DRAFT

NMP Lessons Learned

Urban Runoff

The U.S. Environmental Protection Agency (USEPA) established the National Monitoring Program (NMP) in 1991 under Section 319 of the Clean Water Act (CWA) to achieve the following two objectives:

1. To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution, and
2. To improve our understanding of nonpoint source pollution.

State and local watershed projects included in the NMP conduct six to ten years of intensive water quality and land treatment monitoring in accordance with a nationally consistent set of guidelines to accomplish these objectives. Implementation of pollution control technologies is expected to occur in a controlled manner supportive of the experimental designs (e.g., paired watersheds, upstream-downstream) used by the projects. USEPA funding is directed primarily to monitoring and evaluation, while other sources are typically tapped to fund the implementation of pollution control measures.

As of September 2005, USEPA had approved 25 projects in the lower 48 States. These projects addressed a range of water quality problems caused by such sources as cropland, livestock operations, grazing land, stream modification, urban runoff, septic systems, recreation, and coal mining. Pollution control measures implemented include stream restoration, erosion and sediment control, urban runoff control, nutrient management, riparian protection, acid neutralization, septic system repairs, and a host of others.

While the NMP is ongoing, many of the NMP projects have reported final results, and several others have reported early findings. It is against this backdrop that lessons learned by NMP projects have been gathered and summarized in a series of evaluations including this one focused on urban runoff control. The findings in this document are based on analysis and reporting by Don Meals and Steve Dressing (Tetra Tech, Inc.) of project reports, annual project summaries (Szpir et al. 2005), and direct communication with project personnel.

The primary emphasis of this evaluation relates to the two NMP objectives, but the success of watershed projects is dependent upon a foundation of design, process, cooperation, and resources. For this reason, lessons learned address a range of factors known to play significant roles in determining the outcome of watershed projects.

The Projects

Two NMP projects address urban runoff problems:

- Jordan Cove, Connecticut
- Villanova University Stormwater BMPs, Pennsylvania

The **Jordan Cove, CT** project developed a marketable residential subdivision using a full suite of urban BMPs (permeable road and driveway surfaces, grassed swales, bioretention areas, reduced lawn area, and lawn nutrient management). Water quality data from the BMP watershed and a traditionally developed watershed were compared using a paired-watershed design both during and after construction to measure the impacts of construction and the effectiveness of the BMPs on water quantity and quality.

The **Villanova University Stormwater BMP, PA** project is conducting input/output monitoring to document the effectiveness of four specific urban stormwater BMPs in improving water quality: a biofiltration traffic island, porous concrete, an infiltration trench, and a stormwater wetland. This project is not a traditional land treatment/watershed monitoring project, but rather focuses on testing individual BMPs that can ultimately be applied as retrofits in densely-built urban environments.

The Bottom Line: Water Quality Results

As a result of BMP implementation in the Jordan Cove project, the hydrologic alterations usually observed in response to urban development such as increased peak flows and increased runoff volume did not occur in the BMP watershed; rather a two order of magnitude reduction of stormwater runoff was observed due to BMP treatments. Export of TSS, nutrients, and metals from traditional development increased, but did not increase from the BMP watershed. Export of TKN and NH_3-N from the BMP watershed was reduced by 65% or more by the improved management.

In the Villanova University project, input/output monitoring has documented the effectiveness of four specific urban stormwater BMPs in improving water quality. A bio-infiltration traffic island, in which stormwater is captured and diverted into an infiltration bed, reduced annual runoff by 69% due to increased infiltration. Effective infiltration, neutralization of acidic runoff, and reductions of copper levels have been documented in a porous concrete/infiltration bed BMP and storage bed; experience in installation and performance of porous concrete has contributed to further development of this system. Data on the hydrologic performance of an infiltration trench BMP have shown reduced runoff volumes and documented important design changes for this practice. Finally, a stormwater wetland has been shown to reduce spikes in summer water temperatures, remove ~60% of P and ~80% of N during base flow, and reduce annual fecal coliform levels. During storm events, the wetland reduced peak runoff rates and showed a removal efficiency of nearly 70% for total suspended solids, while dissolved components such as reactive phosphorus and chlorides showed little or no overall removal.

