5 Operational Strategies

A best management practice (BMP) operational strategy is a plan to accomplish the monitoring and maintenance necessary over the lifespan of the BMP after its construction. For the purposes of this document, monitoring means the practice of collecting BMP qualitative and quantitative data over time to provide information regarding its performance and condition. Maintenance means the care of a BMP using procedures to promote intended functionality and longevity of performance. This chapter presents information regarding routine and non-routine operational strategies, factors that should be considered when an operational strategy is being developed for BMPs on a site, cost considerations, prioritization and performance feedback.

The information provided in this chapter may also be used to develop an operations, monitoring and maintenance template for ongoing BMP operations. Resources presented in this section include case studies, sample forms/checklists/reports, and example monitoring/data collection plans to assist users in operations and maintenance (O&M) performance documentation (Figure 5-1).

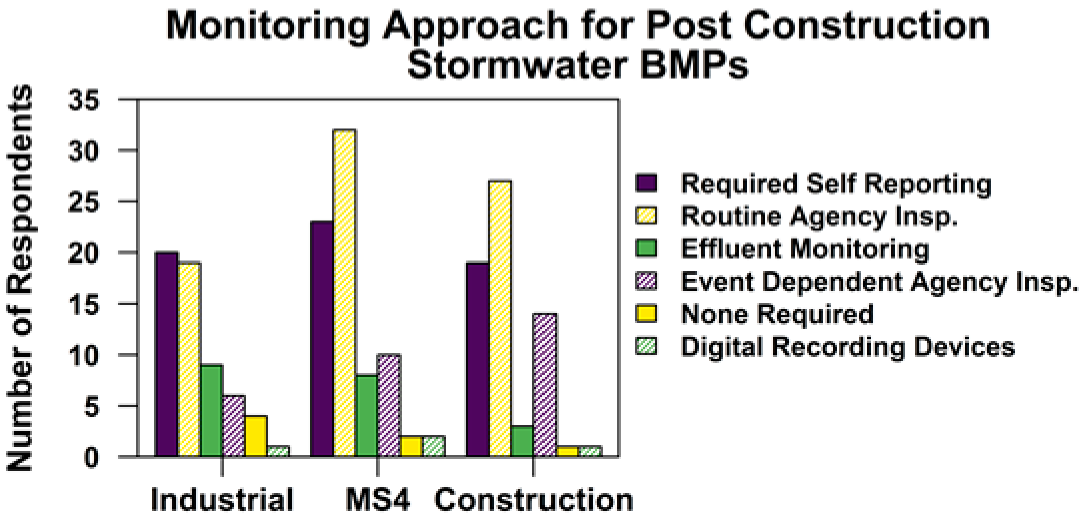

Figure 5-1. ITRC survey results for Question #6. (Appendix A**)**

5.1 Routine Operational Strategies

A Routine operational strategy considers the monitoring and maintenance activities that are generally based on a set schedule and involve tasks that are carried out on a regular basis. Examples of routine maintenance include removal of trash and debris from inlets and ponding areas, mowing, weeding or pruning plants, minor sediment removal, leveling of filtration media and replacement of filter cartridges in manufactured BMPs. These activities keep the BMP functioning as designed and work to prevent a future failure. The BMPs do not need to be taken off-line to perform routine maintenance. This type of maintenance is carried out independent of inspections and reports and is specifically tailored for the individual type and location of the BMP. Sites located in highly urbanized areas that receive high amounts of litter and other debris will need more frequent routine maintenance than the same BMP located in a less developed area.

Although routine maintenance is performed independent of inspections, it is important to keep records of maintenance activities. Approximately half of the agencies surveyed require maintenance documentation for municipal separate stormwater sewer system (MS4) and industrial stormwater BMPs (Figure 5-2). Records of specific routine maintenance activities performed over a range of BMPs provide feedback to refine the maintenance schedule and ensure that BMPs in problem areas receive necessary attention. Records help assess the level of effort in maintaining BMPs to ensure efficient use of time and resources. Records showing recurring maintenance activities may indicate an ongoing problem or failure of a BMP component that requires a higher level of effort than is provided by routine maintenance. For example, a bioretention basin with records showing the need for additional material to level the media could indicate a slow collapse of the underdrain system. With this information, a more extensive investigation of the BMP and changes can be made to correct the deficiency before a total failure occurs.

Effective stormwater management programs have an educational and outreach component, which can reduce the need for routine maintenance action and ensure that serious failures are avoided. Program outreach communication improves BMP operation and maintenance along with the other program elements. When people are educated to understand the objective of stormwater management, (i.e., to protect and preserve public and natural resources), they are much more likely to develop an understanding of BMPs and how they function (USEPA 2005). Tools that provide this educational element include signage noting BMP locations and illustrating their role in stormwater management, as well as storm drain medallions denoting the urban infrastructure's direct connection to the natural system. The sense of stewardship that grows out of this understanding of the larger objectives and systems results in people taking ownership of the operation of BMPs and makes them more likely to avoid throwing trash into facilities and more likely to report observed problems.

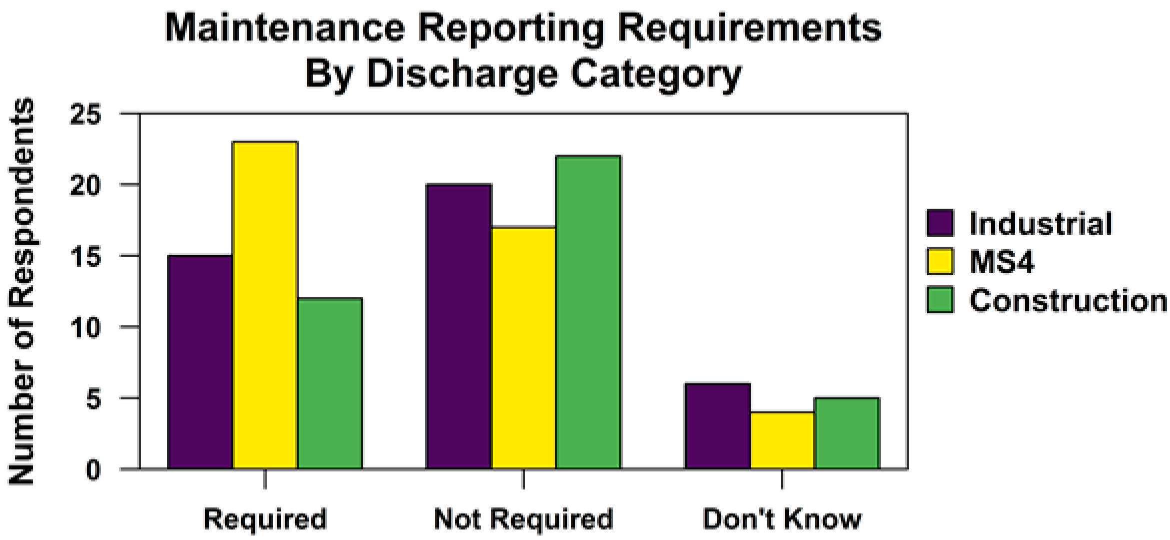

Figure 5-2. Survey responses to survey question, "Does your Agency have mandatory maintenance reporting requirements for post construction BMP performance? (Appendix A**)**

Post-construction monitoring requirements vary widely across jurisdictions. Survey respondents indicated that monitoring primarily occurs through routine agency inspections, and permits require self-reporting (Figure 5-1). These are all examples of routine monitoring.

