# 5


## Storm Water Pollution Prevention Plan

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Site designers/planners and engineers typically pay very close attention to all phases of a construction project. However, the same attention is not always given to storm water management. In fact, it is often overlooked.

This section of the storm water manual outlines and describes a recommended step-by-step process for developing a storm water pollution prevention plan. It is intended as a guide and procedures are written in general terms to be applicable to all types of projects. Site planners and regulatory authorities are urged to become familiar with the contents of this section of the manual.

Once the site designer has completed the initial site assessment, planning, and design process, he or she can begin developing a set of detailed construction plans for the project. Construction plans are a blueprint for the project site. They identify resource issues; describe operational procedures; provide information in regard to project design and layout; identify areas of clearing, grading, and construction limits; and provide information in regard to the installation and maintenance of infrastructure. The content of a construction plan is described in more detail in Chapter 3.

One very important element of a construction plan is a storm water pollution prevention plan. A storm water pollution prevention plan is a working document that serves as a blueprint and principal site reference for the location, design specifications, installation criteria, construction schedule, and maintenance of all storm water quality measures. The plan should be part of the general construction plan and not a separate document because all activities that occur on a project site are interrelated. Changes to one or more aspects of the construction plan can drastically affect elements of the storm water pollution prevention plan and vise versa.

The purpose of a storm water pollution prevention plan is to establish which storm water quality measures will be used to minimize the discharge of pollutants from the project site. Selection of storm water quality measures should focus on the pollutants that are associated with the construction phase of the project as well as the reduction of the pollutants that will be associated with the final post-construction land use. In order to choose the appropriate measures, the plan designer should have an understanding of the project site, pollutants associated with construction and the intended land use, and the sources that generate the pollutants.

Chapter 3 provides a summary of items that should be included in storm water pollution prevention plans. However, it is important to recognize that the content of the storm water pollution prevention plan may vary from one regulating entity to the next because of differences in local ordinances and regulations. Therefore, plan designers should become familiar with the requirements and expectations of each entity having regulatory authority over the project.

As noted above, a storm water pollution prevention plan identifies storm water quality measures that will be used to minimize the discharge of pollutants. Storm water pollution prevention plan drawings should identify where each storm water quality measure is located in the landscape; provide construction details, dimensions, and design specifications for each measure; and provide instructions for the proper installation and maintenance of each measure. Information and drawings provided for each storm water quality measure should be clear, concise, and contain enough detail so that on-site contractors and personnel can install the measures according to accepted industry standards and specifications. Chapters 7 and 8 of this manual provide detailed information in regard to proper installation and maintenance of a variety of storm water quality measures. Proper incorporation of this information into construction plans and, in particular, the storm water pollution prevention plan will assist site designers in addressing the discharge of pollutants associated with construction activities and post-construction land uses.

A very important aspect of storm water pollution prevention plans is the schedule for implementation of each storm water quality measure. Measures will not be effective if they are not installed at appropriate times during the construction process. Most measures should be installed before grading and land disturbance is initiated on active areas of the project site. To meet this objective, storm water pollution prevention plans should contain a construction sequence schedule component.

Construction sequence schedules are a critical element of storm water pollution prevention plans. The sequence of construction is not necessarily a specific date when each storm water quality measure will be implemented, but rather a description of when each measure will be installed in relation to grading and land-disturbing activities. Construction sequencing is time sensitive and requires planning and coordination between all individuals involved with the construction project. The “Development of a Construction Sequence Schedule” section in Chapter 5 provides insight and guidance into the development of a construction sequence schedule.

Another key element of a storm water pollution prevention plan is a quality assurance plan. Quality assurance plans provide guidance and establish procedures for monitoring the construction site and inspecting storm water measures to ensure they are maintained and functioning properly. The “Developing and Implementing a Quality Assurance Program” in Chapter 6 provides an in-depth explanation and insight into developing and implementing a quality assurance plan.

In addition to the above, Indiana’s storm water rule for runoff associated with construction activity, found in the Indiana Administrative Code under Title 327, Article 15, Chapter 5 (327 IAC 15-5), has a requirement that storm water measures be inspected by the end of the next business day following each measurable storm event (defined as a precipitation event that results in total measured precipitation accumulation equal to, or greater than, 0.5 inch of rainfall) and at a minimum of one time per week. Some local ordinances may require more frequent inspections than those required in 327 IAC 15-5.

Inspection frequency intervals and maintenance criteria are unique to every storm water quality measure. Inspection frequencies are generally based on the overall performance of the measure. Some measures require daily inspections whereas others may require, at a minimum, weekly inspections. Each storm water quality measure contained in this manual has been assigned an inspection frequency.

To meet regulatory requirements and storm water quality measure design standards and specifications, a quality assurance plan should identify an inspection schedule for each measure identified in the storm water pollution prevention plan.

There are several valuable resources, including individuals knowledgeable about storm water issues and erosion and sediment control, which can be utilized when developing a storm water pollution prevention plan. Resource information and technical assistance is available from Indiana's local soil and water conservation districts, the Indiana Department of Natural Resources, the Indiana Department of Environmental Management, the U.S. Department of Agriculture's Natural Resources Conservation Service, and city or county engineering staffs. Private environmental and engineering firms are also a valuable resource.

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Up to this point, the site designer has conducted a site assessment and data collection process, analyzed the data, and begun to formulate an overall site design and layout of the project. Using the existing project site data and information that has already been collected and analyzed, the project planning principles in Chapter 4 of this manual, and the construction plans that have been developed to this point, the site designer can now begin to develop a storm water pollution prevention plan.

The goal of any project is to manage storm water runoff and minimize the off-site discharge of pollutants. During the construction phase the focus is on minimizing erosion and sedimentation. However, there are other potential pollutants associated with construction. These pollutants include but are not limited to fuel and construction waste. Appropriate project management and storm water quality measures will need to be implemented to minimize potential off-site pollutant discharges and to reduce the potential impact these pollutants may have on soil and water quality. In regard to post-construction land uses, the focus should be on the reduction of pollutants generated from the type of land use and minimizing the discharge and impacts of storm water runoff pollutants to receiving waters.

Storm water pollution prevention plans are a critical tool for achieving the above goals and objectives. They typically contain a wide array of storm water quality measures designed to protect water quality. On most project sites, these measures need to be implemented and maintained throughout the life of the construction project. It is also important to recognize that several post-construction measures can be incorporated into the early phases of a project and used in the control and management of sediment. These post-construction measures can later be modified or adapted to reduce the impact of pollutants or runoff quantity associated with the post-construction land use.

As site designers begin to make decisions regarding the selection of storm water quality measures for the treatment of construction and post-construction storm water runoff, it may be necessary to make adjustments to the overall site design. This may require re-evaluating previously developed plans and documentation that was collected in earlier stages of the planning process. In situations where the site designer is restricted by the overall site design, the selection of storm water quality measure alternatives may be limited. In addition, the measures chosen may be more expensive to install and have higher maintenance requirements and costs. For these reasons, it is very important that site designers make every effort to prepare the project design and layout simultaneously with the development of the storm water pollution prevention plan.

As previously discussed, storm water pollution prevention plans should address pollutants associated with or that may be associated with the project site during construction and post-construction land use. With this concept in mind, storm water pollution prevention plans can be divided into two distinct components: (1) an erosion and sediment control plan and (2) a post-construction pollution prevention plan.

## Erosion & Sediment Control Plan

The primary purpose of an erosion and sediment control plan is to minimize sedimentation because this is the principle pollutant associated with construction activity. However, other pollutants are also associated with construction activities. Management of these pollutants is just as important as minimizing sedimentation. If these pollutants are not appropriately controlled, they can have a detrimental impact to soil and water quality. Although referred to as an erosion and sediment control plan, the plan should include provisions that address the management of other pollutants associated with construction activities.

### Assessment of Project-Specific Pollutants Associated With Construction Activities

Before selecting any storm water quality measure, it is important to identify the pollutants that will be associated with construction activities. Most construction activities will include clearing and grading. Clearing and grading leaves soil vulnerable to rain and storm water runoff and results in increased erosion and sedimentation. Therefore, sediment is the primary pollutant associated with construction activities.

In addition to sediment, construction activities may include operations that generate other pollutants. The presence of these pollutants will be directly related to the type of construction activity and operations that will take place on the construction project. Activities at the site that may generate pollutants include but are not limited to construction vehicle operation and maintenance (e.g., fueling and changing of hydraulic fluids and oils); concrete washout; improper storage of construction materials; improper disposal of construction trash and debris; improper application or overapplication of fertilizers and pesticides; and improper storage, application, and disposal of soluble materials or other materials that can be mobilized by storm water runoff. Chapter 1 of this manual provides more information about the types of pollutants associated with urban development and their impacts on water quality.

### Site Management & Planning Principles

When developing an erosion and sediment control plan, it is not uncommon to focus, or place primary emphasis on, the selection of specific storm water quality measures designed for the prevention of erosion and control of sediment and overlook a site's physical characteristics which can have a major impact on site planning and management.

Site management techniques such as phasing land-disturbing activities, minimizing the area of soil exposed to the forces of erosion, incorporating natural features of the site into the project design, and using vegetative and mulching practices can significantly reduce a project's construction costs and the impacts it will have on the local environment. When incorporating the above principles into a storm water pollution prevention plan, an assessment should be made with regard to how these principles will affect the selection of storm water quality measures and what affect they will have on the effectiveness of the measures.

Planning and site management techniques can generally be implemented with little or no cost and therefore are as important as the storm water quality measures chosen for the project. By now it should be evident that site planning and management is a critical component of a construction project and can have a significant affect on overall project costs and the effectiveness of erosion, sediment, and storm water runoff control measures. Following is a brief discussion in regard to several site planning and management principles that should be considered and, where applicable, applied to a project site before selecting any storm water quality measures. It is important to note that the list provided here is not all inclusive.

### Retain Existing Vegetation on the Construction Site

Vegetation is a valuable asset on construction sites and a concerted effort should be made to retain existing vegetation whenever possible. A healthy, dense stand of existing vegetative cover will reduce erosion, reduce storm water runoff velocities and volumes, and filter and trap solids suspended in storm water runoff. Existing vegetative cover can be used as a filter zone. The vegetative filter must be of sufficient width and must have a soil surface cover density of 80 percent or more.

Tree selection and preservation can also add value to a project site. They can serve as useful buffer zones and can increase the value of the property by providing an aesthetic feature that prospective property buyers are often willing to pay for.

When developing an erosion and sediment control plan, the plan designer should revisit the project site to verify that the conditions observed at the time of the site assessment and data collection phase have not changed from the original assessment.

### Establish Vegetation on the Construction Site

Vegetation is the most efficient and economical form of erosion control. On active construction sites it is generally cheaper to stabilize an unvegetated area than to repair rills and gullies caused by erosion. It is also easier to prevent or control erosion than trying to trap soil particles that have become suspended in storm water runoff.

Areas void of vegetation or that have crop residue that will decompose should be stabilized as soon as possible. Stabilization can be achieved through the application of temporary or permanent vegetative cover. As a general rule of thumb, temporary seeding should be applied to areas that are scheduled or will likely be left idle for an extended period of time up to one year. Permanent seeding should be applied to all areas that are at final grade, phased projects where each subsequent phase will not be started for a period of eight months or more, and areas scheduled to be idle for a period of one year or more.

Vegetation can also be used as a filter medium around the perimeter of the project site and other key areas on the project site. To effectively remove pollutants from storm water runoff, the vegetative filter must be of sufficient width and well established with a vigorous, dense (80 percent or more vegetative cover over the soil surface) stand of vegetation.

### Phase Project Activities

Minimizing the amount of land left exposed to the forces of erosion is an effective method for reducing erosion and sedimentation. Unfortunately, this is often difficult due to the nature of construction operations. Phasing of project activities is one method of minimizing the amount of soil exposed at any one time. This principle works especially well on large projects.

Limits of clearing and grading should be determined during the planning phase of a project. Decisions should be made to determine which areas must be cleared and graded in order to accommodate immediate construction activities, while paying special attention to critical areas and environmentally sensitive areas that must be protected. To minimize the extent and duration that soil is exposed to the forces of wind and water erosion, temporary or permanent seeding should be applied to all inactive areas of a project site where vegetation is sparse or non-existent.

Whenever possible, clearing and grading should be limited to active areas of construction and only progress as each new project construction area is started. Land-disturbance activities such as mass clearing and grading should be avoided. It is important to recognize that recreational grading does not serve a purpose and can add significant costs (e.g., fuel, personnel salaries, installation of additional storm water measures, increased maintenance of storm water measures, etc.) to a project.

Appropriate erosion and sediment control measures **must** be installed and operational prior to initiating clearing and grading.

### Revegetate or Stabilize Disturbed Areas Immediately

Grading should be completed in the shortest period of time possible and areas stabilized immediately after completion of grading operations. Stabilize areas using measures such as temporary or permanent seeding, sodding, mulching, erosion control blankets, or other measures that will protect the soil surface. Areas that can be graded to finished elevations should be permanently seeded.

## Manage Construction Traffic Flow and Staging Areas

Provide access for all construction traffic by establishing stable construction ingress and egress points. Establish staging areas and provide stable areas for on-site personnel to park their vehicles. Carefully plan the flow of construction traffic and plan construction traffic routes that will avoid vegetation that is to be preserved and newly planted areas.

On sites that require the use of on-site sewage disposal facilities or will utilize storm water infiltration measures, locate staging areas, parking areas, and construction traffic routes outside the limits of areas designated for these uses. This will prevent soil compaction and maintain the integrity of the soil's infiltration capacity.

## Employ Management Measures to Control Pollutants Other than Sediment

Sediment is just one of many pollutants associated with construction activities. Examples of other pollutants include petrochemicals (e.g., oil, gasoline, asphalt), herbicides, solid wastes (e.g., wood, metal, roofing materials), construction chemicals, waste water, and fertilizers.

Many pollutants attach themselves to soil particles and are carried off-site when the soil particles become suspended in storm water runoff. However, on-site containment of all pollutants may not always be feasible if water soluble pollutants are present or the pollutants are attached to fine clay particles. The removal of clay particles is based on the detention time of the measure and will dictate the efficiency of the measure to remove the suspended soil particles. Site management techniques such as proper use, storage, handling, and disposal procedures are generally the most effective method for minimizing the discharge of these pollutants from a construction site. On most construction projects the responsibility of properly managing these pollutants will rest on the shoulders of the contractors and subcontractors working on the site.

Most people involved with construction activities fail to recognize that solid wastes generated at the site are a pollutant. Appropriate solid waste receptacles should be provided at every construction site to allow for the proper disposal of waste and debris. On individual building sites, the project site owner may require individual builders/contractors to provide receptacles for the disposal of their waste building materials and products. This requirement is typically part of the restrictive covenants, included in the sales contract, or a provision in the storm water pollution prevention plan. It is imperative that the project site owner establish requirements and procedures for proper handling and disposal of pollutants associated with the project and that he or she clearly conveys this information to each builder/contractor and informs them of their responsibility to properly dispose of construction waste and debris.

