INVER GROVE HEIGHTS
Northwest Area

Chapter 3

Integrating Stormwater Management Into Site Design

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Integrating Stormwater Management Into Site Design

Chapter 3

Key Topics:	definition of stormwater, effects of development on stormwater movement, physical and water quality impacts due to increased stormwater runoff, definition of integrated stormwater management, general stormwater management principles, treatment train approach, definition of 'best management practice', definition of 'better site design'

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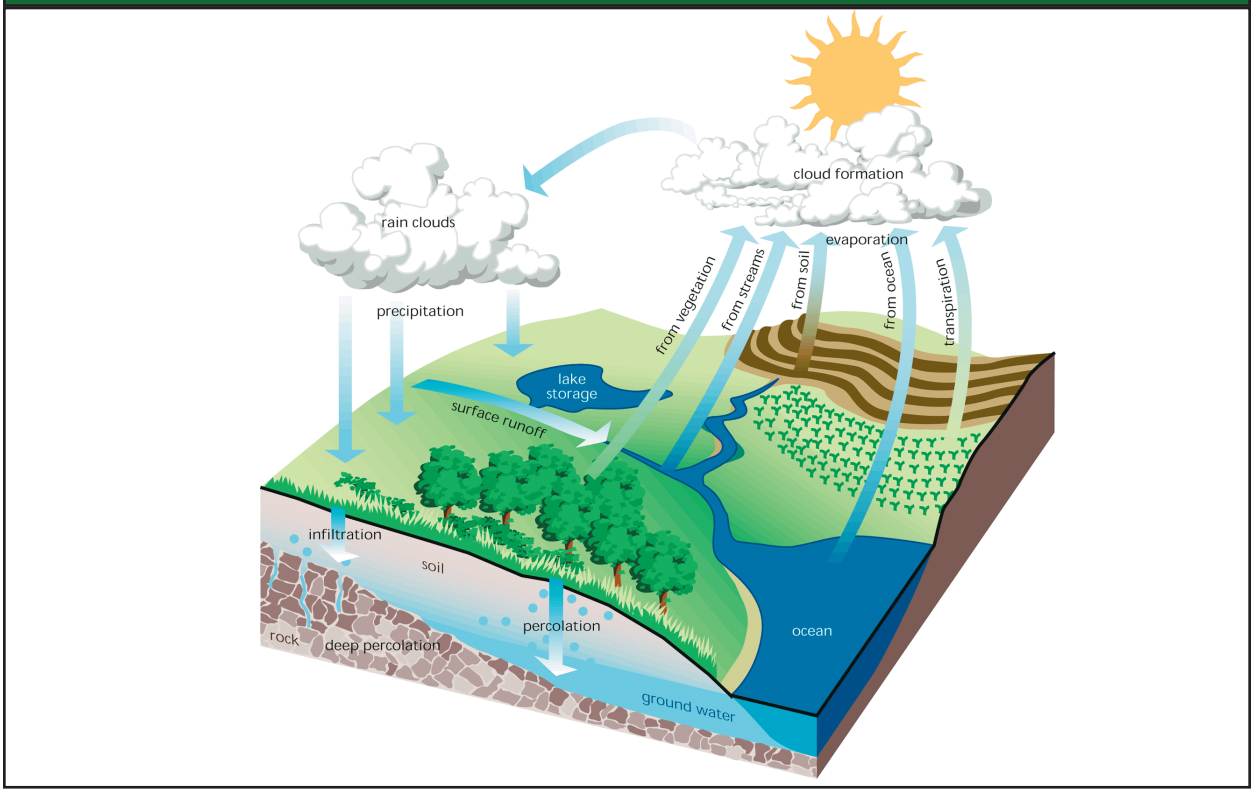
I. What is Stormwater?

Stormwater and stormwater runoff are all-inclusive terms that refer to any of the water running off of the land's surface after a rainfall or snowmelt event. Stormwater is a natural part of the hydrologic cycle, but the effects of development have a profound effect on the way that stormwater moves off of the land.

Hydrologic Cycle

The hydrologic cycle (Figure 3.1) is a representation of the distribution and movement of water between the earth's surface, subsurface, and atmosphere. Water travels from the atmosphere to the land surface in the form of precipitation. Eventually, it travels to surface water bodies through diffuse overland flow, point discharge, or as ground water flow. Water that seeps into the ground eventually replenishes ground water aquifers and surface waters such as lakes, streams, and the oceans. Ground water recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water is returned to the atmosphere through evaporation and transpiration to complete the cycle.

