Chapter 6
DATA MANAGEMENT, VALIDATION, AND REPORTING

Effective data management, validation and reporting are fundamental components of an effective stormwater Best Management Practice (BMP) monitoring study. This chapter provides basic recommendations for general data management, data validation, use of databases, data entry approaches to maximize efficiency and minimize errors, QA/QC techniques, reporting guidelines, and submission of studies to the BMP Database.

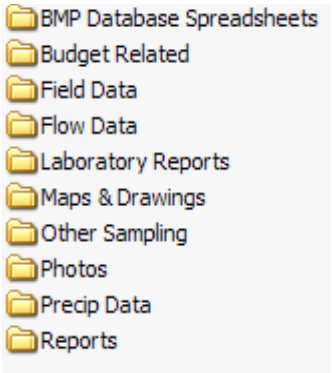
6.1 Recommendations for Data Management

A stormwater BMP monitoring program typically generates a considerable amount of information in a wide variety of forms. Before initiating monitoring, it is important to establish effective data management procedures to enable efficient storage, retrieval, and transfer of monitoring data. The Quality Assurance Project Plan (QAPP) should identify data management procedures, specifying measures such as:

- Central File: A central file to accommodate the hard copy information generated by the program and practical dating and filing procedures to help ensure that superseded information is not confused with current information.

- Field Forms: Well-designed and consistently used field forms promote standardized documentation and enable subsequent verification of field conditions. Field forms can be scanned on most modern copiers and stored electronically, along with other project data. Examples of field forms that can be customized to a particular study can be obtained from a variety of sources (e.g., http://ma.water.usgs.gov/fhwa/fhwaep.htm).

Exhibit 6-1. Example File Directory for BMP Monitoring



- Electronic Database: A database to accommodate electronic results of laboratory analyses, information recorded by data loggers (e.g., flow, precipitation, in-situ water quality measurements), maps in CAD or GIS, spreadsheets, and so on. An example electronic file structure is shown in Exhibit 6-1. As part of this system, it is important to clearly label draft and final reports, as well as validated and unvalidated data. Organizing digital photographs in subfolders according to date is also helpful.

- Contractor Instructions: Clear instructions to contractors regarding both raw data and processed data formats. It is not uncommon for expensive monitoring programs to lose valuable underlying data (e.g., flow data used to calculate event mean concentrations) when a contractor is no longer involved in a project.

- Computer Backup Guidelines: Instructions and requirements for frequency of backup of computer files. Although this may occur automatically in many office settings, simple manual backups onto CDs or DVDs will also work.

In most cases, the laboratory can provide the analytical results in an electronic format [i.e., an "Electronic Data Deliverable" (EDD)] that can be input directly into an internal water quality database, as well as the BMP Database. When preparing the chain of custody for the laboratory, request both PDF and open electronic formats (e.g., delimited text file, database or spreadsheet) of the data. Directly importing laboratory data increases efficiency and reduces data entry errors, as well as ensures a complete record of the results such as the correct name for the constituent analyzed, the test method, the detection limit and appropriate data qualifiers. In some cases, laboratories are also willing to output data to a custom format.

Data reports should be reviewed for completeness as soon as they are received from the laboratory. Reports should be checked against the sampling plan to ensure all requested analyses were performed and all required quality assurance (QA) data are reported for each sample batch. If problems with reporting or laboratory performance are encountered, corrective actions (i.e., re-submittal of data sheets or sample re-analysis) should be performed prior to final data reporting or data analysis.

6.2 Data Validation

Before uploading water quality data into a database or interpreting performance of BMPs, it is critical to evaluate the quality and adequacy of the laboratory analytical results. This evaluation is known as "data validation" or data quality review. The basic steps are listed below.

1) Check that all requested analyses were performed and reported, including QA/QC samples.

2) Check sample holding times to ensure that all samples were extracted and analyzed within the allowed sample holding times. (Typically, laboratories will provide an "H" qualifier when hold times are exceeded.)

3) Check that field QA/QC was acceptable. This includes a check of equipment blanks, field duplicates, and chain-of-custody procedures.

4) Check that the laboratory's performance objectives for accuracy and precision were achieved. This includes a check of method blanks, detection limits, laboratory duplicates, matrix spikes and matrix spike duplicates, laboratory control samples, and standard reference materials.

5) Check that surrogate recoveries were within laboratory control limits.

6) Assign data qualifiers as needed to alert potential users of any uncertainties that should be considered during data interpretation.