Hazardous materials are another potential pollutant that must be properly handled, stored, and disposed of on construction sites. According to federal and Indiana statutes, the term "hazardous waste" means a solid waste, or combination of solid waste that, because of its quantity, concentration, or physical, chemical or infectious characteristics may: (1) cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed. Hazardous waste materials not only pose a threat to receiving waters, but some can percolate into the soil resulting in contaminated soil which may have to be excavated and transported to a hazardous waste disposal facility or may require expensive bioremediation treatment at the project site. Hazardous waste materials should be securely stored in a shed, trailer, or building that can be locked to prevent vandalism or unauthorized access. Contractors and other on-site personnel must comply with hazardous wastes storage and disposal regulations administered by the Indiana Department of Environmental Management, Office of Land Quality.

Construction vehicles and equipment are the source of several potential pollutants associated with a construction site. Maintenance of vehicles should be done in a properly equipped shop, not at the construction site. All petroleum storage tanks should meet state regulatory requirements for containment to prevent spills, leaks, and other discharges from coming in contact with the soil and ground water. Materials and equipment needed for cleanup procedures should be kept readily available on the project site, either at an equipment storage area or on the contractor(s) vehicles.

## Include Provisions to Address Independent Activities that Occur on the Project Site

Many projects include activities that are conducted by independent entities not under the direct control of the project site owner. These entities include but are not limited to utility companies and independent builders. It is in the best interest of the project site owner to coordinate with these entities to ensure that each is aware of the provisions of the storm water pollution prevention plan and that they understand their responsibility for erosion and sediment control and site management as it relates to the activities they are conducting on the project site.

Where possible, utility installation should be scheduled in advance and built into the overall sequence of construction for the project. Utility locations should be predetermined so that installation will not interfere with the location of storm water quality measures. Again, representatives of utility companies should be aware of the provisions of the storm water pollution prevention plan and should have a clear understanding as to who will be responsible for erosion and sediment control and final stabilization as it relates to their construction activities.

Construction on individual building lots creates an additional challenge on development projects. Building construction usually occurs after all infrastructure, including storm sewers, have been installed and are functioning. Sediment yields can be extremely high on projects with a high concentration of building activity. This situation is more common on residential sites due to the number of and size of active building lots. In addition, there are a large number of contractors and subcontractors working on a site at one time. Every plan should contain provisions for erosion and sediment control on individual building lots. The provisions for erosion and sediment control should also be clearly explained to each builder and provided in writing. To ensure their compliance with local and state regulations, some development companies specify conditions for erosion/ sediment control and pollution prevention in their sales contracts or through performance bonds.

### Manage Dust Control

Land that has been disturbed and left void of vegetative cover is vulnerable to the forces of wind and water erosion. Every effort should be made to prevent or control the generation of dust and wind blown particles. Dust can be generated by wind blowing across the soil surface or by vehicles and construction equipment traveling across the project site. Construction site management techniques should employ the use of basic dust control measures designed to reduce the overall impact of dust generation. Watering the soil surface, establishing vegetative cover, and the application of soil bonding agents are just a few examples of dust control techniques that can be deployed on a construction site.

## Selection of Storm Water Quality Measures Associated with Construction Activities

Several criteria must be considered when selecting storm water quality measures. One of these criteria is identifying potential areas that are or will be subject to erosion and the discharge of sediment. Some of these areas should have been identified during the site assessment and data collection process. That information should be reviewed and adjustments made as the planning process proceeds. Areas subject to erosion and the off-site discharge of sediment should be identified on a map.

Selection of storm water quality measures should be based on the potential pollutants associated with the project. Effective management and treatment of storm water runoff requires storm water quality measures to be applied to the correct field situations, designed according to site conditions, installed correctly and at the appropriate time, and maintained.

Watershed sizes and associated information is critical when calculating storm water runoff volumes, assessing erosion potential, estimating sediment yields, and selecting and designing appropriate storm water quality measures. Therefore, watersheds and drainage areas must be determined before the site designer can select, size, and design individual storm water quality measures.

Major watersheds and drainage areas associated with the project site should have been identified at the time of the project site assessment and data collection process. Delineation of drainage areas will help identify the direction of surface water flow. Often, watershed boundaries will extend up slope or down slope of the actual project site boundaries. Working with large drainage areas and an entire project site can be overwhelming. It is generally easier to work with smaller drainage areas than trying to address the overall site. Smaller drainage areas are more manageable units when predicting storm water runoff volumes and selecting control measures. Smaller drainage areas also allow the site designer to select from a larger variety of storm water measures. If a delineated watershed exceeds five acres, the plan designer should attempt to subdivide the watershed into smaller drainage areas.

All storm water quality measures have performance limitations, whether it is trapping efficiency for the targeted pollutant(s) or limitations in appropriately handling the volume of storm water runoff. It is also important to keep in mind that many storm water quality measures have design and application parameters well under the five acre threshold. In fact, the design and application of many measures are typically for one or two acres.

When selecting storm water quality measures, the site designer needs to be cognizant of the dynamics of construction activities. As land-disturbing activities take place, drainage areas may increase or decrease. To compensate for the changes in drainage area size, storm water measures should be selected for the most extreme field conditions. If this is not feasible, an alternative is to identify several measures that can be installed as drainage areas change. This approach will require good communication and coordination with earthmoving contractors.

When selecting measures it is important to consider the consequences of failure. Failure of a measure may result in damage to adjacent properties and water resources.

The first instinct when trying to address erosion and sediment control is to install sediment control measures. Sediment control measures either filter storm water runoff or hold it temporarily to allow soil particles to settle out. It is very difficult to trap sediment with sediment control measures because they have limited trapping efficiencies even when they are performing at their highest level. Sediment will be a consequence of all land-disturbing activities. Therefore, sediment control measures should always be included as part of the storm water pollution prevention plan. However, every plan should also focus on the use of erosion control measures that can be used to minimize the generation of sediment.

Erosion and sediment control measures should be installed as a system. An erosion and sediment control system consists of using multiple measures, in a series, which minimizes erosion and traps or removes suspended sediment from storm water runoff discharges. It is not prudent to rely on a single sediment control measure at the point of discharge. Using multiple measures to minimize erosion and treat sediment-laden storm water runoff will increase the overall efficiency of the erosion and sediment control system and often allows for the use of smaller, less costly measures. For example, it will be much more cost effective to install a variety of erosion and sediment control measures throughout the drainage area than trying to treat the entire drainage area with a single sediment basin at the point of discharge. A well-planned erosion and sediment control system will have an aggressive stabilization plan and provide for the installation of sediment control measures, not only on the site's perimeter but throughout the entire drainage area.

Erosion and sediment control measures are usually a combination of structural and nonstructural measures. They may be temporary and function only during the construction phase or they may be permanent and become part of the completed development. Although the primary focus during this phase of plan development is erosion and sediment control, it can be beneficial to consider post-construction measures as well. It is important to understand that planning post-construction measures during this phase is usually more effective than trying to retrofit a site after all decisions have been made.

Storm water quality measures associated with construction activities can be divided into three major groups (i.e., erosion control, runoff control, and sediment control) with the primary focus on erosion and sediment control. Erosion control is typically achieved through surface stabilization. Runoff and sediment control is typically achieved through the use of more substantial and costly structural measures.

## Erosion Control

The most effective sediment control method is to prevent erosion. Measures that prevent or minimize erosion are called erosion control measures.

Erosion control is often thought of as an annoying proposition and difficult to implement when numerous construction activities are occurring simultaneously at a construction site. Erosion control is usually achieved through the establishment of vegetation or the application of nonerosive materials to the soil surface. Based on this definition, most construction industry personnel usually view this activity as occurring near the completion of the project and do not consider it as an option during construction. However, erosion control is one of the most effective tools available to control sediment. Effective implementation of an erosion control program often requires a change in the perceptions and attitudes of construction site personnel and managers. It will also change the way a construction project is managed and will require a high degree of planning and coordination between site managers, planners, contractors, subcontractors, and others involved with the project.

Erosion control is the first line of defense in protecting water quality at a construction site. Reducing erosion at the source is much more effective and efficient than trying to trap suspended sediment in surface water runoff. Erosion control is achieved by protecting the soil surface from raindrop impact and overland flow of storm water runoff. An effective erosion control program will initially control sheet and rill erosion and minimize gully and channel erosion.

Surface stabilization is achieved through the application of nonerosive materials to the soil surface. Common forms of erosion control are seeding, sodding, mulching, riprap, or application of other nonerosive covers. Effective surface stabilization will minimize erosion and the generation of sediment and can achieve efficiency levels as high as 90 percent to 95 percent.

All erosion and sediment control plans should include an aggressive stabilization program. A well-planned stabilization program is essential and should be implemented throughout the life of the construction project. Vegetative cover is relatively inexpensive to achieve and is often the most practical long-term solution to stabilization. Incorporating an effective stabilization program into the project reduces cost, minimizes maintenance and repair, and makes structural erosion and sediment control measures more effective and less costly to maintain.

The first step in developing an effective erosion control program is to evaluate the slope to be treated and to identify the type of erosion that has occurred or that will potentially occur in an area. Erosion is typically categorized as raindrop, sheet, rill, gully, channel, and shoreline. Areas that are subject to raindrop, sheet, and rill erosion will be addressed differently than runoff that is being conveyed in a channel. Streambank and shoreline erosion from variable water levels and wave action may require a totally different approach. The second step in developing an effective erosion control program involves selecting appropriate methods to control erosion. When selecting a stabilization method, the plan designer should always consider establishment requirements, adaptability to site conditions, aesthetics, and maintenance requirements.

Surface stabilization methods can be categorized as either temporary or permanent. Temporary stabilization includes the application of a fast-growing seed such as wheat or rye and/or the application of a mulch material. Mulch materials must be appropriately anchored to the soil surface to reduce their potential for being blown away or carried away by storm water runoff. Permanent stabilization is the most effective means of erosion control. Permanent stabilization should be utilized where areas are at final grade or where activity will not occur for a period eight months or more.

There is a general misconception that permanent stabilization can only be used when a project's construction activities are complete and all areas are at final grade. In reality, permanent stabilization methods can be used throughout the life of a project. For example, permanent stabilization can be applied to any area at final grade, including drainage swales and the side slopes of basins.

The application of temporary and permanent surface stabilization depends on several factors such as time of the year, the length of time unvegetated areas will be left idle, phasing of land-disturbing activities, and sequencing of land-disturbing activities. Waiting until project construction activities are complete is not an effective approach to surface stabilization as it leaves large areas of soil material exposed to rainfall, the forces of erosion, and the need for a more intensive sediment control program.

Permanent stabilization is typically thought of as permanent seeding. However, there are several other methods including the use of riprap and other hard armor. Vegetative controls are generally preferred and the most cost-effective method of permanent soil stabilization. While many plan designers feel there is a clear line between the use of vegetation and hard armor, the industry has many alternatives available that expand the options for using vegetative cover. For example, there are a number of erosion control blankets available commercially that provide a stable environment until seed can become established thereby reducing the need for hard armor. In addition, there are synthetic blankets and turf reinforcement mats that increase the stability of vegetation once it becomes established. Site designers should evaluate and assess the applicability of these options and make a concerted effort to reduce the use of hard armor and other impervious materials.

A stabilization program can be divided into three categories: 1) phased stabilization, 2) incremental stabilization, and 3) final stabilization.

### 1) Phased Stabilization

There are two distinct categories of phased stabilization. The first category covers projects involving phased construction over several years. For example, if a project site owner plans to develop Phase I of a project with the intent of developing Phases II and III at a later date, it would be in the best interest of the project site owner if the site designer develops a stabilization plan that will adequately protect Phases II and III until such time as they are developed. The site designer's first decision is to identify the existing vegetative cover associated with these areas. If the entire area is pastured and has a good vegetative cover, additional measures may not be required. However, if the site includes areas that are void of vegetative cover or includes crop residue, the plan should specify that these areas be properly prepared and stabilized using an appropriate method of surface stabilization. Stabilization of these areas can be accomplished through a variety of seeding methods that result in minimal disturbance of the soil surface. One such method is applying seed with a no-till drill.

The second category of phased stabilization is applicable to projects where construction or land-disturbing activities are planned in small, workable units. In this scenario, surface stabilization is applied as construction is completed and progresses to the next designated area. Waiting until the project is complete is not an effective approach as it leaves large areas of soil exposed to the forces of erosion and requires implementation of a more intensive sediment control program.

### 2) Incremental Stabilization

Incremental stabilization is similar to phasing but occurs on a smaller scale. Incremental stabilization involves the establishment of vegetative cover or the application of nonerosive cover as work progresses.

Incremental stabilization is well suited for projects requiring extensive cut and fill operations. On these types of projects, as cut slopes are excavated and fill slopes are brought to grade, the slopes can be stabilized with each 10 foot of cut or fill. Another example is the cutting of a conveyance channel. The channel can be stabilized as work progresses on cutting the channel grade.

To maximize the effectiveness of erosion and sediment control systems, site designers should carefully evaluate land-disturbing activities and incorporate an aggressive stabilization program into the plans. A common excuse for not stabilizing areas on a construction site is that additional work is planned for the area. Whether a site is at final grade or not, areas should be stabilized as grading operations are completed. Incremental stabilization works well in these situations.

### 3) Final Stabilization

Final stabilization is typically associated with closure of a project. If an aggressive stabilization program has been implemented throughout the life of the project, this step may be fairly simple. Final stabilization consists of bringing an area to final grade and applying a permanent stabilization method to protect the area from the forces of erosion. Therefore, final stabilization does not have to occur at the end of a project. During the course of construction, areas at final grade can and should be permanently stabilized. Construction traffic should be excluded from areas that have been permanently stabilized. Some examples of areas conducive to final stabilization are privacy berms, basins, common areas, and drainage swales.

It is not always practical to apply vegetative cover or an alternative cover to protect the soil surface during construction and land-disturbing activities. Therefore, it is necessary to use runoff control and sediment trapping measures. These measures should be viewed as a second or third line of defense to manage storm water runoff and retain sediment. As land-disturbing activity increases in size and/or intensity, lower cost erosion control measures will be replaced with more expensive, less efficient, structural runoff control and sediment control measures such as diversions, dikes, and sediment basins. The utilization of larger structural measures will also require an increased level of design and cost more to construct and maintain.

All storm water management measures selected, designed, and constructed on a project site should be in accordance with the standards and specifications provided in Chapter 7 of this manual, similar guidance documents, or proven industry and engineering standards. Improper use or inadequate installation may result in failure of storm water quality measures, off-site discharge of pollutants, and increased costs required for the remediation of problems resulting from the failure.

## Runoff Management – Construction

Effective management of construction activities and associated pollutants requires controlling and managing storm water runoff on the project site. Once storm water runoff begins to move across a project site, it will need to be managed so that it does not seek its own course and impact construction and land-disturbing activities. Several storm water measures have been developed to manage storm water runoff.

The primary purpose of storm water runoff management on a construction site is to control the volume of runoff, divert runoff to appropriate sediment control measures, and discharge runoff in a nonerosive manner. Runoff volume will be one of the determining factors in the selection of runoff management measures. Large drainage areas should be avoided when selecting runoff management measures because it is generally very difficult and costly to handle huge volumes of runoff at concentrated points. When selecting storm water management measures, a concerted effort should be made to balance or minimize the volume of runoff diverted to specific storm water quality measures.