Figure 3.1 Hydrologic Cycle

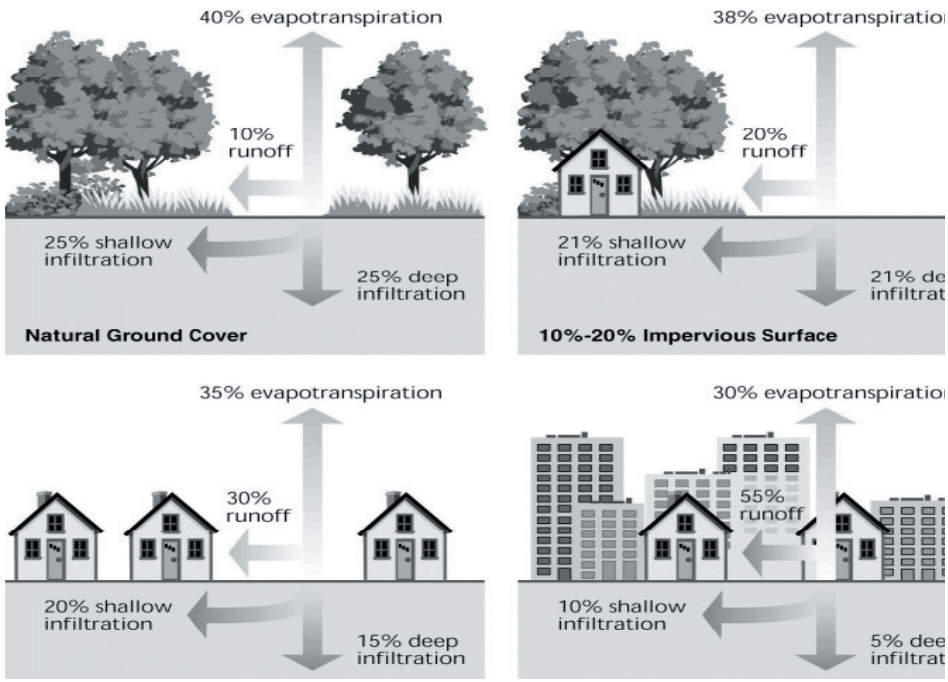


Source: Sustainable Water Resources Alliance

Effects of Development

Prior to development, stormwater runoff is a small component of the annual water balance. An increases in development alters the land cover and the balance of the water cycle changes, resulting in more surface runoff from impervious surfaces and less infiltration into the soil. Figure 3.2 shows how the relative percentages of water soaking into the ground change once development begins.

Figure 3.2 Hydrologic Effect of Imperviousness



Source: Federal Interagency Stream Restoration Work Group, 2000

The changes in the landscape that occur during the transition from rural and open space to urbanized land use have a profound effect on the movement of water off of the land and the hydrology of the local system and landscape. What used to be a small portion of runoff from a rainfall or snowmelt event becomes a major source of rapid runoff volume. This rapid runoff has enough energy to rapidly erode soils and transport particles to receiving water bodies where sedimentation can become a problem. In addition, when infiltration is reduced or eliminated, reduced volumes of ground water are available to ground water dependent resources and deeper ground water aquifer units receive less recharge.

Effects on Downstream Resources

Development within a watershed has a number of direct impacts on downstream resources, including extreme water level fluctuation, degradation of aquatic habitat, and changes to water flow, power, behavior and timing.

Development alters the hydrology of watersheds by disrupting the natural water cycle. Notable responses include:

- *Increased Runoff Volumes* – Land surface changes can dramatically increase the total volume of runoff generated in a developed watershed.
- *Increased Peak Runoff Discharges* – Increased peak discharges for a developed watershed can be two to five times higher than those for an undisturbed watershed.
- *Greater Runoff Velocities* – Impervious surfaces and compacted soils, as well as improvements to the drainage system such as storm drains, pipes and ditches, increase the speed at which rainfall runs off land surfaces within a watershed.
- *Shorter Times of Concentration* – As runoff velocities increase, it takes less time for water to run off the land and reach a wetland or water body.