If the laboratory and field performance objectives were achieved, further data validation is generally not needed. Specifics of the instrument calibration, mass spectral information, and run logs are not usually recommended for review unless there is a suspected problem or unusual circumstances regarding decisions that will be made based on the data. If performance objectives were not achieved (e.g., due to contaminated blanks, matrix interference, or other specific problems in laboratory performance), the resulting data should be qualified. U.S. Environmental Protection Agency (EPA) functional guidelines for data validation should be used as a guide for qualifying data (see EPA 2004). Data qualifiers used in the BMP Database are consistent with the EPA's Water Quality Exchange (WQX) format (http://www.epa.gov/storet/wqx.html).

6.3 Using or Establishing Databases

Databases can be an efficient approach to storing monitoring data in a standardized format that facilitates data analysis. The International Stormwater BMP Database uses a combination of data entry spreadsheets in Microsoft Excel and a master database in Microsoft Access (WWE and Geosyntec 2009). Both the spreadsheets and the master database can be downloaded from http://www.bmpdatabase.org. One of the benefits of the BMP Database is that it identifies the types of data that need to be reported to conduct performance analysis for various BMP types. For various data elements, dropdown lists are provided that follow standardized rules so that future searches (queries) of the database can be conducted on specific parameters. For example, all copper data use identical nomenclature, so a query for copper retrieves all of the copper data. The BMP Database also provides ample space for providing narrative comments.

One of the benefits of relational databases, which include multiple tables linked together on key fields, is that large amounts of data can be stored in a more efficient manner. In the BMP Database for example, the user defines storm or base flow events that are monitoring based on start date and assigning a storm number. Once the storm event has been assigned an identifier (Storm Event #1), then that identifier can be used to link a table of storm event data to a table of flow data to a table of water quality data associated with the event. This approach is particularly valuable when there are "one to many" relationships such as one precipitation event with many water quality constituents monitored. In such relational database structures, it is important to ensure that the identifiers linking each table to event data are accurately assigned (e.g., are the precipitation, flow and water quality data properly linked to each other for Storm #1?).

6.4 Data Entry Approaches

Errors in data entry can cause significant problems in performance analysis and can waste time later if data entry is not carefully checked up front. The following techniques are helpful in reducing data entry errors:

- Require use of electronic data deliverables from laboratories. Hand entry of laboratory data increases the likelihood of errors and is unnecessarily time-

consuming. A common problem to look for in electronic data deliverables is sample location nomenclature errors related to handwriting interpretation by lab technicians. For example, site location MW-1 could easily be confused with MW-7. These types of errors need to be corrected at the time of data upload, rather than at the time of data analysis.

- When entering field data (e.g., pH, temperature, conductivity), it is helpful to have one person enter the data and another back-check the data to field notes.

- In cases where large backlogs of data must be entered by hand, double data entry can be a tool to minimize errors in a time-efficient manner.

Although data entry is the most straightforward aspect of most monitoring programs, it is also an area that requires significant attention to detail so that conclusions drawn from subsequent performance analysis are accurate.

6.5 QA/QC Techniques

Depending on the complexity of the project, a wide range of QA/QC techniques can be implemented. This section focuses on basic outlier screening and preliminary evaluation techniques that are applicable to most monitoring projects.

6.5.1 Outlier Screening/Analysis

Before conducting performance analysis, the water quality, flow, precipitation and other data should be screened for outliers. This screening helps to identify errors in data entry, as well as unusual values reported for an event. Although several specific techniques can be conducted as described below, this is a good time to have an experienced engineer or scientist give the data a "reality check." Outlier screening should include these tasks:

- Precipitation Data: Given that most BMP monitoring programs monitor a limited number of storms, review of precipitation data for outliers is relatively straightforward. If excessively large rainfall events are measured, then a nearby rain gage can be used to cross-check the data set. In cases where the hyetograph for the precipitation event is questionable, consider site factors such as clogging due to bird waste or the influence of spring snow storms then qualify, adjust, or invalidate the data as appropriate. On sites with multiple rain gages, significant variation between gages should be a flag to double-check the data to ensure that the reported differences were real.

- Flow Data: Flow measurement is the portion of stormwater BMP monitoring that is most likely to include errors. Checks on flow data can include rough calculations that combine precipitation with tributary area (e.g., simple Rational Method calculations) and compare the results to the monitored flow, asking common sense questions such as "Is the amount of runoff physically possible, given the amount of rainfall that occurred?" Other checks could include comparing flow data for similar rainfall

events to assess whether the data appear to be reasonably comparable. In some cases, where systematic flow measurement errors are discovered, an adjustment factor can be applied to the flow measurements, provided that the adjusted values are identified as adjusted or estimated. Additionally, it is important to compare inflows to outflows. If outflows are significantly greater than inflows, then the flow data should be carefully checked. In some cases, real contributions from groundwater or sheet flow not captured at the inflow monitoring location need to be taken into consideration and included in study reports. Rather than discarding the inflow data, it may be better to provide a modeled estimate of other flow contributions and include this information when reporting data. This is particularly important in the context of Low Impact Development (LID) monitoring where proper evaluations of volume reduction are study objectives.