Runoff management planning can be divided into distinct components: 1) runoff controls and 2) runoff conveyances and outlets.

### 1) Runoff Controls

Runoff control measures are designed to reduce the velocity of storm water runoff, carry concentrated runoff down slopes without causing erosion, and direct storm water runoff to stable outlets or sediment control measures. Depending on site conditions, some of these measures may also provide limited sediment trapping.

There are several types of runoff control measures that can be used to manage storm water runoff. The most commonly used measures are temporary and permanent diversions. Other runoff control measures include but are not limited to check dams, slope drains, and water bars.

The first principle for controlling storm water runoff is to minimize the length and steepness of slopes. As slope length and grade increases, so does the potential for erosion. One method of reducing the erosion potential in these situations is to break up the length of the slope. Reducing the length of the slope reduces the ability of storm water runoff to flow in an uncontrollable manner. Slope lengths can be shortened by stair-stepping (i.e., benching grades) or installing diversions across the slope. When installing benches on a slope, the cut should be tilted into the slope to allow runoff to be channeled along the inner edge of the bench. Runoff should always be routed to a stable outlet. If the runoff is sediment-laden, it should be directed to a sediment treatment device such as a sediment basin, sediment trap or other appropriate measure.

The second principle of runoff control is to reduce the velocity of storm water runoff. There are several storm water measures and principles that can be used to reduce runoff velocities. Some of these include reducing slope lengths, maintaining existing vegetative cover, preserving vegetated buffer strips around the lower perimeter of the land disturbance, and installing controls, such as check dams and diversions.

The third principle of runoff control is to divert storm water runoff away from active construction zones and other critical areas. This principle can be used to segregate storm water runoff and divert it to either several stable discharge points or to a single point of discharge.

Diversion of storm water runoff can have a major impact on the selection of sediment control measures. The ability to control the direction and volume of runoff to designated points in the landscape allows for greater flexibility in the selection and design of sediment control measures. For example, redirecting runoff to a single discharge point will generally require larger, more expensive sediment control measures and outlet structures, whereas directing the runoff to several discharge points will allow for the use of smaller, more manageable sediment control measures.

In situations where the diverted storm water runoff comes in contact with exposed soil the runoff should always be conveyed to an appropriate sediment control measure.

Storm water runoff associated with a construction site generally includes off-site runoff as well as on-site runoff. One of the major rules or principles of plan development is to design a runoff management system that only treats sediment-laden runoff. To accomplish this objective, it is necessary to segregate off-site runoff from storm water runoff associated with active construction areas. For example, a perimeter dike or diversion can be used to intercept runoff from an area up slope of an active construction zone and divert it around the construction zone. A critical element in implementing this principle is stabilization of the diversion berm and/or conveyance channel. If the flow channel is not adequately stabilized, flows should be directed to appropriate sediment control measures. Diversions can also be used on the down-slope side of construction zones to direct runoff to an appropriate sediment control measure such as a sediment basin.

As noted in earlier discussion, subdividing larger drainage areas into smaller drainage areas allows for the use of smaller, less expensive sediment control measures. This is also true of runoff control measures. A smaller drainage area may allow the use of a sediment trap verses a larger drainage area which might require use of a sediment basin.

### 2) Runoff Conveyances and Outlets

The principle behind runoff conveyance management is to move storm water across a project site without causing erosion. Open channels, drainage swales, and drainage pipes/conduits are examples of runoff conveyance systems. Conveyance systems and outlets should be designed to accommodate the runoff capacity and velocity that will be associated with the construction and post-construction land use.

Conveyance systems should be designed with gentle grades to keep flow velocities low. Flow from the conveyance system should be discharged in a manner that does not cause erosion. This is usually accomplished through the use of outlet protection and grade stabilization structures.

Runoff conveyance systems should be constructed and stabilized prior to becoming functional. Every effort should be made to prevent sediment from entering the conveyance system, especially after it becomes functional.

Runoff conveyed through channels and swales will naturally erode the channel bottom and side slopes if they are not stabilized. Therefore, runoff conveyance systems should be stabilized immediately after construction. Attempting to stabilize channels with straw crimped into the soil is usually ineffective. More substantial erosion control measures such as appropriately applied erosion control blankets and/or turf reinforcement mats are more effective at protecting the soil surface until such time as vegetation becomes well established.

Erosion control blankets are composed of mulch that is sewn or intertwined in a netting material. Mulch materials range from straw, wood and coconut fiber to synthetic fibers. Each has its limitations. However, for higher velocity flows a heavier or special blanket may be required to stabilize the conveyance channel.

Turf reinforcement mats are designed to reinforce vegetation by allowing the root system of the plant to become entwined in the synthetic matrix. These systems are suitable for higher flow velocities than standard erosion control blankets. Another method for stabilizing channels is to line them with a hard armament such as rock.

Both grass-lined and rock-lined channels will help slow flow velocities. Grass-lined channels have an advantage over rock-lined channels in that they are aesthetically pleasing, easily maintained, and provide a minimum level of pollutant removal from storm water runoff associated with the post-construction land use.

In some situations it is necessary to provide a grade transition to maintain low channel gradients within the conveyance system or to provide a stable outlet at the discharge of the conveyance system or a pipe outlet. To preserve the integrity of the receiving channel or water body, it is also important that conveyance systems discharge to a stable outlet which has been designed to accommodate peak runoff volumes and velocities from the conveyance system. In addition to accommodating peak flow volumes and discharge velocities, outlet protection measures should be designed to provide energy dissipation and prevent scouring at the point of discharge. Measures such as riprap aprons and grade stabilization structures are typically used to dissipate energy of the channel flow and pipe discharge points.

### Sediment Control – Construction

Once soil is detached, the soil material becomes suspended in storm water runoff and flows to down-slope positions in the landscape. Soil material that is suspended in runoff is defined as sediment. If left untreated, sediment-laden storm water will discharge from the active construction area and eventually deposit its sediment load in creeks, rivers, wetlands, and other environmentally sensitive areas.

It is not practical to assume that all erosion and sedimentation issues associated with a construction project can be controlled through surface stabilization. Construction, by nature, involves land disturbance and as such will result in soil material being left unprotected as clearing and grading operations occur. Therefore, sediment control must be an integral part of any erosion and sediment control plan.

Sediment controls are typically more difficult to implement, more costly to install and maintain, and less effective than surface stabilization controls. Sediment control measures should be selected as secondary and tertiary treatment measures. They should be implemented on a construction site with the objective of eliminating or, at a minimum, reducing the discharge of sediment-laden storm water runoff to off-site areas, unique resources, and waters of the state.

There are several types of sediment control measures. Types of sediment control measures include but are not limited to sediment basins and traps, sediment barriers and filters, and inlet protection.

Several factors should be considered when evaluating the placement of sediment control measures. Sediment control measures are typically located below active construction areas, below areas that are void of protective cover, and above environmentally sensitive or unique areas such as creeks, streams, lakes, ponds, public streets, and wetlands. They should be located in relatively level areas or in natural depressions. Sediment control measures should not be placed in areas where their construction would result in excessive land disturbance or where it would be difficult to maintain them. It is important to remember that poorly located sediment control measures often create construction site management problems and that they can cause additional erosion and sedimentation problems.

Sediment control measures are typically used around the perimeter of active construction zones to detain sediment-laden runoff and allow for trapping or settling of the sediment. To accomplish these objectives, the control measures must be in place and stable before initiating land clearing and grading activities. While perimeter sediment controls are important, it is also important to remember that there are several other measures that can be used on the project site. A concerted effort should be made to develop a comprehensive plan that includes a complete erosion and sediment control system. A complete erosion and sediment control system will consist of several measures working in concert to treat storm water runoff before it is discharged from the project site.

Sediment control measures can be either temporary or permanent. They typically function by filtering storm water runoff or impounding runoff for an adequate length of time to allow suspended soil particles to settle out. The pollutant removal efficiency of sediment control measures varies greatly. The pollutant removal efficiency of some measures can be as high as 50 percent. Pollutant removal efficiency rates are dependent on many factors including the design of the sediment control measure and the measure's storm water retention time.

Drainage area size must be considered when selecting sediment control measures. For example, most storm drain inlet measures have limitations of one-quarter to one acre maximum drainage area.

In general, the most efficient sediment control measures are sediment basins and traps. Proper sizing of sediment basins and traps is critical to effective sediment control. This manual provides criteria, standards and specifications that can be used by engineers in the design of these measures. Whenever feasible, larger drainage areas should be divided into subwatersheds with each having their own sediment basin. It is best to locate sediment basins in parallel rather than in series. Placing basins in parallel eliminates the possibility of a domino effect if one basin fails. Damage from basin failure will also be substantially less if a small basin fails versus a large basin.

Maximum drainage area limitations have been established for many of the sediment control measures contained in this manual. In some instances, these maximum limits can be exceeded if the measure is designed using approved engineering principles and additional design parameters are taken into consideration.

Site designers are often faced with a situation where a creek or river flows through a project site. The placement of sediment control measures in these conveyances should be avoided. By placing controls within natural conveyance systems, additional watershed acreage is being treated unnecessarily. It is generally best to let these features flow through the site. It is also not logical to trap sediment within a system that the storm water pollution prevention plan is designed to protect in the first place. In fact, locating sediment control measures in these situations generally requires permits from local, state, and federal regulatory authorities. In most situations, it will be almost impossible to obtain approval for the placement of storm water management measures in a natural channel.

### Finalizing the Erosion & Sediment Control Plan

After drainage areas have been determined, site features evaluated, and appropriate measures selected for the situation, the measures should be incorporated into the erosion and sediment control plan. Locations of the measures should be identified in the plans and design standards and specifications included as part of the plan's construction details. Standards and specifications, design parameters, maintenance requirements, and detailed drawings for erosion and sediment control measures can be found in Chapter 7 of this manual.

## Post-Construction Pollution Prevention Plan

The alteration of land can significantly change the dynamics of a watershed. The net impact is dependent on the magnitude of the change to the landscape. Many construction projects are directly related to residential, commercial, highway, and industrial development. Each of these different types of development can have significant impacts on Indiana's soil and water resources.

The primary purpose of post-construction storm water pollution prevention plans is to minimize the discharge of pollutants associated with the final land use of the project. Plans should include storm water quality measures that are specifically targeted to address pollutants that will be generated at the site. The plan should also outline specific operational procedures that will reduce the generation and introduction of pollutants to storm water runoff. In addition to water quality, post-construction storm water pollution prevention plans often incorporate storm water management measures designed to address an increase in runoff volumes.

The recommended approach in developing a post-construction storm water pollution prevention plan is to use a variety of design principles and storm water quality measures to achieve the overall objective of pollution prevention.

## Post-Construction Assessment of Pollutants & Impacts of Development – Project Specific

Before selecting a storm water quality measure it is important to assess the potential pollutants that will be associated with the final land use. Evaluating and understanding the pollutants that will be associated with the project is a critical step in developing a post-construction storm water pollution prevention plan. Evaluation of potential pollutants should be done in the early stages of the planning process. Knowledge of the pollutants that are associated with the final land use of a project allows for advanced planning and the selection of cost-effective storm water quality measures.

The first step in assessing pollutants is to identify the land surfaces that are planned for the project. Examples of surfaces that will generate storm water runoff include building rooftops, pavement, and grassed areas. Once land surfaces have been identified, the next step is to determine the types of activities that will occur on these surfaces and the potential pollutants that will be generated. Some common activities include but are not limited to parked vehicles, storage of processed or manufactured products, service stations, road maintenance, and landscape maintenance (e.g., mowing, fertilizer and pesticide applications, etc.). Chapters 1 and 8 of this manual provide an in-depth discussion of specific land uses and the pollutants associated with each type of use. After the site designer has identified the types of land surfaces and types of activities that will occur on these surfaces, he or she can begin to assemble a list of potential pollutants that must be considered in the development of the post-construction storm water pollution prevention plan.

Water quality impacts can also be affected as a result of increased runoff volumes. Increased runoff volumes and discharge rates, as a result of an increase in impervious surfaces, can directly affect downstream areas. Receiving creeks and streams do not necessarily have the capacity to accommodate and transport the increase in runoff. The overall impact includes changes in the dynamics of the channel, including bank erosion, down cutting of the channel bottom, and increased flooding. It is important that runoff is released in a controlled manner that will not impact associated watersheds.

## Performance Standards

Storm water management measures often have multiple objectives, including water quality protection and water quantity control. While this manual predominately focuses on storm water quality, quantity is also a resource concern. Once the pollutants associated with a project have been identified and an assessment of the storm water runoff has been completed, the site designer can begin developing a post-construction storm water pollution prevention plan. When developing the plan, it is important that site designers have access to performance standards for the selected storm water management measures.

Currently, the state does not include these standards in storm water regulations. However, local governmental entities may have their own regulations and it is the responsibility of the plan designer to investigate these requirements. As a guideline for plan preparation, this manual uses the following standards.

- The basic goal for development is to assure that post-development peak discharge rates and discharge volumes do not exceed the predevelopment levels.

- Storm water quality measures selected should be designed to treat at least one-half inch of storm water runoff (water quality volume or storage), at a minimum, from the impervious surfaces. Treatment goals should be targeted to remove at least 80 percent of the total suspended solids from runoff on an annual average basis before it is discharged into waters of the state or to adjacent properties.

There are numerous storm water management measures and operational activities that can be used to treat storm water runoff and reduce the discharge of pollutants. Each measure alone may not be able to achieve the desired pollutant removal rate of 80 percent. Achieving the 80 percent removal rate may require the use of a variety of measures designed to work in concert with one another. The performance standard of 80 percent targets the removal of total suspended solids and pollutants that attach to those particles. This performance standard does not address the removal of pollutants that remain in solution or that may attach to finer particle matter. To remove these pollutants may require additional measures. This may be particularly important in areas of high pollutant loading (i.e., hotspots), such as gas stations and fueling facilities, to further target the removal of lead, copper, or zinc, in addition to polyaromatic hydrocarbons.

Post-construction treatment systems typically consist of a series of storm water management measures designed to work in concert with one another for the purpose of removing pollutants from storm water runoff. These systems are often referred to as a “treatment train.” Natural site features, site design planning principles (see Chapter 4), and storm water quality measures specifically selected to address the targeted pollutants are the three major factors to consider when designing a treatment train. When all three of these design elements are incorporated into the final plan there will be numerous opportunities to improve water quality, create wildlife habitat and corridors, preserve and create greenways/open space, and protect downstream waters.

A typical treatment train may include a combination of grassed swales, infiltration basins, and the use of a wetland treatment cell. The effectiveness of hydrodynamic separators may also be increased and target other pollutants by providing secondary treatment through the installation of an in-line filtration system. By combining several measures rather than selecting one measure for the treatment of storm water the level of reliability of pollutant removal can be improved. The effective life of a measure can also be increased by combining it with a pretreatment device such as a vegetated buffer strip or grass swale designed to remove total suspended solids from the storm water runoff before it enters a downstream treatment measure.

Storm water measures that are installed as part of a treatment train are usually installed with the least expensive and most easily maintained measure being placed at the highest point in the system. A prime example is the initial treatment of building runoff. The runoff can initially be directed through grassed swales and eventually discharge into other treatment measures.