► *Reduced Ground Water Recharge* – Reduced infiltration of stormwater runoff reduces the amount of rainfall recharging ground water aquifers.

Water Quality Impacts

Quantity is not the only problem resulting from changing runoff patterns. As the changes mentioned previously occur, more water flows off of urban surfaces and is delivered downstream faster. The increased activity on these surfaces means that more polluting material is also available. Stormwater that washes over these new urban surfaces picks up a significant amount of the material laying upon them. The sediment from construction erosion, the oil, grease, and metals from many automobiles, the fertilizer and pesticides from lawns, and many more new pollutants that were not previously present all combine to adversely impact downstream resources. Table 3.1 lists many pollutants of concern and some sources of these pollutants.

Table 3.1. Nonpoint Sources and Associated Pollutants

Pollution Sources	Pollutants of Concern*
Agriculture, parks, lawn and garden maintenance	Phosphorus, nitrogen, fertilizers/pesticides, organic debris, oxygen demand
Air pollution	Organic pollutants (such as PAHs, pesticides, PCBs, phenols), heavy metals, nitrogen and sulfur oxides, hydrocarbons
Animal waste and litter	Bacteria/virus, phosphorus, nitrogen
Construction activity	Sediment, phosphorus, nitrogen, debris, sanitary waste
Illicit connections to storm sewers or improper maintenance of septic systems, sanitary services, roof/sump drains or industrial process water	Bacteria/virus, phosphorus, nitrogen, excess water, heavy metals
Improper disposal of household hazardous wastes	Any household material deemed “hazardous”
Industrial and commercial activities (loading and unloading, raw material and by-product storage, vehicle maintenance and spills)	Any raw material exposed to runoff
Municipal maintenance activities (road repair, salting, dust control, etc.)	Sediment, hydrocarbons, salt
Residential driveway and parking area runoff	Salt, PAHs, hydrocarbons, temperature (increased)
Vehicular traffic including parking lots, roadways and traffic spills	Heavy metals (such as lead, zinc, copper, cadmium, and mercury), hydrocarbons (such as oil and grease, gasoline, cleaning solvents), salt (Na and Cl), sediment

* Representative list only; many additional pollutants can be associated with most of the activities listed

Source: Adapted from *The Stormwater Pollution Prevention Handbook*, Conservation Toronto and Region, 2001

Pollutant Impacts

The impacts of the various pollutants listed in Table 3.1 are felt to varying levels. It is important to recognize that the hydrologic balance of most receiving waters depends on this runoff water. Simply diverting all of

the flow around a water body might help reduce a pollutant load, but it could also cause the water body to dry up.

The water quality impacts from urban runoff vary depending upon the quality and quantity of the stormwater and the natural ability of the receiving water to absorb or accommodate certain pollutants without adverse effects (Conservation Toronto and Region, 2001). Depending on the chemical, biological and physical character of the water body, this assimilative capacity can be quite different and tolerance to pollutants may vary greatly. Some water bodies are inherently more sensitive to types or classes of pollutants than others. Due to its landlocked nature, this is particularly true in the NWA. As part of the Natural Resource Inventory and Management Plan for the Northwest Expansion Area (BRAA, 2004) done in the city, four management classes were set up for wetlands, with the greatest protections being given to the highest quality wetlands. For a map and wetland management standards, see Chapter 2 (insert link to Table 2.3)

Since there is a major focus on infiltration as a best management practice in the NWA, careful thought as to the potential pollutant impacts to ground water must be given when designing and locating the system. Specific pollutants of concern include such things as nitrogen, pesticides, salts, heavy metals, pathogens and other organic compounds. The pollutant impact on ground water depends upon a number of factors including: the concentration of the pollutant in the stormwater, the nature of the soil (i.e.. sandy vs. clayey), separation distance from ground water, and the organic materials present. Risk goes up as the concentration of the pollutant increases, the soils become sandier, separation distances to ground water decrease or organic materials in the soil decrease. With the exception of chlorides and some pathogens which can readily move through the soil column and into ground water, the risk for impacts to ground water in the NWA is low with proper pre-treatment and soil column separation distance from the water table. Risks are typically lowest for residential land uses since concentrations of pollutants tend to be lowest in these areas too. Careful thought should be given when applying infiltration practices in commercial or industrial areas or adjacent to heavily used roads or parking areas. For more specific design considerations, see Chapter 8 (insert link to infiltration guidance).