- Water Quality Data: For hand-entered data, outlier screening for data entry errors can often be found by using simple spreadsheet functions to identify maximum and minimum values. Common errors such as misplaced decimal points can easily be identified for parameters such as pH and temperature using this technique. For other parameters, standard deviations can be calculated to identify results greater than three standard deviations above the mean as a screening tool to flag results that may need to be double-checked. There are no simple approaches for outlier screening for some constituents such as bacteria data, which can vary orders of magnitude between storms. Simple screening should also include checking units reported for each constituent to ensure that simple errors such as reporting mg/L instead of μg/L for metals have not occurred and to be sure that units have been provided for all constituents. Additionally, water quality data screening should include a check of reported results and qualifiers against method detection limits to ensure that appropriate qualifiers have been provided. For example, non-detects should have a "U" qualifier.

Overarching all of these considerations is the simple fact that those interpreting the data need to have direct familiarity with the site. Many errors in BMP reporting can be avoided by taking into consideration common sense understanding of the conditions present at the site.

6.5.2 Preliminary Data Evaluation

After the chemical data have been validated, a preliminary data evaluation should be conducted to determine whether enough data of sufficient quality have been collected to meet the study goals. Using the validated analytical results, graphically plot flow and rainfall data versus time for each storm event in order to produce a storm hydrograph (flow rate versus storm duration). It is often helpful to plot rainfall volume versus storm duration on the same graph and mark the times when the grab or composite samples were collected. See Exhibit 6-2 for an example individual storm report. This information can be very helpful in interpreting the chemical results and, if conducted after the first few storms, can be useful tool in identifying systematic errors in the monitoring (e.g., pacing of sample collection). Individual storm reports can also be included in appendices of the monitoring report to ensure that key information about the monitoring site and event are well documented and that information is not lost over time.

Exhibit 6-2. Example Individual Storm Report (Source: Lenhart 2009)

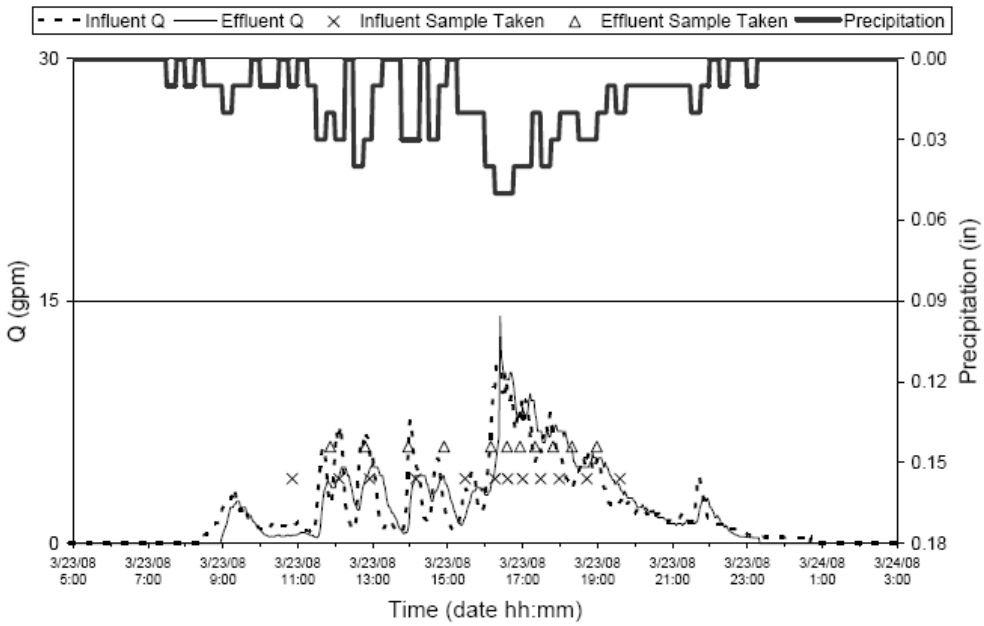
General Information

Site:	Lolo Pass Road (26607), Zigzag, Oregon
System Description:	264 MFS, 2 19-in, Perlite cartridges, 15.1 gal/min/cart (2 gal/min/ft^2)
Event Date:	03/23/08
Date of Last Maintenance:	01/17/08 (online since 03/12/08)
Antecedent Conditions:	42 hours

