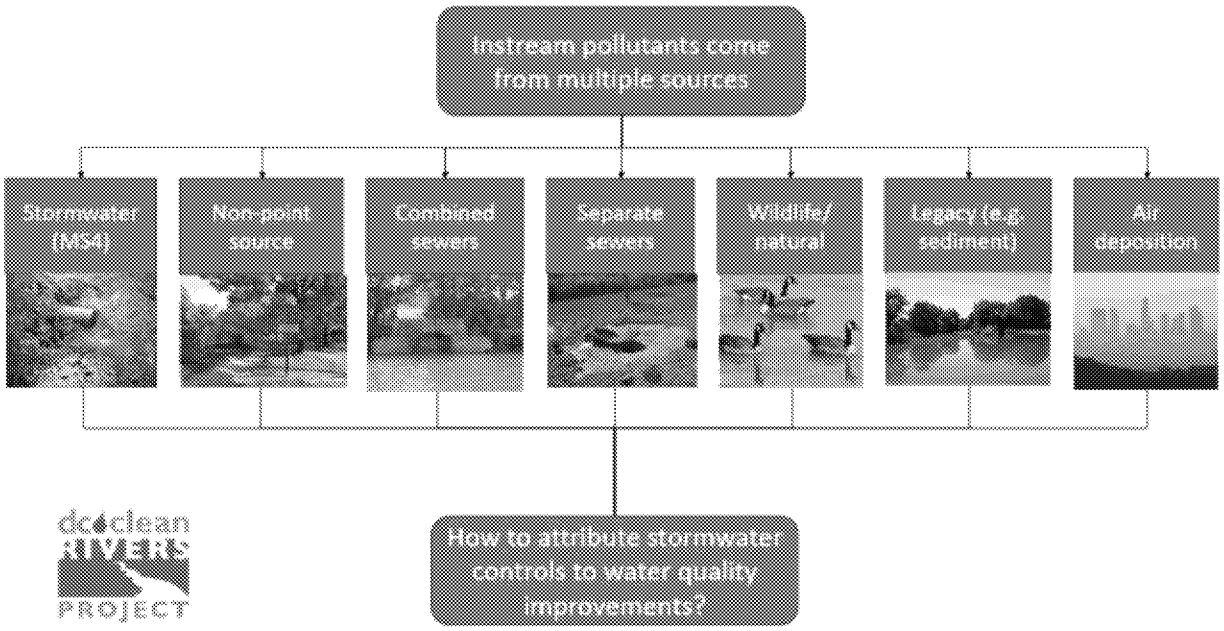

Graphic: DC Water

Figure 5. Various sources of pollutants may contribute to receiving water quality, making it difficult to determine the contribution from stormwater.

Traditionally, stormwater program managers have relied on assumptions about the performance of their program activities and BMPs in gauging their overall program effectiveness. An increased focus on water quality goals and TMDL pollutant reduction requirements has brought an increased emphasis on measuring the performance of BMPs and measuring the effectiveness of municipal stormwater programs overall. Across the country, many local programs are performing some degree of outfall, receiving water, and BMP-level monitoring to determine pollutant levels and demonstrate reduction trends (either in response to a permit requirement or on their own). Tailoring this monitoring/evaluation by making it as robust and discriminating as possible will help dischargers prioritize programmatic approaches to reduce pollution as well as inform planning for and siting of physical BMPs.

Increasing targeted data collection alone, of course, will not automatically lead to improved program effectiveness. One hundred percent of survey respondents agreed that monitoring must go beyond data collection to include data management and analysis that links the acquired information to specific performance metrics. Workshop participants indicated a need for guidance in designing monitoring programs to yield actionable results and for assistance in linking monitoring data to programmatic decision-making. Some participants also expressed a desire to expand the use of real-time monitoring for stormwater operations and supported deploying pilot programs and special projects for innovative monitoring technologies coming to market.

California's Phase II MS4 General Permit requires the development and implementation of a **Program Effectiveness Assessment and Improvement Plan** (PEAIP). A critical component of this is generating and analyzing useful data (e.g., through monitoring) to inform program improvements. In an effort to promote a uniform and effective approach for PEAIP development and implementation, CASQA has developed a PEAIP Framework for Phase II permittees. The framework emphasizes the need to identify and prioritize POCs and determine where they have the most impact. Outfall and receiving water monitoring, coupled with smart data analysis, play a key role in achieving this, as well as in identifying options for POC reduction.

3.3.1 Evaluate Appropriate Scale for Monitoring Efforts to Yield Actionable Results

Workshop participants described the importance of scale in monitoring efforts. By first identifying specific management problems or questions, programs can ensure that monitoring approaches use the appropriate geographical range and time scales to address them. For example, should a monitoring effort be done at a large scale (to supply a broad regional/watershed and longer-term perspective) or a smaller scale (for studying specific areas) and shorter time steps (to assess pollutant contributions and the effectiveness of specific mitigation approaches)?

Defining proper scales for monitoring also depends on the purpose of the monitoring. As discussed above, program effectiveness can appropriately be assessed at a broader scale, while BMP effectiveness can best be evaluated at a smaller scale at representative site locations.

In pursuing monitoring efforts that incorporate multiple jurisdictional scales (e.g., region, watershed, state), each program should share data with the surrounding communities. State agencies, EPA, and/or national organizations should facilitate local data sharing by creating and maintaining mechanisms to more widely share these data. When program functions are shared through partial consolidation at watershed or regional scales, there may be opportunities for more effectively aligning monitoring, tracking, evaluating, and reporting activities.

However, there can also be hurdles in extracting and comparing data for large-scale monitoring efforts that comprise several jurisdictions. Therefore, local MS4 programs should ask themselves several questions before embarking. For example:

- Are there opportunities for resource savings over the long term?
- Can incentives be offered for integrating new jurisdictions into existing monitoring programs?
- Can we design representative monitoring that will provide discriminating results that can be used by multiple jurisdictions?
- Can sampling, analysis, and data management and interpretation be standardized to allow for inter-comparability?
- Do collected data help to answer established management questions for each participating jurisdiction?

DC Water (Washington, D.C.) embarked on intensive pre- and post- monitoring activities for two green infrastructure installations in a small area to demonstrate performance and planned water quality improvements. The utility worked at a relatively small scale within the managed sewersheds to be able to detect signals of change in the receiving water. The $1 million cost (about 2 percent of the overall project budget) was funded through the utility's impervious surface charge. A dedicated team oversaw sensor installations and ensured that equipment stayed in the system over several years.

These are just some of the considerations to address when weighing the pros and cons of increasing the scale of a monitoring effort. Even when no formal partnering is established, workshop participants suggested, monitoring and annual reporting requirements should be structured to provide an opportunity for inter-comparability, information sharing, and technology transfer within the state, region, or country.

Monitoring and evaluation efforts over a larger geographic area tend to be less discriminating (i.e., capable of detecting cause-effect relationships). In the pre-workshop survey, 92 percent of respondents agreed that targeting implementation and monitoring in smaller areas increases likelihood of demonstrating links between implementation activities and water quality responses.

In southern California, local stormwater programs have installed storm drain diversions in some locations to improve water quality at the state's beaches (**Clean Beach Initiative**). To demonstrate effectiveness, monitoring was performed at a scale to assess statistical changes in pre- and post-project mean densities of the pollutants in certain geographic areas.