5.2 Non-routine Operational Strategies

Non-routine maintenance results from an observation made in an inspection or maintenance report or from a complaint about a failure. Non-routine maintenance involves corrective measures that are provided and occur on an as-needed basis. These include repair to inlet or outlet structures; repair to eroded slopes, embankments, or flow paths; replacement of filter media that is no longer effective; removal of accumulated sediment; and replacement of dead plantings. Non-routine maintenance usually requires specialized training for maintenance staff. Special equipment for excavation, compaction and drainage infrastructure installation may be required for more extensive repairs. The most protective maintenance programs utilize routine proactive measures to address operational needs and non-routine reactive measures to address unforeseen issues.

5.3 Predictive Maintenance

Routine and non-routine maintenance are critical components to the ongoing operation of stormwater BMPs. However, thanks to the ever-growing technology industry, a third category of maintenance is now available, predictive maintenance. Predictive maintenance is the ability to forecast and perform necessary repairs, prior to failure, with little to no disruption to system operations; potentially saving valuable resources. A stormwater system operator can only achieve predictive maintenance through the incorporation of technology along with a clear operations plan.

The technology required to achieve predictive maintenance falls within the scope of the Internet of Things (IoT). The IoT is the network of physical objects or things embedded with electronics, software, sensors and network connectivity that enables these objects to collect and exchange data (International Institute for Analytics). Stormwater BMPs are fitted with sensors and software that are connected to the cloud. This provides visibility into a BMPs performance and supports operators in their decision-making processes. Incorporating IoT into stormwater BMPs can improve water quality, reduce flooding and provide valuable insights into BMP performance. An example of IoT in action includes forecast-based decision making in retention ponds to reduce wet weather discharge, increase infiltration, increase retention time, and maximize capacity of the BMP. Through installation of a level sensor and actuated valve in the outlet control structure of a retention pond, real time information may be transmitted to a cloud-based platform and water levels may be controlled remotely via a user's interface from anywhere they have a network connection. Taking action prior to wet weather events may alleviate flooding concerns and maximize the efficiency of the BMP. When multiple BMPs are connected within a watershed, flood management becomes feasible and downstream water quality can be improved. Current applications of this technology may be viewed at www.optirtc.com. (Lefkowitz 2015)

Incorporating IoT into stormwater BMPs requires thoughtful planning and consideration. The information gathered through the incorporation of the technology is only useful when analytical methods are applied to support decision-making processes. With proper analytical review, a feedback loop is created in which operators make informed decisions on when and how to manage, repair and replace stormwater BMPs. This can lead to greater O&M efficiencies, putting less stress on limited resources and time by having real time knowledge of the status of the system when properly incorporated.

5.4 Technology vs. Performance-based Strategies

Stormwater BMPs are designed and constructed to meet specific stormwater management goals related to water quality or quantity. These goals are met by applying either performance-based criteria or technology-based criteria. A performance-based strategy demonstrates compliance with a stormwater management goal by focusing on the discharge or output from a BMP and verifies that the discharge meets or exceeds that goal. In contrast, a technology-based strategy focuses on the physical characteristics of the BMP, in its specific operating environment, and demonstrates compliance by conforming to design standards set by the stormwater management program. Prior research, testing and experience with the BMP standard design provides assurance that the management goal will be met and analysis of the discharge from the BMP is not necessary. The concepts of technology- and performance-based criteria can be applied to O&M situations as well.

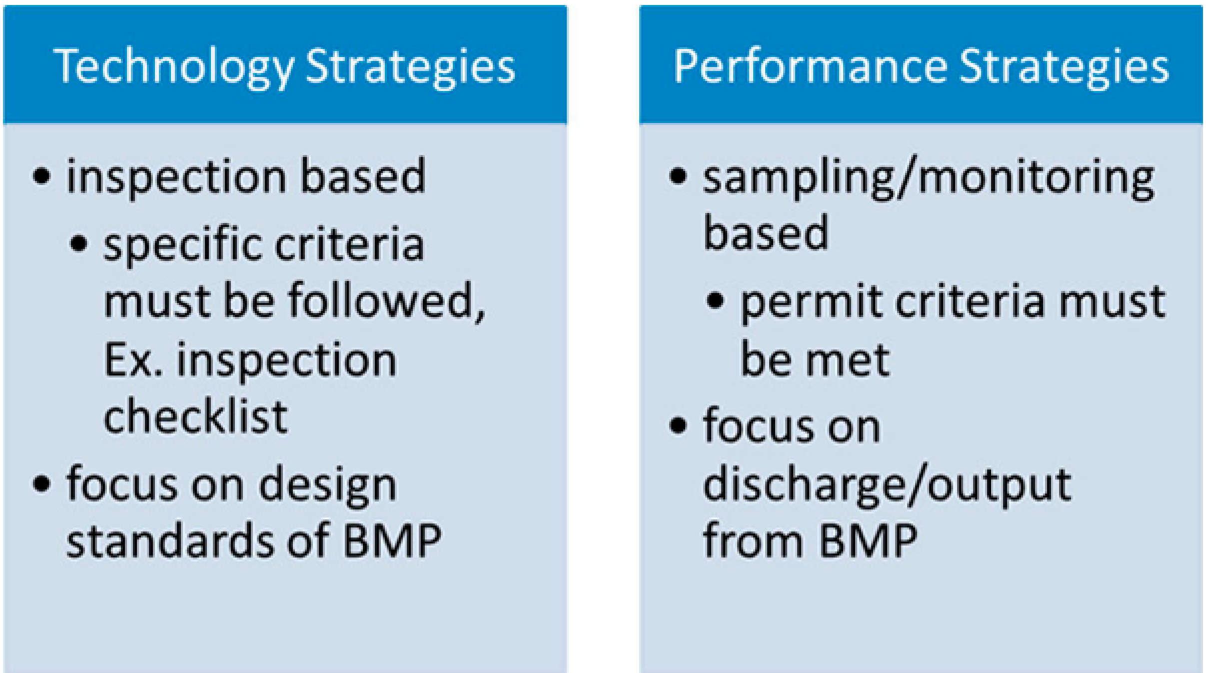

Figure 5-3. Technology Vs. Performance based Strategies

Many non-routine maintenance actions occur because of some failure in the operation of the BMP and are therefore considered performance-based strategies. For example, a citizen reports water pooling for extended periods of time in a bioretention filter. This report results in an investigation and maintenance, or repair, to the facility based on the observed failure in the BMP performance or function. All of the other aspects of the bioretention filter may look fine, but some problem is causing a failure in performance that leads to the necessary maintenance activity.