One example where a treatment train might be used is a large parking facility. These areas are typically associated with a large volume of trash and debris that is carelessly disposed of on the parking area. If a wetland cell were to be installed to treat runoff from this facility, the wetland cell would rapidly fill with paper products, cans, and other trash. It would be difficult to remove trash from the wetland cell and over time, the wetland would become unsightly. In this situation, it would be best to remove the trash through pretreatment before the runoff is discharged to the wetland.

## Selection of Storm Water Management Measures – Post-Construction

Post-construction storm water management measures are selected, implemented, and constructed to minimize the discharge of pollutants and the impact storm water runoff will have on downstream areas. The selection of storm water quality measures will be decided based on the professional judgment and preference of the site designer.

During project layout and design the site designer makes many decisions in regard to the location of storm sewers, streets, and other infrastructure that may have a direct impact on the natural resources of the project site. At this stage of the planning and design process, the site designer should evaluate and consider several of the alternative design concepts and principles listed in Chapter 4 of this manual. These concepts and principles can be used to protect and preserve unique, critical, and environmentally sensitive areas and reduce the amount of impervious surface area associated with the project. Incorporation of these design principles and concepts into the project design and layout can have a significant impact on final land use cover and the amount of pollutants generated from these areas. Using these site design concepts and principles, it is often easier to modify the site design and layout of the project to reduce the amount of pollutants generated than to rely solely on structural storm water treatment measures for pollutant removal. The end result will be improved efficiency and lower maintenance costs of the storm water management system.

At this stage of plan development, all planned conveyance systems and impervious surfaces have been identified by the site designer. The next step is to evaluate the watershed associated with each land use. During this phase of assessment it is important to consider the storm water drainage system (e.g., swales, storm sewers, etc.) as well as overland flow of storm water runoff for the project. At this point, the process of evaluating specific discharge points within the watershed can begin. This process will help identify whether or not any land uses that generate specific pollutants are isolated. If specific pollutants are isolated within a drainage system, the storm water quality measure or measures applied to the situation should be targeted to those pollutants. In addition to pollutants associated with the watershed, selection of storm water management measures should take into consideration post-construction runoff volumes and storm water runoff velocities.

Once a list of potential pollutants is generated, a thorough evaluation of the project must be conducted. The site designer should re-evaluate the project layout and design and determine if modifications can be made to the project to eliminate or significantly reduce pollutant generation or discharge. After all final decisions and modifications related to site design and layout have been made, it will be necessary to re-evaluate the list of potential pollutants and select the appropriate storm water quality measures to minimize their discharge.

Storm water quality measures should be selected based on the pollutants associated with the land use. Site designers should be cognizant of the fact that additional measures may be required to effectively control storm water discharge rates. To ensure that each storm water measure functions effectively and efficiently, measures must be applied to the correct field conditions, designed according to site conditions, installed correctly and at the appropriate time, and properly monitored and maintained.

## Post-Construction Site Management Goals

In addition to project site design considerations, pollutants can be reduced through project management, operational procedures, and program implementation. These measures are often referred to as source controls. Source controls focus on activities that limit the generation of pollutants at the source rather than the treatment of runoff. Source controls include day-to-day activities that include but are not limited to trash recycling/disposal, washing equipment and vehicles, and periodic street sweeping.

Land use planning can be an effective tool in addressing storm water issues. Local planning decisions can have a great influence on the balance between growth and development needs and the resource issues within a community. This can be achieved through the establishment of local ordinances that incorporate creative approaches to land development. Chapter 4 of this manual provides information on common resource issues and alternatives for creative site planning and design. Other local initiatives include watershed protection plans, protection of critical resource areas, and implementation of master plans that allow for development while minimizing the effects of urbanization.

Important, unique, and environmentally sensitive resource areas can be protected or preserved by implementing programs or ordinances that require buffer zones, easements, and setbacks. Several communities in Indiana have enacted ordinances for the protection of wetlands and karst features to protect local natural resources.

Private citizens can play a role by collecting and properly disposing of pet waste, reducing and/or properly applying fertilizers and pesticides, participating in neighborhood recycling programs, and properly disposing of household chemicals and wastes.

Education is another method that can be used to achieve pollution prevention. Education and public outreach efforts should be used to educate both youth and adults. Educational programs should focus on creating an understanding of how everyday activities contribute to storm water pollution. Education and public outreach can be achieved through public meetings, school programs, adoption of highways and waterbodies, storm drain marking, and other similar programs.

Source controls are discussed in more detail in Chapter 9 of this manual. Source controls should not be substituted for the implementation of effective permanent storm water quality measures.

## Storm Water Management and Flood Control

A change in land use can significantly increase runoff and have a detrimental impact on receiving water. It is important that the plan designer reduce the impact of additional runoff and the rate at which the runoff is released.

One of the primary goals of storm water management is to mimic the way runoff left the site before development. Land development creates impervious surfaces which result in less infiltration. Less infiltration results in a greater volume of runoff. The additional runoff, together with an improved and more efficient conveyance system, results in an increase in runoff rates. Land that is developed will typically change in its overall characteristics and result in the generation of a new set of pollutants based on land use. The runoff will tend to contain more pollutants and be discharged from the site at a greater rate and volume. One of the challenges is to develop land in a manner where post-construction discharges resemble predevelopment discharges.

Historically, Indiana communities have addressed storm water issues with relation to flooding. Many communities across Indiana have established ordinances that require detention and retention standards by establishing peak discharge limits. Typically, these standards do not address pollutants that are associated with the land use. These standards indirectly reduce pollutant loading by releasing storm water at rates that do not cause bank erosion and scouring in the receiving body of water.

Several multipurpose storm water management measures can be used in conjunction with flood control measures. These measures include infiltration systems, wetland cells, pretreatment measures, and modification of detention/ retention structures that have been designed to enhance the removal of storm water pollutants.

## Pollution Treatment

The post-construction storm water measures listed in this manual are designed to remove storm water pollutants through several different methods or processes (e.g., filtration and infiltration). For simplicity the measures have been grouped or categorized based on primary pollutant removal processes and similar design characteristics. The four major categories are 1) filtration systems, 2) infiltration systems, 3) settling and flocculation measures, and 4) proprietary measures. Below is a brief discussion of each category. Specific information on the individual measures is contained in Chapter 8 of this manual.

### 1) Filtration Systems

Storm water filtration systems operate on the principal that runoff is intercepted and allowed to pass through a filtering medium such as vegetation, sand, or organic material for pollutant removal. There are two basic types of filtration systems: 1) surface filtration and 2) underground treatment. Surface filtration systems include measures such as compost filters, filter strips, vegetated swales, and riparian buffer zones. Underground systems include measures such as sand filters and peat filters.

Filtration systems are primarily designed to remove pollutants. They are not intended for use as storm water retention measures. Filtration systems are typically used to treat runoff from small residential, commercial, and industrial sites and parking lots.

Surface flow filtration systems are typically designed to intercept sheet flow runoff and allow the runoff to pass through the filtering medium. Grass filters and compost mulch berms are two of the most common filtering mediums. Riparian buffer zone systems are also an effective filtration system because part of the riparian zone includes a grass filter as part of the overall system. In addition to conveying storm water runoff, vegetated swales can provide some filtering of storm water runoff, especially during low flows. Surface flow filtration systems are similar to those used during the construction phase of a project.

Underground filtration systems are used to treat runoff below the surface. These systems are often used in areas with limited space because they can be placed under parking lots and other areas within a project site. Underground filtration systems are typically designed to provide for different levels of pollutant removal. After runoff is filtered it can either be returned to the conveyance system or collected by an underdrain and allowed to percolate into the underlying soil material or infiltration medium (refer to the following infiltration measures).

### 2) Infiltration Systems

Storm water infiltration systems are designed and work on the principle of collecting storm water runoff and then slowly releasing the stored runoff, via percolation, into the underlying soil or contain it in an underground detention reservoir, where it may or may not be treated, before it is allowed to infiltrate into the underlying soil or discharge through a pipe connected to the storm water conveyance system or a secondary treatment system. Storm water infiltration systems generally reduce storm water runoff volumes and the associated suspended solids and pollutants attached to those solids. The level of pollutant removal effectiveness is highly dependent on the permeability of the underlying soil material. Highly permeable soils are relatively ineffective at removing many types of pollutants from runoff, especially if the pollutants are soluble or easily dissolved in the runoff. Soils with a low permeability rate may not provide sufficient residency time between storm events or the soil interface may seal over, which severely limits pollutant removal. Therefore, infiltration measures may require some form of storm water runoff pretreatment before runoff is allowed to enter the infiltration bed, or the infiltration bed may require modification to ensure appropriate permeability rates for the targeted pollutants.

Storm water infiltration measures should be carefully sited and designed to minimize the risk of ground water contamination. When considering the use of storm water infiltration measures, land use and potential pollutants generated within the drainage area of the infiltration measure should be carefully evaluated, especially in areas that are designated wellhead protection areas. Pretreatment systems that target specific pollutants and are designed to high removal standards may alleviate these concerns.

Infiltration measures are usually best suited for treating storm water runoff from small drainage areas. In general, these systems should not be used in areas where the land use of the contributing drainage area is associated with high traffic volumes, industrial and manufacturing facilities, chemical storage, high levels of pesticides, the washing and maintenance of vehicles or equipment, or where wastes are handled. In addition, infiltration measures should not be used in areas with high sediment loads or during construction, especially in situations where sediment-laden runoff from disturbed areas will be directed into the system.

Project site owners may be required to obtain special permits in situations where infiltration systems have the potential to be a conduit to ground water supplies. Permits may be required through the U.S. Environmental Protection Agency, the Indiana Department of Environmental Management, or local units of government. For example, storm water management systems that may have an effect on ground water supplies may be required to comply with the U.S. Environmental Protection Agency's Class V Injection Well Section of the Underground Injection Control Program.

By definition, a Class V injection well is any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, an improved sinkhole, or a subsurface fluid distribution system. Improved sinkholes are natural karst depressions or open fractures that have been intentionally modified or designed for storm water management. A subsurface fluid distribution system is defined by the U.S. Environmental Protection Agency as an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground.

The U.S. EPA administers Indiana's Underground Injection Control Program. For more information regarding Class V injection wells, the plan designer should refer to the U.S. EPA, Region V guidance requirements.

Infiltration measures are prone to sealing or plugging. Therefore, it is often necessary to provide pretreatment of storm water runoff to remove pollutants such as oil, grease, solids and other floatables that would affect the integrity of the infiltration measure. It is equally important to provide pretreatment of storm water runoff if the underlying soil material is highly permeable and there is a high potential for pollutants to percolate or infiltrate into the underlying soil or filtering medium and adversely affect ground water quality.

Secondary treatment should be considered when soil permeability rates are too slow and there is a potential for pollutants to bypass the system, or when a closed underground storage system is used. Closed underground systems are designed to collect surface runoff through percolation or as direct flow into an enclosed, impermeable underground reservoir or chamber. Water collected in the closed system is usually routed to a conveyance system. The storm water discharging to the conveyance system may require secondary treatment to remove pollutants associated with the inherent land use.

Pretreatment and secondary treatment systems can be used in tandem to effectively treat storm water runoff.

Infiltration measures include but are not limited to porous pavement, porous pavers, infiltration trenches, infiltration chambers, infiltration ponds, and bioretention.

Porous pavers and porous pavement are two types of infiltration systems that are an alternative to conventional paving methods. These systems are designed to allow rainwater to pass through the system and discharge or percolate into an underlying filter medium. These types of systems reduce runoff, promote ground water recharge, and provide limited pollutant removal. Porous paver systems typically include grass grid pavers (e.g., plastic or concrete) and paving blocks. Porous pavement includes both pervious concrete and porous asphalt. Use of these systems are typically applicable to low-traffic areas including but not limited to overflow parking, residential driveways, light commercial use, commercial fire and emergency access lanes, and sidewalks. Decisions to use these systems can be identified early in the planning process and later factored into final design and the selection of storm water quality measures.

Infiltration trenches and infiltration basins are measures designed to reduce runoff volume, remove suspended solids and pollutants attached to the solids, and promote ground water recharge by allowing storm water runoff to infiltrate into the ground. Infiltration trench systems consist of shallow excavated trenches filled with a suitable medium to promote infiltration. The use of these systems is typically limited to smaller drainage areas. Conversely, infiltration basins, even though they function similarly to an infiltration trench, are impoundments designed to retain storm water runoff above ground over a short period of time and allow it to infiltrate into the soil. Filtration basins are more suitable for use on larger drainage areas.

Bioretention systems are shallow, depressional areas designed to manage and treat storm water runoff. They typically include a soil filtering medium and selected plants. Pollutants are removed through plant uptake and deposition when pollutants bond with soil particles as the runoff flows through the vegetation. Runoff collected in the bioretention system is allowed to either percolate through the soil, providing additional treatment and pollutant removal, or it may be collected by an underdrain and discharged to the storm conveyance system.

### 3) Settling and Flocculation Measures

Settling and flocculation measures are typically storm water management measures that have been modified to allow for the settling or flocculation of suspended solids and pollutants that may be attached to the solids. Measures in this category include but are not limited to dry ponds, wet ponds, storm water wetlands, and subsurface detention structures. The following discussion provides a brief overview of some of these measures and some of their limitations.

Dry detention basins are usually designed to temporarily hold storm water runoff and release it gradually. They help to reduce peak discharges to the receiving channel and are usually designed to completely dewater within a short time frame, typically 24 hours or less. Because of the short retention time, this type of basin does not address the issues of reducing storm water runoff volumes or pollutant removal. They are limited in their ability to retain suspended solids as subsequent storm events may resuspend trapped solids. By releasing water at a controlled rate, dry detention basins can provide water quantity control and protection of downstream areas. Dry detention basins can be useful as part of a treatment train that includes other measures designed to remove pollutants from storm water runoff.

Extended dry detention ponds are modified dry detention basins. They are designed to provide some measure of water quality enhancement by incorporating forebay ponds and/or isolated extended detention storage cells in the design of the pond. These appendages allow for the storage of additional storm water runoff and extend retention times to allow for the settling of solids.

Wet ponds provide pollutant removal as well as attenuation of peak flows and channel protection. Wet ponds are storm water ponds that provide for removal of pollutants by allowing solids to settle to the bottom of the pond. These systems are designed to remove suspended solids and pollutants attached to the suspended solids. Wet ponds can provide some removal of soluble pollutants through the biological processes of aquatic and pond fringe vegetation. Increased pollutant removal can also be achieved through basin design variations such as the addition of forebay ponds and multiple cells (e.g., wet pools, wetlands). These cells should be aligned in series to increase overall pollutant removal.

Storm water wetlands are man-made systems that incorporate a variety of plant material and are designed to increase retention time of runoff by increasing the travel time for storm water to flow through the system. Runoff entering the wetland system is designed to remove pollutants through deposition of solids and plant uptake.