One workshop participant noted that, in their state, there is a lot of monitoring data for small drainage areas that can show water quality improvement or degradation; however, the quality trends are not evident for larger drainage areas, due to the obscuring effects of other inputs (e.g., agriculture) on a larger scale. Several participants specifically suggested that permits allow for small-scale implementation and assessment to better validate effectiveness. To help illustrate the importance of more targeted monitoring, workshop participants identified several small-scale efforts (e.g., DC Water's green infrastructure monitoring) that have produced tangible results linking program efforts to water quality improvement. Participants thought successful small-scale efforts should be identified and included in guidance, case studies, or other means to inform future efforts and provide lessons learned.

3.3.2 Convene a Visioning Session for Deploying Sensors in MS4 Programs

During workshop discussions, participants discussed the use of new sensor technologies (e.g., pollutants, flow, real-time, or near real-time) within the municipal stormwater program. Several participants were working on projects with real-time controls in storm sewer systems to actively control whether runoff is directed to a groundwater infiltration basin to augment supplies or discharged to receiving waters. These systems use sensors and telemetry to measure flows, water quality, and volume of available storage in different parts of the system and make decisions accordingly. Some voiced concern about whether it was viable to use these types of technologies for compliance determinations, given the lack of 40 CFR 136 approval and the volume of data that would be produced. Others put forth some ideas of how new sensor technologies could enable enhanced operation of a municipal stormwater program for early identification of illicit discharges and flooding, or even real-time decisions to direct stormwater flow to groundwater recharge basins when conditions allow.

The **Southern California Coastal Water Research Project** has used **conductivity sensors** in tandem with flow sensors to dictate when to sample in estuaries. These devices have been helpful because the two-way tidal flows during storm events make it hard to know when you are sampling runoff versus estuarine receiving water.

In south **Orange County**, permittees are using **remote water quality and flow sensors** at outfalls to develop a better understanding of water balance in urbanized catchments. The water quality sensors can be configured to send out automatic notifications when thresholds for parameters such as turbidity are exceeded, making it possible to begin responses to potential illicit discharges as they are occurring. The combined real-time flow and water quality data are informing the implementation of strategies to address unnatural water balance.

Workshop participants suggested convening a visioning session focused on the identification, acceptance, and deployment of sensors in municipal stormwater programs. Visioning topics should include the use of sensors for improving system operations (e.g., illicit discharge detection, pipe clogging, flooding) as well as for designing and implementing real-time control programs to better manage water resources. These topics align well with existing and ongoing work being done through EPA's Office of Water on water technology and innovation (e.g., "Intelligent Water"). The visioning sessions should acknowledge the challenges discussed above and present a range of remedies.

Workshop participants acknowledged a need for more impactful studies surrounding innovative technology, particularly for sensors and real-time controls. Further, there is a need for broader dissemination of information on current technologies and best practices available for water quality monitoring. The visioning session could be used to identify further opportunities for special projects for permit inclusion to pilot innovative technologies to improve water management and enhance decision-making.

WRF's **Leaders in Innovation Forum for Technology** (LIFT) is a multi-pronged initiative to help bring new water technology to the field quickly and efficiently. "**Intelligent Water Systems**" has been selected as one of its key focus areas. Subscribers can participate in regular discussion forums and presentations on the topic, access technology evaluations, and review the latest research.

3.4 Improving Our Ability to Quantify Effectiveness—Approaches to Link Water Quality Outcomes to Actions

Since MS4 program inception, many regulators have largely taken a "best intentions" approach in assessing program effectiveness related to water quality improvements: if the components of a permit are implemented adequately, they assume it will lead to improved water quality. But there is little or no assembled data to firmly support such conclusions. To date, very few programs have gone so far as to analyze and document the actual effectiveness of their programmatic measures and physical BMPs at removing pollution from stormwater runoff.

Photo: EPA

Some permittees have established sophisticated monitoring and modeling to better quantify the effectiveness of their stormwater programs; however, for the majority, a realistic and effective way to reveal the specific link between actions and water quality improvements has been elusive. This can be due to many factors. For example, watersheds and drainage areas may be quite large, with many small sub-drainage areas where stormwater is managed, either through targeted programmatic practices or physical BMP treatment. This can create the need for many upstream and downstream monitoring locations to accurately determine the effectiveness of implemented actions. Beyond the logistical hurdles a permittee may face, a widespread monitoring effort would likely be cost-prohibitive for the average permittee. There is often a significant lag between implementation of controls and discernable water quality benefits. This may occur in part because of the slow pace of BMP implementation in many watersheds and in part because wet weather-related water quality responses are often highly variable and difficult to detect. Further, stormwater pollution sources are often dynamic (constantly changing) and vary widely.

> *"There is a resounding need to develop and convey better analytical methods for drawing linkages between implementation activities and water quality effects and outcomes (both prospective and after the fact). This can likely be accomplished through modeling and non-modeling methods to make more reliable connections."*
>
> *—Comment from a workshop participant*

Workshop participants agreed that MS4 programs should move away from the best intentions approach and focus on improving capabilities for determining and quantifying the actual effectiveness of specific actions in improving water quality. They acknowledged that useful data may exist that have not yet been tapped for this purpose (e.g., turbidity and sediment loss data for

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construction sites, data collected for rulemaking purposes). Likewise, potentially transferable approaches have been deployed in other programs, such as for combined sewer overflows. Workshop participants communicated the need for better tools, guidance, and methods for accurately quantifying BMP performance and integrating information about BMP effectiveness across larger geographical scales.

Participants agreed that a crucial first step is improving tracking of BMP implementation, maintenance, and condition. Without a thorough understanding of where BMPs have been implemented (and whether they have been enacted properly) and a system for ensuring that they receive timely maintenance, MS4 managers will likely be unable to evaluate BMP effectiveness at site-specific or system-wide scales. Attendees discussed the need to expand use of asset management systems to provide the management and tracking framework necessary to properly account for and maintain stormwater BMPs (see EPA, 2017a).

3.4.1 Document the Current State of Knowledge of BMP Performance and Effectiveness

Workshop participants were divided in their assessment of the current state of knowledge on BMP performance and effectiveness. Some thought there was a robust cache of data available, while others saw a clear need for more and better information. It was generally agreed that available BMP effectiveness information is limited for certain pollutants (e.g., polychlorinated biphenyl [PCBs], mercury). Participants highlighted the need to better account for and distinguish the effectiveness of BMPs for different pollutants in different implementation settings, considering factors such as watershed characteristics, land use types, and BMP condition. There was also broad acknowledgement of the need for improvement in interpreting and disseminating the results of unique and beneficial datasets on BMP performance and effectiveness to promote better knowledge transfer.

During the previous workshop, participants stated that performance of treatment and source control BMPs[3] needs to be better measured and reported for existing approaches as well as new technologies as they come to market. The resultant report acknowledged that available data and information are particularly limited concerning effectiveness of source control BMPs such as public education, illicit discharge controls, and facility inspections. These source control elements are important building blocks of the traditional MS4 programs.

Some publicly accessible resources do have documented examples of BMP performance data. For example, the International Stormwater BMP Database includes over 600 datasets, publications, and tools related to stormwater BMP effectiveness. The database is well positioned to host and disseminate documented test results and studies from many of the leading

Some cities have done excellent work to evaluate and document BMP effectiveness. For example, **Portland, Oregon's stormwater program** has conducted detailed performance evaluations of stormwater management facilities in the city. Portland's detailed evaluation accounted for differences in practice design, placement, and performance, which helped in future practice siting and design to optimize effectiveness (see, for example, City of Portland, 2006).

[3] In the stormwater program, there is often overlap and ambiguity in the terms used to describe practices to control the volume and/or quality of stormwater runoff (e.g., post-construction BMPs, permanent stormwater controls, structural BMPs, non-structural BMPs, treatment controls, source controls, MCMs). For simplicity and consistency, this report uses "BMPs" to include these types of control measures in both gray and green infrastructure applications.

