. Some unforeseen issues can result in major setbacks. While guidance at the national level is rapidly evolving, the 'new' regulatory frontier created by the Jordan and Falls existing development requirements suggest that the Department could better support local implementation of these requirements by evaluating the current state of the practice here and elsewhere and developing state-specific feasibility assessment guidance for affected parties.

Reconsider Regulatory Barriers to Instream Structures: In efforts to find workable, affordable solutions for affected parties, one tool that local governments on the Board believe can be very cost-effective involves the impoundment of smaller streams to allow the establishment of a variety of nutrient-reducing environments. Opportunities for such applications may be fairly limited, but can be quite valuable where, for example, a stream has been channelized and disconnected from its floodplain, or in developed watersheds that lack retrofit opportunities other than low-lying open space that would be best utilized for water quality purposes by a design utilizing an instream structure. Such structuring allows treatment of the drainage from a fairly large area at very low cost. It is our understanding that the existing climate is not open to entertaining such proposals. As an alternative, we see value in the state considering such proposals under close and conservative regulatory scrutiny. Such a process might reasonably benefit from the establishment of criteria defining geomorphologic, land use and other conditions that may be suitable for such applications.

Next Steps

The Board expects to advise Division of Water Quality staff on a number of activities to meet a July 2013 deadline for the Division to submit for Commission approval a model program for nutrient control from existing development under both the Jordan and Falls nutrient regulations.

- The Board's primary focus for the coming year will be to assist in establishment of credit accounting and design standards for the most promising non-standard stormwater BMPs that have been identified. We will similarly seek to obtain approval for as many other, alternative nutrient-reducing practices as feasible.
- The Board may advise the Division on its development of methods to account for discharging sand filters, malfunctioning septic systems, and leaking collection systems, which are to be included in the Falls model program.
- To foster the establishment of creditable practices, the Board will advise Division staff on the design of a more standardized process for obtaining Division approval of nutrient-reducing measures. The Division intends to include this process in the model program.
- The Division will also seek advice from the Board on other elements that will be useful to include in the model program, such as ordinances.
- The Division may consult the Board on methods for assigning Stage I load reduction needs to local governments in the Falls watershed for inclusion in that model program.

In the coming year, the Board will also seek to set priorities for approval of additional load-reducing actions beyond July 2013, and will likely identify research needs to support development of credit accounting in some cases. Candidate activities identified so far vary in complexity of need, and we expect the pursuit of accountable options to continue into the future, particularly where science is limiting.

The Board will continue to work with Division staff beyond July 2013 to establish additional and more cost-effective options for load reduction. These actions will assist local programs, which are required to commence implementation in June 2015 or June 2018.

The Board will play an active role over the next year and a half in the development of the Jordan watershed model. We will provide recommendations to TJCOG and the Division on the choice of a consultant, on the final scope of consultant services, and will receive reports from, and interact with, the consultant at key points during model development.

Attachments

A. NSAB Composition and Member List
B. Guidance on Nutrient Load-Reducing Measures for Existing Development

For additional information, please see the Division of Water Quality's website for the Nutrient Scientific Advisory Board, which includes links to meeting agendas, minutes, and other relevant information: http://portal.ncdenr.org/web/wq/nutrient-scientific-advisory-board.

Appendix A

Composition and Membership of the Nutrient Scientific Advisory Board

SL 2009-216 (4)(a) calls for establishment of the Board and stipulates a membership of five to ten members with the expertise or experience quoted below. Names and affiliations of the members currently occupying the applicable seats are provided following each experience requirement.

"(1) Representatives of one or more local governments in the Jordan Reservoir watershed. Local government representatives shall have experience in stormwater management, flood control, or management of a water or wastewater utility."

1. John Cox - City of Durham
2. Trish D'Arconte - Town of Chapel Hill
3. Matt Flynn – Town of Cary
4. Josh Johnson - Cities of Mebane and Graham, Towns of Elon and Gibsonville
5. Michael Layne - City of Burlington
6. David Phlegar - City of Greensboro

"(2) One member with a least 10 years of professional or academic experience relevant to the management of nutrients in impaired water bodies and possessing a graduate degree in a related scientific discipline, such as aquatic science, biology, chemistry, geology, hydrology, environmental science, engineering, economics, or limnology."

7. Dr. Lawrence Band – UNC Institute of the Environment

"(3) One professional engineer with expertise in stormwater management, hydrology, or flood control."

8. Dr. Bill Hunt - NCSU Department of Biological and Agricultural Engineering

"(4) One representative of the Department of Transportation with expertise in stormwater management."

9. Matt Lauffer – NC DOT Hydraulics Unit

"(5) One representative of a conservation organization with expertise in stormwater management, urban landscape design, nutrient reduction, or water quality."

10. Grady McCallie – NC Conservation Network

Appendix B

Guidance on Nutrient Load-Reducing Measures for Existing Development

Introduction

This guidance identifies practices that are currently available to local governments and other parties subject to existing development requirements of the Jordan and Falls nutrient strategies for reducing nutrient loads from developed lands. The Nutrient Sensitive Waters Scientific Advisory Board, established under Session Law 2009-216, collaborated with Division of Water Quality staff to develop this guidance as required by the session law. While formal approval of these practices is the responsibility of the NC Environmental Management Commission and is scheduled for July 2013 as part of a model program for existing development, the Board understands that the practices identified as available in this guidance will be included in that model program. This guidance also identifies the load reduction credit assignment methods currently supported by the Division of Water Quality for these practices, and calculates ranges of potential load reductions produced by these methods. Costs for installation and maintenance of practices are drawn from published reports and combined with load reduction ranges to provide ranges of cost-effectiveness. Other benefits of practices are identified and discussed, and information on the feasibility of implementing practices is summarized.

Beyond the currently creditable measures recognized here, the Board has identified a range of additional measures that will be evaluated for credit potential. Those measures are also identified in this guidance. They range widely in their potential for near-term creditability. We will continue to work with the Division to expand the set of approved practices for nutrient purposes, and have identified a subset of additions for inclusion in the Division's model program scheduled for July 2013 Commission approval. Certain other practices will likely be completed in the foreseeable future beyond July 2013.

The Board recognizes the precedent-setting nature of existing development stormwater requirements in this state and our role in providing direction and tools for local governments and state and federal entities in Jordan and Falls Lake watersheds and potentially beyond. We share the keen interest of affected parties in having additional, more cost-effective and diverse options for addressing load reduction needs for existing development and we are committed to securing such measures in as timely a manner as possible.

Background

Session Laws 2009-216 and 2009-484 established staged implementation requirements for local governments and state and federal entities in the Jordan Lake watershed, aimed at reducing nutrient loading from existing developed lands. In addition, given the precedent-setting nature of the requirements in this evolving area of technology, the drafters of the session law felt it was important to include a process for evaluating current practice and providing guidance to local governments in Jordan and other watersheds that may face similar requirements in the future. Therefore, SL 2009-216 also established a Scientific Advisory Board for nutrient-impaired waters. As specified in the legislation, six of the Board's ten members are representatives of local governments in the Jordan Lake watershed, while the remainder represent DOT, the conservation community, water quality science and stormwater engineering expertise (see Attachment A for Board composition and membership).