Hydrology

Total Precipitation (in):	1.02
Peak Flow, (gpm):	11.0 influent, 14.1 effluent
Total Runoff Volume (gal):	2799 influent, 2720 effluent
Storm Coverage (nearest 10%)	90 influent, 80 effluent

Event Hydrograph



Analytical

Number of Aliquots:
IN: 12
EFF: 11

Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	MRL	Dup. RPD
SSC	607	20.0	4.00	3.72%
TVSS	248	4.00	4.00	20%
TSS	435	15.0	5.00	0.00%
SSC (<500 µm)	409	18.9	4.05	3.72%
TVSS (<500 µm)	101	3.79	4.05	20%
SSC (<50 µm)	162	16.9	4.26	3.72%
TVSS (<50 µm)	25.5	4.24	4.26	20%
Gross Solids (mineral)	51.0	ND	4.05	20%
Sand (mineral)	172	ND	4.26	20%
Silt (mineral)	137	12.7	4.26	20%
Total Zn	0.154	0.150	0.00500	0.114%
Dissolved P	ND	ND	0.200	20%
Total P	0.452	0.0710	0.0125	12.5%
TKN	ND	ND	1.00	20%
Nitrate/Nitrite-N	0.0483	0.0612	0.0100	2.39%
Ammonia	ND	ND	0.100	0.826%
Hardness	31.5	15.6	0.662	20%

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. SSC Dup. RPD based upon replicate influent sample for SSC. Underlined parameters are calculated: Gross Solids defined as >500-um, Sand as between 500 and 50-um, and Silt as <50-um; mineral fraction determined through subtraction of volatile from total results. Elevated Hardness observations suggest the application of deicing agents. Sample processing for this event was overseen by the Technical Advisor as per Project Plan.

Generally, stormwater quality variability is so high that statistical evaluation is not worthwhile until several events (at least four) have been monitored. Once results for several events are available, basic summary statistics should be calculated that indicate how well sample results represent stormwater quality at a given site. Summary statistics include sample mean; variance; standard deviation; coefficient of variation; coefficient of skewness; median; and kurtosis. Because stormwater quality typically exhibits a lognormal distribution (EPA 1983), calculate these descriptive statistics based on an assumed lognormal distribution unless other information suggests an alternative distribution is more appropriate. Use the initial statistical analysis to determine whether it will be useful to statistically test various hypotheses regarding the existing data set. For example, if the standard deviations are several times larger than the means (i.e., the coefficient of variation is 3 or more), hypothesis testing may not be worthwhile. It may be necessary to conduct additional monitoring to compensate for the observed variability and allow statistically significant differences to be discerned. If initial statistical analysis indicates that the samples are representative of water quality at the site, then move forward with more definitive evaluations using the techniques described in Chapter 7.

6.6 Reporting Results

Most monitoring programs involve two types of reports: status (or progress) reports and final reports. To determine the appropriate frequency of status reports, consider the monitoring frequency and objectives, particularly any permit requirements. Many programs produce status reports on a quarterly or semi-annual basis. A typical status report may contain the following information:

- Summary of work accomplished during the reporting period, including an assessment of how the work completed compared to project objectives and goals (e.g., number of qualified storms collected versus number of storms targeted).
- Summary of findings.
- Summary of contacts with representatives of the local community, public interest groups, or state federal agencies.
- Changes in key project personnel, equipment or monitoring approach.
- Projected work for the next reporting period.

Prepare more comprehensive reports at the end of the monitoring program (for short-term programs) or at the end of each year (for multi-year programs). Consider including the above-listed information and the following information in the annual or final report:

- Executive summary.
- Monitoring program background and objectives.

- Tributary watershed characteristics and land use conditions.
- Adequate BMP design description (e.g., key parameters, photos, sketch plan).
- Monitoring station descriptions, analytical parameters, analytical methods, and method reporting limits.
- Summary descriptions of the site conditions and monitoring locations, equipment inspections and calibrations, and so on.
- Sample collection, precipitation, and flow measurement methods.
- Flow, precipitation, and water quality results and data validation information.
- Unusual or unexpected site conditions affecting use of the data.
- Qualitative and statistical data evaluations/hypothesis testing as required for the specific program objectives.
- Summary and conclusions, including any caveats or qualifying statements that will help the reader understand and use the reported information in the appropriate context.
- Recommendations regarding management actions (e.g., changes in monitoring program).
- Appendices with individual storm reports, laboratory data, and so on. Data CDs can be included with printed reports as an appendix.