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organizations addressing the topic of BMP effectiveness, such as WEF and its National Stormwater Testing and Evaluation for Products and Practices (STEPP) Initiative, which is aimed at validating the performance of innovative stormwater management technologies. However, workshop participants noted that the International Stormwater BMP Database has limited capacity to store data and information in a way that enables evaluation of how BMP performance might vary in different implementation settings and for pollutants that were not the focus of initial testing. Other organizations like CASQA are working at the state or regional level to develop more locally focused tools to help quantify the water quality impact of stormwater program actions (e.g., calculating source-load reduction).

Workshop participants acknowledged that despite the currently available resources, there is still a need for more research and information sharing to improve the ability to quantify the effectiveness of stormwater program actions. Broadly inclusive databases can be a good starting point, but more data location-specific data (e.g., on geomorphology, hydrology, climate, O&M strategy, and the presence of unique or emerging pollutants) are needed. Ultimately, increasing the variety and robustness of data and information about different BMPs' performance and effectiveness is needed to build the capacity of local programs, public agencies, and private parties to implement the most appropriate methods for addressing specific pollutants under local conditions. Participants agreed that expanding our understanding of BMP effectiveness is not solely the responsibility of any one sector of the stormwater management community. It was agreed that permitting authorities, permittees, technology vendors, researchers, and trade organizations will need to cooperate in organizing research to more fully understand BMP effectiveness over time across a wide range of settings.

3.4.2 Improve the Applicability and Usefulness of Modeling Through Collecting and Incorporating Better Performance Data

It is very difficult to project long-term stormwater management needs, opportunities, and effectiveness at watershed or broader geographic scales. Modeling is—and will likely remain—a primary tool for long-term stormwater planning and project siting. Workshop participants acknowledged that models are increasingly being used to supplement water quality monitoring and provide flexibility to permittees when a widespread comprehensive monitoring program is infeasible. For example, several states have developed MS4 permitting frameworks that allow for "reasonable assurance analysis" (RAA) based on modeling to demonstrate permit compliance (EPA, 2017b). As this practice becomes more commonplace, there will be a need to improve models' ability to demonstrate water quality impacts from stormwater management activities.

Used properly, modeling can also greatly assist in the evaluation of stormwater program effectiveness and BMP performance at a wider landscape scale. Workshop participants expressed concern that the current limitations in effectiveness and performance data have led to low confidence in the ability of models to be useful across a wide variety of stormwater management settings (e.g., different regions, climates, hydrology, geomorphology). They emphasized the need to collect more and better effectiveness data for all BMPs to improve the usefulness of modeling, especially for source control BMPs (e.g., public education and outreach, illicit discharge detection and elimination, facility inspections).

Source control BMPs can be critical for reducing runoff pollution, but their effectiveness is often estimated roughly—or they are left out of stormwater models entirely because their effectiveness is

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difficult to quantify and data are limited. Proactive and preventative pollutant source control methods such as illicit source detection and good housekeeping measures also tend to be underrepresented.

In stormwater modeling, the effectiveness of BMPs has traditionally been calculated based on runoff volume reduction (i.e., pollutants are reduced through decreasing the volume of runoff carrying those pollutants). Flow may be a suitable surrogate for certain pollutants (especially those that build up and wash off impervious surfaces over time) in place of BMP removal efficiency calculations. Participants indicated that a wide range of available models from simple to complex are available. EPA Region 9's guide on model-based analysis (EPA, 2017b) provides some information on choosing a model appropriate to a MS4 communities needs and capabilities. Workshop participants suggested that many communities will need further technical support in choosing and using models and, in some cases, in transitioning from simple models to more complex ones as their planning, assessment, and management needs change over time.

Ultimately, stormwater managers need useful models that inform decisions and quantify progress. This requires modeling tools that can represent all factors contributing to pollutant reduction and incorporate new information and adapt model outputs over time. To this end, there was an acknowledged need for guidance on how to effectively calibrate stormwater management models and link them with siting tools.

Models need proper calibration before they can be relied on as an alternative to widespread monitoring. Workshop participants had questions about how many locations or which activities need to be monitored to provide sufficient data for calibrating a useful model. What is the optimal density of monitoring to inform modeling; is it a cost-effective approach? Workshop participants from southern California indicated that they are moving toward relying more on models for predicting water quality impacts because they are responsible for hundreds of water bodies impaired by a wide variety of pollutants. While no model will ever be 100 percent accurate, models can become more useful through the use of high-quality data, representative of real-life conditions, to assist model calibration and validation.

Example EPA Stormwater Planning Models

EPA's **Storm Water Management Model** (SWMM) is a robust tool used worldwide to estimate the effects of stormwater runoff on collection systems and the environment. SWMM conducts hydraulic and hydrologic simulations and can estimate pollution reductions related to BMP implementation (EPA, 2016).

EPA's **National Stormwater Calculator** helps developers assess the impacts of runoff from the impervious surfaces on their projects. It also provides guidance and runoff reduction estimates that can help in a choice of low impact development controls (EPA, 2017c).

EPA's **System for Urban Stormwater Treatment and Analysis IntegratioN** (SUSTAIN) uses SWMM to help develop, evaluate, and choose optimal BMP combinations at various watershed scales based on cost and effectiveness. Some are using SUSTAIN coupled with the **Hydrologic Simulation Program** (HSPF) and other watershed models to support long-term planning efforts and evaluate effectiveness.

3.4.3 Evaluate Methods to Account for True Source Controls in Models

Participants at both workshops acknowledged a need for better effectiveness data related to source controls and better methods for accounting for such data in stormwater modeling. "True source control" refers to actions that eliminate the actual pollution before it can be discharged (e.g., eliminating copper in brake pads, narrowing authorized pesticide uses, and banning use of plastic

bags). Since source control is preventative, not treatment-based, it is often difficult to accurately quantify the impact that total or partial removal of a specific source has on the quality of a water body. Typical stormwater management models only account for pollutant removal after a rainfall event (e.g., pollutants are already on the ground and are transported via runoff into conveyances and treatment control BMPs). True source controls remove pollutants from the environment before they have a chance to contact runoff. Several workshop participants expressed the belief that true source control is the most effective BMP and contributes greatly toward meeting regulatory goals like TMDL wasteload allocations. There was an acknowledged need to find better ways to represent these impacts in predictive models.

3.5 Improving Program Tracking and Reporting

Tracking and reporting are often discussed in tandem, yet it is important to differentiate between them. As part NPDES MS4 permit requirements, Phase I and many Phase II MS4 programs must report on their implementation actions (and, often, associated program effectiveness) every year, so they must perform tracking. Since the quality of a tracking program generally is not evaluated as part of the regulatory obligation, this time- and resource-intensive endeavor can amount to little more than a "bean-counting" exercise if not structured properly. Voluminous paper reporting is another common problem, especially in programs where NPDES permitting authorities cannot fully review annual reports.

Ninety-two percent of respondents agreed that *"Reporting requirements should move beyond passive activity and data tallies to incorporate active effectiveness evaluation and clear linkages to program action."*

Workshop participants indicated that tracking and reporting should have a clear link to the required program activities to enable a true effectiveness assessment. The forthcoming NPDES E-Reporting Rule, which requires entities to electronically submit specific permit and compliance monitoring information instead of filing paper reports beginning in 2020, presents a key opportunity to re-envision how tracking and reporting can yield more useful and usable data. It should be noted that 88 percent of survey respondents agreed that e-reporting will not improve reporting quality unless more measurable and evaluative metrics are associated with program activities.