The Board is charged with completing certain tasks by July 2012 that will facilitate stormwater management on existing development in the state:

(1) *Identify management strategies that can be used by local governments to reduce nutrient loading from existing development.*
(2) *Evaluate the feasibility, costs, and benefits of implementing the identified management strategies.*
(3) *Develop an accounting system for assignment of nutrient reduction credits for the identified management strategies.*
(4) *Identify the need for any improvements or refinements to modeling and other analytical tools used to evaluate water quality in nutrient-impaired waters and nutrient management strategies.*

In both the Jordan and Falls watersheds, the products of these tasks will be used by the Department to develop a model program for EMC approval by July 2013. In the Falls watershed, local governments will use the model program to prepare and submit programs for Division review in January 2014, while the local governments simultaneously begin implementing those programs. In the Jordan watershed, the model program will be used by local governments in the Upper New Hope subwatershed to develop and implement their programs as early as 2014, contingent upon results of monitoring in the corresponding arm of Jordan Lake to be reported by the Division in March 2014. Haw and Lower New Hope subwatershed communities in the Jordan watershed face corresponding requirements based on March 2017 monitoring results.

This guidance addresses Items (1) through (3) above, and is provided as Appendix B to the Board's 2nd annual report to the Secretary of the Department of Environment and Natural Resources. The Board's recommendations addressing Item (4) are offered primarily for the Department's consideration, and thus are provided in the body of the annual report.

Available Nutrient Load-Reducing Measures and Credit Accounting

Session Law 2009-216 tasked the Board with identifying management strategies that can be used by local governments to reduce nutrient loading from existing development toward meeting nutrient strategy regulatory requirements. At present, the available options are those currently used to meet new development requirements as well as certain procedural measures involving developed and developing lands. These measures have established accounting methods for estimating load reductions, and substantial improvements to the central accounting tool were recently approved by the Environmental Management Commission.

The Board anticipates that additional load-reducing options will become available in the near future. The primary focus during our first two years of activity has been to guide development of a watershed model that will yield assignments of existing development load allocations and load reduction requirements to local jurisdictions and state and federal entities in the Jordan Lake watershed. A contract has now been initiated for this modeling, and the Board and Division are finalizing selection of a consultant to carry out the modeling over the next year and a half. With that process launched, the Board will now devote its primary attention to guiding development of additional measures and their accounting. Specifics of upcoming activities are provided in the sections that follow.

Structural Stormwater Practices (Stormwater BMPs)

Structural stormwater practices currently in use for new development load reduction are equally suitable for existing development. Table 1 below identifies these practices and associated accounting methods approved by the Commission. Most of these measures can be found in the Division's Stormwater Best Management Practices Manual and are used to meet new development requirements under Neuse and Tar-Pamlico nutrient strategies. These practices will also be used to meet new development requirements of the Jordan and Falls rules, which are scheduled for local implementation beginning in July through late 2012. The accounting tool for most of these measures, the Jordan/Falls Nutrient Load Accounting Tool, was developed by stormwater researchers with the NCSU Biological and Agricultural Engineering Department, and was approved by the Commission in March 2011 as the compliance tool for new development activities in the Jordan and Falls watersheds.

A challenge with applying stormwater BMPs to existing developed landscapes is that drainage and space constraints can result in practices being undersized or oversized for the available catchment. An innovation incorporated in the Jordan/Falls tool is the option of oversizing or undersizing BMPs for commensurate additional or reduced nutrient reduction credit. The Board considers this a valuable addition for existing development purposes. The tool can be found at http://portal.ncdenr.org/web/jordanlake/implementation-guidance-archive.

To help gauge the relative benefit of stormwater BMPs, Table 1 includes for each one ranges of estimated percent removal efficiency of nitrogen and phosphorus that result from applying the Jordan/Falls Tool to the full range of possible development land cover types, from zero to 100% impervious. This is detailed further in the "Load Reduction Cost Effectiveness" section.

The Jordan existing development session law includes a requirement that load assignments be set and load reductions be calculated and judged in terms of delivered-to-lake values. The original Jordan watershed model included delivery factors for all 58 14-digit hydrologic units comprising the Jordan watershed. Table 1 identifies these delivery factors as appropriate for estimation of delivered fractions of at-source N and P loads produced by the Jordan/Falls Tool. The Division does not propose the use of delivery factors in the Falls watershed. Assessment made as part of the Falls watershed modeling found that nutrient delivery differences were sufficiently small from disparate points within that watershed, which is roughly half the size of Jordan and more concentrically shaped, to reasonably forego the additional regulatory complication involved with applying delivery factors.

Other Available Load-Reducing Measures

In additional to conventional stormwater BMPs, Table 1 identifies a number of other practices that may be available to affected parties. Several are procedural options for local governments, while others identify creditable modifications to developed or other land covers.

Procedural Practices:

- Redevelopment projects that exceed land disturbance thresholds and increase built-upon area are required by state new development rules to reduce loads. In these cases, by implementing state requirements loads are being reduced from existing developed lands, and local governments and state or federal entities may credit those net reductions towards their existing development needs. Over time, a local government could make substantial progress toward existing development goals.
- Local governments could also go beyond state minimums on redevelopment and require through ordinance load reductions on redevelopment that does not increase built-upon area. Again the local government could retain the net load reductions from the previously developed condition toward existing development needs.
- Local governments could by ordinance set more stringent loading rate targets for new development than those required by the state and retain the 'extra' reductions toward existing development needs. This would include obtaining treatment on development projects that fall below the state's new development loading rate targets without treatment. This option would be more feasible for Lower New Hope and Haw watershed communities, where state loading rate targets are not particularly stringent.
- Local governments could adopt ordinances that require treatment on other new development that is not required to treat under the state's new development rules. This would include development that does not exceed land disturbance thresholds or projects that would be vested under the state's implementation timeframes.

- Local governments could purchase nutrient reduction credits from private banks or the NC Ecosystem Enhancement Program.

Land Cover Modification Practices:

- Removal of existing impervious cover or replacement of existing pavement with permeable pavement would decrease runoff and increase infiltration, decreasing nutrient loading. Local governments could seek such opportunities on lands they control or on private lands. To facilitate such projects, communities could revisit parking requirements in existing ordinances for the potential to reduce mandates, to allow for shared parking, or other approaches.
- Reforestation of managed open space on developed lands combined with protection through conservation easement or other protective instrument could decrease runoff and nutrient loading. Using the Jordan/Falls Tool, the load reductions attributed to conversion of managed landscape to forest are over 50% for both nitrogen and phosphorus.