Conclusions:

- Implementation of urban stormwater measures in developing and developed areas can yield significant water quality improvements, both at the individual practice and the watershed level.
- The CT project demonstrated that it is possible to build a practical, saleable residential subdivision using a full suite of urban BMPs.
- Urban residential BMPs can maintain post-development runoff volumes at or below pre-development rates compared to traditional residential development.
- Urban residential BMPs can reduce significantly N export.
- Individual stormwater BMPs such as biofiltration, porous concrete, and infiltration trenches can successfully attenuate urban stormwater runoff in a real-world setting.
- A stormwater wetland demonstrated significant removal of sediment and nutrients during base flow and storm events.

Table 1. Urban Runoff

State	Treatment	Peak Runoff	Runoff Volume	Concentration				Load				Temperature	Other	Notes
				TSS	P	N	Metals	TSS	P	N	Metals			
CT	BMP during const.	↓	↓	↑	↑	↑		⇔	⇔		⇔			
	BMP post-const.	↓	↓					↓	↓	↓	↓			1
Range of % change			78 - 97%							65%				
PA	Biofiltration traffic island		↓				↓							2
	Porous concrete	↓	↓				↓ Cu						⇔ Cl	2
	Infiltration trench		↓											2
	Stormwater wetland	↓		↓	↓	↓	↓					↓	↓ FC ⇔ Cl	2,3
Range of % change			69%	70%	43 – 75%	71 – 100%								

1. Some seasonal differences in nutrient losses from different driveway treatments were documented. Also, there were higher P losses in runoff during turf development.
2. Project is in relatively early stages of effectiveness monitoring and more definitive results are expected as further studies are ongoing
3. Little or no removal of dissolved P, but total P was reduced.

Table explanation and caveats:

- Downward arrows (↓) represent significant decrease in concentration or load. Upward arrows (↑) represent significant increase in concentration or load or significant improvement (e.g., in invertebrates). Sideways arrows (⇔) indicate no significant change. Empty cells indicate that project did not measure that variable or has not reported results.
- Percent reductions should be interpreted only as very general examples. Their utility is limited by the facts that:
  a) Some important variables like habitat cannot be expressed as a percent;
  b) For simplicity, the matrix does not distinguish between concentration and load; concentration and load may change in opposite directions if, for example, a BMP greatly reduces flow while slightly increasing concentration;
  c) Percent reduction depends largely on the starting point – the same BMP may give a much larger percent reduction in a situation of extreme impairment compared to a lesser initial problem; and
  d) In most cases, the range of percent reductions is so wide that choosing a specific value becomes an arbitrary exercise.

Impacts on State Nonpoint Source programs: Applicability of results to state policies and programs

Experiences and results of NMP projects in this group have direct applicability to state nonpoint source policies and programs. These applications occurred in several categories:

- **Understanding of nonpoint source pollution**:
  - Results of homeowner surveys in the Jordan Cove project could provide information on behaviors of residents that influence nps pollution and nps control measures;
  - Monitoring at the Villanova BMPs showed that input levels of nutrients and metals are extremely low because of good maintenance and only pedestrian traffic in the runoff source areas;
  - At the Villanova sites, chlorides from winter deicing pass through the BMPs unaffected.

- **Design of treatments for nonpoint sources**:
  - Lessons learned from both the Jordan Cove and the Villanova projects experience with installation of novel BMPs such as rain gardens and porous concrete could benefit future treatment design and construction;
  - Monitoring data from the traditional watershed in the Jordan Cove project showed that current erosion and sediment control practices for construction activities are effective;
  - "Accidental BMPs" in the Jordan Cove project such as open cellar holes that functioned as stormwater ponds and berms to prevent runoff from leaving the construction site could influence future construction management practices;
  - Observed performance of the infiltration trench in the Villanova project will provide design changes for these BMPs in Pennsylvania.