3.5.1 Identify an Approach for Using Established Performance Metrics to Guide Tracking and Reporting Efforts

Section 3.1.3 described the need to establish key performance metrics. The Phase II MS4 regulations introduce the concept of establishing "measurable goals" as a component of stormwater management programs to "evaluate the effectiveness of individual control measures and the storm water management program as a whole" (EPA, n.d.). EPA's 2016 MS4 General Permit Remand Rule made this a federal requirement for Phase II MS4 permits by requiring that permit terms and conditions "be expressed in clear, specific, and measurable terms" (40 CFR 122.34[a]). EPA's *Measurable Goals Guidance for Phase II MS4s* (EPA, n.d.) explains that local programs can write their measurable goals in various ways, which fall into five main categories:

1. Tracking implementation over time.
2. Measuring progress in implementing the BMP.
3. Tracking total numbers of BMPs implemented.

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4. Tracking program/BMP effectiveness.
5. Tracking environmental improvement.

Some of these loosely align with the six CASQA outcome levels, with the highest outcome (or measurable goal category) related to improvement in receiving waters. However, measurable goals for most Phase II MS4 programs tend to be more focused on tracking activities or outputs rather than outcomes (categories 1 to 3). The programs then report on a myriad of activities in their annual reports, which can be cumbersome, time-consuming, and minimally informative about the programs' effectiveness.

A dynamic activity tracking, evaluation, and reporting system enables more coordinated program management and adjustment and clearer permit reporting. Focusing on program elements that are linked directly to quantifiable water quality outcomes (e.g., BMP maintenance) and reporting tools that provide transparent accounting of benefits and are field-verifiable will accelerate progress and provide useful information to decision-makers. Once a program determines what elements need to be monitored, it should seek out a more integrated information and data management system that synthesizes data geographically and supports real-time management decision-making. An increasing number of programs are beginning to adopt asset management approaches for integrating disparate data systems.[4] One workshop participant noted that a more holistic asset management approach provides an appropriate framework for systematic performance tracking. This in turn can promote a better understanding of the correlation between activities and outcomes and generate actionable information on overall performance.

The **City of Salinas, California**, started using an ESRI-based geospatial tool called **2NFORM** in 2017 to streamline its stormwater program tracking and evaluation process. Rather than spend months compiling hard copy inspection reports, public works staff can now enter data directly into a centralized database synced with information on hydrology and local geographic features. This rich, readily accessible data set is intended to enable better BMP performance assessment and overall decision-making.

Workshop participants stressed the importance of tracking locations, capacity, types, and performance (or maintenance status) of treatment control BMPs. Collectively, these serve as useful metrics for program progress and permit compliance on short time frames and can guide action prioritization. Another participant noted that collecting better data on the health of receiving waters is critical not only for program management but also for effective public outreach. Training and examples will be needed to help communities implement new methods and incorporating them in permits.

[4] Asset management is a means to capture information on stormwater asset location, age, type, condition, maintenance history, and cost to help facilitate long-term planning and budgeting, staffing and workflow analyses, enhanced tracking and reporting, proactive maintenance, development of multi-benefit projects, and visual demonstration of progress with identified service levels. The report from the 2017 MS4 workshop included recommendations to (1) build capacity for asset management and (2) incentivize asset management.

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3.5.2 Determine the Most Effective MS4 Program Reporting Mechanisms and Formats

Improving the functionality of reporting mechanisms will help streamline the process for program staff, making them more likely to fully engage in the effort. Workshop participants suggested that a national stormwater organization (e.g., WEF, NMSA) could survey states to identify the most effective reporting mechanisms currently in place. The results could then be used to inform the development of a web-based template for implementation under the new E-Reporting Rule. Baseline components would likely include data on receiving waters, outfall monitoring, and interim progress on milestones towards water quality requirements (e.g., wasteload allocation progress for TMDL compliance). Enabling the reporting of more and better data can in turn support the continued development of the local program.

During the workshop, a Phase I permittee representative described how one of their MS4 annual reports **filled 18 file boxes when printed**. Permittees and regulators alike acknowledged the immense effort often expended by permittees on annual reporting and a common lack of resources at regulatory agencies to fully review and interpret submitted materials.

Ultimately, this program information is shared in annual reports. These serve a specific regulatory purpose, but improving their usability would promote knowledge transfer across different programs. Workshop participants expressed support for a watershed approach that aggregates information from across the municipalities. Several workshop participants suggested developing a method for annual reporting that shows a permittee's answers to clear reporting questions and their "work" (or calculations/tracking information) demonstrating how they arrived at those answers; this could benefit multiple audiences such as regulators and other permittees attempting to address similar requirements. Participants described a few exemplary local examples that let regulators and the public alike dig into program information online. This would necessitate a platform for more robust tracking so that annual reports could be more digestible. Indeed, the need to declutter and slim down annual reports to the essential components was a common refrain.

Future reporting systems should be able to incorporate new information as permit requirements, opportunities, and technology shift over time while providing outputs that clearly communicate actionable information about program activities and effectiveness. Guidance and training on new reporting frameworks and how to incorporate them in permits will be needed to advance reporting approaches at the state and local levels.

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4 Opportunities and Next Steps

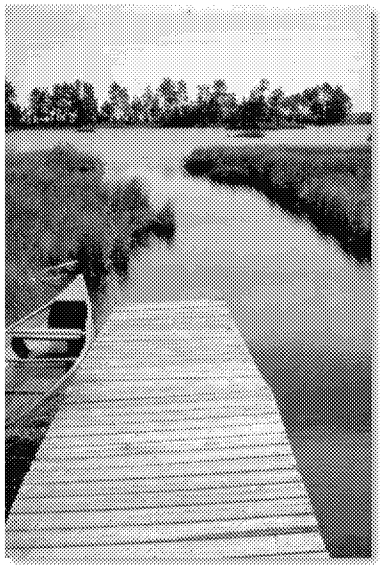
Photo: EPA

EPA Region 9, in partnership with the State of California and EPA Headquarters, convened the *Improving Stormwater Permit Approaches to Monitoring, Evaluation, Tracking, and Reporting* workshop to generate concepts for an overall better framework for stormwater program assessment and adaptation. Through facilitated dialogues, participants helped to identify more impactful, innovative approaches aimed at optimizing the use of scarce permitting and program implementation resources. Specifically, they highlighted opportunities to improve water quality outcomes through optimized design and implementation of monitoring and evaluation tools and tracking and reporting approaches.

Key findings from this workshop and the first workshop on improving overall approaches to stormwater permitting and program implementation will be broadly shared among EPA, state permitting agencies, local MS4 permitting agencies, permittee and research associations, and associated consultants and stakeholders. Workshop participants recommended specific actions and strategies to address the issues and opportunities discussed at the workshop. The following table identifies these actions and strategies within relevant activity categories and identifies organizations that may be best suited to carry out these recommendations.

EPA anticipates working with these parties to conduct further program evaluations and identify specific actions for implementation. For example, EPA is currently developing an online training course on stormwater program finance methods, a key recommendation from the first workshop. Collectively, these recommendations provide a strong foundation for strengthening monitoring, evaluation, tracking, and reporting approaches to improve stormwater programs and permits and, ultimately, water quality.

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Table 4. Recommended actions to improve program performance.