Riparian Buffer Restoration:

Local governments and state and federal entities may restore riparian buffers on developed or agricultural lands where riparian zones are currently under cultivation or other managed vegetative cover. Buffers restored to meet other regulatory mitigation requirements may not also be credited for existing development purposes. Nutrient load reductions are estimated using the Division's credit yield calculation method, available at http://portal.ncdenr.org/web/wq/nutrient-offset-practices.

Table 1. Load-Reducing Practices with DWQ-Approved Accounting

Practice[1]	Accounting Method	Removal Efficiency	Description
Stormwater Wetland	Jordan/Falls Tool[2] + DF[3]	TN = 32 - 56% TP = 61 - 86%	• Runoff routed to BMP, treated • Fixed effluent concentration • Volume reduction via ET, infiltration
Bioretention w/ IWS **Bioretention w/o IWS**	Jordan/Falls Tool[2] + DF[3]	TN = 61-73% TP = 61 - 84% TN = 48 - 66% TP = 49 - 80%	• " • " • " • Internal Water Storage improves N removal
Wet Detention Basin	Jordan/Falls Tool[2] + DF[3]	TN = 28 - 52% TP = 34 -76%	• " • " • "
Sand Filter	Jordan/Falls Tool[2] + DF[3]	TN = 30 - 55% TP = 17 - 75%	• " • " • "
Level Spreader + Filter Strip	Jordan/Falls Tool[2] + DF[3]	TN = 48 - 66% TP = 43 - 88%	• " • " • "
Dry Extended Detention Basin	Jordan/Falls Tool[2] + DF[3]	TN = 8 - 41% TP = -21 - 75%	• " • " • Volume reduction via ET, infiltration in Coastal Plain/Sandhills
Grassed Swale	Jordan/Falls Tool[2] + DF[3]	TN = 8 - 50% TP = -59 – 78%	• " • " • Volume reduc via ET, infiltration CP/Sandhills
Green Roof	Jordan/Falls Tool[2] + DF[3]	TN = 50 - 51% TP = 48 – 76%	• Direct precipitation to BMP • No nutrient treatment - fixed effluent concentration equal to roof EMC • Volume reduction via ET • Can be routed to stormwater system (see Rainwater Harvesting)
Permeable Pavement - CP/Sandhills	Jordan/Falls Tool[2] + DF[3]	TN = -10 – 35% TP = -82% - 65%	• Direct precipitation, option of routed runoff • Currently case-by-case approval, soil infiltration > 0.52 in/hr - Coastal Plain/Sandhills • No nutrient treatment - fixed effluent concentration equal to parking lot EMC • Volume reduction via infiltration CP/Sandhills

[1] To qualify, practices shall meet design specifications in current version of DWQ Stormwater BMP Manual except as noted.
[2] *Jordan/Falls Lake Stormwater Nutrient Load Accounting Tool*, approved by NC EMC March 2011 for load compliance accounting under Jordan & Falls New Development rules. Uses the Simple Method, does not account for stormwater routing. Recommended only for catchments ≤ 1mi^2 (640 acres).
[3] For Jordan watershed applications only, nonpoint source N, P delivery factors translating 14-digit HU loads to lake-delivered loads. Estimated with SPARROW-based Stream Network Delivery Model by Tetra Tech, Inc. for DWQ. Approved by NC EMC 11/03. Delivery factors available at http://portal.ncdenr.org/web/jordanlake/home.

Table 1 (continued). Load-Reducing Practices with DWQ-Approved Accounting

Practice[1]	Accounting Method	Description
(Rooftop) Rainwater Harvesting (See also Table 2a)	Jordan/Falls Tool[2] + DF[3]	***DWQ Technical Guidance Memo:*** • Runoff routed to storage, then to dedicated use • Case-by-case approval, incl. dedicated end use • No nutrient reduction by roof - fixed effluent concentration equal to roof EMC • Treatment/volume reduction are use-specific • If stormwater BMP used, storage reduces size • Dedicated use may not be vegetated area
Require Treatment of New Development Where DWQ Does Not	Jordan/Falls Tool[2] + DF[3]	Require treatment on new development that DWQ New D rule does not require, i.e. not above loading rate targets or land disturbance thresholds, or vested
Overtreatment of New Development	Jordan/Falls Tool[2] + DF[3]	Require development to meet loading rate targets below New Development Rule requirements.
Load Reduction on Redevelopment	Jordan/Falls Tool[2] + DF[3]	1. Quantify net load reduction credit on redevelopment that increases BUA and is thus required to treat under New Development Rule. 2. Require treatment on redevelopment that is not otherwise required to treat under New Development rule - no increase in BUA or below land disturbance thresholds.
Removal of Impervious Surface	Jordan/Falls Tool[2] + DF[3]	Replace impervious with pervious cover, increasing infiltration and decreasing runoff.
Restoration of Riparian Buffer (See Also Table 2b)	DWQ Credit Yield Calculation[4] + DF[3]	• Diffuse inflow required, e.g. level spreader • Load reduction via up to 3 mechanisms: 1. Treatment of catchment drainage 2. Treatment of overbank flooding 3. Land conversion of buffer footprint • Mitigation under Buffer Rule not eligible. • Buffer required on New Development ineligible.
Upland Reforestation on Developed Land (See also Table 2b)	Jordan/Falls Tool[2] + DF[3]	Requires conservation easement or other protective covenant.
Payment to EEP or Private Bank	DWQ Credit Yield Calculation[4] or Jordan/Falls Tool[2]	Calculation method dependent on practice. See above.

[1] To qualify, practices shall meet design specifications in current version of DWQ Stormwater BMP Manual except as noted.

[2] *Jordan/Falls Lake Stormwater Nutrient Load Accounting Tool*, approved by NC EMC March 2011 for load compliance accounting under Jordan & Falls New Development rules. Uses the Simple Method, does not account for stormwater routing. Recommended only for catchments $\leq 1 mi^2$ (640 acres).

[3] For Jordan watershed applications only, nonpoint source N, P delivery factors translating 14-digit HU loads to lake-delivered loads. Estimated with SPARROW-based Stream Network Delivery Model by Tetra Tech, Inc. for DWQ. Approved by NC EMC 11/03. Delivery factors available at http://portal.ncdenr.org/web/jordanlake/home.

[4] N and P load reduction estimate for riparian buffer restoration, developed by DWQ and NCWRP, 1998. Used as credit value in setting of EEP and private bank nutrient offset rates for buffer restoration under stormwater rules for Neuse, Tar-Pamlico, Jordan and Falls watersheds. Available at http://portal.ncdenr.org/web/wq/nutrient-offset-practices.

Costs of Available Measures

While costs for installation of conventional stormwater BMPs on greenfield development are fairly well-known, costs for retrofitting of practices into existing developed landscapes are less common and more uncertain, reflective of the young state of retrofitting experience in general. A 2007 Chesapeake Bay region study was perhaps the first to estimate practice-specific multipliers for retrofitting of BMPs (CWP, 2007). That study found that the challenges of retrofitting could increase costs anywhere from 50% to seven-fold depending on the practice.