II. Integrated Stormwater Management

Integrated stormwater management is a comprehensive approach to stormwater management. It is a proactive method that can be used to evaluate the factors that affect precipitation as it moves through the hydrologic cycle, while at the same time accommodating the land development activities that come with population growth. The process begins with reducing the initial generation of excess runoff and then focuses on ways to control runoff rates and volumes, preserve water quality and promote ground water recharge in a logical way using the simplest techniques possible to achieve the desired management outcome. Evaluating the system in this way helps to avoid inadvertent mistakes that could eventually harm a resource.

Ground Water/Surface Water Interaction

Integrated stormwater management often takes advantage of the interaction that takes place between ground water and surface water. For example, the slow infiltration and movement of surface water into the shallow ground water system results in both peak and volume reduction, filtration through cleansing soil, and ground water replenishment. Although stormwater management is often interpreted as a surface water program, many of the BMPs suggested for the NWA rely on the ground water system to make them effective. Infiltration BMPs, for example, rely on the soil's capacity to soak water up and transmit it downward away from the practice. By recognizing this innate ability of the landscape, stormwater designers can maximize opportunities to enhance infiltration on-site to meet treatment goals in an efficient and cost effective way.

However, there must be caution used when utilizing a system that has the potential to affect ground water resources. For example, although soil adsorption is an effective scavenger of some soluble pollutants, one could argue that the introduction of runoff into any system that discharges to the ground is merely trading

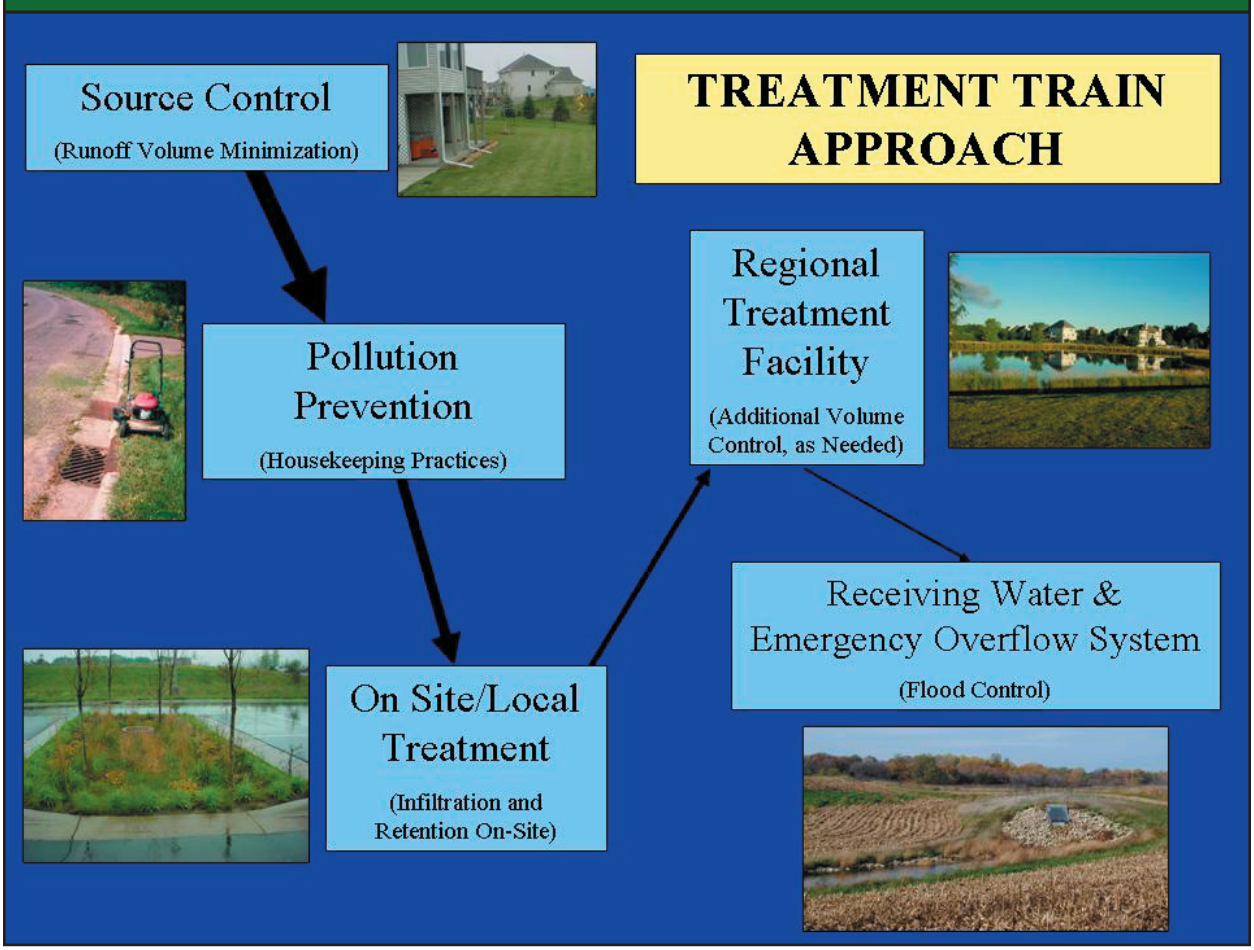
pollution of one water for another. Specific areas of caution in the NWA include areas of high ground water tables, tight soils, source water/wellhead protection areas, and stormwater hotspots (i.e.. discharges from gas stations or industrial areas).