Routine inspections and maintenance activities are technology-based approaches. These activities are in response to a schedule, not any observable performance factor. For example, routine maintenance performed on a bioretention basin can include mowing, pruning, leveling of the media and removal of trash and sediment from the inlet and outlet structures. Although there may be no observed failure in performance of the filter, the technology-based maintenance actions are required because the design standards for the basin specify that the grass shall not be longer than six inches in height, the plants shall not stand higher than four feet, the media shall be level and inlets and outlets shall be kept clear of obstruction by debris and sediment. The proscriptive nature of technology-based criteria tends to work well with maintenance staff who may not be familiar with the performance goals of the BMP, but understand the specifications of the standard and can provide the maintenance actions needed to keep the BMP in conformance with those specifications.

5.5 Considerations in an Operational Strategy

The first consideration in developing an operational strategy is identification of an inventory of the BMPs within the jurisdiction of the maintenance program. The inventory should include information locating each BMP and describing its specific type and function. Additional information detailing the facility's context, construction and connections to the overall drainage system will aid in developing the maintenance strategy.

Once the BMPs are inventoried and assessed, a plan for carrying out inspections and maintenance activities can be developed, aiming to ultimately achieve the performance goals. The plan should be devised to fit both the level of need for maintenance presented by the inventoried BMPs and the ability of the organization to meet those needs. There are very few organizations that have all of the resources required to carry out all of the actions needed to maintain BMPs. Therefore it is necessary to plan what activities will be performed in-house and what activities will be provided by parties outside of the responsible organization. Once the scope of operations to be conducted in-house is determined, detailed schedules, policies and procedures for inspections and proactive maintenance activities can be developed. In conjunction with the development of schedules and procedures, standard documents should be created to ensure consistency in the execution of maintenance activities. These documents include standard inspection report checklists and forms, notices for needed reactive maintenance, documentation of maintenance actions provided, and other more narrowly focused documents, depending on the level of sophistication intended for the program. These informational and directional documents may be compiled into a maintenance handbook where all the program materials are readily available.

Record keeping and tracking is necessary to maintain the BMP inventory and the associated standard procedures and documents. The tracking system should document conditions reported in inspections, actions taken, actions required in the future and provide a means of analyzing collected data to identify trends and/or deficiencies in the maintenance program. From this tracked data, informed decisions can be made regarding maintenance planning, staffing and other program resource needs, budgeting and unforeseen factors that are revealed in data trends. The level of complexity or sophistication of the tracking system will be developed to match the level of the maintenance program itself.

Once the scope of BMPs to be covered by the maintenance program is known, the facilities should be evaluated to assess how technologically complex they are and what level of maintenance they will require. BMPs functioning on precise chemical treatment processes or management of stormwater through a train of connected BMPs, will require a higher level of expertise, skill and ability from the maintenance staff than less complex BMPs. This may require a strategy to include contracting maintenance work on complex BMPs, outside of the responsible organization, to parties that have the required level of expertise. Likewise, contracting maintenance work may be a necessary consideration if activities are required that employ specialized equipment such as excavating or grading machinery, often needed to carry out reactive maintenance operations.

5.5.1 Geographic Factors

It is important when developing an operational strategy to be aware of geographic factors such as eco-regional variation, climate, ecology, soils and geology, groundwater elevation, as well as population density variation. These factors can influence operations in a variety of ways, such as the frequency of monitoring required and expected maintenance. The following sections discuss varying geographic factors; however, it should be noted that this not an exhaustive list and additional factors may need to be considered for unique environmental conditions.

5.5.1.1 Eco-regional Variation

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An eco-region is defined as a relatively large area of land and water than contain geographically distinct groupings of natural communities. These communities share a large majority of their species, dynamics and environmental conditions, and function together as a cohesive unit. A variety of ecoregions may exist at or near the selected BMP. More information on eco-regional variation may be accessed through *Washington's Comprehensice Wildlife Conservation Strategy* (Wildlife 2005). A BMP's O&M will be influenced by its ecoregion, or ecoregions as the case may be, and should also consider its effect on maintaining the biodiversity inherent to the BMP's location. A thorough environmental survey and literature review describing previous baseline conditions, and expected changes to the eco-region should be incorporated into the planning/installation portion as well as the O&M. Operators should be trained to observe and document any changes to the environment as well as changes to the BMP by the environment, as discussed in more detail in the following sections.

Climate not only should be considered when selecting a BMP, but also when developing an operational strategy. Extreme temperatures can affect worker safety during inspections (e.g., heatstroke), the ability to perform monitoring by blocking site access (e.g., washed out/snow packed roads), stream flow (e.g., flash flooding) as well as the lifecycle of working components within a device (e.g., freeze/thaw cycles, UV damage to plastic components) or system. When selecting a BMP, consider planning for periodic monitoring and maintenance after extreme weather events (e.g., 100-year flood) or periodically after predicable weather events (e.g., pre/post-wet season). Colder regions may have a shorter window for maintenance and monitoring of BMPs due to access, as well as a shorter growing season for vegetation. Wetter regions may require a greater frequency of inspection/monitoring as well as increased requirements for vegetation control, such as removal of invasive plant species, or mowing. (See Biology and Control of Aquatic Plants). Drier regions may require an adjusted schedule for monitoring due to temperature fluctuations as well as lower frequency of rain events. Climatic conditions may change over time (refer to NOAA Atlas 14 Precipitation Data Server) and it is important to also consider a schedule to re-visit monitoring and maintenance routines over the lifetime of the BMP and to make adjustments as necessary.

5.5.1.2 Ecology and Wildlife

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Consider native and invasive plant species typical for the region, and the potential impact they may have on the device or system when selecting a BMP (e.g., weed control). Plant growth may impact the frequency and schedule of monitoring due to site access (e.g., poison ivy), or growing season (e.g., inspection of vegetative covers). Plant growth may impact the schedule of maintenance with overgrowth potentially hindering access or damaging the BMP, or undergrowth potentially destabilizing erosional conditions.

BMP selection should also consider native and invasive wildlife typical for the region, and the potential impact and interactions they may have with the device or system. Wildlife may impact frequency of monitoring as well as worker safety. Sensitive, threatened or endangered species may require additional considerations when scheduling monitoring and maintenance, such as avoiding high impact work during known mating or roosting seasons. (See Endangered Species Act Section 7). Nuisance species may require additional control measures, such as guards or fencing to protect the BMP. Wildlife species may also play a role in the spread of disease, and efforts should be implemented to reduce conditions, such as stagnant, mosquito-infested water, which may increase vectors. This control measure is particularly important if the BMP is located near populated areas.

At sites with known pollutants of potential concern, consider the bioavailability of those constituents when scheduling monitoring and maintenance in order to mitigate the uptake or consumption of constituents.