6.7 Submitting Data to the International Stormwater BMP Database

To submit data to the BMP Database, data must be entered into the most current version of the Microsoft Excel spreadsheet package available for free download from the BMP Database website (http://www.bmpdatabase.org/DataEntry.htm). Appendix A provides a hard copy of forms identifying the data requested for each study and/or BMP type as of 2008. A description of the key data requested is briefly described throughout the remainder of this section.

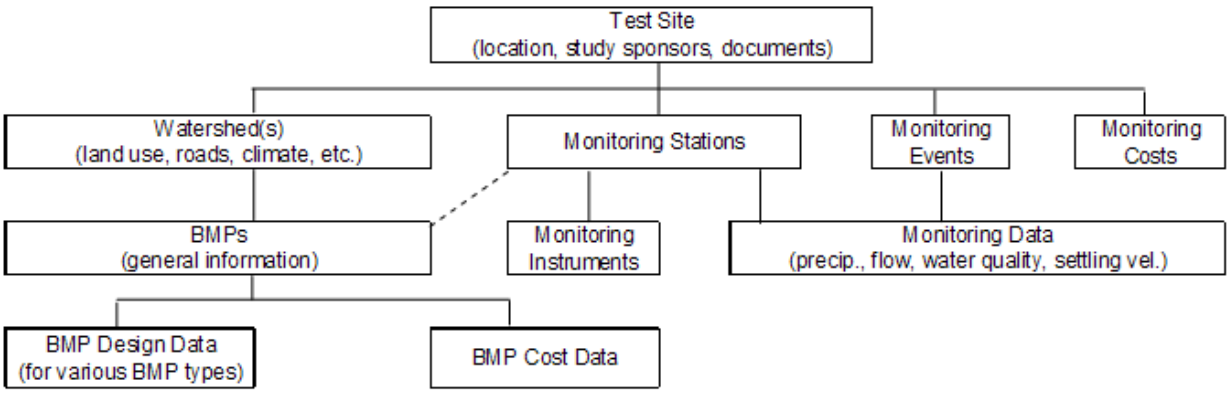
In order for a study to be accepted for inclusion in the database, all field designated as "required" fields must be provided. Depending on file size, the spreadsheet package can be "zipped" and emailed to the current BMP database contact identified on the project website, or a CD containing the data can be submitted. The submitted study is then reviewed for completeness and a series of reasonableness checks for the data (comparable to those described in Section 6.5) are completed prior to acceptance in the database. In most cases, minor follow-up is required to clarify issues related to the data submittal. Once the study is

accepted in the database, it will be posted to the BMP Database website for public access. Provided that the study meets the performance analysis criteria for the database, statistical analyses will be conducted and made available to the public. In some cases, studies accepted into the database are not included in statistical analysis due to unique study designs that are not suitable for large-scale data set analysis.

6.7.1 Overview of Data Requirements for the BMP Database

Exhibit 6-3 contains a summary of the types of data requested by the BMP Database followed by descriptions of each data category.

Exhibit 6-3.
Conceptual Overview of Data Requirements for Submittal to the BMP Database



6.7.2 General Test Site Information

The purpose of the general test site data set is to identify the study, the study location, all involved parties, and the cost of monitoring for the study. Additionally, the study document spreadsheet enables the user to attach supporting information such as links to published studies, quality assurance plans, photos, BMP and site layouts, and other information. Climate information is also entered at the test site level based on an EPA-sponsored report by Driscoll et al. (1990) *Analysis of Storm Event Characteristics for Selected Rainfall Gages throughout the United States*. Only one test site can be entered in each spreadsheet package.

6.7.3 Monitored Events

The purpose of the monitoring event table is to develop a user-defined list of events monitored at the test site so that precipitation, flow, and water quality data can easily be paired together. Events are defined at the test site level since most monitoring designs will monitor the same events at reference watersheds, and multiple BMPs may be monitored for the same events. Additionally, LID studies may be monitored for the test site as a whole rather than at each individual BMP or integrated management practice (IMP) at the study site. For example, rather than monitoring 50 individual rain gardens, an assessment of runoff for the overall development may occur at the downstream portion of the site.

6.7.4 Watershed Information

The purpose of the watershed table is to identify the conditions in the area tributary to the BMP. For example, important factors for successful designs of infiltration-type BMPs include watershed parameters such as soil type, imperviousness, and storm drainage system efficiency. Since initial release of the BMP Database, the Federal Highway Administration and various state departments of transportation have taken interest in the database. As a result, additional information is now being requested for sites located along highways.