In North Carolina, stormwater researchers at NCSU recently released the fullest state-specific retrofit cost projections to date as part of a retrofit feasibility study in small watersheds in seven of the state's largest municipalities under a Section 319 grant (Hunt, Hatch and DeBusk 2011). The cost numbers in Tables 2 and 3 below are drawn from this study. These values include planning/design, permitting and construction. They represent retrofit cost projections for conventional and certain 'green' stormwater practices based on previously developed cost formulas with the CWP retrofit factors applied. Construction costs were increased by 35% for the planning/design and permitting based on guidance in the CWP study.

Table 2 presents costs per acre of drainage area as a practical basis for comparison. Practices are ordered from least to most expensive. The range in cost for a given BMP reflects the impact of land cover type, which was varied from zero to 100% impervious cover; increased impervious percentage and resulting runoff volume increases the cost of BMPs to varying degrees. Practices in which runoff can be stacked vertically after meeting basic dimension-setting criteria show no increase in cost with added storage volume.

Table 2. Projected Stormwater BMP Retrofit Costs for North Carolina - Planning, Design, Permitting and Construction Cost (based on Hunt, Hatch and DeBusk, 2011)

Retrofit Practice	Cost per Acre of Drainage Area ($/Ac D.A.)
Constructed Wetland	$700 - $25,600
Level Spreader/Filter Strip	$2,000
Dry Detention	$1,200 - $11,600
Bioretention w/o IWS	$2,600 - $139,000
Grassed Swale	$3,100 - $58,200
Rainwater Harvesting	$3,600 - $70,000
Bioretention with IWS	$3,900- $139,000
Sand Filter	$16,000 - $300,000
Wet Detention	$31,000
Permeable Pavement	$560,000
Green Roof	$1,050,000

The values in Table 2 do not include land purchase or long-term operation and maintenance costs. The extent to which local governments and others will ultimately purchase or pay full market value for retrofit lands under these regulations is not yet known. Certain retrofits – green roofs, permeable pavement, rainwater harvesting – likely do not require land acquisition. Operation and maintenance costs do become substantial over the life of a practice, eventually leading to repair, renovation or replacement costs. Given that stormwater quality regulatory programs around the country really only got underway in the 1980's and 1990's, data on the long-term costs of maintaining stormwater practices are emerging now.

Table 3 provides costs for additional practices also projected by Hunt, Hatch and DeBusk. The unit costs for planning/design, permitting and construction (with the exception of streetsweeper) of these 'green' practices are useful for general information purposes.

Table 3. Projected Stormwater BMP Retrofit Costs – Planning, Design, Permitting and Construction (based on Hunt, Hatch and DeBusk, 2011)

Practice	Estimated Construction Cost
Blue Roof	\$20 per 1 ft^2 of surface area
Daylight Downpsouts	\$68 per downspout
Level Spreader	\$2000 each
Proprietary BMP	\$23,000 per acre of impervious surface treated
Constructed Wetland	\$26,200 per acre of impervious surface treated
Street Sweeper	\$375,000 per streetsweeper

Benefits of Available Measures

We first discuss nutrient load reduction cost-effectiveness as the benefit of primary interest, followed by other, non-nutrient benefits that local governments and other affected parties will weigh into decisions on whether to install practices within their jurisdictions.

Nutrient Load Reduction Cost-Effectiveness: Beyond percent nutrient removal efficiencies of BMPs in Table 1, cost-effectiveness provides greater insight into the overall nutrient benefit of a practice. Division of Water Quality staff developed nutrient reduction cost-effectiveness estimates for stormwater retrofits by combining the retrofit cost projections from Table 2 above with load reduction ranges estimated with the Jordan/Falls Tool. Results appear in Table 4 below. Practices are arranged in general order of increasing cost-effectiveness for nitrogen removal.

For a given BMP type, both cost and load reduction are affected by the land cover mixture draining to the practice. Load reduction ranges were developed for each BMP by varying land cover through the range of impervious fractions and cover types, with the extremes represented by 100% parking lot and 100% forest. In estimating total load reductions over a BMP's lifespan to allow pairing against BMP cost, a life expectancy of 20 or 30 years was assumed; 30 years was used at the most cost-effective end of the range and 20 years at the least cost-effective end. As noted in the cost description above, installation costs do not include land acquisition or operation and maintenance costs.

Table 4. Projected Cost-Effectiveness of Retrofit Practices Based on Jordan/Falls Accounting Tool and Table 2 Costs

Practice	$/lb N removed	$/lb P Removed
Level Spreader/Filter Strip	$8 - $200	$8 - $300
Constructed Wetland	$18 - $236	$76 - $1,600
Dry Detention	$50 - $440	$34 - $3,900
Bioretention with IWS	$80 - $670	$300 - $54,000
Bioretention w/o IWS	$85 - $850	$320- $6,700
Rainwater Harvesting	$90- $1,000	$170 – $8,200
Grassed Swale	$146 - $2,200	$164 - $1,700
Wet Detention	$220 - $5,300	$100 - $7,300
Sand Filter	$630 - $2,900	$2,200 – $42,800
Permeable Pavement	$2,000 - $3,000	$7,300 – 26,500
Green Roof	$4,900 - $7,400	$35,400 - $53,100

Table values suggest that some practices can be very cost-effective at either nitrogen or phosphorus removal. Phosphorus removal generally tends to be roughly an order of magnitude less cost-effective than nitrogen, but this is generally offset by comparably lower rates of phosphorus loss from the landscape, putting phosphorus benefit roughly on par with nitrogen. However, it can be seen that the ranking of relative cost-effectiveness for phosphorus removal does not track consistently with that of nitrogen. This is due to several differences between the two nutrients including landscape sources, movement forms and removal mechanisms. The different relative value of practices for phosphorus removal compared to the rank order for nitrogen removal implies that depending on the nutrient of greater concern, a different prioritization of practices should be considered.

Based on our calculations, permeable pavement is one of the least cost-effective practices for nitrogen removal. We note that our calculation assumed the only input to the practice was direct rainfall. If permeable pavement is allowed to receive runoff from other areas, its cost-effectiveness will improve proportionally. The Division is currently considering modifications to the permeable pavement design standards that will broaden its applicability and may allow for it to receive runoff from other surfaces.

The rainwater harvesting practice allows variation in the type and level of dedicated water reuse. For this calculation, the range of water reuse and volume reduction assumed was 20% and 90%.

Other Benefits: The Board identified a number of other benefits of stormwater BMPs in addition to nutrient load reduction. Local governments will likely consider one or more of these factors to some degree when choosing existing development practices. For this report, we simply identify these several categories of other benefits. It may be useful to summarize basic findings from study on these other benefits in a future report.