Strategy/Action	Key Organizations	
CAPACITY BUILDING AND PROGRAM SUPPORT		
• Clarify vision for future stormwater monitoring • Develop monitoring program improvement guide • Establish key activity and outcome-based performance metrics • Identify ways to leverage existing data	☐ ACWA ☑ **Consultants** ☑ **EPA** ☑ **NMSA**	☑ **Permittee groups** ☑ **States** ☑ **Universities** ☑ **WEF**
PERMITTING STRATEGIES		
• Clarify permit requirements for monitoring, assessment, tracking, and reporting • Adjust permits to make special studies and focused monitoring more useful • Evaluate whether lack of 40 CFR 136 methods approval inhibits use of new technologies	☑ **ACWA** ☐ Consultants ☑ **EPA** ☑ **NMSA**	☑ **Permittee groups** ☑ **States** ☑ **Universities** ☑ **WEF**
MAKING MONITORING MORE DISCRIMINATING		
• Evaluate appropriate scales for monitoring to yield actionable results • Explore opportunities for broader use of sensors in MS4 programs	☐ ACWA ☑ **Consultants** ☑ **EPA** ☑ **NMSA**	☑ **Permittee groups** ☑ **States** ☑ **Universities** ☑ **WEF**
IMPROVING METHODS TO LINK WATER QUALITY OUTCOMES TO ACTIONS		
• Improve documentation of BMP effectiveness • Improve modeling performance data • Evaluate methods for accounting for true source control	☐ ACWA ☑ **Consultants** ☑ **EPA** ☐ NMSA	☑ **Permittee groups** ☑ **States** ☑ **Universities** ☑ **WEF**
IMPROVE PROGRAM TRACKING AND REPORTING		
• Identify methods to use performance metrics to guide tracking and reporting • Determine more effective MS4 program reporting mechanisms and formats	☐ ACWA ☑ **Consultants** ☑ **EPA** ☑ **NMSA**	☑ **Permittee groups** ☑ **States** ☐ Universities ☑ **WEF**

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APPENDIX A: WORKSHOP ATTENDEES

Name	Organization	Location
Karen Ashby	Larry Walker Associates	Davis, CA
Nicole Beck	2nd Nature	Santa Cruz, CA
Bethany Bezak	DC Water	Washington, D.C.
Ellen Blake	EPA Region 9	San Francisco, CA
Sean Bothwell	California Coastkeeper Alliance	San Francisco, CA
Eugene Bromley	EPA Region 9	San Francisco, CA
Geoff Brosseau	California Stormwater Quality Association	Menlo Park, CA
Seth Brown	Water Environment Federation; Storm and Stream	Alexandria, VA
Steve Carter	Paradigm H2O	San Diego, CA
Matt Fabry	San Mateo County	Redwood City, CA
Wes Ganter	PG Environmental	Golden, CO
Chad Helmle	Tetra Tech	San Diego, CA
Bobby Jacobsen	PG Environmental	Golden, CO
Peter Kozelka	EPA Region 9	San Francisco, CA
Keith Lichten	San Francisco Bay Regional Water Quality Control Board	Oakland, CA
Chris Minton	Larry Walker Associates	Seattle, WA
Thomas Mumley	San Francisco Bay Regional Water Quality Control Board	Oakland, CA
Randy Neprash	National Municipal Stormwater Alliance; Minnesota Cities Stormwater Coalition; Stantec, Inc.	St. Paul, MN
Nell Green Nylen	University of California, Berkeley	Berkeley, CA
Matt O'Malley	Coastkeeper	San Diego, CA
Elizabeth Ottinger	EPA Region 3	Philadelphia, PA
Gayleen Perreira	California State Water Resources Control Board	Sacramento, CA
Renee Purdy	Los Angeles Regional Water Quality Control Board	Los Angeles, CA
Dominic Rocques	Central Coast Regional Water Quality Control Board	San Luis Obispo, CA
Ken Schiff	Southern California Coastal Water Research Project	Costa Mesa, CA
Grant Sharp	Orange County	Orange County, CA
Dave Smith	EPA Region 9	San Francisco, CA
Chris Sommers	EOA, Inc.	San Francisco, CA
Michael Trapp	MBI	Carlsbad, CA
Suzanne Warner	EPA Region 1	Boston, MA
Richard Watson	RWA Planning	Mission Viejo, CA

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APPENDIX B: WORKSHOP AGENDA

Overview

This workshop is the second of two planned meetings that will focus on the evolution of stormwater programs and permitting requirements. The first meeting (in December 2017) addressed minimum control measures, industrial/construction program requirements, and water quality-based control requirements. This second workshop will focus on municipal stormwater program monitoring, evaluation, tracking, and reporting provisions. We will evaluate experiences to date and opportunities to improve in how we:

- ☐ ***Establish Performance Metrics*** *that form the basis of tangible targets and goals for the program and program elements.*
- ☐ ***Monitor stormwate****r, with an eye toward strengthening the linkage between stormwater program actions and our ability to quantify change in stormwater and receiving water quality,*
- ☐ ***Use other evaluation methods*** *(e.g., measuring surrogate measures, activity metrics, BMP implementation, etc.) with, or instead of, water quality measures,*
- ☐ ***Track program implementation*** *and progress in meeting goals (both water quality and other types of program goals), and*
- ☐ ***Report on program progress*** *and accomplishments to stakeholders and permitting authorities.*

As we did in the December meeting, we will focus to a significant degree on how NPDES MS4 permits can be better structured or restructured to encourage/require more useful, cost-effective approaches and reduce or eliminate less effective methods and requirements. Workshop feedback will be synthesized with other existing research to produce a white paper discussing opportunities to strengthen how MS4 permits and implementation programs address monitoring, tracking, evaluation, and reporting.

Structure

Throughout the workshop, participants will be encouraged to consider whether and how existing MS4 program requirements concerning monitoring, evaluation, tracking, and reporting add value and to identify ways to improve permit and program effectiveness. To enable these discussions, each session will follow the same general structure:

- ☐ **Conversation starter**. A guest speaker will provide a 5-10-minute overview, outlining the current state of monitoring and assessment, summarizing evolution over time, or sharing a brief example case study. In some cases, more than one conversation starter may speak.
- ☐ **Hypothesis review**. As we did for the prior meeting, we will conduct a pre-meeting survey of participants to test a series of hypotheses concerning the effectiveness of current monitoring, evaluation, tracking, and reporting approaches and permit requirements. We will summarize survey responses to help identify the degree of

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agreement or disagreement concerning key lessons learned and improvement opportunities.

- ☐ **Discussion.** The facilitator will then lead in-depth group discussions. For each permit element, we will consider 3 basic questions:
  1. How effective has these program tools/requirements been in improving water quality, telling the story about what program effectiveness, and achieving other program objectives?

  2. How can implementation of monitoring, evaluation, tracking, and reporting be improved in the future?

  3. How can permits be improved to facilitate desired changes in monitoring, tracking, evaluation, and reporting?

- ☐ **Findings/Recommendations**. Each session will be focused to solicit important findings and specific actions to strengthen and improve the corresponding MS4 program/permit element. The workshop will conclude with a recap in an effort to identify areas of agreement and disagreement and issues needing further evaluation before adjourning. The work we do at the workshop will inform preparation of a paper that will summarize our work and hopefully help guide future actions to help improve MS4 permits and programs.

Key Terms

It is imperative that participants understand and attempt to use a common set of terms. Some of these key terms include:

- **Program Assessment** – Using a combination of methods, an analysis of the overall effectiveness of the MS4 program.
- **Monitoring** – Water quality monitoring typically performed at end-of-pipe, in-stream, or in a receiving water.
- **Evaluation** – A determination if the program element, activity, or an individual BMP is meeting stated objectives and performance metrics.
- **Tracking** – Collecting and compiling information on program implementation.
- **Reporting** – Presenting collected information to (1) assist with compliance determinations, (2) demonstrate adherence with Performance metrics, or (3) disseminate information to stakeholders.
- **Activity** – An action taken by a permittee or a regulated entity within the permittees jurisdiction that may provide a water quality benefit.
- **BMP** – A specific structural or non-structural management practice that is known to provide a water quality benefit.
- **Performance Metric** – a qualitative or quantitative measure of an objective or goal.
  - **Activity-based** – A measure of output whose benefit to water quality cannot be clearly quantified.