More than one watershed may be present at a BMP test site for studies that use a reference (i.e., control) watershed to compare BMP performance. This approach is often the case for non-structural BMP and LID studies. For LID studies, there may be more than one reference watershed in cases where pre-development hydrology and water quality for the site is monitored, as well as a comparative watershed developed using traditional development designs. In order to conduct valid comparisons of performance between test watersheds and reference watersheds, it is critical to thoroughly document the watershed conditions for both. For example, a test and reference watershed could have the same tributary area and number of homes (e.g., "look the same"), but the underlying soil types could be dramatically different, which would be a critical difference between the two watersheds in terms of evaluating performance of the LID design.

6.7.5 General BMP Information

General information and cost data for BMPs are requested for all BMP types, including structural and non-structural BMPs and LID sites. General information requested includes parameters such as date of installation, various design parameters, maintenance and rehabilitation types and frequencies, and cost data. An overview of the type of information requested for structural, non-structural, and LID sites is provided below.

Structural BMPs

Data requested for each structural BMP vary according to the following common groups of BMPs: Detention (Dry) Basins, Manufactured Devices, Retention (Wet) Ponds, Infiltration Basins, Percolation Trenches/Dry Wells, Porous Pavement, Wetland Basins, Wetland Channels/Swales, Grass Filter Strips, Media Filters, Bioretention, Stormwater Harvesting (cisterns), and Green Roofs. An "Other" BMP category is also provided to enable flexibility for entry of BMPs that may not fit a pre-defined category. A "Treatment Train" BMP option is also provided. Most of the parameters requested in the structural BMP tables are required in order to compare the effectiveness of various BMP designs. Exhibit 6-4 provides an example of design data requested for a bioretention BMP.

In order for monitoring data to be interpreted in proper context, it is important to provide thorough documentation of the BMP as constructed in the field, identify whether engineering oversight was provided during construction, and provide a proper description of the BMP's condition during the study. For example, a common problem with bioretention cells and pervious pavements is that the as-built condition deviates from the design (Personal Communication with Bill Hunt, North Carolina State University). Without such information,

poor performance of a BMP may be falsely attributed to design characteristics, when the design conditions did not actually exist in the field. Additionally, a well designed and properly installed, but poorly maintained BMP, is unlikely to perform well. It is important to clearly document the maintenance and/or rehabilitation status of the BMP so that researchers using data from the study can appropriately group BMPs with comparable maintenance conditions for performance analysis. The BMP Database accepts properly conducted studies, regardless of whether the BMP performs well, because one of the primary long-term purposes of the BMP Database is to identify factors affecting BMP performance. Improper installation and poor maintenance are key factors that must be properly documented.

Non-Structural BMPs

Non-structural BMP data requested are generally narrative/descriptive information on the type and extent of BMP practice being implemented, as well as cost data. For the purposes of the BMP Database, non-structural BMPs have been divided into the general categories of education, maintenance, recycling, and source controls. LID strategies often incorporate a variety of site planning and development approaches that include non-structural measures such as conservation of natural areas, preservation of soils with high infiltration capacities, minimizing disturbance, preservation of natural drainage paths, and so on. These types of non-structural LID practices would be entered into the database under the Site-level LID BMP type, as opposed to the traditional non-structural BMP category.

Evaluating non-structural BMP characteristics is new ground for many. Defining measurable (i.e., quantifiable) parameters for non-structural BMPs is an evolving science. When more than one non-structural BMP is employed, it can be extremely difficult, if not impossible, to isolate the effectiveness of one BMP from the effects of other non-structural BMP(s) being tested at the same site. Also, a significant amount of data is needed to discern differences in water quality results between comparable watersheds with and without non-structural BMPs. For this reason, non-structural BMP testing programs will typically need to take place over more than one year. It is likely that confounding variables will be difficult to identify and to isolate in non-structural BMP tests.

LID Sites

Because LID sites attempt to mimic pre-development site hydrologic conditions by controlling runoff close to its source, BMPs (or Integrated Management Practices) are typically dispersed throughout a development site. Reporting for LID sites includes both individual practices and performance for the overall site. In cases where individual LID practices (e.g., bioretention cells) are monitored, reporting protocols the individual practices described under “structural BMPs” would be used, whereas when site-scale LID monitoring is conducted, a set of parameters describing the extent to which a broad suite of LID practices is implemented would be used. These reporting parameters would be provided in addition to previously described watershed and monitoring data provided for conventional studies. Exhibit 6-5 contains initial recommendations for reporting for site-scale LID studies. These recommendations are focused on describing the extent to which LID has been implemented at a site. Chapter 8 provides additional information on study design for LID sites and other metrics that can be used to evaluate and compare performance of LID sites.