- **Significant water quality response to land treatment**:
  - The Jordan Cove project demonstrated that significant runoff and export savings can be achieved using low impact development (LID) BMPs as compared to traditional residential development;
  - The Jordan Cove project also demonstrated water quality response to specific treatments within the residential development, e.g.,
    - A driveway study showed that runoff flow and TSS/nutrient export was greatest from asphalt driveways, followed by concrete paver driveways, and lowest from crushed stone driveways; and
    - A lawn nutrient study showed lawns in the BMP watershed have lower soil water nitrate levels than do non-BMP lawns.
  - The Villanova project has demonstrated the ability of the biofiltration traffic island, porous concrete, and infiltration trench BMPs to effectively capture stormwater runoff and promote infiltration and has documented significant reductions in nutrients, metals, and fecal coliforms through a stormwater wetland.

Impacts on State Nonpoint Source programs: Communications by projects to disseminate results

The Jordan Cove project communicated project results to municipal, state, and regional partners through regular reporting and advisory committee meetings. The project also made efforts to communicate results to residents of the study watersheds in the course of the annual resident surveys.

The Villanova project is just one of many similar efforts within the Villanova University Stormwater Program (VUSP). Technology transfer is the prime mission of VUSP, and is approached through on-campus symposia including workshop for municipal officials, presentations, publications (brochures, theses, journal articles), and tours of the research and demonstration park. VUSP has made specific recommendations to state stormwater manual oversight committee. The VUSP web site is extremely content-rich, with links to all BMPs, design information, monitoring data, lessons learned, theses and other publications, and presentations.

Impacts on State Nonpoint Source programs: Documented impacts on state programs

No significant impacts on state nonpoint source programs have been documented for the two projects in this group, but residential subdivision BMPs such as permeable pavement, grassed swales, and bioretention basins tested in the Jordan Cove watershed have received greater statewide application. In addition, infiltration practices including porous concrete and a biofiltration traffic island from the Villanova project are included in the draft Pennsylvania urban stormwater BMP manual.

Project Design and Execution: Observations and Lessons

Measured water quality improvements are the end product of a series of choices and actions that begin with project selection. USEPA selected NMP projects using criteria that addressed problem identification, nonpoint source control objectives, size of the project area, institutional roles and responsibilities, critical areas, the watershed treatment plan, monitoring, and evaluation (USEPA, 1991). Observations and lessons learned by the two urban runoff projects in these and related areas are discussed below to aid future projects. Note that some design criteria such as critical area selection and land treatment monitoring may not fully apply to these projects because their design and function is distinct from that of the typical agricultural watershed project.

Project Design: Water quality problem characterization

Both projects were designed to evaluate BMPs that could be broadly applied to urban stormwater problems, rather than to address specific local water quality impairments

Both projects focused on testing solutions to problems of urban stormwater that are well-documented nationwide and in their respective regions, although neither project was designed to remedy a specific, known local impairment. The Jordan Cove project identified Long Island Sound as impaired due to low DO, toxic contaminants, pathogen contamination, and habitat degradation and noted failure of Jordan Cove to meet bacteriological water quality standards for shellfish. The Villanova project noted that two local creeks were cited on the Pennsylvania 303d list as degraded by urban runoff. However, both projects were designed to evaluate urban stormwater BMPs that could be applied in state, regional, and national settings.

- For a project engaged in research and evaluation of specific BMPs, it is appropriate to address "generic" water quality impairments rather than to focus on remediation of specific water quality impairments.

Project Design: Nonpoint source control objectives

The overall goal of both projects was to demonstrate water quantity and quality benefits from applying specific stormwater BMPs.

The Jordan Cove project stated specific objectives for testing BMPs for developing urban residential subdivisions:

1. To implement BMPs on 100% of the lots in the BMP watershed;
2. To maintain post-development peak runoff rate and volume at levels equal to pre-development rates;
3. To maintain post-development loading of TSS at levels equal to pre-development rates.
4. To retain sediment onsite during construction;
5. To reduce nitrogen export by 65%;
6. To reduce bacterial export by 85%; and
7. To reduce phosphorus export by 40%.