5.5.1.3 Geography

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Site conditions such as topography, soil type and site geology may impact the lifecycle of BMPs, and should be considered when developing an operational strategy. Sites with increased slope are likely to experience greater stress to BMPs due in part to increased hydraulic and sediment load, as well as more hazardous working conditions due to surface instability. Flatter regions are likely to experience reduced runoff volumes of stormwater per event, increased groundwater transport, ponding conditions, and may be subject to standing water time limits to facilitate vector control (e.g., the spread of blood-borne diseases due to insects or rodents).

5.5.1.4 Soils and Geology

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Areas with a higher sand content are likely to experience a higher rate of infiltration due to high permeability, whereas areas with a higher clay content are likely to experience increased runoff events due to low permeability and destabilizing conditions (Soils, Erosion, and Runoff). Geologic conditions and available mineral deposits, commonly called parent material, directly affect soil composition. Areas with reduced organic load will have a reduced ability to support vegetative cover, and may require adjustments to the maintenance schedule and/or addition of soil amendments. BMPs located in less stable soil conditions will require periodic monitoring, and may require specific contingency plans as well as requirements for monitoring extreme destabilizing events (such as mudslides).

Site geology may also play an important role in BMP stability and durability. For example, geologic conditions can impact worker safety during inspections (e.g., fall hazards, confined space hazards), the ability to perform monitoring by blocking site access (e.g., rock fall, sink holes), stream flow (e.g., flash flooding) as well as the lifecycle of working components within a device or system (e.g., freeze/thaw cycles, UV damage to plastic components).

When considering site geologic conditions, users should plan periodic monitoring and maintenance after extreme geologic or erosional events (e.g., earthquakes, mudslides). Cave and karst regions may require additional inspections and confined space safety training for maintenance and monitoring of BMPs. These may also have additional hazards due to infiltration of stormwater or groundwater causing unstable conditions. Aside from the physical effect of site geology, the geochemical effect must also be considered while planning for the O&M of BMPs, namely through and understanding of parent material onsite and its reactivity with stormwater.

Parent material may impact the availability of elements present in the system with the potential to impact chemical processes within the BMP. For instance, in an area with increased calcium deposits, the BMP is likely to become more alkaline over time or experience the buildup of concretions, potentially damaging or blocking BMP components from functioning. Parent material, such as volcanic tuff, may also increase contamination levels (e.g., metals) over time as the material is degraded due to weathering events, and may require additional monitoring and sediment management.

As geologic conditions may change slightly over time, it is important to also consider a schedule to reassess operations plans over the lifetime of the BMP, or after unexpected geologic events, and to make adjustments as necessary.

5.5.1.5 Groundwater Elevation

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Groundwater elevation may also play an important role in BMP stability and durability. Groundwater elevation may impact worker safety during inspections (e.g., confined aquifer collapse), the ability to perform monitoring by blocking site access (e.g., over saturation of groundwater), as well as the lifecycle of working components within a device or system. As groundwater elevations may change over time, it is important to consider a schedule to reassess operational plans over the lifetime of the BMP, or after unexpected events, and to make adjustments as necessary.

5.5.1.6 Population Density Variation – Visibility, Site Contamination, Land Use

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Population density is usually measured as the number of people per square acres, or in more sparsely populated regions it may be measured in miles to residential homes. Population density will have a large impact on overall maintenance requirements, and effort should be made to predict the likelihood that the general public will come in contact with the BMP.

Areas with high population density are likely to require more stringent barrier systems to reduce unsupervised contact with the BMP, to reduce the risk of accidents or potential contamination from the BMP. Barrier systems also serve to protect the BMP from inadvertent interference (e.g., trash) as well as malicious interference (e.g., vandalism). Formal inspection of barrier systems should be scheduled regularly based on contact with populations. However, informal inspections by responsible persons (such as trained maintenance staff) likely to have regular contact with the BMP, may also be used to supplemental inspections.

BMPs may be co-located in areas with site contamination (e.g., brownfield or areas with contaminated sediments or vapor plumes); infiltrated stormwater may migrate to, and/or mobilize those contaminants. BMPs may also potentially change the hydrologic setting of the contaminant plumes. Owners and operators should be aware of contamination when planning monitoring and maintenance over the lifetime of the BMP. Owners should also be aware of liability issues involving contaminated sediments. (Minnesota Stormwater Manual)

Areas with less population density may still require additional considerations depending on land use; for instance, BMPs located near all-terrain vehicle (ATV) or sport utility recreational sites are likely to require specialized barrier systems, as well as erosional maintenance compared to other rural sites. Owners and operators should conduct an overview of the BMP and likely populations that will come in contact with the BMP when planning monitoring and maintenance over the lifetime of the BMP after unexpected events, and to make adjustments as necessary.

5.5.2 Cost Factors

Cost of operations should be incorporated into any evaluation of BMP options for a site. Such costs can be difficult to predict in advance; however, planning for these costs must be initiated early to ensure that funds are available to perform the necessary work. For most BMPs, routine annual maintenance costs are approximately 2-4% of the original construction cost, and non-routine costs require an additional annual allocation of approximately 2-5% of the original construction cost (King 2011) Northern Virginia Planning Commission (Commission 2000). The USEPA also provides a cost estimator for updated average annual national and regional operational costs. This annual allocation should be saved in a long-term maintenance fund to be used when these activities are required. The American Society of Civil Engineers developed a book titled, *Cost of Maintaining Green Infrastructure* for purchase at the following website ASCE (American Society of Civil Engineers).

Several tools are available to assist owners in budgeting for the lifecycle of BMPs, including maintenance. For example, the BMP Evaluation Tool presented by the National Cooperative Highway Research Program (Taylor 2014), provides an estimate of average or likely capital, routine and non-routine maintenance, and retrofit (USEPA 2017b) and whole-lifecycle costs. The Whole Life Cost spreadsheets integrated into the tool calculate individual BMP maintenance costs based on national averages. The estimates can be adjusted by adding or editing the maintenance activities already built into the spreadsheets. The BMP whole-lifecycle cost estimate and summary in the spreadsheets enable users to plan and budget for future O&M requirements.

5.5.2.1 Site-specific Cost Factors

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Site-specific factors can heavily influence operational costs. To some extent, designs can be adjusted to minimize costs to the extent practicable. For example, steep slopes may require more specialized landscaping equipment or personnel for mowing or other maintenance. Regional climate can influence the number and intensity of storm events to which a BMP is exposed, which may impact the amount of routine and non-routine maintenance tasks. Climate may also influence the establishment and maintenance of vegetation (USEPA 2017b). Vegetation that is ill suited for the area may require additional maintenance costs. A BMP that is located in an easily accessible area, or that is designed with an access road and is near to the professional services needed for maintenance, such as landscaping companies, contractors, landfills for media or sediment disposal, etc., may have lower ongoing maintenance and mobilization costs for non-routine maintenance. On the other hand, BMPs that are in more urbanized areas tend to have more maintenance requests from the public due to aesthetic concerns and expectations of the surrounding community (Taylor 2014). This, combined with higher labor rates in urban areas, may outweigh the financial benefits of proximity to services.