- **BMP Performance-based** – Monitoring results for a particular BMP or set of BMPs; expressed as pollutant concentration, pollutant reduction, or flow reduction.
- **Water Quality-based** – Monitoring results as determined from samples collected at an outfall, in-stream, or within a receiving water.

Other key terms will be identified and defined during the course of the workshop.

Agenda

Wednesday, March 21, 2018

9:00-9:30 am	**Welcome and Overview of Workshop Agenda**
	Tom Mumley, San Francisco Bay RWQCB and Wes Ganter, PG Environmental □ Welcome □ Introductions □ Review of Workshop Purpose and Agenda
9:30-10:45 am	**Session 1: Current Condition - Are the current Monitoring, Evaluation, Tracking and Reporting requirements effective?**
Conversation Starters: Dave Smith (EPA Region 9) and Grant Sharp (Orange County) *The objective of this retrospective session is to hear positive perspectives on the usefulness of current monitoring, evaluation, tracking and reporting requirements and to identify elements that are working well.* **Discussion:** *How effective has these program tools/requirements been in improving water quality, telling the story about what program effectiveness, and achieving other program objectives?*	
10:45-11:00 am	**Break**
11:00-2:00 pm	**Session 2: How Can We Better Use Performance Metrics To Facilitate Improved Monitoring, tracking, evaluation, and reporting?**
Conversation Starters: Nicole Beck (2nd Nature) and Dominic Roques (Central Coast Regional Water Board) **Discussion and Development of Findings and Recommendations** *1. Is it feasible to develop Performance Metrics for the Program and program elements and will this be helpful in improving water quality, telling the story about what program effectiveness, and achieving other program objectives?* *2. Does the proposed construct and use of Activity-based, BMP-Performance-based, and Water-quality based Performance Metrics make sense? If not, what other approaches should be considered?* *3. How can permits be improved to facilitate desired changes?*	

12:30-1:15 pm	**Obtain Lunch + Special Attraction- WEF's Stormwater Testing and Evaluation for Products and Practices (STEPP) initiative (Seth Brown, WEF)**
1:15-2:00 pm	**Continuation of Session 2 -**
2:00-2:30 pm	**Break**
2:30-4:15 pm	**Session 3: How Can We Make Outfall and Receiving Water Monitoring More Useful?**
Conversation Starters: Ken Schiff (Southern California Coastal Water Research Project) and Chris Minton (Larry Walker & Associates) **Discussion and Development of Findings and Recommendations:** *1. How effective has monitoring program tools/requirements been in improving water quality, telling the story about what program effectiveness, and achieving other program objectives?* *2. How can implementation of monitoring and evaluation be improved in the future?* *3. How can permits be improved to facilitate desired changes in monitoring and evaluation?*	
4:15-4:45	**Review of Day 1 and Initial Synthesis**

Thursday, March 22, 2018

8:30-8:45	**Reset and Chart Day 2** Wes Ganter, PG Environmental
8:45-10:00	**Session 4: Linking Activities To Expected Water Quality Outcomes**
Conversation Starter: Bethany Bezak (DC Water) **Discussion and Development of Findings and Recommendations:** *1. How effective has these program tools/requirements been in improving water quality, telling the story about what program effectiveness, and achieving other program objectives?* *2. How can implementation of models and linked planning, monitoring, and data collection methods improve evaluation techniques in the future?* *3. How can permits be improved to facilitate desired changes in evaluation?*	
10:00-10:15 am	**Break**

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10:15-11:30 am	**Session 5: How Can We Improve Program Performance Tracking?**
Conversation Starter: Randy Neprash (NMSA) **Discussion and Development of Findings and Recommendations:** *1. How effective have tracking tools/requirements been in improving water quality, telling the story about what program effectiveness, and achieving other program objectives?* *2. How can implementation of tracking be improved in the future? Are asset management programs the desired solution?* *3. How can permits be improved to facilitate desired changes in tracking?*	
11:30-12:30 pm	**Lunch: Special Attraction: Using Real Time Controls To Optimize Stormwater Management (Chad Helmle, Tetra Tech)**
12:30-1:45 pm	**Session 6: Reforming Reporting Approaches To Help Move Programs Forward and Give Permitting Authorities What They Need**
Conversation Starter: Elizabeth Ottinger (EPA Region 3- Philadelphia) **Discussion and Development of Findings and Recommendations:** *1. How can implementation of reporting be improved in the future?* *2. How can permits be improved to facilitate desired changes in reporting?* *3. Is there a model reporting format(s) that can be used as an example or template for programs and permits?*	
1:45-2:15 pm	**Break**
2:15-4:00 pm	**Session 7: Reflection, Synthesis, and Wrap Up**
☐ Identify areas of agreement, disagreement, or warranting more exploration. ☐ Review and fine tune findings and recommendations. ☐ How do we build capacity to use improved methods and approaches? ☐ How can we best bring about desirable change in permitting approaches (next steps)?	
4:00-4:30pm	**Meeting Evaluation and Closing**

APPENDIX C: PRE-WORKSHOP QUESTIONNAIRE RESULTS

On the right side of each table, responses were summarized and shaded in cases where responses were particularly strong in one direction or the other, or very balanced. Please keep in mind this is not intended to be a statistically valid survey instrument. Thank you for your responses.

Key to Shading

- 80% or more agree or see improvement opportunity
- 70-79% agree or see improvement opportunity
- Even, <20% difference
- 70-79% disagree
- 80% or more disagree

1. Effectiveness evaluations, program tracking, and reporting - Assuming it is possible to improve and adjust these activities, how would you rate the potential for significant improvement (toward cost-effective environmental outcomes) for each element?

	Significant potential	Some potential	Little potential	No potential	No opinion or insufficient knowledge	TOTAL	Significant or Some Potential	Little or No Potential
Water Quality Monitoring (receiving water, outfall, within collection system, at project or practice scale)	19	5	0	0	0	24	100%	0%
Non-Water Quality Evaluation (activity evaluation, effectiveness evaluation)	15	6	2	0	1	24	88%	8%
Tracking (tracking discreet activities (e.g. inspections, street sweeping, BMP installation), active asset management planning and tracking)	12	12	0	0	0	24	100%	0%
Reporting (annual reporting to permit authorities, reporting to public or elected officials)	16	5	3	0	0	24	88%	13%

2. What are the key elements of program effectiveness? *(responses copied directly from survey results; not edited for grammar or spelling)*

1) Solid definition of performance metrics
2) Metrics that are linked to meaningful outcomes
3) Suite of activities that directly move those metrics in a measurable way

- We don't really know how our effective our programs are, generally. At the end of the day, we should be measuring impacts on water quality, but that has not been a focus for most programs for both political and financial reasons. Until we start to consistently and comprehensively measure performance, we will have no idea of real progress (or lack of progress).
- Key Elements are:
  - Enhanced Awareness
  - Behavior Change
  - Estimating/Modeling Pollutant Reductions
  - MS4 Monitoring
  - Receiving Water Monitoring
- Clear articulation of the question wanting to answer, including time, space, and degree of change you're wanting to observe
- Clear and concise permit language that provides flexibility to meet water quality standards while requiring robust monitoring to demonstrate compliance.
- Improvements in water quality (both discharge quality and receiving water quality); reduction in pollutant load discharged (either through stormwater treatment or capture); elimination of non-stormwater discharges; elimination of waterbody impairments (and delisting from CWA section 303(d) list)
- Tracking progress of implementation efforts to improve water quality, including reporting of BMPs laid out in a plan (e.g., EWMP, WQIP, GI Plan).
- Clear and measurable performance metrics and the ability to gauge activities and actions versus those metrics; in the case of MS4 there has to be a tie to water quality improvement and/or protection - this is why we invest the time, money, and effort
- Effectiveness measurements that are:
  - primarily outcomes (as opposed to outputs)
  - appropriate for the specific BMP
  - measured as close as possible in time and space to the result of a BMP
  - expressed in a meaningful way (e.g., relative (%) as opposed to absolute)
  - as appropriate and possible, expressed in lay terms
- We need clear articulation of program requirements, clear methods for associating actions with expected or observed water responses, and clear accountability expectations to ensure the stormwater agency communicates results clearly to the public and the permitting authority.
- Objective, outcome-based performance metrics. Not just checkboxes of "miles of street swept."
- Engagement and expertise at the MS4 level, adequate funding and authority, good asset management