Exhibit 6-4. Example of BMP Design Information Requested for Bioretention

Part 1. General BMP Design Information	Part 2. Bioretention Design Information
BMP Name	Type of Bioretention (pick from drop-down list)
Type of BMP Being Tested	Ratio of Tributary Area to Bioretention Surface Area
Basis of Design (e.g., 2-yr, 24 hr storm, design treatment flow rate)	Is Pretreatment Provided? (Y/N)
Purpose of BMP (treatment objectives)	Description of Pretreatment, if present
Source of Design Guidance for BMP	Description of Flow Entrance
Date Facility Placed in Service	Bioretention Surface Area
Number of Inflow Points	Average Ponding Depth above Bioretention Media Surface
BMP Designed to Bypass or Overflow	Ponding Volume above Bioretention Media Surface
Upstream Treatment Provided? (Y/N)	General Shape of Bioretention Feature (triangle, oval, rectangle, etc.)
Describe Upstream Treatment (if any)	Is "Internal Water Storage Zone" Created? (via underdrain placement above bottom of media)
Name of Upstream BMP(s) (list sequence)	Subsurface Storage Volume
General Configuration of BMP in Tributary Watershed (i.e., end of pipe, source control, off-line)	If subsurface storage provided, then height of outlet above bottom of bioretention media
Was qualified engineering oversight provided at construction?	Bioretention Media: Natural or Amended
Was structure installed as designed?	Bioretention Media Depth
General Description of Site Activities/Conditions Influencing Pollutant Loading to BMP	Bioretention Media Design Specifications
Maintenance Type and Frequency	Bioretention Media "P" Index (Phosphorus)
Last Rehabilitation Date	Description of Supplemental Bioretention Media Characteristics
Type of Rehabilitation	Description of Vegetation Community
Description, Types, and Designs of Outlets	Description of Mulch (if present)
Qualitative Evaluation of BMP Condition (vegetation, soils, odors, etc.)	Surface Infiltration Rate (at time of study)
For BMPs without permanent pool, does surface ponding exist beyond design drain time? (Y/N)	Design Infiltration Rate (including safety factor for clogging)
If clogging present, estimate % of total surface area of structure affected	Number, Description and Dimensions of Underdrain(s), if present
Describe BMP/Comments	Underdrain Gravel Layer Thickness, if present
	Description/Dimensions of Surface Overflow
	Is a Hydraulic Restriction Layer (Liner) Provided?
	Description of Hydraulic Restriction Layer, if present
	Seasonal High Water Table Position Relative to Invert
	Comments

Exhibit 6-5. Low Impact Development at Site Level (Horner 2009)

Data Element	Brief Description
BMP Name (Overall LID Site Name)	User-defined site name relates back to "General BMP" data entry spreadsheet.
Describe Site Design (include key elements of design)	Provide "big picture" of site design objectives and key design elements.
Describe Monitoring Design (to ensure proper use of data)	Describe monitoring design relationship to design elements.
Instructions for Describing Site Features: Quantitative data should be provided to the extent it is available. If the practice is not implemented, this should be stated instead of leaving the field blank. For discrete practices (e.g., permeable pavement, bioretention), design data should also be provided in their respective BMP tables.	
Conservation Features	Includes preservation of existing trees, other vegetation, and soils.
Minimizing Disturbance	Includes minimizing soil excavation and compaction and vegetation disturbance.
Minimizing Building Coverage	Includes minimizing impervious rooftops and building footprints.
Minimizing Travelway Coverage	Includes constructing streets, driveways, sidewalks, and parking lot aisles to the minimum widths necessary, provided that public safety and a walkable environment for pedestrians are not compromised.
Maintaining Natural Drainage Patterns and Designing Drainage Paths to Increase Time of Concentration	Includes measures such as maintaining depressions and natural swales; emphasizing sheet flow instead of concentrated flow; increasing the number and lengths of flow paths; maximizing non-hardened drainage conveyances; and maximizing vegetation in areas that generate and convey runoff.
Source Controls	Includes measures such as minimizing pollutants; isolating pollutants from contact with rainfall or runoff by segregating, covering, containing, and/or enclosing pollutant-generating materials, wastes, and activities; conserving water to reduce non-stormwater discharges.
Permeable Pavements	Includes constructing low-traffic areas with permeable surfaces such as porous asphalt, open-graded Portland cement concrete, coarse granular materials, concrete or plastic unit pavers, and plastic grid systems. Representative applications may include driveways, patio slabs, walkways and sidewalks, trails, alleys, and overflow or otherwise lightly-used parking lots.
Natural Drainage System Elements	Includes bioretention areas (rain gardens), vegetated swales, vegetated filter strips, and other similar features.
Stormwater Harvesting	Includes use of cisterns, rain barrels, or rain storage units.
Green Roof (vegetated)	Includes vegetated roofs with stormwater-related design components.
Other Site Features	Enables user to define other key site features or traditional BMPs.
Additional Facilities for Flood Control	Used to assess extent to which LID is used for water quality and flood control, or water quality only. Some LID sites have "hybrid" characteristics incorporating LID practices with traditional flood control approaches (e.g., are centralized detention and LID techniques).
List BMPs Monitored Within LID Site	Relates overall LID site design to individual practices monitored and/or implemented at the site (e.g., bioretention, permeable pavement).
Comments/Other Description	Describe other unique aspects of the site design or general comments.