5.5.2.2 Frequency Cost Factors

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O&M costs can be separated into routine and non-routine (Section 5-1 and 5-2). Costs of routine maintenance may be rather predictable considering specifically identified items such as inspections, litter control or vegetation management. Inspections, vegetative control, and other such activities that are conducted on a regular basis will often enable an operator to identify minor issues early, and prevent them from escalating to major and expensive repairs. Costs of non-routine maintenance requirements, such as repairs or replacement of structures, sediment removal, or grading, can be costly, and should be completed under the guidance of a stormwater professional. Estimates for these tasks should be made during the design phase, so that money may be allocated for a long-term O&M fund.

5.5.2.3 BMP-specific Cost Factors

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Operational costs will vary widely across individual BMP types. BMPs that rely on specific vegetation types and hydrologic conditions, such as constructed wetlands, may require more specialized and intensive maintenance than a less complex BMP, such as a grassed swale, which may only require sediment removal and vegetative maintenance (Kang 2008). Current and future owners of BMPs should consider complexity and frequency of required O&M tasks during planning and selection of a BMP for a specific site.

5.5.2.4 Personnel Cost Factors

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Staffing O&M duties often have a significant influence on the cost of such activities. Safety, effectiveness and qualifications should be balanced with cost in determining the appropriate personnel to complete maintenance activities. A facility owner or volunteers may assume frequent self-inspections, outreach, litter control, and minor landscaping, at little or no cost. Any volunteer or unspecialized labor, however, should be made aware of and avoid potential safety hazards, such as steep slopes, confined spaces, potential exposure to sharps, vermin, snakes, or other hazards. A BMP device that contains more complex structural components, or requires large-scale, long-term maintenance, such as sediment removal, will necessitate expenditures to employ stormwater professionals or specialized contractors to complete the work. In addition, inspections by a qualified stormwater professional should be completed on a regular basis, regardless of the frequency of the owner's self-inspections. Some BMPs, such as underground systems that have confined spaces, will always require inspections by qualified maintenance personnel (Commission 2000).

5.5.2.5 Waste Characterization and Disposal Cost Factors

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One of the most common long-term maintenance activities is sediment, media or accumulated pollutant removal. Almost half of ITRC survey respondents indicate BMP sediment management disposal strategies and guidance are being addressed (Table 5-1).

Responses to "Is your State Agency or Municipality addressing:"	
Response Options	**Count**
BMP sediment disposal management strategies and guidance	13
Economic impacts from BMP sediment disposal management	3
Developing a mechanism for managing economic impacts (e.g. grant reimbursement funds, other financial assistance) for managing BMP pond sediments?	0
Other (please explain)	17

Table 5-1. Responses from 29 respondents who answered ITRC Survey Question 9. Twenty-two survey respondents skipped this question. (Appendix A**)**

In addition to the costs associated with mobilization and actual dredging or other removal actions, the waste (including sediment) generated from the removal must be characterized (tested) and properly disposed of, both of which add cost to the maintenance activity. The scope of testing needed to determine appropriate disposal methods will vary. Survey results indicate a variety of characterization methodologies (Figure 5-4).

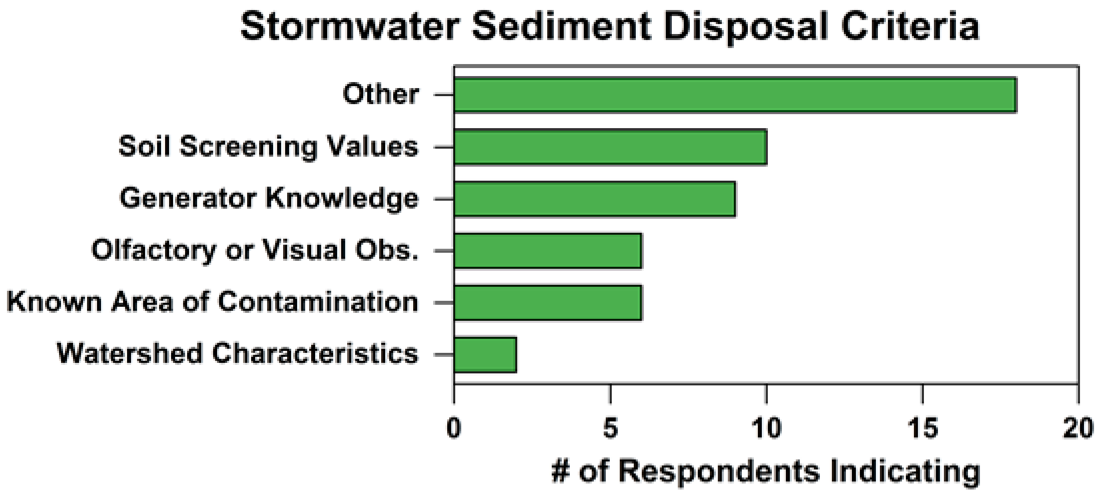

Figure 5-4. State Survey Question #10: "How is stormwater pond sediment characterized for disposal in your state or municipality?" (Appendix A**)**

At a minimum, the Toxicity Characteristic Leaching Procedure (TCLP) should be used to determine if a waste should be characterized as a hazardous waste due to toxicity by simulating the conditions it would be exposed to in a landfill. Hazardous wastes must be disposed of at a facility authorized to accept such wastes. Current and previous land uses within the watershed will provide insight into additional constituents that may need to be evaluated to ensure proper disposal. For example a BMP that drains roadways or parking areas may receive significant loadings of petroleum hydrocarbons or other related constituents. BMPs located in residential or heavily landscaped areas may have concentrations of pesticides or herbicides within their sediments or other media that require special handling. Sediments or other media within BMPs that drain industrial operations may need evaluation for constituents specific to those operations. Landfills and dredge material disposal facilities may have contaminant concentration limits on the waste that they can accept. In addition, state agencies may have set contaminant concentration limits for sediment that can be reused as fill or spread over land (Quality 2012). However, based on survey responses further development is needed for guidance on pollutant characterization and disposal for BMP sediments (Figure 5-5).