The primary goal of the Villanova project is research and documentation of BMP performance through input/output monitoring. The main project objective is to evaluate performance of several stormwater BMPs on water quantity and quality (sediment, nutrients, metals) of urban stormwater.

- ❖ As in all NMP projects, clear statements of quantitative goals are important to project evaluation.

Project Design: Identification of critical areas

Critical areas in the sense typically applied in agricultural watersheds were not a relevant concept to these urban runoff projects. The Jordan Cove project identified activities associated with construction and residential land use, as well as traditional erosion controls, as critical source activities. The entire area of the small study watersheds were "critical areas" to be treated. The critical area concept was not applicable in the Villanova project, where the project is documenting performance of individual BMPs on an input/output basis.

Project Design: Land treatment plan

Unlike most other NMP projects that relied on voluntary implementation of control measures by landowners, the two projects in this group had essentially full control over the selection, design, and implementation of land treatments. In Jordan Cove, project directors applied BMPs to all potential locations in the BMP watershed; conventional erosion and sediment control practices were applied in the traditional watershed according to local ordinance requirements. The project PI indicates that it is important to consider the landowner's ability to maintain and operate the practices. The specific BMPs to be evaluated in the Villanova project were selected by the managing board of the VUSP and the locations were selected based on engineering criteria for retrofit opportunities.

- ❖ Implementation of planned BMPs was greatly facilitated in both projects because project managers had full control over the planning of land treatment and did not have to depend on voluntary adoption by individual landowners.

Project Design: Water quality monitoring

Both projects in this group had carefully-designed monitoring programs appropriate for their settings. The Jordan Cove project employed a paired-watershed design covering two periods – construction and post-construction. Although the project used an established residential subdivision as a control watershed, the project PI indicated that a second, non-urbanized control watershed would have been helpful. The Villanova project used an inflow/outflow design appropriate for urban structural BMPs. Although the inflow/outflow design is conceptually simple, the Villanova project found that successful monitoring of small urban stormwater devices is complex; especially as it is difficult to capture flow and water quality in inflow and outflow, particularly with regard to infiltrating water. Experience in the first year of monitoring helped develop an effective monitoring scheme.

It is difficult to measure and attribute changes in water quality to land treatment without a specific, well-funded monitoring design and plan. General sampling after BMP installation is not effectiveness monitoring.

As with other NMP projects, it is evident that those conducting monitoring must be knowledgeable of the water quality problems, the BMP implementation plan, and the monitoring design options prior to planning the monitoring program. It is also clear that adequate funding to achieve monitoring objectives must be secured before any monitoring occurs to ensure that suitable data are collected without interruption. In turn, those who conduct the monitoring should be held accountable for at least the following:

- Detailed monitoring budgets with a justification for each monitoring site, parameter, and collection frequency, including funding for some degree of "over sampling," particularly in the early years as those conducting the monitoring learn more about the system and problems through the collection and analysis of data.
- Clear statistical analysis plans before monitoring begins, with annual reassessments to ensure adequacy.
- Annual or more frequent analysis and reporting of monitoring data to ensure that the monitoring program is on track and capable of achieving its objectives.
- Annual reassessment of the monitoring program, with adjustments made as needed to ensure that monitoring objectives are achieved in the most cost efficient manner.

Monitoring needs to be focused on the parameters most directly related to the water quality goals, the parameters most likely to be affected by the implemented practices, and explanatory variables that can be used to improve the resolution of statistical analyses. Additional monitoring stations, parameters, or samples may be needed to quantify unexpected inputs. This additional monitoring may be temporary or "permanent" depending upon project needs, and project planners should develop contingency plans for such flexibility. The Jordan Cove project, for example, conducted additional monitoring of infiltration and runoff from different driveway surfaces, the results of which are useful in interpreting overall watershed results.