- Ability to show water quality improvement, behavior change, and an overall understanding of the benefits and challenges associated with urban stormwater
- Spatially-explicit, quantifiable information on pollutant loading-reducing structural BMPs and implementation activities
- Close relationship between measured metrics and expected outcomes
- Receiving water quality improvements are the ultimate goal
- The key element of program effectiveness to me is the ability to establish a relationship between the BMP/action/activity and a reduction in pollutant loads.
- Understanding current level of effort (including common definitions to ensure consistent understanding of those efforts)
  Understanding desired outcomes and meaningful and measurable metrics
- What makes for an effective program?
  Effective programs need continual streams of funding. To obtain funding, program managers need the ability to communicate actions and environmental return both pre- and post-spend in formats easy to understand. Money is spent in specific locations. Spatially-based asset management allows implementation optimization and simplifies tracking and reporting.

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3. Are program assessment requirements outdated and ineffectual?

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	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	TOTAL	Strongly Agree or Agree	Strongly Disagree or Disagree
Permits have been relatively inflexible, resulting in retention of less effective monitoring requirements and difficulty in initiating more effective and innovative approaches.	9	13	0	2	0	24	92%	8%
Permits have failed to include clearly defined performance metrics that can be fulfilled through coherent monitoring and evaluation approaches.	9	12	3	0	0	24	88%	0%
Permit monitoring and evaluation requirements have failed to adequately consider program size, complexity, and pollutants of concern.	8	8	5	2	1	24	67%	13%
Stormwater quality monitoring has been largely ineffective in assisting compliance evaluation, problem targeting, and program improvement.	12	9	2	1	0	24	88%	4%
The stormwater quality monitoring problems are attributable to lack of experimental designs that have well defined objectives, minimize sampling error and constrain the hydrologic variability in stormwater quality.	7	7	8	1	1	24	58%	8%
Receiving water monitoring has been only moderately effective for trend analysis and assessing attainment of water quality standards.	5	10	7	2	0	24	63%	8%
Receiving water problems are attributable to the inherent variability in receiving water quality, lack of expertise and time in evaluating collected data, difficulty of associating changes in receiving water quality to watershed sources, and high monitoring costs.	10	7	3	1	3	24	71%	17%
Making linkages between BMPs and activities and water quality outcomes has been hampered due to stagnant monitoring designs and a lack of defined performance metrics.	8	10	3	2	1	24	75%	13%
Monitoring data management and analysis systems have not evolved sufficiently to enable effective evaluation and comparison of monitoring results.	8	8	5	2	1	24	67%	13%
Tracking and reporting frameworks have not been adequately tied to performance metrics which hamper assessment and reduce cost-effectiveness.	14	6	3	1	0	24	83%	4%
Tracking and reporting frameworks have yet to acknowledge or endorse asset management systems.	11	11	2	0	0	24	92%	0%

Program and effectiveness evaluation should not be limited to permittees. The regulators (state and federal) should produce self-evaluations. These evaluations should include input from the full range of stakeholders (including permittees). The results of these evaluations should be made public for widespread distribution.	6	9	7	1	1	24	63%	8%
The programs for stormwater research have to change. Identifying, describing, and prioritizing research needs must be an open process that includes the full range of stakeholders (including permittees). The process should clearly define the research needs and publicize corresponding grant opportunities.	10	8	5	1	0	24	75%	4%
An improved process for technology transfer that translates and distributes research results useful for local implementers is needed.	13	9	1	0	1	24	92%	4%

4. Should we move toward a mix of Activity-based, BMP Performance-based, and Water Quality-based Performance Metrics, tailored to the local program design?

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	TOTAL	Strongly Agree or Agree	Strongly Disagree or Disagree
No one monitoring and evaluation method addresses all the assessment needs; multiple approaches tailored to local circumstances are needed.	14	8	1	1	0	24	92%	4%
If permitees adopt a consistent performance metric-based accounting system (spatial or otherwise), permits can increase emphasis on performance achievement and reduce emphasis on burdensome record keeping.	10	6	6	2	0	24	67%	8%
It is recognized that permittees or regulators cannot reliably assess program effectiveness at spatial and time scales relevant to management decision making based solely on measured water quality outcomes.	11	7	5	0	1	24	75%	4%
Program managers and regulators need to continually review and update management/compliance questions to reflect changes in water quality issues and evolution of program approaches to inform monitoring program adaptation.	8	9	5	2	0	24	71%	8%
Extensive training and outreach for permit writers, program staff and elected officials will be needed to enable local programs to take this approach.	12	6	5	1	0	24	75%	4%
Asset management systems provide the ability to define and track a wide array of activity-based metrics.	10	10	4	0	0	24	83%	0%

Mobile enabled platforms are the most efficient way to facilitate and conduct field assessments and monitoring.	6	9	6	2	0	23	65%	9%
Metrics should enable evaluation not just of what was done, but also of whether those actions were effective.	16	7	1	0	0	24	96%	0%
Activity-based metrics should only be developed where BMP performance or water quality is difficult or impossible to measure.	4	5	2	9	4	24	38%	54%
Where programs have completed comprehensive plans identifying specific BMPs (e.g. through reasonable or other modeling), BMP Performance monitoring should be used to assess effectiveness.	6	14	1	2	1	24	83%	13%
BMP performance monitoring (water quality and/or volume reduction) should be used when stormwater assets are integrated with hydrologic tools to quantify impacts to receiving waters and cumulative BMP benefits.	6	12	4	2	0	24	75%	8%
Performance-based monitoring (water quality and volume reduction) can be used when BMPs are deployed in series to measure BMP effectiveness, assess maintenance needs, or to educate community stakeholders on program effectiveness.	5	13	6	0	0	24	75%	0%
Increased sampling of outfalls and locations within the collection system is needed to accurately target pollutant sources and evaluate BMP effectiveness within time scales of interest to permitting authorities and program managers.	7	8	4	3	2	24	63%	21%
Small systems may not need to perform water quality monitoring if alternative program evaluation and tracking approaches demonstrate effective BMP implementation and maintenance.	4	6	8	6	0	24	42%	25%
Performance metrics need to be established in concert with improved monitoring designs and methods (as more fully discussed in Session 3).	8	15	1	0	0	24	96%	0%
Focusing implementation actions and associated monitoring (and possibly even permits) in smaller watersheds or sewersheds improves capacity to evaluate implementation effectiveness and water quality responses.	8	10	6	0	0	24	75%	0%

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5. How Can We Make Outfall and Receiving Water Monitoring More Useful?