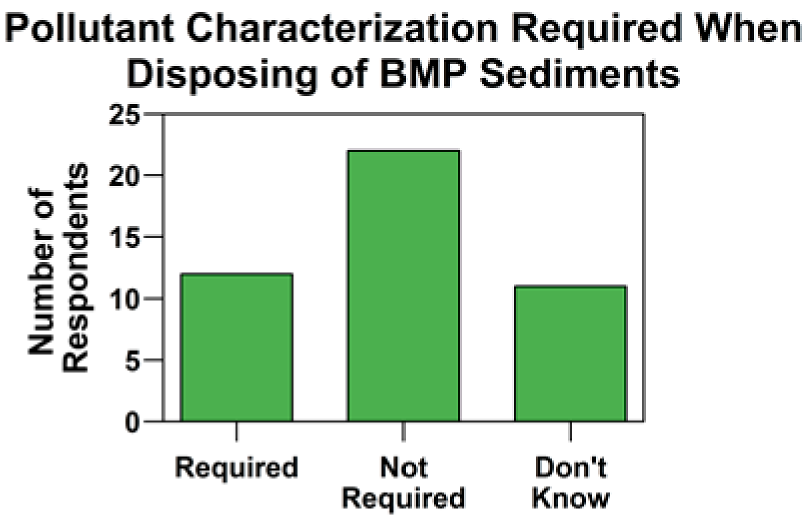

Figure 5-5. Responses to ITRC Survey Question 8. (Appendix A**)**

The extent of contamination of sediment or media to be disposed of will impact disposal costs. If onsite disposal is prohibited, transportation and disposal facility costs should be factored into cost estimates.

5.5.3 Accountability

Accountability is an increasing point of focus for stormwater BMP management (Figure 5-5). Operation, Maintenance and Monitoring (OM&M) plans are only effective if stormwater BMP operators are held accountable for BMP performance. To illustrate this point, USEPA has included accountability as the key component of its model stormwater O&M ordinance. The model ordinance specifically calls out the necessity to identify and record the O&M responsible party, funding sources, repairs and inspections (USEPA 2015b). OM&M accountability provides reasonable assurance that BMPs will properly function, yielding water quality benefits, while meeting legal requirements, protecting public safety and the communities' financial investments. Identification of the responsible parties in legally binding agreements provide strong incentives for responsible parties to ensure proper maintenance activities are performed or risk non-compliance penalties (USEPA 2015a).

Identification of the OM&M plan responsible party has improved over the years with the addition of technology and tools, such as, geographic information systems (GIS) and asset tracking software. Inspections have also gained traction with many local municipalities employing inspectors with technology and tools to identify gaps in BMP performance. Local enforcement, however, appears to be hit or miss due to one key element that is generally lacking in execution of stormwater ordinances – funding sources. Implementation of stormwater fees, performance bonds, and property owner associations are working to fill this budget gap, but many private parties struggle to clarify and account for funding prior to BMP failure.

Permits and maintenance agreements, discussed in greater detail in the following sections, are two key legal documents utilized to compel accountability for stormwater BMP performance. Additionally, performance bonds, easement and access agreements, and a variety of other real estate agreements may be drafted and executed or recorded for identification of responsible parties and accountability of performance. At this point, it is critical to identify a step that is often overlooked during real estate transactions – the transfer of these agreements as the property changes hands and the necessity of identifying the new responsible party. BMP ownership may change multiple times through the lifespan of the asset. For each of these transition periods, it is important to have the responsible party identified and the OM&M plan active to achieve optimal BMP performance.

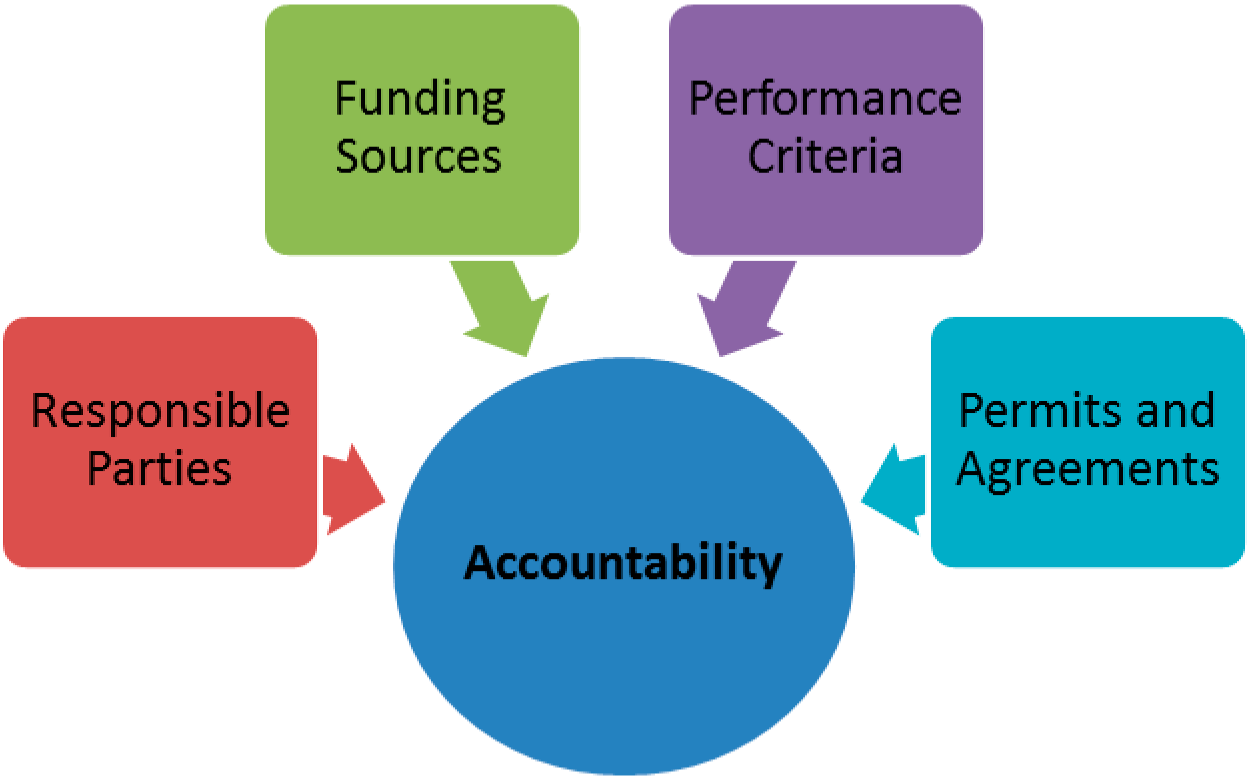

Figure 5-6. Accountability.

5.5.3.1 Defining Responsible Parties

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There are three main approaches for identifying the responsible party for maintenance, repairs and inspections. In general, the three options are:

- *Public (Municipal)*. BMP maintenance is performed on a local level with public funding sources and subject to in-house inspections and repairs.
- *Private*. BMP maintenance and repairs are performed by private property owners (e.g., individual property owners, businesses, or home owner associations) using private funding sources. In certain cases, a public entity

may provide oversight (inspections) and guidance.

- *Hybrid (Public-Private Partnership*). A combination of public and private oversight and guidance is utilized to provide the necessary maintenance, repairs and inspections. Funding may be a combination of public and private contributions.