Underground detention systems are storm water management systems designed to provide below grade storm water retention, thus freeing the land surface for development. This type of storm water management measure can be very useful in situations where land is not available for an alternative storm water quality measure. Underground detention systems do not reduce storm water runoff volumes due to their relatively quick dewatering times, but they are an appropriate measure for controlling storm water quantities. They can be used to control peak flows, reduce downstream flooding, and provide downstream channel protection. Underground detention systems are of little benefit for improving water quality. They do allow for settlement of coarse, suspended solids, but the solids will usually become resuspended during subsequent rain events. Therefore, underground detention systems should be used as part of a treatment train that uses other storm water measures as pretreatment and secondary treatment devices for the removal of pollutants, reduction of runoff volumes, and ground water recharge.

### 4) Proprietary Measures

Proprietary measures are manufactured systems designed to treat storm water runoff. There are a variety of proprietary systems available commercially. The systems consist of a wide variety of technologies designed to remove pollutants from storm water runoff. Manufacturers will typically provide data on pollutant removal and removal efficiency. Many manufacturers provide independent testing as testimony to the performance of their product.

Catch basin inserts are proprietary devices that treat runoff entering a catch basin. There are a variety of catch basin inserts available commercially. They typically contain a filtering medium such as sand, carbon, or geotextile. Sediment is the primary pollutant targeted, however selection of an appropriate filtering medium can provide for removal of oils and metals. These systems have limited capacity, short retention time, and require frequent cleaning or replacement to maintain efficiency. They are susceptible to clogging and may result in flooding when not properly maintained. These systems are limited in use due to low efficiency and are best used as part of a treatment train that incorporates other storm water management measures.

Hydrodynamic separators consist of a series of treatment chambers that operate on a principle known as swirl concentration. These systems are modifications of the traditional oil/grit separator. Hydrodynamic separators commonly rely on vortex-enhanced design to remove sediments from runoff. They will typically remove suspended solids, oil, and floatables. Swirl concentration is the most common technology used in hydrodynamic separators. Other systems use combinations of screens, baffles, and inlet and outlet structures to remove debris, suspended solids, and oil. There are many different types of hydrodynamic separators available commercially; each has its own variation of technology.

Hydrodynamic separators are well suited for use in areas where there is a need for removal of pollutants and high sediment loads over a wide range of flow conditions. These devices can be used to treat runoff from relatively small areas with high traffic volumes or areas that have a high potential for spills such as parking lots, streets, loading docks, service stations, refueling areas, automotive repair facilities, fleet maintenance areas, commercial vehicle washing, and industrial facilities that have a high potential for accumulation of fuels, oils, grease, and other pollutants associated with mechanical equipment. Hydrodynamic separators alone may not remove 80 percent of the pollutants often associated with gas stations or other storm water hotspots. A secondary in-line filter may be required to achieve the overall objective.

When used in conjunction with storm water detention facilities, hydrodynamic separators should be placed upstream of the detention facility to provide runoff pretreatment and help prevent the loss of detention volume, especially when underground facilities are used.

Hydrodynamic separators can be used as a primary storm water runoff treatment device or as a pretreatment system for other storm water quality measures. Hydrodynamic separators are also an excellent retrofit option when upgrading storm sewer systems in highly urbanized areas where more conventional or aboveground treatment is not practical due to space limitations.

## Inspection & Maintenance

All post-construction storm water quality measures require periodic inspection and maintenance to ensure they are functioning according to design standards. The operation and maintenance provisions for each storm water management measure should be outlined in the storm water pollution prevention plan. The plan should include inspection frequency, maintenance requirements, and identification of the person or entity responsible for operation, inspection and maintenance of the storm water management system.

Long-term maintenance is a key factor in the evaluation, selection, and design of post-construction storm water management measures. The selection, siting, and design of measures should provide easy access for the entity that will be responsible for inspection and maintenance of the measures. All storm water quality measures must be maintained to remain operational and functional. The level of maintenance will vary with each measure. Some measures are more easily maintained than others. For example, swales only require periodic fertilization and mowing. Other measures will require intensive maintenance. Structural measures typically have higher, more intense maintenance requirements. These measures include but are not limited to hydrodynamic separators, infiltration systems, and filters. Some measures may only require hand tools or small landscape equipment. Other measures will require use of heavy or specialized equipment. When larger equipment is required for maintenance, the site designer should provide maintenance roads or access lanes that can be used for easy access to the measure.

The final consideration in maintenance of post-construction management measures is ownership and who will have long-term responsibility for operation, inspection, and maintenance of the measures. This issue is vital to ensuring that the measures will remain functional. Project site owners should continue to maintain the storm water management system until such time as the system is transferred to the person or entity that will assume long-term responsibility for operation, inspection, and maintenance.

Following the completion of construction, responsibility for storm sewer systems, including post-construction measures, are often transferred to local governmental entities. Systems that are owned or operated by a municipality or public utility are typically not a major concern for long-term maintenance. Local government and public entities can ensure long-term maintenance and monitoring through fees, taxes, or other funding sources. Typically, this approach is taken with residential developments.

It is generally not prudent to transfer operation and maintenance responsibilities to a homeowners association. The long-term maintenance and functionality of measures is critical to their operation. Failure of these systems can result in flooding, harbor vectors, or cause a nuisance. Homeowners associations are not necessarily solvent and at some point may cease to function. Permanent storm water management measures should also not be located on individual residential lots. The responsibility to maintain these measures may be costly and homeowners usually do not understand the consequences associated with failure to maintain the system. Local governmental entities usually maintain regulatory responsibility for the functionality of the measures. In these situations, the local governmental entity would be responsible to ensure that a homeowner or homeowners association is maintaining the measure. Failure of the homeowner or an association to maintain the measure may require the local governmental entity to take enforcement action against individuals within the community.

Storm water management systems that are associated with multi-family residential developments, commercial developments, and industrial developments or multi-lot parcels will typically be maintained by the facility/property owner. In these situations, the local governmental entity may require agreements or permits to ensure long-term operation and maintenance of the storm water management system.

The maintenance requirements described above should always be incorporated into the storm water pollution prevention plan. Details for maintenance should always be discussed early in the development process and final decisions on long-term maintenance agreed to before finalizing the measures that will be used to manage and treat storm water on the project site.

## Modifying Existing Storm Water Management Systems

It is relatively easy to incorporate storm water quality and quantity management measures into new development projects. This is especially true when the plan designer considers post-construction land use issues early in the planning process. However, there are situations where a storm water system will require modification to address either a water quality or quantity issue. Modification of an existing storm water management system is often referred to as a retrofit.

Retrofits are applicable to situations in existing and redevelopment areas that are highly urbanized. Retrofits can apply to existing drainage systems, storm water management structures, outfalls, road culverts, highway right-of-ways, and parking lots to name a few. One of the purposes of retrofitting an existing system is to correct problems associated with older and poorly designed or maintained storm water management systems. The objective of a retrofit project may be to reduce pollutant loadings, address runoff quantities, address nuisance issues, or resolve maintenance issues.

Retrofits are a viable option for enhancing existing storm water management systems when the current land use or space limitations prohibit the use of other types of storm water management measures. Accessibility for maintenance may also be a limiting factor.

Incorporating storm water retrofits into existing or redevelopment projects can reduce the adverse impacts associated with storm water runoff. This manual describes many methods to reduce the impact of storm water runoff including the reduction of impervious surfaces and the installation of storm water management measures that specifically target pollutant reduction and removal and management of storm water runoff quantities. Site conditions may prohibit or eliminate the use of several of the measures listed in Chapter 8 of this manual. Storm water management measures used to retrofit a drainage system in existing or redevelopment areas may be less effective at pollutant removal versus their pollutant removal rate in new developments.

Modification of storm water management systems can be achieved through careful planning and design. If a measure cannot be completely adapted to a field situation, it may be possible to incorporate some of the site design principles, contained in Chapter 4 of this manual, into the existing storm water management system to accommodate treatment of storm water runoff. Where possible system retrofits should be used in conjunction with other storm water management measures to increase the overall effectiveness of the system.

# DEVELOPMENT OF A CONSTRUCTION SEQUENCE SCHEDULE

A construction sequence schedule is a predetermined chronological listing of erosion protection, sedimentation control, and storm water management measures that are scheduled to be deployed in a timely manner with various land-disturbing phases of a construction project.

The purpose of a construction sequence schedule is to minimize the duration and amount of soil exposed to erosion by wind, rain, storm water runoff, and vehicle tracking and to provide adequate treatment measures to minimize the introduction of pollutants to storm water runoff.

A construction sequence schedule should be developed for and implemented on every construction project involving clearing, grading, and/or filling of the land surface. Implementation of a construction sequence schedule is especially important during periods of intense or prolonged rainfall.

Developing a construction sequence schedule for a project helps to establish a timetable for installing erosion and sediment control measures and post-construction storm water management measures and shows their likely compatibility with the project's general construction schedule. Appropriate sequencing of construction activities can be an efficient and cost-effective way to help accomplish these goals. Often, a proper construction sequence schedule can eliminate the use of more costly, yet less effective storm water measures.

A properly developed and implemented construction sequence schedule will provide for timely installation of storm water management measures that will protect the construction site from erosion and off-site sedimentation, regardless of the stage of construction or time of year. For a construction sequence schedule to be effective, it must clearly communicate to contractors, plan review authorities, and inspecting authorities what control measures are needed, where they are to be installed, and when installation is to occur. The schedule can be written in very general terms or it can be very specific and detailed. In the latter case, the construction sequence schedule might specify when each individual erosion and sediment control measure or device is to be installed (e.g., when each individual sediment trap or basin is to be installed or when each individual storm drain inlet protection device is to be installed) as land-disturbing activities progress across the project site. In either case, the schedule needs to be site specific.

Construction sequence schedules must be flexible. Project representatives and contractors must be given the opportunity to use construction techniques that are not scheduled, but because of timeliness, can greatly reduce erosion potential at the project site (i.e., reshaping earthen fills periodically to prevent overflows or construction of temporary diversions ahead of anticipated storm events). It is impossible to incorporate activities such as those listed above into a construction sequence schedule but they should be used whenever possible.

Construction sequence schedules should be followed as closely as possible throughout development of the project. Project representatives should monitor the weather forecast on a regular basis. When rainfall is predicted they should have the ability to adjust the construction sequence to allow for the  implementation of soil stabilization and appropriate sediment control measures prior to the onset of any rain.

When construction activities must be changed, the changes should be discussed at the project's coordination meetings or directly with the project site manager/inspector. These discussions should occur prior to implementing the changes and if necessary, the schedule should be amended in advance to reflect those changes and maintain management control. Orderly modifications ensure coordination of construction activities and installation of the storm water quality measures. Orderly modifications also minimize the potential for erosion and sedimentation problems. If major changes are necessary, it may be beneficial to send a copy of the revised schedule to the local permitting authority.

## Developing a Construction Sequence Schedule

Developing a construction sequence schedule is very similar to project planning and design and incorporates many of the same principles. Some of the more important factors to consider when developing a construction sequence schedule include weather, soil conditions, growing season, and phasing of the project to minimize the amount of area to be disturbed at any one time.

At a minimum, a construction sequence schedule should show the following:

- Principal development activities.
- Storm water quality control measures to be installed.
- Specific measures that should be in place before other activities are begun.
- Compatibility with the general construction schedule of the overall project.

In general, a construction sequence schedule is developed by first listing all construction activities associated with the project. This list should include any off-site activities associated with the project. A construction activity list will typically include but is not limited to preconstruction activities, access to the construction site, perimeter controls, storm water runoff control, land clearing and grading, storm water conveyance system installation, infrastructure construction/installation, and final stabilization. Other activities that might be included as subitems in the list are activities that may require non-storm water discharges such as dewatering, saw cutting, grinding, drilling, boring, crushing, blasting, painting, hydrodemolition, mortar mixing, pavement cleaning, etc.

The second step in developing a construction sequence schedule is to establish the sequencing of construction activities and a general timetable for the start and completion of each item such as site clearing and grubbing, grading, excavation, paving, foundation pouring, utilities installation, etc. Development of the timetable should take into consideration the effect extended periods of rain may have on each specific soil-disturbing activity and on restabilization activities. Where feasible, adjust construction activity time frames to minimize soil exposure during anticipated rainy periods which frequently occur in spring and early autumn.

The third step in developing a construction sequence schedule is to list the erosion control measures, sediment control measures, post-construction storm water measures, and non-storm water pollutant control measures associated with each construction activity listed in step one. Other control measures should include tracking control measures, wind erosion control measures, and provisions for waste management and materials pollution control. The schedule should address but is not limited to the deployment of each of these measures in relation to land-disturbing activities and other operational schedules associated with the construction project. The schedule should provide details for the deployment of these measures in both dry weather conditions and extended periods of rain.

The next step is to merge everything into a logical sequence that will provide a practical and effective method of installation. If the schedule becomes too large or complicated, multiple plan "windows" or multiple sheets can be used for clarity.

The final step of developing a construction sequence schedule is to incorporate it into the storm water pollution prevention plan.

Often, it is easier to develop a construction sequence schedule by answering a series of questions. For example, one of the first basic questions to ask is, "**Will the removal of existing soil surface ground cover leave the site vulnerable to accelerated erosion?**" In most instances, the answer to this question will be yes. The next basic question that might be asked is, "**Can this project be developed in phases?**" If the answer to this question is yes, it might be beneficial to develop a separate schedule for each phase of the project. The following discussion addresses various types of construction activities and associated concerns that need to be taken into account when developing a construction sequence schedule.

## Preconstruction Activities

**The purpose of preconstruction activities is to evaluate and protect important site features such as trees, vegetation, unique site features, etc. that may be associated with construction activities.**

The preservation of trees, existing vegetation, unique site features, etc. on a project site requires forethought and planning in order to ensure that these features are not damaged or destroyed by construction activities. Frequently these resources are destroyed in the interval between purchasing the property and completing construction activities. Damage to these areas is generally the result of direct contact with construction equipment. However, damage can also be caused as a result of root zone stress from filling, excavating, or compaction of soil within and around root zones and tree driplines. It is quite common to see dead trees within a year or two after their rooting system has been damaged. This generally leads to costly removal and can result in property damage if the trees fall. Therefore, storage of equipment, vehicles, and construction materials under trees or on other areas to be protected should be prohibited.

Preservation/protection of important project site features begins with the development of a construction sequence schedule that identifies measures which can be used to manage construction activities, or at the very least minimize damage, in these areas. As the preconstruction activity section of a schedule is developed, it is important to evaluate what measures can be used to minimize the clearing of existing vegetative cover; maximize the preservation of wetlands, sensitive areas, etc.; and/or buffer stream corridors. Areas down slope of building sites should be evaluated to determine if they should be preserved or protected for the purpose of flow control and water quality enhancement via flow dispersion through the native vegetation.

Following are some basic but very important questions that often need to be answered when developing a construction sequence schedule for preconstruction activities. It must be noted that this list is not all inclusive and other questions may need to be addressed, depending on the scope of the proposed construction project.

The first basic question to ask in regard to developing a schedule for preconstruction activities is, "**Does this project require working around buried utility lines?**" If the scope of a project requires working in and around underground utilities, the construction sequence schedule should identify measures such as contacting the appropriate underground plant protection agency [e.g., Indiana Underground Plant Protection Service (also known as "Holey Moley") 1-800-382-5544] at least two working days before initiating any construction activities.