Best Management Practices and the Treatment Train

Best management practices (BMPs) are proven, effective measures for managing stormwater runoff that are readily available to designers and managers in both structural and non-structural ways. While there are no "best" solutions that apply universally in every location and for every situation, there are best solutions that can be chosen for specific applications and to solve specific problems.

BMPs located in series can efficiently achieve several stormwater treatment objectives for both water quantity and water quality while optimizing use of space, on-site natural features, and available budget. This configuration, also called a "treatment train", consists of a series of BMPs each designated to address a different component of stormwater runoff with the goal of maximizing stormwater rate, volume control and pollutant removal (Figure 3.3).

Figure 3.3 Treatment Train Approach to Stormwater Management



Source: Adapted from Minnesota Stormwater Manual, 2005

The recommended approach to stormwater management for the NWA is organized around this treatment train approach with the goal being to start simply and increase complexity only as necessary to address the

unique situation found at each site. Beginning on-site with pollution prevention and simple runoff volume reduction, BMPs are progressively added to the treatment train first at the local level, and then at the regional level until stormwater management goals are met.

The first step in stormwater management is to reduce the amount of runoff generated on site by exposing precipitation to pervious areas and promoting infiltration. This includes design techniques such as reducing the impervious areas on the site, and disconnecting impervious surfaces. Because full runoff reduction is usually not possible, housekeeping activities to keep land surfaces clean, such as street sweeping and control of lawn clippings, is also a component in the treatment train to reduce exposing polluting materials to runoff.

When runoff cannot be controlled at the site, or polluting materials cannot be kept out of runoff, best management practices are designed to reduce the amount and rate of water leaving the site and of pollution that gets carried to downstream resources. Under this strategy, simple methods are used to keep water in place after rainfall or snowmelt events and potential pollutants are kept off of the land surface. Then, if needed, further controls are implemented to manage water that is moving within or away from the site. In addition to space and cost savings, the treatment train approach can increase the level and reliability of pollutant removal, increase the effective lifetime of a practice by removing suspended particulates prior to treatment in the downstream unit, and reduce the potential for re-suspension of deposited sediments by reducing flow energy levels or by providing longer flow paths for runoff.

Effective stormwater practices are integrated into the urban landscape to improve their function and performance. Twelve principles that help define the successful integration of a stormwater practice in the landscape are included in Table 3.2.

Table 3.2 Integrated Stormwater Design Principles

Principle	Goal
Provides reliable pollutant removal performance	The practice should be sized so that it captures sufficient volume of runoff and employs a sequence of pollutant removal mechanisms via a treatment train approach to maximize the removal of key pollutants of concern.
Mimics pre-development hydrology	The practice should operate in a manner so as to replicate pre-development hydrology for a range of storm events such that it safely recharges ground water, protects downstream channels and reduces off-site flood damage.
Integrates the practice into overall site design	The overall design of the site should support the function and performance of the practice, by minimizing or disconnecting impervious cover, implementing source controls, and utilizing better site design practices that reduce the quantity and adverse quality effects of runoff generated by the site.
Has a sustainable maintenance burden	Both routine and long–term maintenance tasks should be carefully considered throughout the design process to reduce life cycle maintenance costs and promote longevity of the practice.
Is accepted by the public	The practice should be viewed as an attractive community amenity by adjacent residents or business owners, as measured by interviews, surveys, testimonials, increased property values and other yardsticks.