Determining which party should be responsible for BMP performance is dependent upon personnel resources, knowledge of the system, funding sources, access to BMPs, and ability to perform the necessary maintenance and repair tasks. These factors have led to a hybrid approach becoming increasingly popular due to its flexibility. To ensure long-term BMP performance, it is important for tasks to be assigned to the best equipped party according to funding or expertise. For example if a private party does not possess the knowledge or skills to repair or oversee repair of an outlet control structure, then it is in the public's best interest to remit repair oversight to the local program authorities. The local program should assess program execution and increase training to achieve the optimal blend of public/private oversight and ensure BMP performance is maintained for the long term. If utilizing a hybrid solution, it is critical that responsibility is clearly identified and any changes in responsibility are made in writing.

5.5.3.2 Permits

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Permits are an important element of stormwater management programs operated by the federal, state or local agencies responsible for maintaining water quality. Obtaining a permit prior to the discharge of stormwater is generally required by §402 of the Clean Water Act, and sometimes other state or local laws and ordinances. Stormwater BMPs are one of the tools these programs employ to ensure that federal and state water quality standards are met, although the role that permits play is different for industrial and post-construction stormwater management facilities.

Stormwater BMPs that function in the context of an industrial activity most often operate on a performance basis. When functioning properly, these BMPs sufficiently reduce pollutants to meet discharge limits or water quality benchmarks specified in the permit. The proper operation of these industrial BMPs is verified through monitoring and periodic testing of the effluent (discharged stormwater). The agency or authority responsible for the permit program will require submittal of reports documenting the results of the discharge monitoring tests as a condition of the permit. Reports that show the BMP is not performing adequately to meet the specified discharge limit or benchmark require corrective action by the permittee and may subject the permittee to enforcement action by the agency. The industrial stormwater permit is an operational permit. It is required as long as the regulated industrial activity continues, and does not terminate until that activity has ceased.

One of the principal reasons for requiring a permit governing construction of a post-development construction stormwater management BMP is to require that all facets of stormwater management are considered and addressed prior to construction. For example, as a prerequisite to permit issuance, stormwater programs may require that the project design demonstrate compliance with specified water quality and quantity technical criteria, provide drawings and details that adhere to program design standards (or detail non-standard facilities), and meet the technical criteria that address the requirements for long-term O&M of the BMP.

Provisions for post-construction O&M requirements vary across states. Most states require execution of a maintenance agreement that is recorded in the chain of title to a property. The maintenance agreement assigns responsibility for O&M to a property owner or operator and is required before construction can begin. Once construction is complete and the program authority verifies that a required post-construction BMP has been built in accordance with the approved design, the permit is terminated. Future O&M of the BMP is assured through the maintenance agreement and periodic inspection by, or reporting to, the program authority.

5.5.3.3 Maintenance Agreements

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Over the last decade, multiple types of post-construction BMPs have been installed to improve the long-term quality of stormwater runoff. Hundreds of thousands of these types of BMPs have been installed throughout the country. However, the life span of some BMPs has been significantly shortened because the BMPs were not effectively operated and maintained. Many property owners, businesses and homeowner's associations have not understood or conducted the required maintenance activities. In order to address these shortcomings, many programs now require execution of a legal instrument known as an operations and maintenance agreement, which is permanently placed in the chain of title for the site on which a BMP is located. The operations and maintenance agreement is an affirmative covenant between a landowner and the local stormwater management authority that is recorded in the local land records office. As a result, the agreement runs with the land, and assigns the responsibility for maintenance, monitoring or other actions to current and future landowners.

Typically, the operations and maintenance agreement includes the following components:

- Legal description of the property(ies) and names of the parties to the agreement
- Legal authority or legal requirements applicable to the agreement
- Reference to the approved stormwater plan and/or maintenance schedule
- Agreement to perform operations, maintenance and other actions, such as inspections
- Agreement that if required actions are not performed, then the local stormwater authority may perform them at the landowner's expense and/or assess civil charges or fines
- Right of entry for local stormwater authority staff and liability waiver

An operations and maintenance agreement has several benefits, including clear assignment of maintenance and monitoring responsibilities and consequences if those responsibilities are not fulfilled. By being recorded within the chain of title to a property, a title search should disclose these obligations to any potential future landowners prior to property transfer. Potential concerns include the necessity to ensure language within the agreement is clear, consistent with state real estate law and is enforceable. Sample operations and maintenance agreements may be found in the following citations and links: (USEPA None provided) (USEPA 2009) (Richmond No Date) (Association 2012) (Rockville 2012), and Connecticut Stormwater Quality Manual, Maintenance Inspection Checklist. An Additional Inspection Checklist can be found in Appendix B.

5.5.4 Prioritization & Frequency

Prioritization and frequency are important factors when developing an operational strategy for a stormwater BMP. Depending on the type of BMP, or train of BMPs, the operational strategy should be evaluated for the entire lifecycle of the BMP.

Prioritization refers to the relative intensity of operational items with respect to the beginning, middle or end of the BMP lifecycle. These may be referred to as frontloaded, averaged or back-loaded priorities. Frequency refers to the expected number of operational events during a given period.

In order to control costs, higher effort operational tasks may be staged throughout the lifecycle of the BMP. As discussed in preceding portions of this document, informed design (e.g., upsizing, capacity selection, treatment train development), installation (e.g., effective QA/QC of installation), and operations (e.g., proactive versus reactive maintenance) may alleviate higher effort maintenance activities and cost. The frontload versus backload of operational tasks is very important for BMP selection. For example, a wet pond can be designed to provide sufficient solids accumulation such that a dredging activity is not required until very late in the life of the BMP.

Likewise, frequency can be used to adjust the operational requirements such that high effort maintenance activities can be reduced to smaller effort, but more frequent operations. Proactive maintenance is often characterized by frequent, smaller effort events versus singular, higher effort events. For example, a structural BMP that is expected to experience a high sediment load due to site development activities will likely have a frontloaded, high frequency operational strategy, whereas oversizing the actual capacity of the BMP may result in large scale, less frequent operations activities. Of course a cost-benefit analysis can be undertaken to distill a good, better, best set of options for capacity versus anticipated monitoring and maintenance.

5.5.4.1 Expected Lifecycle

Examination of the expected lifecycle of a BMP is another important aspect of developing prioritization and frequency expectations for an operational strategy (Figure 5-5). Depending on the type of BMP (structural versus non-structural), there may be structural (e.g., subsurface concrete structures), mechanical (e.g., weirs), chemical (e.g., adsorption canisters), or physical (e.g., trash nets) components as part of the BMP or train of BMPs. Lifecycle management should be considered when employing any BMP. A useful life of the various BMP components needs to be evaluated in order to assist in the development of inspection and maintenance frequencies. Certain elements within the BMP require more frequent inspections and/or maintenance due to capacity limitations (e.g., adsorption canisters, trash nets). These tend to be obvious and are identified either by the manufacturer of the BMP or the operators. Examination of the structural and mechanical features of the BMP are just as critical, but due to the nature of the BMPs, tend to be back loaded with respect to inspection and maintenance and are often not considered until the BMP has already reached its end of life. For example, a failure of a sub-surface concrete vault is typically characterized by cracking, erosion or spalling well before a structural incident occurs. Operational management of the BMP lifecycle requires recognition of what conditions the BMP will exist under. Developing an effective inspection and maintenance program allows detection of life ending issues before they occur.