Another key question that should be addressed on projects associated with open waterbodies, wooded areas and wetlands is, "**Does the project site owner need any local, state, or federal permits to work in or around these areas?**" Various permits are frequently required if there is potential for a project to degrade water quality or have a significant impact on endangered plant or animal species. If permits are needed the sequence schedule needs to allow sufficient lead time for permit application and issuance of the permit by the appropriate regulatory agency.

"**Are there any existing site features, sensitive areas, unique areas, etc. that need to be preserved on the project site?**" is another question that should be addressed before starting construction on a project site. Where applicable, construction sequence schedules should identify measures that can be deployed on the construction site to prevent, or at the very least minimize, damage from construction operations. Placement of temporary fencing around tree driplines and placement of thick protective mulches over rooting zones are just two examples of management measures that might be used at a construction site to minimize damage to trees that are to be protected. A construction sequence schedule might also specify that physical barriers be erected around on-site sewage disposal absorption fields, unique cultural areas, areas with aesthetic value, etc. before beginning any land-disturbing activities of the project.

Another preconstruction activity question to ask is "**Are there any existing areas suitable for use as vegetative filter strips or riparian buffers?**" Areas suitable for use as vegetative filter strips or riparian buffers should be protected. The sequence schedule should identify measures that contractor(s) can install to protect these areas from construction traffic and from being used as materials storage areas. Again, the most obvious measure for protecting these types of areas is to clearly mark the area(s) and erect a physical barrier around them.

One more key preconstruction activity question that needs to be addressed is, "**Does this site require the use of on-site waste disposal facilities for developments that will not be served by sanitary sewers?**" Areas of a project site that are identified for use as on-site sewage disposal facilities should be protected to ensure the soil's ability to process or treat sewage effluent. In these situations the construction sequence schedule should identify appropriate measures such as temporary fencing that can be used to protect designated areas from vehicular traffic, excavating, or filling.

Areas to be preserved should be shown on all property maps and should be clearly marked, preferably with a physical barrier, during clearing and construction on the project site. If feasible, areas to be preserved should be placed in a separate tract or protected through recorded easements.

## Construction Site Access

*This item is applicable to construction entrances, construction routes, equipment staging areas, and employee parking areas, etc.*

**The purpose of installing construction access protection measures is to minimize the potential of soil being tracked onto public or private roadways from vehicles as they exit an active construction site.**

When a site is opened up, care must be taken to avoid damaging valuable trees, disturbing designated buffer zones, and creating avenues for sediment-laden storm water runoff to flow off of the project site.

Construction site access for construction vehicles, contractors and their employees, and materials vendors is normally the first land-disturbing activity associated with a project site. Therefore, steps should be taken to provide stable ingress/egress and minimize the potential for the tracking of soil onto public or private roadways.

Two basic questions to ask for this phase of construction are, "**Is there potential for vehicles (i.e., construction vehicles, contractor vehicles, materials vendors vehicles, etc.) to track soil from the project site onto public or private roadways?**" and "**Do on-site construction routes, construction vehicle staging and maintenance areas, designated employee parking areas, etc. need to be stabilized to prevent tracking of sediment onto public and/or private roadways?**" If the answer to either of these questions is yes, the schedule should identify appropriate measures to minimize the potential for tracking, such as stabilized ingress/egress pads, staging areas, etc., and specify that these measures must be installed before proceeding with any additional earthmoving activities. In instances where it is necessary to remove trees, shrubs, and/or brush to achieve site access and/or install perimeter control measures, clearing and grubbing should be limited to those areas needed for installation of the ingress/egress pads and perimeter storm water measures.

## Perimeter Protection

**The purpose of installing perimeter protection measures is to minimize the potential for off-site sedimentation when mass earthmoving activities are taking place.**

Perimeter protection is a key element of most construction sequence schedules. Typically this is thought of as providing erosion and sediment control protection at the perimeter of the overall project site. However, perimeter protection can also be a key element in protecting areas adjacent to active construction zones within the project site itself.

When developing the perimeter protection section of a construction sequence schedule, the first goal should be to protect all adjacent properties from potential erosion and sedimentation that may result from the active construction project. Two basic questions to ask in regard to this section of the schedule are, "**Is there potential for storm water runoff to discharge from the project site and cause erosion or sediment damage on adjoining properties or affect waters of the state of Indiana?**" and "**Will storm water runoff from adjoining properties interfere with land-disturbing operations on the project site?**" If the answer to either of these questions is yes, then the construction sequence schedule might specify the installation of temporary or permanent measures such as the protection of existing vegetative filter strips, establishing new vegetative filter strips, installing sediment barriers/filters, constructing diversion ridges and/or channels, constructing sediment traps/basins, etc.

In regard to perimeter protection as it applies to active construction zones within the project site, again there are two basic questions to ask. The first question that must be answered is, "**Will storm water runoff from up slope areas interfere with land-disturbing operations?**" The second question that needs to be answered is, "**Will the discharge of sediment-laden water from the active construction zone create problems on other areas of the project site?**" If the answer to either of these questions is yes, the construction sequence schedule should specify measures such as the protection of existing vegetative filter strips, establishing new vegetative filter strips, installing sediment barriers/filters, constructing temporary diversion ridges and/or channels, constructing temporary sediment traps/basins, etc. that can be used to control and treat the storm water runoff.

The measures specified in any perimeter protection phase of a construction sequence schedule should be installed before beginning any land clearing and grading operations.

## Storm Water Runoff Control

**Storm water runoff control measures serve two primary purposes. They are used to divert storm water runoff away from active construction areas and to divert sediment-laden storm water runoff from construction zones into sediment-trapping devices.**

When developing a construction sequence schedule, it will most likely be necessary to specify measures for the control of storm water runoff. As is so often typical, measures selected for one construction phase may overlap with one or more of the other construction phases. For example, as with perimeter protection, one of the questions that must be asked when developing this section of a construction sequence schedule is, "**Will storm water runoff from adjacent, up slope areas interfere with construction activities?**" If the answer to this question is yes, measures such as temporary diversion dikes and drainage swales might be specified for the purpose of diverting storm water runoff away from and/or around construction areas.

A second question to answer when developing a schedule for this phase of construction is, "**What measures do contractors need to install to divert sediment-laden storm water runoff from active construction areas into sediment trapping/treatment devices?**" In this situation, the construction sequence schedule might specify the installation of temporary or permanent diversions, temporary slope drains, etc.

Key storm water runoff control measures should be located in conjunction with sediment-trapping devices such as those specified in the perimeter protection section of the construction sequence schedule. Measures should be selected based on their ability to divert storm water runoff from undisturbed areas away from sediment traps/basins and divert sediment-laden storm water runoff into the traps/basins. Storm water runoff control measures should be installed, stable, and discharge to a stable outlet prior to opening any major areas for mass clearing or grading.

Construction sequence schedules must be flexible enough to allow for the installation of additional storm water runoff control measures and sediment-laden storm water runoff treatment measures which may be needed as grading operations progress across the project site.

## Land Clearing & Mass Grading

*This item is applicable to cutting, filling, and grading operations.*

**All construction site access, perimeter protection, and storm water runoff control measures should be in place, stabilized, and where applicable, have a stable outlet. It is important that these measures are in place to contain sediment, minimize off-site sedimentation, and treat sediment-laden storm water runoff as major land clearing and earthmoving activities commence. These measures must also be maintained throughout all phases of construction to ensure their effectiveness.**

Principal sediment traps, basins, filters, barriers, and storm water runoff control measures should be installed and stabilized before any major site clearing or grading takes place.

When developing a construction sequence schedule for this phase of a construction project, try to schedule major grading operations during periods of minimal rainfall. Allow enough time before anticipated rainy periods to stabilize graded soils with vegetation or other nonerosive measures and/or install sediment-trapping devices. Leave adjoining areas planned for development or designated borrow/disposal areas undisturbed as long as possible, taking advantage of their ability to serve as natural buffer zones. On larger projects, phase land-disturbing activities to reduce the amount of soil exposed to erosive forces. Reducing the amount of surface area exposed to soil erosion will minimize the sediment yield and will often allow for the use of smaller storm water quality measures.

A basic question to ask when developing this section of a construction sequence schedule is, "**What measures will contractors have to utilize to contain soil stockpiles on the construction site?**" As soil materials are stripped and relocated on the project site they should be stockpiled in areas that will not interfere with other construction activities or in areas where they might cause damage to adjoining properties, waterways, or waterbodies. The construction sequence schedule should identify measures to contain and/or stabilize the soil stockpiles. For example the schedule might specify the installation of sediment barrier measures along the down-slope side of all soil stockpiles/borrow areas prior to placement of the stockpiles or removal of any material from the borrow area. The construction sequence schedule may further require the application of temporary cover such as temporary seeding, mulching, or covering of the soil stockpile with an artificial cover.

"**Will any construction areas be inactive for a period of 15 days or more (local ordinances may be more restrictive)?**" is an important question to answer when developing a construction sequence schedule for land clearing and mass grading construction activities. If the answer to this question is yes, the sequence schedule should identify measures appropriate for the season that can be used to temporarily stabilize the inactive areas.

Clearing, grubbing, and construction activities typically increase storm water runoff and can make streambank and shoreline stabilization work more difficult and costly. Therefore, another key question to ask is "**Are there existing water features such as streams, rivers, lakes, wetlands, etc. on the project site that need to be protected during clearing and grading operations?**" If the answer to this question is yes, the schedule should identify streambank and/or shoreline stabilization measures that should be installed and stabilized before proceeding with additional land-disturbing activities. It is usually best to schedule this work as soon as weather conditions permit.

"**What measures do contractors need to install to contain sediment on-site as mass earthmoving takes place?**" is still one more vital question that should be addressed in a construction sequence schedule. The schedule should identify erosion and sediment control measures, including but not limited to temporary seeding, sediment traps and basins, swale and channel protection, and temporary slope protection, that should be installed prior to or immediately following rough or finished grading operations. For example, the schedule might require temporary seeding on all graded areas that will be inactive for seven days or more. Furthermore, it might specify that seeding be done daily while the soil is still loose and moist, or at a minimum of weekly. On larger projects, the sequence schedule should incorporate staged seeding and revegetation of graded slopes as work progresses across the project site.

Flexibility of a construction sequence schedule is particularly applicable to this phase of a construction project. Timely installation of additional storm water runoff control and treatment measures not shown on the construction plans can be very effective in controlling erosion and sedimentation during clearing, grubbing, and grading operations. Therefore, a construction sequence schedule should be flexible enough to allow for the installation of additional storm water measures as needed.

## Storm Water Runoff Conveyance System

*This item is applicable to drainage swales, open channels, storm sewers, etc.*

**Storm water runoff conveyance systems should be installed early in the mass grading phase of construction and the main conveyance system used to convey storm water runoff through the development site without causing erosion.**

Construction of the storm water conveyance system for a project often occurs in conjunction with mass grading activities or in the period just after achieving rough grade of the project site. It is generally best to install the main runoff conveyance system as early as possible in the land grading process and use it to manage and convey storm water runoff through the development. Controlling storm water runoff from the active construction zone will help reduce the erosion potential and allow for the placement of storm water treatment measures for the removal of sediment at strategic locations on the project site.

There are two primary questions that need to be addressed when developing the construction sequence schedule for this phase of construction. The first question is, "**What measures are required to prevent erosion/scour at storm water drainage system discharge points?**" Storm water from the conveyance system must be discharged to a stable outlet so that it does not cause erosion in the receiving channel or to the banks of the receiving basin or pond. Therefore, the construction sequence schedule should identify appropriate storm drain outlet protection measures, such as riprap over geotextile fabric, for each respective storm drain outfall. In the event that it is not feasible to construct and stabilize the outlet because of unavailable end sections or other materials or there is a delay in the installation of permanent outlet protection, the schedule should specify that temporary riprap outlet protection be installed until the outlet can be permanently stabilized.

Construction sequence schedules should specify that installation of the storm water runoff conveyance systems commence at the discharge (outlet) end of the storm drain system and proceed up slope, installing and protecting storm drain inlets as they are installed. This allows for placement and stabilization of storm drain outlet protection prior to discharging any concentrated flow into the receiving channel, basin, or pond. Constructing the drainage system in this manner reduces the potential for erosion/scour in the receiving channel, basin, or pond and generally allows contractors to work under dry conditions because they are working up slope, away from conveyance system drainage discharges. The construction sequence schedule should require that open drainage channels or swales be brought to final grade as soon as possible and stabilized immediately after construction.

The second question that needs to be addressed is, "**What measures can be incorporated into the project to minimize or eliminate the introduction of sediment and other storm water contaminates into the functional storm sewer system or drainage system?**" A construction sequence schedule should identify appropriate storm drain inlet protection measures designed to keep sediment and other suspended solids out of drainage system drop inlets, curb inlets, and culvert pipe inlets. Measures should be selected based on their ability to trap sediment in shallow pools without creating a safety hazard on the construction site and to allow flood flows to safely enter the storm drain system. Examples of measures that might be used to accomplish this goal include excavated drop inlet protection, block and aggregate curb inlet protection, geotextile fabric drop inlet protection, etc. A construction sequence schedule should also specify that storm drain inlet protection devices must be installed as soon as each respective storm drain inlet becomes functional.

## Surface Stabilization

**Surface stabilization should occur throughout the life of the project. Temporary and permanent stabilization measures should be identified for all seasons of the year.**

Surface stabilization is one of those activities that can be integrated throughout the life of a construction project. Surface stabilization generally involves the application or installation of temporary or permanent storm water quality measures to minimize erosion from unvegetated areas such as rough graded areas, soil stockpiles and borrow areas, and building pads. Two basic questions that need to be addressed during this phase of construction are, "**What are the measures that need to be deployed on this project to control erosion and treat sediment-laden storm water runoff?**" and "**What are the measures needed to stabilize unvegetated areas that will be inactive or idle?"**

In regard to the first question, the construction sequence schedule should identify measures appropriate for the season and associated weather conditions, including measures that can be deployed to control erosion and sedimentation caused by unseasonal rainfall, wind, and/or vehicle tracking during a dry season. For example, the schedule might require surface stabilization on unvegetated areas within a specified time frame following the completion of earthmoving activities or one day prior to the onset of precipitation, or it might require temporary seeding and/or mulching during extreme weather conditions with permanent vegetation measures delayed until a more suitable installation time.

A construction sequence schedule might address the second question listed above by requiring that areas scheduled to be idle or inactive for seven days or more be seeded with a temporary vegetative cover at the end of each workday while the soil is still loose and moist, or that these areas be protected with an anchored mulch cover.

## Infrastructure Activities

*This item is applicable to roads, utilities, etc.*

**Major utility installation should be done during periods of minimal rainfall and when feasible, should be completed before starting the building construction phase. Installing utilities during dry weather minimizes rutting and damage to any existing measures the project site owner has installed.**

Infrastructure installation should be coordinated with other development activities so that all work can take place in an orderly manner and on schedule. Experience shows that careful project scheduling improves efficiency, reduces cost, and lowers the potential for erosion and sedimentation problems.