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	TOTAL	Strongly Agree or Agree	Strongly Disagree or Disagree
Program managers and regulators need to continually review and update management/compliance questions to reflect changes in water quality issues and evolution of program approaches to inform monitoring program adaptation.	9	11	4	0	0	24	83%	0%
Water monitoring should continue but based on improved design and methods and tighter connection to performance metrics and program objectives.	13	8	2	0	1	24	88%	4%
Surrogate measures (e.g., fine sediment, flow) are a viable option for reducing analytical costs and increasing power for identifying spatial patterns and changes over time.	7	9	7	1	0	24	67%	4%
Instream monitoring requirements should be reduced in order to increase monitoring of outfalls, BMP effectiveness, and/or BMP assessments.	10	6	4	3	1	24	67%	17%
Water quality change detection will be enhanced with accounting of flow conditions coincident with sampling and guidance for how to use flow data to improve analysis	10	7	6	1	0	24	71%	4%
Monitoring designs must go beyond just data collection methods to include data management, data analysis, and reporting formats that clearly link data collected with Performance metrics.	13	11	0	0	0	24	100%	0%
New sampling methods (e.g. automated samplers) and designs can yield more reliable data to help answer management questions and assist real-time project and system management.	8	9	6	1	0	24	71%	4%
Permit language will need to be modified to authorize use of new methods and designs.	10	7	6	1	0	24	71%	4%
Training and outreach for permit writers, program staff, and elected officials on new methods and designs are needed to familiarize these groups with their benefits and limitations.	12	10	0	2	0	24	92%	8%

6. How can we better link activities to outcomes?

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	TOTAL	Strongly Agree or Agree	Strongly Disagree or Disagree
Targeting implementation and monitoring in smaller areas increases likelihood of demonstrating linkages between implementation activities and water quality responses.	10	12	1	1	0	24	92%	4%
Using predictive watershed and BMP siting models can provide the analytical framework necessary to relate activity/BMP implementation measures to expected water quality outcomes.	6	11	5	2	0	24	71%	8%
Where model-based approaches are used for linkage in planning, monitoring may need to focus more on collection of data to support model validation and sensitivity analysis.	14	8	2	0	0	24	92%	0%
Where robust models and associated implementation plans are in place, it may be appropriate to reduce and/or strategically focus annual water quality monitoring requirements.	10	10	2	1	1	24	83%	8%
More complicated linkage methods may be unnecessary for simpler Phase II permits or other permits that do not focus on specific water quality issues.	7	12	3	2	0	24	79%	8%
Outreach and training will be needed to build local capacity to implement these planning and linkage methods.	11	11	1	1	0	24	92%	4%

7. How can we improve program tracking performance?

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	TOTAL	Strongly Agree or Agree	Strongly Disagree or Disagree
Building an integrated activity tracking, evaluation, and reporting system enables more coordinated program management and adjustment, and clearer permit reporting.	13	8	2	1	0	24	88%	4%
Information/data management needs to improve to move past static compilation of activity measures to use of integrated information management systems that synthesize data geographically and support real-time management decision making.	16	5	3	0	0	24	88%	0%
Tracking locations, capacity, types, and performance (or maintenance status) of structural BMPs are a useful metric for determining program progress and permit compliance on short time frames, and this information can inform planning and prioritization.	14	7	3	0	0	24	88%	0%
Implementing more holistic asset management approaches provides appropriate framework for systematic performance tracking.	10	9	5	0	0	24	79%	0%
Training and examples will be needed to assist communities in implementing new methods and incorporating them in permits.	13	7	3	1	0	24	83%	4%

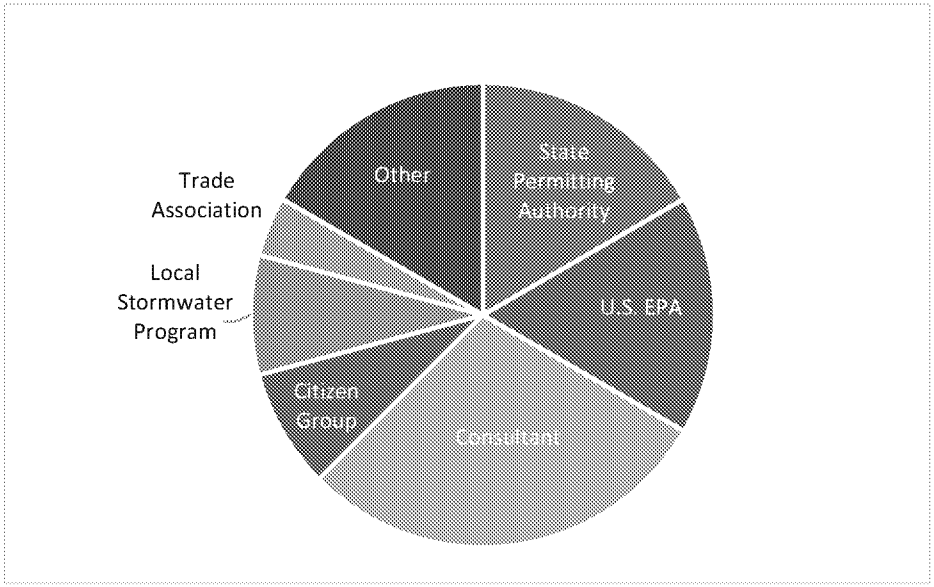
8. How can we reform reporting approaches to help move programs forward and give permitting authorities what they need?

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	TOTAL	Strongly Agree or Agree	Strongly Disagree or Disagree
Reporting requirements should move beyond passive activity and data tallies to incorporate active effectiveness evaluation and clear linkages to program actions.	15	7	1	1	0	24	92%	4%
Focusing more on program elements that are linked directly to quantifiable water quality outcomes (e.g. BMP maintenance), and reporting tools that provide transparent accounting of benefits and are field verifiable will accelerate progress and provide useful information to decision makers.	12	10	1	1	0	24	92%	4%
Future reporting systems should be able to incorporate new information as permit requirements, opportunities and technology shifts over time while providing outputs that clearly communicate program implementation/success.	13	8	2	1	0	24	88%	4%
Better guidance and training on new reporting frameworks and how to incorporate them in permits will be needed to advance reporting approaches at the state and local levels.	12	10	1	1	0	24	92%	4%
Electronic reporting will not improve reporting quality unless more measurable and evaluative metrics are associated with program activities.	10	11	3	0	0	24	88%	0%
Reporting requirements should be scaled based on program complexity; smaller programs need not report in as much detail as larger programs.	9	5	6	1	2	23	61%	13%

9. Do you have any additional comments or suggestions for the workshop? *(responses copied directly from survey results; not edited for grammar or spelling)*

- These questions are very thoughtful and should be plenty to start the discussion.
- There isn't one right answer for every program, but there must be a better monitoring/tracking/assessment framework that could be used to build more effective programs across the country.
- Effectiveness assessment is element-specific. No one measurement fits all. So, rather than specifying a measurement, specify a process to follow between the different elements to identify the appropriate measurement, etc. Process would be something like:
  Inquiry (question, permit req, exceedance) → POC → BMP → Effectiveness measurement → Effectiveness methodology → Report
- Focus on solutions, and try to identify how and by whom recommended actions can be implemented.
- I wish similar workshops were conducted throughout the entire country for all levels of MS4 implementers (permitttees, permit writers, regulators, inspectors, etc.). Perhaps that will be an outcome of this workshop (fingers crossed!).
- It's going to be awesome!
- Great job with the hypotheses - they are very thorough. I was energized just by reading through them.
- We should discuss the role sand responsibilities of the regulators (EPA & states) as well as the permittees.

What type of organization do you represent (or is your employer)?



Answer Choices	Responses	
State Permitting Authority	4	17%
U.S. EPA	4	17%
Consultant	7	30%
Citizen Group	2	9%
Local Stormwater Program	2	9%
Trade Association	1	4%
Other	4	17%