Project Design: Land treatment and land use monitoring

Land use and land treatment tracking was highly effective in the Jordan Cove project because it was conducted directly by water quality monitoring personnel in the small watersheds, rather than relying on an external agency in a larger basin.

Land treatment/land use data can be obtained in a variety of ways including conservation plans, satellite imagery/aerial photography, and intensive field surveys. It is most important to track land use/land treatment variables that relate to the water quality problem and are expected to be impacted by the implementation of practices.

The two projects in this group handled this task very differently. The Villanova project had no formal land use/treatment monitoring because all BMPs were on campus and essentially no land use change occurred. The structural BMPs were under constant scrutiny because of the input/output monitoring.

Frequent direct observation of construction events and site conditions allowed the Jordan Cove project to document significant water quantity and quality effects, e.g., storage of water in cellar excavations, rainfall ponding on pavement. The project also used annual household surveys to track information on pets, lawn care, fertilizer use, watering, leaf disposal, car washing, and other behaviors that might affect water quality and quantity.

Project Design: Evaluation and reporting plan

Priority and time need to be given to effective evaluation, reporting, and communication of project results.

Regular reporting, including frequent (e.g., quarterly) progress reports, keep participating agencies and stakeholders informed and facilitate early detection of trends, changes, problems, etc. in the stream of monitoring data. Both projects in this group were designed with rigorous evaluation plans. The Jordan Cove project follows the paired-watershed design and monitoring data have been evaluated based on the requirements of that design. The Villanova BMPs are evaluated in an academic setting, usually as supervised graduate student projects.

Both projects engage in active evaluation and reporting plans, although the specific activities are quite different because of the different project designs. The Jordan Cove project used NPSMS initially to summarize monitoring data and prepares an annual report for wide distribution, held two project meetings each year and provided quarterly reports and separate annual write-ups to the state environmental agency. Results of the Villanova project are reported in graduate theses and in broader reports and web information published by the VUSP.

- ❖ Both urban projects demonstrate the results of attention and effort applied to evaluation and reporting of project results.

Land treatment implementation: Treatment levels achieved

The Jordan Cove project achieved its goal of implementing BMPs on 100 percent of the lots in the BMP watershed; this was accomplished in large measure because the design and construction of the BMP subdivision was under the direct supervision of the project investigator. The Jordan Cove project noted that a strong project presence in the watershed was required to ensure that implementation occurred as planned and to respond to difficulties and surprises. Treatment levels were not relevant in the Villanova project because it tested individual structural BMPs.

Installation of innovative BMPs may be foreign territory to contractors. Careful supervision, evaluation of results, and even replacement or reconstruction may be necessary to ensure that the BMPs are correctly installed.

Both the Connecticut and Pennsylvania projects learned important lessons about construction of innovative BMPs. In Jordan Cove, rain gardens and some other BMPs were unfamiliar to contractors and required some re-installation. At Villanova, porous concrete installation experienced repeated failure due to lack of contractor knowledge and experience and climate factors.

Land treatment implementation: Incentives and technical assistance
Incentives and technical assistance to landowners were not critical issues for either of the two projects in this group. The Jordan Cove project provided some technical assistance to residents of the BMP subdivision through its information and education program addressing behavioral issues.

Land treatment implementation: Scheduling of land treatment with water quality monitoring design
As with any paired watershed design, scheduling of land treatment to result in clear calibration and treatment periods was key to the Jordan Cove project. Scheduling was even more important in this case because two post-calibration periods were monitored – construction and post-construction. The Jordan Cove project succeeded in controlling scheduling because of strong leadership from the project investigator and because of the involvement of many partners in overall project management.

Scheduling of land treatment was not relevant to the Villanova project.

Land treatment implementation: Tracking of installed land treatments
For monitoring projects such as those in the NMP, more specific and intensive land treatment tracking is necessary than is generally done in large, broad-scale projects. The two projects in this group did a better job of tracking participation and implementation within their highly focused areas than did most of the NMP projects that took place in large watershed areas. Both projects did a better job of tracking operation and maintenance of BMPs after implementation than other NMP projects, mostly through direct observation by monitoring personnel in frequent presence in the project area. This was particularly important in the Jordan Cove project, where observations on BMPs and erosion and sediment control measures were key in explaining observed water quality patterns. The Villanova project carefully monitored their BMPs as part of their research into design and performance of the structures.