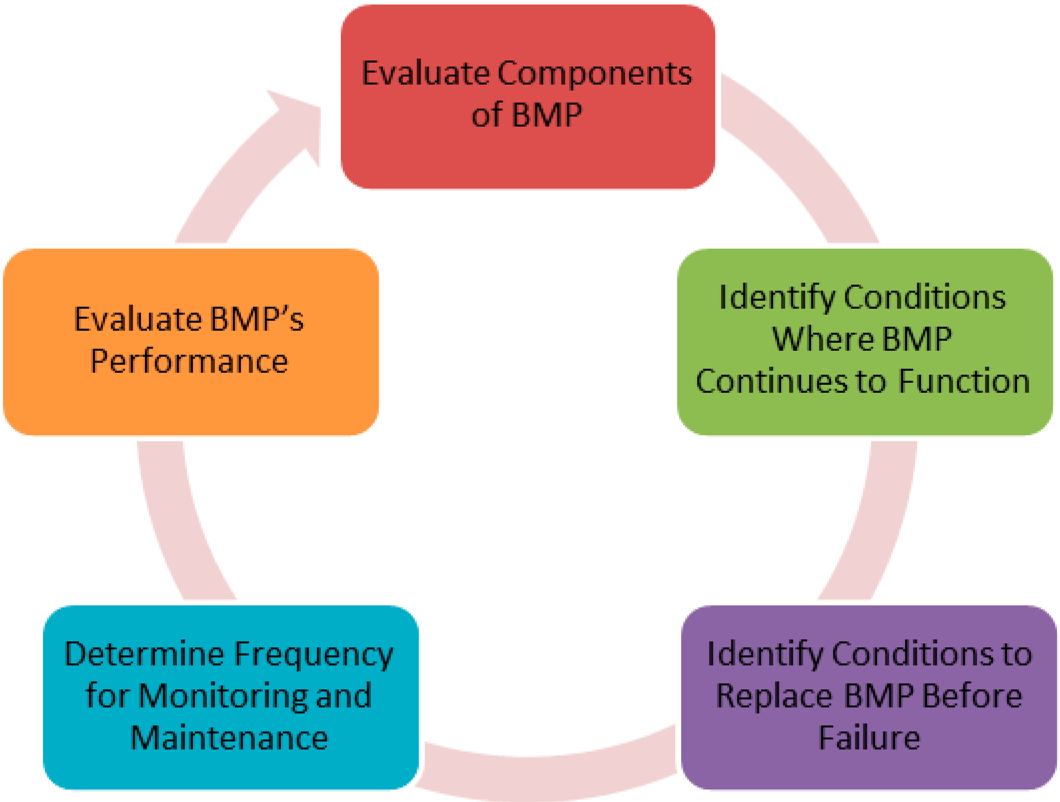

Figure 5-7. Lifecycle of a BMP.

5.5.5 Performance Feedback Loop

Stormwater BMP performance is largely dependent upon the creation and implementation of an OM&M plan. Over time, without the implementation of an OM&M plan, a stormwater BMP will eventually fail causing negative impacts to water quality. However, even when an OM&M plan is properly implemented, a stormwater BMP will fail if no performance feedback loop (Figure 5-6) exists. The performance feedback loop provides a mechanism to identify and remedy gaps present in individual BMP performance Asset Management Programs for Stormwater and Wastewater Systems: Overcoming Barriers to Development and Implementation. As previously stated, preventative and reactive maintenance is necessary for stormwater BMPs to operate effectively. These maintenance intervals are generally influenced via the feedback received through various inspections and checklists; without this information an operator cannot determine whether a BMP is operating effectively or not. Yet it is important to take a step back and look at the performance feedback loop in a broader context.

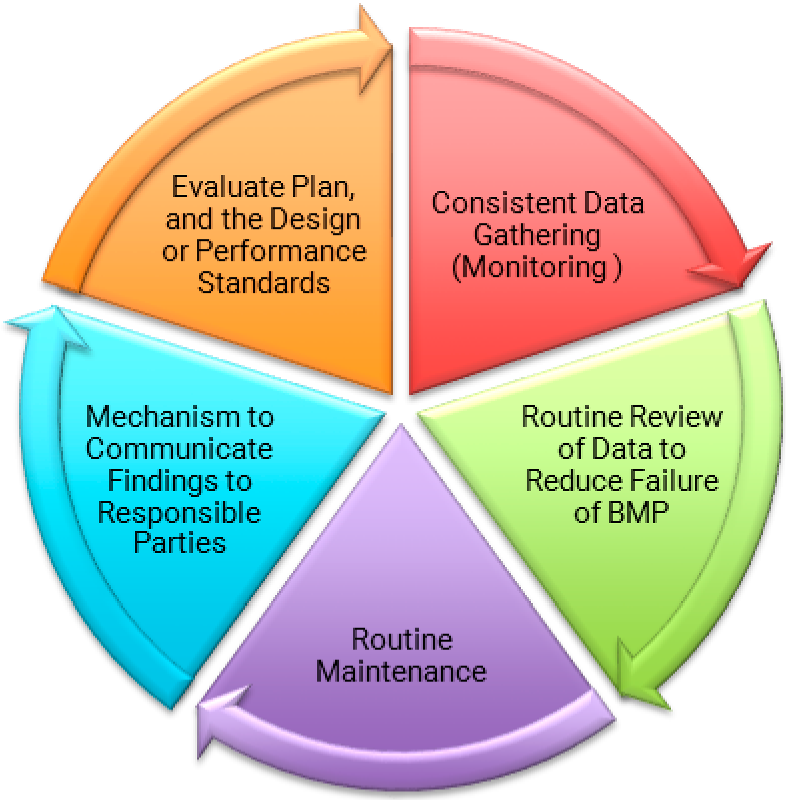

Figure 5-8. BMP performance feedback loop.

Designers, installers and operators can all benefit from insights gained through an effective performance feedback loop. Use of a tracking system to capture BMP data consistently over a period of time provides valuable information to improve the design, implementation and operation of BMPs. This data gathering exercise provides a feedback loop to critical insights of which factors most influence BMP effectiveness and failure. Limiting instances of failure leads to improved water quality. In addition, systematic review can steer program strategies and provide a basis for budgeting future repairs and projects. Use of a performance feedback loop, beyond the individual BMPs, assists in identifying and implementing ongoing program improvements to better protect water quality. (Taylor 2014)

Critical elements to the performance feedback loop include:

- Consistency in data gathering
- Routine review, evaluation and collating the information on a routine basis identifies trends early and reduces failures
- Effective communication – there must be a mechanism to provide findings back to the relevant parties
- Metrics – establish design or performance standards that are measurable, some targets will be set and others may change depending upon requirements and expectations
- Technology – from systems to sensors