6.7.6 Monitoring Stations

Monitoring stations must be identified for the test site as a whole, and then the relationship of each monitoring station to each BMP at the test site must be identified as monitoring inflow, outflow, subsurface conditions, sediment/solids, or some type of intermediate location within the BMP. For test sites that contain more than one BMP, two BMPs may share the same monitoring station; the station monitors the effluent from one BMP which is also the influent to a downstream BMP. In such cases, the relationship of the monitoring station must be identified relative to each BMP. A unique monitoring station name must be assigned to each monitoring station at a test site. At LID sites, it is not uncommon to have distributed controls throughout the watershed in combination with a larger flood control structure at the downstream end of the development. A clear understanding of the relationship of multiple monitoring stations to the site design is important for all BMPs, but is particularly important for proper interpretation of data from LID sites.

Information on instruments installed at monitoring stations is also important. Multiple instruments may be present at a single monitoring station. This information provides much insight into the flow gaging and sampling techniques used and the reliability of the data collected at the site. As a result, instrumentation reporting should be encouraged for all new evaluation efforts.

6.7.7 Monitoring Results

Monitoring results may include precipitation, storm runoff or base flow, water quality data, particle size distribution and/or settling velocity distributions associated with a monitoring event. Monitoring results must be reported in association with previously defined monitoring events and monitoring stations. For sites also monitoring groundwater levels, the water quality spreadsheet can be used to enter depth to groundwater. Each data set is briefly described below.

Precipitation

Precipitation data such as date and time that the event began and ended, total depth and peak one-hour precipitation rate are useful parameters for evaluating BMP performance. For example, a BMP may perform well for a low-intensity, short duration storm, but perform poorly for storms of longer duration. This type of information can help to explain variations in BMP performance.

Flow (Runoff and Base Flow)

Storm runoff directly affects the hydraulics of BMPs. Base flow data are also useful to understand the type of pollutant loading that occurs under dry weather conditions. Types of runoff data requested include runoff volumes into, from, or bypassing the BMP, and peak flow rates. Base flow data requested include flow rates. The BMP Database requests summary flow data, as opposed to continuous flow records; however, researchers may also submit raw data separately for archiving with the BMP Database. Although continuous flow data are valuable to researchers, management of continuous flow data for numerous studies is beyond the current scope of the BMP Database.

For LID sites and techniques, estimates of infiltration and/or groundwater measurements are valuable for evaluating performance of the site. These measurements can be entered into the Water Quality table, which follows EPA's WQX protocols for a variety of measurements in addition to water quality. (See the pick-list in the BMP Database spreadsheets for appropriate reporting parameters.)

Water Quality

Water quality data in combination with flow data for a monitoring event are used to calculate loads of each constituent, which are fundamental for comparing the performance of BMPs at different sites, locations, and regions. The BMP Database spreadsheets are designed to be compatible with many EDD formats now offered by laboratories and are generally based on EPA's WQX format, using "Modern" STORET terminology. The spreadsheet data entry approach enables pasting of EDDs into the database, thereby reducing the likelihood of data entry errors.

Particle size distribution data, which are important to evaluating the performance of many BMP types (particularly manufactured devices), can be entered into the water quality data table using WQX codes provided in a pick-list. As previously noted, a variety of hydrologic parameters such as soil moisture measurements and water quality samples from lysimeters and groundwater depths can also be entered into the Water Quality table as well. (Also see Chapter 4 for a discussion of suspended sediment sample collection and analysis issues.)

6.8 Conclusion

Proper data management, validation, and reporting are essential for a successful monitoring program. Many of these tasks are based on common sense, but are often overlooked in stormwater BMP monitoring. A well validated and documented data set is a fundamental building block for sound data evaluation and long-term value of the monitoring program. The BMP Database is a tool that can be used to ensure that key characteristics of stormwater BMP studies are systematically reported in a manner that enables comparisons of BMP performance locally and nationally.

6.9 References

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