- Other Water Quality – In addition to nutrient removal, most practices capture and treat other pollutants in stormwater runoff to varying degrees, including sediment, pathogens and metals. Most practices also reduce to hydrologic impacts to receiving waters.
- Ecosystem Services – This term refers to the collective benefits of resources and processes supplied by natural ecosystems to humans and other wildlife. This is a fairly young and growing area of study. Information on ecosystem services research can be found at the following EPA website, http://www.epa.gov/research/ecoscience/. The term "ecosystem services" in relation to stormwater practices can cover a wide variety of benefits, including most of the other benefits listed in this report.
- Jobs – Practices have the potential to create new jobs. The planning, design, permitting, installation and long-term inspections and maintenance of BMPs all generate work.
- Groundwater Recharge – Many stormwater practices capture and detain stormwater, and result in infiltration. Table 5 lists the percent volume reductions attributed to practices in the Jordan/Falls Tool. The values in the table represent volume reduction in the Piedmont region. Greater reductions would be achieved in the coastal and sandhill regions, and less reduction occurs in the Triassic basin and the mountain regions.

Table 5. Volume Reductions Attributed to BMPs in the Piedmont Region, Jordan/Falls Stormwater Nutrient Load Accounting Tool

Practice	Volume Reduction
Bioretention with IWS	50%
Bioretention w/o IWS	35%
Dry Detention	0%
Grassed Swale	0%
Green Roof	50%
Level Spreader/Filter Strip	40%
Permeable Pavement	0%
Sand Filter	55
Rainwater Harvesting	User defined
Wet Detention	10%
Wetland	20%

Recharge is beneficial for a variety of reasons. Infiltrated water is filtered as it makes its way to the groundwater. In the Piedmont, the majority of community water supplies are surface waters, which are fed in part by shallow groundwater. Greater infiltration of runoff helps to shift the hydrology of developed areas back toward undeveloped conditions. This generally decreases the extreme peaks of stormflows in streams, returning more rainfall to shallow groundwater that feeds baseflows, moderating and better distributing stream flow to reservoirs across wet and dry seasons, making for more reliable water supplies.

- Stream Recovery – In urban environments, streams are typically degraded by hydrologic changes resulting from the addition of impervious surfaces, enhancement of drainage networks and soil compaction. Urban streams become destabilized, undercut and erode their banks, exacerbate flooding problems, and become poor aquatic habitats. Flooding and loss of property are direct human impacts. Stormwater practices may benefit stream recovery through peak flow attenuation and reduction in stormwater runoff, aiding in flood control. Recovering the stream could potentially add recreational sites for swimming, boating and fishing. It may also improve aesthetics and provide wildlife habitat.
- Amenity - Different practices offer different amenity values. For example, bioretention is often used as part of the landscape, and may offer a flexible adaption to urban retrofits. Wetlands can also be aesthetically pleasing when properly landscaped and maintained and can provide an excellent habitat for wildlife. Filter strips are very cheap and only require a stable vegetated area. They also can be used to effectively meet the diffuse flow requirements of the buffer rules. Green roofs are considered valuable for energy savings and for the added green space and urban refuge they can offer a property owner.

Feasibility of Measures

Item (2) of the Board's charge (provided in the Background section of this document) calls for it to:

> *(2) Evaluate the feasibility, costs, and benefits of implementing the identified management strategies.*

The feasibility element may be interpreted at several levels. The broadest sense that fits the context may be the practical achievability of compliance with the overall existing development regulatory reduction requirements across Jordan watershed communities by implementing the range of currently creditable practices. In this respect, the Board would consider it premature to offer such summary judgments of feasibility. Below we identify key factors that challenge attempts to evaluate feasibility at this level.

However, at perhaps the next narrower level of feasibility assessment, the watershed scale, several studies have been completed in communities around the state since the NSAB/Jordan session law was enacted, and they begin to put bounds on our understanding of the feasibility of using the current suite of practices to make meaningful watershed load reductions. We provide relevant findings from those studies below.

A different and perhaps narrower view of the feasibility term as used in the session law would be to separately evaluate the practicality of individual management practices in various developed landscapes. The same studies mentioned above shed light on this question as well, and we provide summary points below. These findings may offer the most useful insights of general applicability available for the state at this point.

Of course, evaluation of individual practice feasibility ultimately becomes a site-specific determination. Such evaluation would likely start from calculated ranges of load reduction cost-effectiveness, would factor in a range of quantifiable site-specific issues, and may include qualitative weighing of intangible benefits and liabilities. We identify a set of site-scale considerations below that may be informative for local governments.

Feasibility of Local Compliance with Jordan Existing Development Goals

The Board believes it is premature at this point to offer judgments on the overall feasibility of compliance with the Jordan session law requirements for existing development. The following factors inform this view:

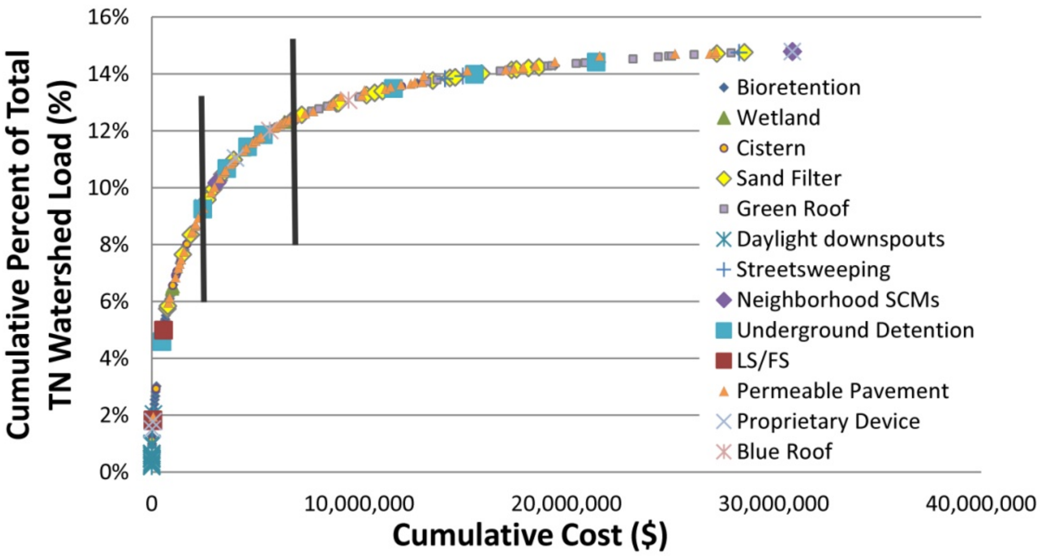
- The Board and the Division fully intend to establish credit for any number of additional measures in the coming years, which will presumably provide not only additional opportunities on the landscape but also more cost-effective options. The set of practices identified in this report has been limited by Board and staff time constraints to essentially those with established, state-supported load reduction credit values.
- A fundamental procedural element of the session law is that compliance timeframes are not specified. The law allows local governments to propose time horizons for achieving the goals. Implications of this regulation are:
    - Presumably feasibility will not be jeopardized by insufficient funds, as the pace of implementation will likely be tailored to local budget projections; and
    - The greater the time span allowed for compliance:
        - The greater the opportunity for scientific and technical advances to support additional and more cost-effective management options.
        - The greater the likely extent of shifts in land use, particularly in terms of redevelopment that can be required to treat its runoff to produce creditable load reductions.