Table 3.2 Integrated Stormwater Design Principles	
Principle	**Goal**
Creates attractive landscape features	The practice should be an integrated practice designed to be highly visible within the site and serve as an attractive and inviting landscape feature.
Confers multiple community benefits	An integrated practice should also contribute to other community benefits such as promoting neighborhood revitalization, expanding recreational opportunities, and educating residents about stormwater.
Creatively uses vegetation	An integrated practice not only greens up the site, but also uses vegetation to effectively promote cooling, shading, screening, habitat and enhanced pollutant removal functions. The design should also explicitly consider how vegetation will be managed over time to maintain functions and minimize maintenance costs.
Provides a model for future improvement	An integrated practice is inspected, evaluated, or monitored so that lessons can be learned to improve the performance and integrate future designs.
Realizes additional environmental benefits	The design of an integrated practice maximizes other environmental benefits at the site, such as the creation of aquatic or terrestrial habitat, protection of existing natural areas, reduction of urban heat island effects and other urban amenities.
Reduces infrastructure costs	An integrated practice reduces the amount of paving, curbs, storm drain pipes and other infrastructure that would have otherwise been employed in a traditional stormwater practice design within the community.
Acceptable life cycle costs	An integrated practice will not result in high life cycle costs over its useful life.

Source: Center for Watershed Protection

III. Integrated Stormwater Management Process

Project Scope

The first step in integrated stormwater management is to determine the scope of the project and the likely solutions that will be needed. For on-site treatment, simple practices will most likely solve the problem and a non- or minimum-structural approach can be pursued. If the downstream water body is more sensitive to stormwater impacts (Manage 1 or Manage 2 wetland classification) additional on site or regional treatment may be required.

Watershed Approach

For every project, the question that should always be asked is “Where does water come from that enters my site and where does it go?” This single question becomes the basis for a future management approach. For example, if the water leaving the site discharges to an infiltration basin rather than a lake, a different set of BMPs focusing on sediment control rather than nutrient removal will be pursued.

Use and Restoration of Natural Resources

The occurrence of natural features, such as wetlands, forest, natural drainage features, and open space on a site should be viewed as a positive attribute. Features such as these can be preserved to minimize the impact of development, used as an integral part of the treatment train, or even enhanced to improve site hydrology or the quality of runoff leaving the site.

Many of the basic tenets of “low impact development”, “better site design” and “sustainable development” are rooted in the preservation, restoration and enhancement of the natural drainage system. Following this approach can lead to site development cost savings, as well as added environmental protection and an increase in market value.

Water Quantity and Quality

Integrated stormwater management requires a complete look at both the volume and pollutant concentration of runoff water. Focusing exclusively on one or the other might meet a specific regulatory requirement, but will not result in effective overall stormwater management.

Rate and Volume Control

In its early stages, stormwater management was primarily concerned only with quantity control. Urban hydrology techniques focused mostly on rate control and addressed volume in terms of flood control. The standard approaches for rate control have been greatly refined over the years, with more attention on mimicking pre-development or natural conditions. The following section addresses the techniques that should be considered when a need exists to address stormwater quantity leaving a site.

Rate Reduction Techniques

In the past, rate control was primarily used to prevent downstream flooding. Relying solely on rate reduction for stormwater control led to many system failures as volume and quality factors were left uncontrolled. Although not universally true, advancement in the state of the art practices for rate control generally came about as urbanization increased and greater protection from water leaving these largely impervious places was needed.

Chapters within this manual go beyond flood protection to hydrograph frequency matching and rate control techniques designed to mitigate the effects of the commonly occurring events that account for most of the runoff. The following sections of this chapter and chapters 4, 6, and 7 provide information on the reasons for rate control and tools available to accomplish it.

Volume Reduction Techniques

The term “volume reduction” can be easily confused with “infiltration”. One does not, however, necessarily equate to the other. There are many additional techniques and BMPs that can be applied to yield volume reductions.
Any technique that allows water to soak into the ground, makes water available for evaporation and/or transpiration, stores water for re-use, or in any way diverts stormwater away from the drainage system can be considered a volume reduction practice. Infiltration is certainly one of these practices, but it is only one of many. In circumstances where soils are too tight or where infiltration would endanger ground water, many alternatives are available to reduce volume.