Unfortunately, even with the best of planning, delays in the installation of infrastructure often occur and should be anticipated. In anticipation of these delays, the construction sequence schedule should include provisions for temporary seeding and/or mulching of all graded areas immediately following rough grading. This minimizes the potential for erosion of the construction site yet still allows for the installation/construction of infrastructure at a later date. Installation of infrastructure into these seeded areas will have little impact on the existing vegetation.

Development of a construction sequence schedule for the infrastructure phase of a construction project should address questions such as, "**Do any construction activities have to cross open drainage channels and/or open waterbodies or wetlands?**", "**Can utility installation operations be timed to coincide with dry weather conditions?**", and "**Will any areas require dewatering operations?**"

If infrastructure construction must occur in or around any open drainage channel or open waterbody, the construction sequence schedule should identify measures that the contractor(s) can use to isolate the work area from the open waterbody, streambank, or shoreline. The construction sequence schedule should also identify storm water management measures that can be used to minimize erosion and treat sediment-laden water which may flow from the construction zone. If directional boring is the method of choice for crossing waterbodies, the construction sequence schedule should identify measures that can be used to manage and treat water discharges from the drilling operations.

On some project sites it may be necessary to dewater open excavations as the infrastructure is installed. In these situations the schedule should identify measures for the treatment of any sediment-laden water that must be pumped from the open excavations. For example, the schedule might specify that sediment-laden water be pumped into a temporary dewatering structure or into a pump discharge bag before it is allowed to discharge into any waterbody. Where possible, it can be advantageous to adjust the construction sequence schedule so that installation is done during drier periods of the year. To the greatest extent practical, the schedule should provide for daily backfilling of open trenches, including seeding and mulching of work areas, as trenching progresses.

## Building Construction

As with infrastructure activities, building activities should be coordinated with other development activities so that all work can take place in an orderly manner and on schedule.

Development of a construction sequence schedule for this phase of construction requires answering the basic question of, "**What storm water quality measures do building contractors need to install on individual building lots to minimize erosion, prevent off-site sedimentation, and minimize the introduction of potential pollutants to storm water runoff?**" The construction sequence schedule should identify appropriate measures to control erosion and contain sediment on the individual building sites as home/building construction takes place. For example, the construction sequence schedule might specify the use of storm drain inlet protection devices if the building site is in close proximity to a storm drain inlet. The next item in the sequence might specify the installation of perimeter sediment barriers/filters and stabilized ingress/egress pads to minimize the amount of sediment washed or tracked from individual building sites to road surfaces, storm sewers, and/or established grassed waterways. The schedule could then require selective placement of dumpsters and other appropriate disposal containers for the proper disposal of construction materials, solvents, etc. and identification and marking of concrete washout disposal areas.

## Landscaping And Final Cover

*This item is applicable to topsoil application, permanent seeding and mulching, sodding, and planting shrubs and trees.*

Landscaping and final stabilization is the last major construction phase of any project. Topsoil stockpiling, tree preservation, undisturbed buffer areas, and well-planned road locations established earlier in the project may determine the ease or difficulty of this activity.

At this stage of a project, the construction sequence schedule should identify appropriate permanent stabilization measures for all remaining unvegetated areas, including borrow and disposal areas, and specify an installation timetable for each of the measures. The schedule should allow for the establishment of permanent vegetation during appropriate planting times for the vegetation specified in the plans.

In addition to permanent stabilization measures, the schedule should provide for the removal of all remaining temporary storm water management measures after construction, final grading, landscaping, and permanent stabilization has been completed and all disturbed areas up slope of the temporary measures have been properly stabilized. The construction sequence schedule should specify that sediment be removed from sediment basins/traps and that the sediment be incorporated into the topsoil, not just spread on the soil surface.

## Post-Construction Storm Water Quality

There will be a variety of issues associated with the post-construction land use of a project. The two primary issues that are typically addressed are pollutants associated with the land use and storm water quantity. Each project will have a unique set of storm water measures that will be required to address quality and quantity.

The installation of post-construction storm water measures should also be part of the construction sequence schedule. Erosion control measures should be planned and implemented as a management tool to reduce the generation of sedimentation. Measures that are targeted to manage or control runoff and to trap sediment should clearly be scheduled for implementation prior to land disturbance. The schedules described for erosion and sediment control do not necessarily apply to the installation of post-construction storm water management measures.

The installation of post-construction storm water measures is not necessarily related to timing of the land-disturbing activities. Post-construction measures can be installed at any phase of the project. If contractors are working in a specific area it may be more efficient to install the measure to coincide with the work activity. The most appropriate time may coincide with the installation of infrastructure. In other situations, it may be best to wait to install the measure towards the end of the project. Part of this decision process will be directly related to the type of measure that has been selected. The plan designer needs to be cognizant that some post-construction storm water measures may be subject to failure or high maintenance requirements if installed when the overall activity at the site has the potential to generate sediment loads that could plug the system with excessive sediment.

There are two primary questions that need to be addressed when developing the construction sequence schedule for post-construction storm water measures. The first question is, "**What measures can be installed during the early stages of construction activity that will not be negatively impacted by sediment from construction activity?**" For example, it may be opportune to install a storm water basin early in the project and modify the design to act as a sediment basin. Prior to the basin being utilized for its post-construction intent, sediment should be removed to re-establish the design storage capacity and structural modification implemented to return the basin to its original design.

The second question is, "**What measures would be subject to failure if installed during active construction?**" The second part to this question is, "**If a measure is installed, can appropriate precautions be taken to reduce the sediment load that is directed to the measure?**" There are several measures that are subject to failure and are not adapted to the types of sediment loads that are associated with active construction. If these conditions exist, maintenance can often be costly or may even require reinstallation of the measure. Infiltration measures are one example of a measure that is subject to failure under these conditions. If measures subject to failure are installed during active construction it would be extremely important that the drainage area above the measure is stabilized or that an effective sediment control measure or measures are installed to protect the integrity of the infiltration measure. The plan should also specify provisions to isolate construction activity from areas that could compromise the measure.

The plan designer should carefully evaluate when it is best to schedule the installation of each post-construction storm water quality measure. The schedule of implementation measures will be specific to the measure and should be based on activities that need to be performed to maintain the long-term functionality of the measure.

## Non-Storm Water Discharges

Construction sequence schedules often overlook or do not address non-storm water discharges associated with dewatering, saw cutting, grinding, drilling, boring, crushing, blasting, painting, hydrodemolition, mortar mixing, pavement cleaning, etc. The cumulative effect of water discharges from these operations can have a bearing on water quality and therefore should be addressed in the sequence schedule.

When there is potential for surface water or ground water contamination from non-storm water discharges associated with construction activities on the project site, the construction sequence schedule should identify measures that can be used to collect and treat the discharges. For example, when there is a potential for wet excavations, the schedule should provide for the discharge of sediment-laden water into an appropriately sized sediment trap or basin, a dewatering treatment/filter structure, or pump discharge filter bag before allowing it to discharge into a waterbody or off-site storm sewer system.

## Examples of a Construction Sequence Schedule

Construction sequence schedules can be developed in many different formats. The most common forms of construction sequence schedules are bar charts, numeric listings, and tables. At the end of this section is an example of each format showing a hypothetical construction sequence schedule that might be associated with a construction project. It must be noted that the activities listed in these examples do not usually occur in any specific linear sequence and that schedules will vary due to the type and scope of the project, weather conditions, and other unpredictable factors. It is important to note that every set of construction plans should have a proposed construction sequence schedule tailored to the specific project site.

In the bar chart format example, construction activities are listed down the left side of the chart and projected time frames are listed across the top of the chart. Storm water measures are listed as sub-items under each of the respective construction activities with the appropriate time frames marked in the body of the chart.

In the numeric list format example, construction activities are listed in a numerical sequence.

In the table format example, the construction activities are listed in the first column. The second column lists the various storm water measures associated with each construction activity. Column three identifies the location of the respective control and treatment measures and the timing of installation is identified in the last column.

No matter what format the plan designer chooses, it is important to keep in mind that the construction sequence schedule must be very flexible because there is no sure way to predict weather delays or delays in the permitting process.

## Example of a Bar Chart Construction Sequence Schedule for a Residential Project (Land-Disturbance & Infrastructure Phase)

| | Construction Sequence Schedule Time Frame | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Week** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| **Construction Sequence** | | | | | | | | | | | | | | |
| **Preconstruction Activities (evaluation/protection of important site features):** | | | | | | | | | | | | | | |
| Preconstruction conference | ■ | | | | | | | | | | | | | |
| Preconstruction actions | ■ | | | | | | | | | | | | | |
| Contact utility locater | ■ | | | | | | | | | | | | | |
| Protect existing streams, lakes, wetlands, etc. | ■ | | | | | | | | | | | | | |
| Protect other important & aesthetic features | ■ | | | | | | | | | | | | | |
| **Construction Access (construction entrances, construction routes, equipment parking areas):** | | | | | | | | | | | | | | |
| Install gravel construction entrance | ■ | | | | | | | | | | | | | |
| Install gravel equipment parking area(s) | ■ | | | | | | | | | | | | | |
| **Perimeter Controls:** | | | | | | | | | | | | | | |
| Install sediment barriers & filters (silt fence, etc.) | | ■ | | | | | | | | | | | | |
| Install outlets & outlet protection devices | | ■ | | | | | | | | | | | | |
| Install sediment traps & basins | | ■ | | | | | | | | | | | | |
| **Initial Land Clearing and Grading Activities:** | | | | | | | | | | | | | | |
| Grub & clear vegetation | | ■ | | | | | | | | | | | | |
| Strip & stockpile topsoil | | | ■ | | | | | | | | | | | |
| Stabilize topsoil stockpiles | | | ■ | | | | | | | | | | | |
| **Secondary Land Grading Activities (cutting/ filling/ grading, drains, sediment traps, barriers, diversions, surface roughening):** | | | | | | | | | | | | | | |
| **Runoff Control (outlet protection, sediment traps & basins, diversions, perimeter dikes, water bars):** | | | | | | | | | | | | | | |
| Install outlets & outlet protection devices | | | | ■ | ■ | | | | | | | | | |
| Construct on-site sediment traps & basins | | | | ■ | ■ | | | | | | | | | |
| Construct diversion channels, berms, water bars, etc. | | | | ■ | ■ | | | | | | | | | |

## Example of a Bar Chart Construction Sequence Schedule for a Residential Project (Land-Disturbance & Infrastructure Phase) [*continued*]

| | Construction Sequence Schedule Time Frame | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Week** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** |
| **Construction Sequence** | | | | | | | | | | | | | | | | | | | |
| **Runoff Conveyance System (stabilized streambanks, storm drains, inlet and outlet protections, channels):** | | | | | | | | | | | | | | | | | | | |
| Install storm sewer system | | | ■ | ■ | ■ | ■ | | | | | | | | | | | | | |
| Protect storm drain inlets | | | | ■ | ■ | ■ | | | | | | | | | | | | | |
| Construct swales | | | | | | | ■ | ■ | ■ | | | | | | | | | | |
| Install sediment traps | | | | | | | | | ■ | | | | | | | | | | |
| Seed and/or mulch swales | | | | | | | | | ■ | ■ | | | | | | | | | |
| **Excavate Subsoil to Grades Shown on Plans:** | | | | | | | | | | | | | | | | | | | |
| Stockpile subsoil in designated areas | | | | | | | | | | | ■ | | | | | | | | |
| Stabilize subsoil stockpiles | | | | | | | | | | | ■ | | | | | | | | |
| **Temporary Surface Stabilization:** | | | | | | | | | | | | | | | | | | | |
| Seed and/or mulch disturbed areas daily/weekly | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Permanent seed all areas at final grade | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Install Infrastructure:** | | | | | | | | | | | | | | | | | | | |
| Construct streets/roadways | | | | | | | | | | | | ■ | ■ | ■ | ■ | | | | |
| Install curb and gutter | | | | | | | | | | | | | | ■ | ■ | ■ | | | |
| Pave streets/roadways | | | | | | | | | | | | | | | | ■ | ■ | | |
| Install utilities | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ |

### Example of a Bar Chart Construction Sequence Schedule for a Residential Project (Building Construction Phase)

| | Construction Sequence Schedule Time Frame | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Week** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| **Construction Sequence** | | | | | | | | | | |
| **Building Construction (buildings, utilities, paving):** | | | | | | | | | | |
| Protect storm drain inlets | | | | ■ | | | | | | |
| Install stone access drive | | | | ■ | | | | | | |
| Install perimeter protection (silt fence) | | | | ■ | | | | | | |
| Protect & maintain drainage swales | | | | ■ | | | | | | |
| Excavate for foundations and footings | | | | ■ | | | | | | |
| Construct building(s) | | | | ■ | ■ | ■ | ■ | | | |
| Install downspout extenders | | | | | | | | ■ | | |
| Seed & mulch lawn | | | | | | | | ■ | | |
| **Final Shaping/Landscaping/Stabilization:** | | | | | | | | | | |
| Apply topsoil and soil amendments | | | | | | | | ■ | | |
| Plant trees and shrubs | | | | | | | | ■ | ■ | |
| Permanent seeding & mulching, sodding | | | | | | | | | ■ | |
| **Maintenance of Erosion & Sediment Control Practices:** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Remove temporary structural measures, Seed and mulch any remaining unvegetated areas | | | | | | | | | | ■ |

## Example of a Numerical List Construction Sequence Schedule for a Residential Development

NOTE: The soils engineer will be on site to inspect and certify all grading operations.

1. The site superintendent and/or the party that will be directly responsible for maintaining the sediment control devices must meet with the "Anywhere County" sediment control inspector for a preconstruction meeting at the site with a print of the approved sediment control plan prior to issuance of the grading permit.

2. Obtain grading permit from "Anywhere County Department of Environmental Resources."

3. Install stabilized construction entrance with mountable berm and 12-inch temporary corrugated metal pipe culvert. (1 day)

4. Clear and grub areas as necessary for the installation of sediment control devices as shown on this plan. (2 weeks)

5. Install the following sediment control devices and stabilize per temporary seeding specifications. (3 weeks)
    a. Install stone outlet structure #1, adjoining earth dike A-4 and silt fence (insert A, sheet 6 of 9).
    b. Excavate sediment basin #2 and use excavated soil to fill existing area draining to stone outlet structure #1. Compact and provide positive drainage as shown on insert A, sheet 6 of 9.
    c. Construct 240 feet of earth dike A-1 extending from north side of basin #2 and temporary swale shown on sheet 2 of 9.
    d. Install sediment traps and remaining basins, all remaining perimeter earth dikes, pipe culvert #8, all remaining stone outlet structures, all silt fences except on Block C, Lots 3 & 4 and Block D, Lot 23.
    NOTE: Do not install sediment control devices for utilities until work begins. Do not proceed to step #6 without approval of sediment control inspector.

6. Upon acceptance of sediment control, clear and grub site, starting with road right-of -way. (2 weeks)

7. Begin rough grading of site starting with roads. In the following areas, the roads shall be put on grade before completing grading in adjacent areas. (15 weeks)
    a. Bring Carlene Drive to grade from station 47+00 to 55+00 before grading on Lots 1-7, Block C. After Carlene Drive is on grade, earth dike A-1 and earth dike B-3 may be removed and the silt fence on Lots 2 and 3 installed, but only with the approval of the sediment control inspector.
    b. Bring Carlene Drive from Station 16+50 to 20+50 and area to east to grade. When this area is at grade, the side slopes shall be stabilized per the specifications. When area is stabilized, remove earth dike A-1 (sheet 4 of 9).