Feasibility of Substantial Watershed-Scale Load Reductions

Three studies completed in North Carolina subsequent to enactment of the NSAB/Jordan session law do suggest that cost-effective load reduction potential on developed lands is limited based on the currently creditable set of practices. Importantly, two of the studies characterized points of diminishing returns in terms of cumulative load reduction per cumulative dollar spent. Watershed percent reductions projected as cost-effectively attainable differed between the two studies, but ranged from approximately 5% to 30% for nitrogen and approximately 6% to 40% for phosphorus. Less optimistically, the third study projected that implementation of all available practices at all identified sites in the study watershed, as opposed to only the most cost-effective options, could achieve a total of only about 13%

reduction in nitrogen load and about 16% reduction in phosphorus load. Figure 1, a nitrogen cost-benefit relationship for one study watershed illustrates the diminishing returns concept.

Figure 1. Sample Watershed Cumulative TN Load Reduction vs Cumulative Cost Projection (from Hunt, Hatch and DeBusk, 2011)



While the diminishing returns effect described here is not surprising, we also recognize the potential for the addition of other practices and procedures to improve the reduction levels at which it occurs. Local government procedures could include requiring treatment on redevelopment. In fact, where redevelopment yields a net increase in impervious cover, treatment is required by the Jordan and Falls New Development rules and reductions will be creditable toward existing development requirements. We also recognize that the nutrient strategies allow local governments to use load reductions obtained by other sources that are not used toward those sources' requirements. Such reductions could include those obtained by requiring overtreatment of new development or treatment of redevelopment that does not increase impervious cover. Other factors that could improve reductions include that these studies did not evaluate the potential for altering existing land covers such as removing pavement, and did not consider the potential for installing practices without having to purchase the land. Altogether, the percent reduction values identified in this report as points of diminishing returns should not be assumed as the limits of existing development reduction potential.

Summaries of the three studies mentioned above are provided in the following paragraphs.

North Buffalo Creek Watershed: A retrofit study was completed for the City of Greensboro in March 2012 (CDM, 2012) on the urbanized 44 mi^2 North Buffalo Creek watershed, located in Jordan's Haw subwatershed. The study watershed comprises one USGS 12-digit hydrologic unit that encompasses much of downtown Greensboro and includes about 37% coverage in the more intensively developed land use categories of commercial, industrial, institutional, multi-family and office. Single family residential land use occupies approximately 44% of the watershed. The study used a GIS and data-based candidate site selection process followed by field screening to evaluate the watershed's potential for retrofitting with currently creditable stormwater BMPs plus stream restoration. Results suggested a cost-effective cutoff point in BMP implementation that would yield estimated watershed load reductions of 5.7% TN and 8.3% TP, with approximately 22% of the watershed area treated and 20-year cost-effectiveness values ranging from $3 to $366 per pound nitrogen and from $18 to $1,307 per pound phosphorus.

Ellerbe Creek Watershed: A retrofit study was completed for the City of Durham in December 2009 (Brown and Caldwell, 2009) on the predominantly urban 37 mi^2 Ellerbe Creek watershed, located in the upper Falls Lake watershed. Commercial, industrial, institutional, right-of-ways and high density residential lands occupy 33% of the watershed while other residential covers 41%. Similar remote and field inventories to the first study were used to evaluate retrofit opportunities for a similar set of practices. The study projected that implementation of all available practices at all identified sites in the study watershed, as opposed to only the most cost-effective options, could achieve a total of only about 13% reduction in nitrogen load and about 16% reduction in phosphorus load.

Urban Stormwater Consortium Watersheds: In 2011, investigators at North Carolina State University completed a Section 319-funded retrofit feasibility study of nine watersheds in seven municipalities - six Piedmont and one Coastal Plain – that participate in the WRRI Urban Stormwater Consortium (Hunt, Hatch and DeBusk, 2011). These watersheds were much smaller than those in the first two studies, ranging from .52 to 1.9 mi^2. They were chosen to span the range of developed land use types. Similar remote and field inventories to the first two studies were used to evaluate retrofit opportunities. A similar set of practices was considered as well as several alternative practices – blue roofs, cisterns, proprietary devices, downspout daylighting, street sweeping and underground detention. Results indicated that use of the most cost-effective measures could yield watershed N and P reductions ranging from 4 to 32% and 6 to 42% respectively. Results also suggested that achieving N and P reductions in excess of 20% and 50% respectively would be very difficult in the watersheds studied. The investigators found that the inflection point toward diminishing returns would occur after implementation of approximately one-third to one-half of all candidate practices identified. N reductions of 15% correlated to treatment of 40% of watersheds' surface area.

This study also provided insights on the developed land use types most conducive to retrofitting. While ultra-urban and downtown areas varied greatly in their retrofit potential, most institutional, commercial and industrial areas provided substantial retrofit opportunities. In general, older residential areas afforded opportunities while newer ones were more limited. Roadways provided perhaps the fewest opportunities due to space constraints and the presence of utilities.

Individual Practice Feasibility

As noted in the introduction to this feasibility discussion, practice feasibility and cost-effectiveness are ultimately site-dependent outcomes. Site factors that can influence these parameters include:

- Physical: utility conflicts, space constraints, slope, bedrock, catchment size, depth to storm water system, outfall suitability.
- Logistical: scale economy, serial inefficiency, maintainability.
- Temporal: future changes to drainage area.
- Social: landowner willingness, public acceptance.
- Regulatory: permitting hurdles.

In addition to site factors, as discussed in the cost-benefit section above, the decision to install a given measure on a given site also depends not only on nutrient reduction cost-effectiveness but consideration of other, often less quantifiable benefits. In the overall consideration of practices, different measures will likely have their strengths and more suitable site types, and some measures will likely prove to be more useful more often. To some extent, this will be determined once local programs are implemented.

The 2011 NCSU study also provided valuable insights on relative cost-effectiveness of individual practices. It aggregated projected cost-effectiveness trends of practices across land use types and watersheds. Cost-effectiveness also varies by nutrient, however three practices proved most cost-effective for both N and P removal: level spreader-vegetated filter strips; constructed wetlands; and bioretention. The following table summarizes the study's findings on the aggregate cost-effectiveness of practices. Measures are listed in descending order of aggregate cost-effectiveness.