The following categorical methods for volume reduction, while certainly not all-inclusive, can provide some ideas for how a stormwater manager/designer could reduce the volume of runoff leaving a parcel of land.

Infiltration
The most commonly used method to reduce stormwater volume is to allow it to soak into the soil. The result of this action is a direct reduction in volume running off of the land surface. The biggest requirement for use of infiltration is the ability of the soil to accept the water.

Low Impact Development (LID), Better Site Design (BSD) and Sustainable Development are all variations of practices that mimic natural conditions by allowing water to soak into the ground close to where it falls. Use of these methods dramatically reduces overall runoff volume. Reduction of connected impervious area and retention of natural drainage patterns and surfaces are the heart of these methods.

Evapotranspiration
The combined process of evaporating and/or transpiring (vegetative uptake and release of water) is called evapotranspiration (ET). This process typically results whenever water is held in storage (evaporation, or sublimation of snow in the winter) and allowed to be taken up by roots and released through leaves (transpiration). In areas with tight soils, holding water in wetlands, depressions, swales or any similar land feature that exposes water to the air will result in evaporation of that water. In addition, allowing it to come in contact with roots either in standing water (wetland) or by soaking into the root zone, will yield volume reduction through transpiration.

Where soils provide a constraint, under-drains can provide a means through which water can be routed through the root zone for root uptake, but excess can be captured (after filtration) and drained to a collection system. This option results in some net reduction in volume and adds filtration as a supplemental treatment. Wetland treatment techniques take advantage of this method of volume reduction, as do under-drained bioretention (i.e. rain garden) facilities.

Routing water to areas where it can soak into the ground or to areas with vegetation that can take it up through root action are two very good ways to reduce overall stormwater volume.

Storage
Retaining water somewhere along the path from where it falls to where it enters a drainage system is another way to limit volume. Simple contained storage directly connected to buildings or impervious areas are effective volume reducers and provide an opportunity for water re-use. A rain barrel, cistern or even a yard ornamental pond can hold enough water to almost eliminate the entire volume coming from a home. A green roof can reduce annual runoff by up to 75% because it soaks and stores water that falls on it, then transpires it away. Even a pond or a wetland can reduce overall volume because they provide a quiescent area where water can collect and evaporate.

Conveyance
Getting rid of water was the common way to deal with stormwater before the results of that action were fully realized. Rushing water to a drain pipe, then into a receiving water is now considered a last resort when better options are not available. Using pervious approaches such as vegetated drainage swales and native grass filter strips, in combination with check dams give water a chance to soak into the ground or be filtered before it reaches a location where damage could be done. As with the practices above, volume reduction is an outcome of exposing stormwater to a pervious surface even while it is moving.

Landscaping
Many of the previous practices could also be included in a general category that stresses the importance of stable landscapes with native vegetation. In many respects, this is LID/BSD with an added emphasis on structuring the land surface to handle moving water from impervious surfaces. Routing water to low-lying (sump) areas where it can soak in, placing planter boxes or grated inlets for watering trees, and contouring slopes to reduce runoff velocity are all variations on the landscaping theme.

Tying low impact drainage features together via corridors or designed natural treatment trains can further enhance overall site volume reduction by creating a string of reduction possibilities. Safety can always be assured by placing an overflow or even an under-drain to capture any excess flow and route it to the next BMP catchment area.

Table 3.3 Volume Reduction Techniques

Process	BMP*	Comments	Location in Manual
Infiltration	LID/BSD/Sustainable Development	Includes such things as reduced street and sidewalk width, less curb and gutter drainage, scattered bioretention, shared pavement	Chapter 4
	Trench or basin	Must be properly engineered in adequate soils; proper maintenance essential	Chapter 9, Infiltration BMPs
	Perforated sub-surface pipes, tanks and storage systems	Expensive but effective and space-saving	Chapter 9, Infiltration Supplemental BMP sections
	Disconnected imperviousness	Includes primarily rooftop drains and roadway/ parking surfaces	Chapter 9, Runoff Volume Minimization
	Pervious surfaces	Includes a number of paving and block methods, or simple parking on reinforced grassed surfaces	Chapter 9, Runoff Volume Minimization
	Bioretention (if contains infiltration element)	Some bioretention facilities are designed to infiltrate	Chapter 9, Bioretention BMPs
Evapotranspiration	Bioretention (rain gardens)	Exposes runoff water to plant roots for uptake; can be under-drained and still effective	Chapter 9, Bioretention BMPs
	Vegetated swales	Exposes water surface during transport for evaporation and exposes runoff water to plant roots for uptake and evapotranspiration	Chapter 9, Filtration BMPs