Project management: Agency participation, roles and responsibilities
In both projects, primary leadership was by university researchers, but the right agencies participated to both facilitate the development of the project and to effectively disseminate results. Participants in the Jordan Cove project included the University of Connecticut, the state Department of Environmental Protection, the state Extension system, the municipality, the contractor and engineering companies, and USDA-NRCS. The Villanova project included both the University and the Pennsylvania Department of Environmental Protection.

Project management: Coordination methods, success, and failure
In Jordan Cove, a project advisory committee provided a forum for a continuing dialog through the project. At Villanova, the projects were coordinated through the overall VUSP. Both project PIs found coordination to be effective.

The Jordan Cove project (along with other NMP projects) noted that annual funding is not an effective way to run a ten-year project.

Project management: Stakeholder involvement

Both projects pursued active stakeholder involvement. In Jordan Cove, agency stakeholders were involved through the advisory committee and the project met with each of the watershed landowners at least once during the project, as well as communicating via the annual resident survey. At Villanova, technical transfer is the prime mission of the program. Stakeholders were approached through on-campus symposia attracting attendance from across the U.S., workshops for public officials, speaking engagements, masters theses, visitors to the BMP Research and Demonstration Park, and the VUSP web site. The project director also provides input to the PA state stormwater manual.

Project management: Information and education (I&E)

As for most NMP projects, the projects in this group included some I&E activities, which typically included newsletters, field demonstrations, meetings, and media releases. In Jordan Cove, I&E focused on the residents of the study watersheds, as behavior change was part of the BMP equation. Although the project staff met with individual landowners and with homeowners' associations, the project PI remains uncertain about the effectiveness of the I&E activities. At Villanova, on-campus national symposia, workshops for public officials, PI presentations, masters theses, the Villanova BMP Research and Demonstration Park, and the VUSP web site are all employed to disseminate information from the project. The project director also provides direct input to the state stormwater manual.

Water quality response: Documented water quality improvements

Water quality response was measured at several scales by the projects in this group using a range of parameters and study designs (See Table 1 above). Water chemistry reductions presented in this report are the result of statistical analyses performed by project personnel and are typically but not always values that have been adjusted using data collected at control sites. Year to year variations in precipitation and runoff, for example, can have enormous influence on measured nonpoint source pollutant loads; these variations are accounted for in the paired-watershed design. For this reason, an 80% reduction in phosphorus load, for example, may not be an actual 80% reduction in the stream but rather an 80% reduction *compared* to the control site used in the analysis. These reductions, however, show the generally strong capability these two NMP projects had to measure changes that could then be related to the implementation of practices.

Water quality response: Relating water quality improvements to land treatment

As noted in other project groups, projects taking place in small watersheds with clearly defined BMPs, appropriate monitoring designs, and effective land use/land treatment tracking (including operation and maintenance) stand the best chance of clearly relating water quality response to land treatment. Sub-studies of specific treatment-related phenomena within treated watersheds can help corroborate inferences with regard to cause and effect. The two projects in this group exemplify this point. The Jordan Cove project used a tight paired-watershed design, rigorous monitoring, and close observation of practice performance to relate the changes in water quantity and quality to the treatments implemented. Sub-studies of driveway permeability, lawn nutrient applications, and homeowner behavior helped explain observed changes in water quantity and quality.

The input/output design of BMP monitoring at Villanova leaves no doubt about relating changes in water quantity and quality to the implemented practices.

Water quality response: Interpretation and presentation of results
The Jordan Cove project has produced technical annual reports and made regular presentations both to local stakeholders and to audiences at national conferences. Although the Villanova project has not published a specific annual report on the NMP portion of their stormwater monitoring program, the activities discussed above have presented project results to a wide audience in a variety of ways.

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