Table 6. Most Cost-Effective Stormwater Control Measures with Respect to Cost per Kilogram of Nutrient Removed, in Descending Order (from Hunt, Hatch, and DeBusk, 2011)

Most Cost-Effective at TN Removal	Most Cost-Effective at TP Removal
Daylighting Downspouts	Level Spreader-Filter Strips
Level Spreader-Filter Strips	Street Sweeping
Bioretention	Daylighting Downspouts
Stormwater Wetlands	Stormwater Wetlands
Water Harvesting	Grassed Swales
Sand Filters	Bioretention

Measures by July 2013

Session Law 2009-216 tasks the Division of Water Quality with developing a model local existing development program by July 1, 2013. The model program is to include specific load reduction practices and reduction credit associated with each practice. As outlined in the Next Steps section of this report's body, the Board anticipates using ongoing research to include additional load-reducing measures to those in Table 1 in the model program. The set of additions over the next year will likely involve diversification of design criteria for a number of current conventional and 'green' stormwater practices to make them more versatile for retrofit purposes, along with associated enhancements or curtailments to load reduction credit.

The Board has also initiated efforts to add alternative load-reducing measures to the set of options available to affected parties. Table 7 provides an initial listing of measures that will be pursued. They are grouped by practice type in five sub-tables: stormwater; ecosystem restoration; agriculture; programmatic; and wastewater. Each type includes promising candidates, including: diversion of impervious runoff to pervious areas; stream/floodplain restoration; improved street sweeping; gross solids reduction; reducing non-stormwater discharges; and remedying discharging sand filters.

A next step for the Board will be to clarify priorities within each category and among categories based on understanding of technical readiness, cost-effectiveness and implementability. For the highest priorities, we will more clearly define prioritization assumptions and actions needed. The ability to incorporate alternative measures into the 2013 model program will be limited, but additions will be made in as timely a manner as possible whether in the next year or later.

Structural Stormwater Practices

Dr. William F. Hunt, a member of the NSAB, and fellow researchers in the Biological and Agricultural Engineering Department at NCSU have in recent years made substantial contributions to broadening the set of stormwater practices available to developers as recognized by the Division of Water Quality, and to improving practice design standards and accounting. More recently Dr. Hunt has focused on diversifying design standards for existing practices to allow for varying levels of nutrient and other pollutant removal. This research would allow regulation to depart from the conventional approach of using a single set of presumptively protective design standards for each BMP, and is responsive to nutrient regulations that require specific load reductions. These innovations would make practices more adaptable, giving site designers greater flexibility on new development and local governments a larger set of opportunities on existing development. Dr. Hunt is working to bring a number of these practice adaptations that appear in Table 2a to fruition over the next several years, with several that may be available for the 2013 model program. The following adaptations to existing structural stormwater measures are currently under investigation with good potential for near-term completion:

- Permeable Pavement –This practice is currently approved for use in soils with infiltration rates greater than .52 in/hr. However, current research supports its use in less permeable soils. Based on this, in June 2012 the Division released a draft change to the permeable pavement section of its Stormwater BMP Manual that would allow its use statewide with attendant nutrient reduction credit via infiltration losses. An initial revision is expected to the BMP manual in the summer of 2012. Complementing revisions will be needed to the Jordan/Falls Nutrient Accounting Tool. These should be completed by the summer of 2013.
- Bioretention – Application of the agricultural drainage model DRAIMOD has been shown through monitoring to very accurately simulate load reductions for different designs of bioretention cells, including variations in soil type, depth, fill media, and size. A matrix of design standard combinations is planned to allow for up to 400 different design scenarios, including undersizing and oversizing options relative to catchment area, along with associated TSS and nutrient load reductions. This modeling is expected to be finished in late 2012.
- Level Spreader/Vegetated Filter Strip – A similar approach of correlating modeled nutrient values to existing research datasets for varying designs of this practice will allow the mapping of load reduction effectiveness for designs that vary all major elements such as soils, dimensions, slope, and drainage to treatment area. This work may be completed in Spring 2013.
- Grassed Swales – Research on this practice is following the vegetated filter strip approach combined with evaluation of particle size distribution and settling patterns. Expanded options may be recommended by summer 2013.
- Green Roofs – A leading green roof researcher from Australia will be visiting NCSU this fall. She has published one of the most comprehensive documents on green roofs to date. Her research could be applied to the similar North Carolina conditions for expanded options by July 2013.

Non-Stormwater Measures

Board members have also identified certain programmatic measures that communities already implement to varying degrees that we believe should result in nutrient load reductions. Certain programs initiated in recent history under other regulatory mandates or voluntarily to address non-stormwater discharges may have promise. These include programs to tighten wastewater collection systems, to remove illegal wastewater connections to stormwater systems, to educate commercial site owners on proper discharges to storm drains, to collect or pre-treat grease, and to respond to and contain sewage spills. To the extent that these activities were commenced or enhanced subsequent to the baseline period for a given nutrient strategy, and nutrient reduction values can reasonably be attributed to them, they would be creditable under that strategy.

Additional Measures Beyond July 2013

As described above, the Board will pursue development of alternative measures such as those identified in Table 7. In addition, Dr. Hunt has identified a number of stormwater practices that hold promise for diversification beyond 2013. They include:

- Rainwater Harvesting – Another practice that is currently included in the Division's BMP manual, rainwater harvesting is currently being researched to provide for essentially unlimited design combinations, including uses such as irrigation during winter months, and associated nutrient load reductions. Research findings are expected to become available by winter 2013.
- Pond Retrofits – Promising innovations that could be applied to retrofit existing stormwater volume ponds to achieve water quality benefits are floating wetland islands and upflow filters. An obvious advantage of such modifications is that no land purchase would be necessary. Initial research on wetland islands suggests that substantial areal coverage would be required to achieve meaningful load reductions. Filter retrofits would require regular maintenance to ensure continued function.
- Other practices for which flexible accounting should be possible include: constructed wetlands; sand filters; soil amendments; grassed swale modifications; and proprietary devices.

Approval Process for Alternative Measures

Board discussions have highlighted an interest in the Division of Water Quality developing a more structured approval process for additional nutrient load-reducing measures than is currently available. Board members see value in providing a clear path and approval standards that would more effectively stimulate affected parties to seek innovative solutions. The Division currently has an explicit process for approval of proprietary practices, but this is considered overly burdensome for the purposes described here. The Division is open to developing such a process and has begun to consider standards that would provide reasonable assurance for nutrient strategy purposes, including:

- Applicability of available data – climatic, physiographic, loading source characteristics
- Richness of available data
- Quality of available data
- Existing depth of scientific knowledge on measure's process elements
- Measure specifications
- Potential approval tiers based on uncertainty, risk level

The Board hopes to work with the Division to substantially develop such an approval process for inclusion in the 2013 model program.