Table 3.3 Volume Reduction Techniques			
Process	**BMP***	**Comments**	**Location in Manual**
Evapotranspiration	Wetland/pond storage	Combination of standing water surface and vegetative root exposure yields dramatic volume reductions through evapotranspiration	Chapter 9, Ponds and Wetland BMP sections
	Vegetated drainage corridor	Connecting numerous features increases opportunities	Chapter 4
	Recessed road/parking drainage	Routing paved surface runoff to vegetated sump areas keeps it out of receiving waters	Chapter 9, Bioretention BMPs
Storage	Rain barrel/cistern	Small-scale runoff collectors keep water around for later re-use or slow release	Chapter 9, Runoff Volume Minimization
	Rooftop (green roof)	Storage on a roof prevents water from leaving the site; combining with vegetation (engineered green roof) makes it even better	Chapter 9, Runoff Volume Minimization
	Wetland/pond storage	Combination of standing water surface and vegetative root exposure yields dramatic volume reductions	Chapter 9, Pond and Wetland BMP sections
Conveyance	Vegetated swale	Provides water a chance to soak into the ground and be filtered as it flows	Chapter 9, Bioretention BMPs
	Filter strips/buffers	Variation on vegetated swale with side slope protection	Chapter 9, Temporary Construction Erosion Control and Bioretention BMP sections

Table 3.3 Volume Reduction Techniques			
Process	**BMP***	**Comments**	**Location in Manual**
Landscaping	LID/BSD	Includes such things as scattered bioretention, shared pavement; native or prairie plantings	Chapter 4
	Bioretention (rain gardens)	Exposes runoff water to plant roots for uptake; can be under-drained and still effective	Chapter 9, Bioretention BMPs

Source: Adapted from Minnesota Stormwater Manual, 2005

Cautions for Volume Control Techniques

As with all stormwater management techniques, some caution is advised when applying them under certain circumstances. Following are some advisory cautions that would apply:

- Techniques using any infiltration should abide by the cautionary statements made in the Chapter 9 guidance sheet for infiltration practices and avoid such things as introduction of runoff from potential stormwater hotspots and use of infiltration practices that could influence drinking water wells.
- A hydrologic analysis should be undertaken to determine the impact of excessive water (flooding) on the installation; that is, where excess water would go and any problems that would result. Similarly, an assessment should be done on whether additional ground water volume is likely to cause any local problems, for example with flooded basements.
- Evapotranspiration values go down dramatically in the cold weather. Consideration is needed on how this may impact operation assumptions for installation.
- Chapter 6 contains mosquito breeding cautions and recommendations for minimization of mosquito breeding habitat for any system in Minnesota that results in standing water.

Pollution Prevention

The old adage "*An ounce of prevention is worth a pound of cure*" is never more appropriate than when used to describe integrated stormwater management. All of the elements above have described the physical processes involved, but preventing pollution from coming into contact with runoff is a common sense element. The simple separation of runoff and those materials that cause pollution, such as oil, fertilizer, salt and sediment, will go a long way toward controlling urban pollution problems at a very low cost.

Pollution prevention methods are far too numerous to cover in their entirety, but include such common-sense practices as keeping yard and animal waste off of impervious surfaces, preventing soil erosion at all construction sites, disposing of household products properly, repairing leaky automotive parts, and careful storage and use of any polluting chemicals. Following these simple precautions can make a dramatic difference in the type and amount of polluting material available for wash-off or aerial mobilization. An overview of pollution prevention techniques is presented in the Chapter 7 guidance.

IV. Link to Better Site Design

More detail on integrated stormwater management is part of the discussion in Chapter 4 on better site design (Insert link to Chapter 4). Better site design is used as an all-inclusive term that includes low impact development, sustainable development, design with nature or any other approach consistent with the treatment train design philosophy.

V. References

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