8. Install water and sewer. Provide sediment control for construction outside main perimeter sediment control devices. (8 weeks)
    NOTE: All sediment controls will be repaired the same day as utility construction.

### Example of a Numerical List Construction Sequence Schedule for a Residential Development (*continued*)

9. Install storm drain as follows. (10 weeks)
   NOTE: Install riprap channel outlet protection in Parcel F (sheet 2 of 9) and Block B, Lot 1 (sheet 4 of 9) where first outfall discharges into stream. Start at lower end and work upstream.
   NOTE: All sediment controls will be repaired the same day as utility construction. Soils engineer will determine in field if underdrains are needed in Morley soils areas. Rough grading permit shall be resubmitted for approval by Department of Environmental Resources.

   a. Build endwall 57A and manhole 57 and pipe between the same. Install remaining storm drain line beginning at manhole 57 and working upstream.
      NOTE: Inlets 61 and 60 are to be bricked shut. Install riprap channel outlet protection at endwall 57A (sheet 6 of 9).
   b. Build inlet 54 and inlet 55 and pipe between the same. Install approximately 40 feet of 18-inch PVC pipe at inlet 54 and temporarily discharge it into Basin #7. Install remaining storm drain line beginning at inlet 55 and working upstream to structure #56.
      NOTE: Endwall 53B and manhole 53A and pipe between the same may be built at this time. Install remaining storm drain line beginning at manhole 53A and working upstream; however, the 18-inch reinforced concrete pipe between inlet 54 and manhole 54A must be bricked shut at inlet 54. Install riprap channel outlet protection at endwall 53B (sheet 7 of 9).
   c. Build endwall 47 and manhole 48A and pipe between the same. Brick shut 18-inch reinforced concrete pipe between these at manhole 48A. Install approximately 75 feet of 18-inch PVC pipe at manhole 48A and work upstream. Install riprap channel outlet protection at endwall 47. Once storm drain diversion is
      functioning, pipe culvert #8 may be removed (sheet 7 of 9).
   d. Build endwall 39 and manhole 46A and pipe between the same. Install remaining storm drain line beginning at manhole 40A and working upstream.
      NOTE: Inlets 43, 44, and 45 are to be bricked shut. Install riprap channel outlet protection at endwall 39. Provide inlet protection at inlet 41 (sheet 5 of 9).
   e. Build endwall 35 and manhole 36 and pipe between the same. Install remaining storm drain line beginning at manhole 36 and working upstream. Install approximately 165 feet of 15-inch PVC at inlet 38 and temporarily discharge it into trap #1.
      NOTE: Brick shut 15-inch reinforced concrete pipe between structure 37 and 36 at structure 37. Install riprap channel outlet protection at endwall 35 (sheets 2 and 5 of 9).
   f. Build manhole 32 and inlet 33 and pipe between the same. Install approximately 30 feet of 15-inch PVC pipe at manhole and temporarily discharge it into trap #6. Endwall 30 and manhole 31 may be built at this time.
      NOTE: Brick shut 15-inch pipe between structures 32 and 31 at structure 31. Install remaining storm drain line beginning at inlet 33 and working upstream. Install riprap channel outlet protection at endwall 30 (sheet 5 of 9).

### Example of a Numerical List Construction Sequence Schedule for a Residential Development (*continued*)

g. Build inlet 26A and manhole 26 and pipe between the same. Install approximately 30 feet of 18-inch PVC pipe at inlet 26A and temporarily discharge it into trap #4.
NOTE: Endwall 17 and manhole 18 may be built at this time. In one day, construct structure #24 and install approximately 30 feet of 18-inch PVC pipe and adjust in field to connect to temporary 18-inch PVC pipe that discharges from trap #4. Build pipe between structures 24 and 18. Install remaining storm drain line beginning at structure 24 and working upstream to structure 26A. Install riprap channel outlet protection at endwall #7 (sheet 4 of 9).

h. Build inlet 19 and pipe between inlet 19 and existing manhole 18. Install approximately 55 feet of 18-inch PVC pipe at inlet 19 and temporarily discharge it into trap #3. Brick shut 18-inch reinforced concrete pipe between inlet 19 and existing manhole 18 at inlet 19. Install remaining storm drain line beginning at existing manhole 18 and working upstream (sheet 3 of 9).

i. Build endwall 4 and manhole 8 and pipe between same. Install remaining storm drain line beginning at structure 6 and working upstream to structure 12. Install riprap channel outlet protection at structures 4, 12 and 13 (sheet 2 of 9).

j. Concurrently, starting at structure #10, build remaining storm drain line working upstream to structure #26.
NOTE: Provide inlet protection at structures 14, 15, and 16 (sheet 2 of 9).

k. Build endwall 1 and manhole 2 and pipe between the same. Install remaining storm drain line beginning at manhole #2 and working upstream.
NOTE: The 15-inch reinforced concrete pipe between manhole 3 and manhole 2 will be bricked shut at manhole 3. Install approximately 83 feet of 15 -inch PVC pipe at manhole 3 and temporarily discharge it into basin #2.

l. Build endwall 27B and manhole 27A and pipe between the same. Build remaining storm drain line working upstream starting at structure #27A. Brick shut 18-inch reinforced concrete pipe between structure 28 and 28A at structure 28. Install approximately 56 feet of 18-inch pipe at inlet 28 and temporarily discharge it into trap #5 (sheet 4 of 9).

10. Construct curb, gutter and sidewalks. Base pave the streets. (6 weeks)

11. Fine grade site and stabilize per the permanent seeding specifications. (3 weeks)

12. Upon site stabilization, flush storm drain systems then remove structure blocking and temporary storm drain diversions only with the permission of the sediment control inspector. (1 day)

13. Remove all sediment control devices, except sediment basin #8, only with permission of the sediment control inspector and stabilize per permanent specifications. For removal of trap #3, silt fence must be installed as shown on plan. (1 week)

14. When the area to basin #8 is stabilized, temporarily de-water the basin. The basin shall be filled starting at the upstream end of the basin and working towards the

## Example of a Numerical List Construction Sequence Schedule for a Residential Development (*continued*)

dam. Grade to area as shown in Insert "B" on sheet 9 of 9 and stabilize per permanent seeding specifications. (1 week)
NOTE: Do not proceed to step #15 without approval of sediment control inspector.

15. Upon approval of grading and stabilization remove trap #9 including 42-inch barrel and 60-inch riser. Install riprap channel as shown in Insert "C." Stabilize per permanent seeding specifications. (1 week)

## Example of a Table Construction Sequence Schedule for a Residential Project

| Construction Activity | Measures Needed | Location of Measure | Timing of Installation |
|---|---|---|---|
| **Preconstruction Activity** | | | |
| • Work around existing utility lines | • Contact Indiana Underground Plant Protection Service ("Holey Moley")<br>• 1-800-382-5544 | ----- | • Week 1 |
| • Provide notification of actual construction start date to reviewing agency(s) | • Contact plan reviewing/ inspection agency(s) | ----- | • Week 1 |
| • Protection of important site features, sensitive areas, unique areas, etc. | • Fencing or other physical barrier | • Around perimeter of area(s) to be protected/preserved | • Week 1 |
| • Protection of areas suitable for use as vegetative filter strips | • Fencing or other physical barrier | • Up-slope side of vegetative filter strip | • Week 1 |
| • Protection of areas designated for on-site sewage disposal from compaction and disturbance | • Fencing or other physical barrier | • Around area(s) designated for use as on-site sewage disposal facilities | • Week 1 |
| **Construction Site Access:** | | | |
| • Stabilization of site access drives to prevent or minimize tracking of sediment onto public or private roadways | • Aggregate ingress/egress pads | • At all points where vehicles enter and exit the site | • Week 1 |
| • Stabilization of construction routes, construction vehicle staging and maintenance areas, designated employee parking areas, etc. to prevent or minimize tracking of sediment onto public or private roadways | • Aggregate staging pads<br>• Stabilized construction routes<br>• Dust control | • All staging and parking areas<br>• Project site construction routes | • Weeks 1 and 2 |
| **Perimeter Controls:** | | | |
| • Diversion of storm water runoff from up-slope properties away from the project site | • Perimeter dike | • Up-slope side of areas scheduled for grading and massive earthwork | • Week 2 |
| • Collection and treatment of sediment-laden storm water runoff before it discharges onto properties down slope of the project site | • Permanent diversion<br>• Sediment barriers/filters<br>• Sediment traps/basins | • At locations where storm water may discharge from project site | • Weeks 2 and 3 |
| • Diversion of storm water runoff away from the active construction zone | • Temporary diversion | • Up-slope side of active construction zone | • Weeks 2 and 3 |
| • Collection and treatment of sediment-laden storm water runoff flowing from the active construction zone | • Temporary diversion<br>• Sediment traps/basins | • Down-slope side of construction zone | • Weeks 2 and 3 |
| **Initial Land Clearing and Grading Activities:** | | | |
| • Clearing and grubbing of vegetation | • Sediment barriers/filters<br>• Sediment traps/basins<br>• Diversions | • Down-slope side of active construction zones | • Weeks 2 and 3 |

## Example of Table Construction Sequence Schedule for a Residential Project *(continued)*

| Construction Activity | Measures Needed | Location of Measure | Timing of Installation |
|---|---|---|---|
| • Stripping and stockpiling of topsoil | • Sediment barriers/filters<br>• Sediment traps/basins | • Down slope of active construction zones | • Weeks 2 and 3 |
| • Stabilization of topsoil stockpiles | • Sediment barriers/filters<br>• Temporary seeding<br>• Mulching | • Perimeter of soil stockpiles<br>• Over top of soil stockpiles | • Weeks 2 and 3 |
| **Secondary Land Grading Activities:** | | | |
| Runoff Control (outlet protection, sediment traps & basins, diversions, perimeter dikes, water bars): | ----- | ----- | ----- |
| • Construction of primary sediment traps and basins | • Sediment barriers/filters | • Down slope of active construction zones | • Weeks 3 through 6 |
| • Construction of primary detention/retention basins/ponds | • Sediment barriers/filters<br>• Sediment traps | • Down slope of active construction zones | • Weeks 3 through 6 |
| • Installation and stabilization of outlets for storm water drainage system | • Riprap outlet protection<br>• Turf reinforcement mats | • Basin outlets<br>• Storm drain outlets<br>• Open channel outlets<br>• Culvert pipe outlets | • Weeks 3 through 6 |
| • Construction of diversion channels, berms, water bars, etc. | • Sediment barriers/filters<br>• Sediment traps/basins | • Down slope of active construction zones | • Weeks 3 through 7 |
| Runoff Conveyance System (stabilized streambanks, storm drains, inlet and outlet protection, channels): | ----- | ----- | ----- |
| • Installation of storm sewer system | • Sediment barriers/filters<br>• Sediment traps/basins | • Down slope of active construction zones | • Weeks 7 through 12 |
| • Protection of storm drain inlets | • Drop inlet protection<br>• Curb inlet protection | • Storm drain inlets<br>• Culvert pipe inlets | • Weeks 7 through 12 |
| • Stabilization of areas disturbed for storm sewer installation | • Temporary seeding<br>• Mulching | • Areas where storm sewer lines have been installed | • Weeks 7 through 12 |
| • Construction of drainage swales | • Sediment barriers/filters<br>• Sediment traps/basins | • Down slope of active construction zones | • Weeks 7 through 12 |
| • Stabilization of drainage swales | • Permanent seeding<br>• Mulching | • Areas where construction of drainage swales has been completed | • Weeks 7 through 12 |
| Excavate Subsoil to Grades Shown on Plans: | ----- | ----- | ----- |
| • Rough grading and stockpiling of subsoil in designated areas | • Sediment barriers/filters<br>• Sediment traps/basins | • Down slope of active construction zones | • Weeks 12 through 15 |
| • Stabilization of soil stockpiles | • Sediment barriers/filters<br>• Temporary seeding<br>• Mulching | • Perimeter of soil stockpiles<br>• Over top of soil stockpiles | • Weeks 12 through 15 |
| **Temporary Surface Stabilization:** | | | |
| • Temporary surface stabilization of rough graded areas | • Temporary seeding<br>• Mulching | • All rough graded areas that will be inactive for a period of seven days or more | • Weeks 2 through 19 |

## Example of Table Construction Sequence Schedule for a Residential Project *(continued)*

| Construction Activity | Measures Needed | Location of Measure | Timing of Installation |
|---|---|---|---|
| | | | |
| • Permanent surface stabilization of areas at final grade | • Permanent seeding<br>• Mulching | • Detention/retention basins<br>• Drainage swales | • Weeks 2 through 23 |
| **Install Infrastructure:** | | | |
| • Cut in roads/streets and construct roadway subgrade/base | • Sediment barriers/filters<br>• Sediment traps/basins | • Down slope of active construction zones | • Weeks 15 and 16 |
| • Install curb and gutter | • Sediment barriers/filters<br>• Sediment traps/basins<br>• Curb inlet protection | • Down slope of active construction zones<br>• Storm drain curb inlets | • Weeks 17 and 18 |
| • Pave Streets/Roadways | ----- | ----- | • Week 19 |
| • Install Utilities | • Sediment barriers/filters<br>• Sediment traps/basins<br>• Temporary seeding<br>• Mulching | • Down slope of active construction zones | • Weeks 19 through 22 |
| **Building Construction:** | | | |
| • Protection of existing storm drain inlets | • Drop inlet protection<br>• Curb inlet protection | • Operational storm drain inlets | • Weeks 18 through 23 |
| • Installation and stabilization of site access | • Stone ingress/egress pads | • At all points where vehicles enter and exit the site | • Weeks 18 through 23 |
| • Installation of perimeter protection | • Sediment barriers/filters | • Down-slope side of construction areas | • Weeks 18 through 23 |
| • Protection and maintenance of drainage swales/channels | • Sediment barriers/filters | • Down-slope side of construction areas | • Weeks 18 through 23 |
| • Excavating for foundation footers | • Sediment barriers/filters | • Down-slope side of construction areas | • Weeks 18 through 23 |
| • Construction of buildings/structures | • Sediment barriers/filters | • Down-slope side of construction areas | • Weeks 18 through 23 |
| • Installation of downspout extenders | ----- | • End of downspouts | • Week 18 through 23 |
| **Final Shaping/Landscaping/Stabilization:** | | | |
| • Application of topsoil and soil amendments | • Topsoil salvage and utilization | • Unvegetated areas that are at final grade | • Weeks 21 through 24 |
| • Planting of trees and shrubs | • Topsoil salvage and utilization | ----- | • Weeks 21 through 24 |
| • Final site stabilization | • Permanent Seeding<br>• Mulching<br>• Sod | • All remaining unvegetated areas | • Weeks 21 through 24 |
| **Maintenance of Erosion and Sediment Control Measures:** | | | |
| • Removal of temporary storm water management measures and stabilization of remaining unvegetated areas | • Permanent seeding<br>• Mulching | • Areas disturbed when removing temporary storm water management measures | • Week 24 |