Table 7. Potentially Creditable Nutrient Load-Reducing Practices
Table 7a: Stormwater Practices

Practice	Potential Accounting Method	Description
Permeable Pavement (See also Table 1)	Modify Jordan/Falls Tool[2]	Statewide infiltration credit, soil-specific
<u>Table 1 BMP Modifications:</u> • **Rainwater Harvest** • **LS/Filter Strip** • **Bioretention** • **Green Roof** • **Permeable Pavement** • **Grass Swales**	Jordan/Falls Tool[2]& DF[3]	Various research efforts in progress - Dr. Hunt: • Credit updates based on additional research • Design modifications for improved removal • Undersize/oversize treatment effects
Retrofit Stormwater Ponds: • **BMP Manual Designs** • **Floating Wetlands**	Jordan/Falls Tool[2]	Improve volume control ponds for nutrient removal
Infiltration Devices, including Infiltration Basins	Modify Jordan/Falls Tool[2]	• SW routed to BMP, fully infiltrated • Data needed: effluent concentrations, volume reduction • Consider using BMP manual specs
Rainwater Harvesting (See also Table 1)	Modify Jordan/Falls Tool[2]?	Expand dedicated uses to allow for directing SW to vegetated area for infiltration
Divert Impervious Runoff to Pervious Areas	Modify Jordan/Falls Tool[2]	Develop criteria, e.g.: o Area & dimensional ratios o Soil and slope variables
Soil Amendments	Calculation based on literature findings	Reduce runoff volume via improved infiltration
Repairing Failing BMPs or Updating Design Standards	Jordan/Falls Tool[2]	• Investigate potential with DWQ SPU • Would require evidence of failure during baseline
Off-line Regional Treatment	Jordan/Falls Tool[2]	Route large catchment to treatment with ponding retrofit practice
Proprietary Devices	Depends	• DWQ has process for evaluating and approving • Credit BMP-specific o Tree boxes, hydraulic vortex units….
Peak Flow Control	Watershed Remodel?	• Study load benefits instream • Flow Modification • Prevent Erosion

Abbreviations:

- BMP = Best Management Practice
- BUA = Built-upon area
- DF = Delivery Factors
- EMC = Event Mean Concentration
- ET = Evapotranspiration
- IWS = Internal Water Storage
- PP = Permeable Pavement
- SW = Stormwater
- WW = Wastewater

Table 7b: Ecosystem Restoration Practices

Practice	Potential Accounting Method	Description
Riparian Buffer Restoration, Variable Width	DWQ Draft Method & DF[3]	• DWQ Draft Method o Diminishing credit with increased width o Site-specific elements
Repairing/Enhancement of Existing Riparian Buffers	Watershed Model or separate calculation (additional data required)	• Literature review, research • Potential Activities o Hydrologic restoration including diffuse flow o Removal of invasive species • Credit will depend on type of improvement
Stream restoration	Calculation based on literature findings	• Reduce erosion of stream bank soils • Restore stream assimilation functions
Flood Plain Restoration	DWQ Draft Credit Yield Method?	• Increase floodplain storage; encourage stream to overflow in larger storms; increase infiltration; remove structures; add grade-control structures, etc.
Increase Tree Canopy	Calculation based on literature findings or WS Remodel	• Reduce runoff via interception – potential volume/load reduction • Requires means of tracking and assurance of long-term maintenance
Land/Forest Protection		

Abbreviations:

- BMP = Best Management Practice
- BUA = Built-upon area
- DF = Delivery Factors
- EMC = Event Mean Concentration
- ET = Evapotranspiration
- IWS = Internal Water Storage
- PP = Permeable Pavement
- SW = Stormwater
- WW = Wastewater

Table 7c: Agricultural Practices

Practice	**Potential Accounting Method**	**Description**
Agriculture BMPs w/ Credit Method Available • **Cropland Conversion to Trees/Grass** • **Buffer Restoration** • **Exclusion** • **Excluded Buffers**	• Calculation • DWQ Credit Yield Method • Calculation • Calculation	• Literature-based export coefficient comparison • Revisions currently being drafted • Pasture Point System Method with export coefficients • Pasture Point System Method with export coefficients and DWQ Draft Buffer Credit Yield
Other Ag BMPs • **Managed Grazing** • **Water Control Structures** • **Cover Crops** • **Conservation Tillage**	Calculation based on literature findings or WS Remodel	Have BMP efficiencies, need load reductions in-stream
Potential Ag BMPs • **Pond creation** • **Pond renovation**	Calculation based on literature findings or WS Remodel	Work with agriculture community to develop specifications

Table 7d: Programmatic Practices

Practice	**Potential Accounting Method**	**Description**
Improved street sweeping	Calculation based on literature findings or WS Remodel	Decrease organic matter entrained in runoff to surface water
Source control, such as pet waste and fertilizer ordinances	Calculation based on literature findings or WS Remodel	Decrease "fertilizer rates" to landscape areas
Emission Reduction (Atmospheric Deposition)	Watershed Remodel?	• Correlate emission reductions to deposition reduction to impervious surfaces, effect on event mean concentrations
Improved Biosolids Management	Calculation based on literature findings or WS Remodel	• Reduce application rates blow Fertilizer Management Rule requirements • Sampling design to determine reduction in loading to surface
Non-Stormwater Discharge Programs	Comparative calculation	• Programs to systematically reduce SSO's, contain SSO spills, remove illegal connections, educate businesses, improve collection systems

Table 7e: Wastewater Practices

Practice	Potential Accounting Method	Description
Overtreatment of WW	Calculation of annual mass load difference between existing and new treatment of discharge volume	Long-term dedication of unused allocation
Improvement/ Regionalization of WW facilities	Calculation of annual mass load difference between existing and new treatment of discharge volume	Redirecting discharge not treated for nutrients into larger system that does, or adding nutrient removal to an existing system
Remedy Discharging Sand Filter	Calculation of annual mass load difference between existing and replacement	Options: • Connect to central sewer; • Replace with non-discharge alternative; • Replace with higher nutrient removal type.
Repair Malfunctioning Septic System	Calculation based on literature findings or WS Remodel	• Restore nutrient removal functions • Connect to central sewer, improve treatment, or replace with non-discharge alternatives • Sampling of discharge and calculation of annual mass load discharge difference between existing and proposed
Improvement of Functioning Septic System	Calculation based on literature findings or WS Remodel	• Increase nutrient removal efficiency • Account for different flows • Account for rising groundwater table
Removal of Illegal Discharges to Surface Waters	Calculation of specific discharges	Decrease illegal discharges to stormwater system or directly to streams, including: • Sanitary sewer overflows • Piped connections to stormwater system • Commercial site surface discharges
Improvement of Wastewater Collection Systems	Calculation of annual mass load difference between existing and improved	• Reduce dry weather leaks to surface water • Reduce wet weather overflows

Abbreviations:

- BMP = Best Management Practice
- BUA = Built-upon area
- DF = Delivery Factors
- EMC = Event Mean Concentration
- ET = Evapotranspiration
- IWS = Internal Water Storage
- PP = Permeable Pavement
- SW = Stormwater
- WW = Wastewater

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