INTRODUCTION

Accelerated stormwater runoff from lands undergoing urban development, and from already developed areas causes significant problems for downstream landowners as well as local governments. Problems have become widespread as suburbs have sprawled across the landscape: eroded sites must be regraded and sometimes resoiled before the site is usable and stable; sediment must be removed at great cost from culverts and storm sewers to restore their capacity; sediment fills drainage ditches and channels, causing frequent flooding; water quality is degraded; accelerated stream velocities cause bank erosion and loss of valuable property; seldom flooded areas become frequently inundated.

This guidebook has been prepared to illustrate a wide range of solutions to the problems of stormwater control and management. They are presented as concepts and feasible approaches to the problem and not as hard and fast rules. The main objective is to illustrate that sound planning and good design create stormwater management facilities that are beautiful, safe, efficient and provide multiple uses and benefits to the community, as well as substantial savings in development costs. Developers, contractors, designers and local officials will all find useful information here directed toward imaginative and effective stormwater management.

This guidebook is intended to apply primarily to urban and urbanizing areas. Included would be land used or being developed for commercial, industrial or residential purposes; for streets, railroads, airports and other transportation facilities; or for public or private recreation. Specifically not included is rural farm land.

The Division of Soil and Water Districts in Ohio’s Department of Natural Resources (ODNR) and Ohio’s 88 county soil and water conservation districts (SWCDs) are prepared to offer considerable assistance to private citizens and local agencies in dealing with urban sediment/stormwater problems and implementing standards adopted by the state. For further information, the reader should contact a county SWCD office.
CHAPTER ONE

BACKGROUND

The Problem
In an undeveloped area, the stormwater management system is part of the natural environment. The cycle begins with heavy rainfall — the storm. Some of the water that falls evaporates; some is absorbed into the ground near the surface, to be taken up by living plants, ultimately to be returned to the atmosphere by transpiration. Some percolates deep into the ground and replenishes the groundwater supply. The remainder collects into rivulets, travels down the watershed through drainages and streams to rivers and then the sea, to begin the cycle again.

hydrologic cycle
This, of course, is a simplified explanation of a complex system — a system that in undeveloped areas maintains a dynamic balance. Natural drainage systems are not static in design but are constantly changing: streams change course, natural erosion takes place, vegetation and soil permeability change with the seasons.

Man-made development and urbanization have fostered new drainage systems. The impervious nature of streets, sidewalks, parking lots and building roofs coupled with removal of the natural vegetative cover and soil compaction have created significant increases in the amount and rate of stormwater runoff. Historically, the primary concern about this runoff was to remove it from the developed area as quickly as possible after a storm. Unfortunately, this has usually been translated into a drainage system that maximizes local convenience and protection, without considering other significant factors such as off-site damage from accelerated flow.
Damage

The problems created by accelerated stormwater runoff are many: accelerated channel erosion (that is, erosion which is more rapid than natural erosion and which results from man's activities) and flooding, deposition of sediment, flood plain erosion as well as the resulting loss of property or its use, and loss of natural vegetation due to accelerated flooding and erosion.

In an undeveloped area, a natural stream normally adjusts its cross section and slope so that they are in approximate equilibrium. Accelerated amounts and rates of stormwater runoff produce drastic changes in the natural stream channel. Eroded banks and frequent flooding are not only unsightly but cause real damage to adjacent property. Structures are undermined, recreation areas are threatened and the unique beauty of natural streams is destroyed.

A further consequence of accelerated channel erosion is the damage caused by eventual deposition of the eroded sediment. Lakes and reservoirs fill, storm sewers and culverts become clogged, and areas adjacent to the stream (such as recreational facilities) are frequently covered with mud and debris from flood water deposition.

Increased stream volumes and velocities associated with accelerated runoff from developed areas produce more frequent flooding. Areas that previously flooded only once every four or five years now may flood three or four times every year. As a result, flood plain erosion and related damage to structures and vegetation are increased, rendering some downstream land useless.
Responsibility

Although the problems resulting from accelerated stormwater runoff are often borne by downstream property owners and governments, the responsibility must lie with development that fails to plan for the stormwater impact of land disturbing activities. Landowners, developers, contractors, and local officials must realize the consequences of development on the natural drainage system, and provide appropriate control measures. The cost of correcting stormwater problems may no longer be shouldered by downstream residents who had no part in causing them. Recent court decisions in Ohio have (in specific cases) fixed responsibility and cost for correcting downstream problems on the project developer as well as the local government which permitted the development without appropriate control measures.

The damage caused by stormwater problems is both physical and visual, and the cost of correcting it is always high. The practical approach should be to prevent these problems from the beginning. With proper control measures designed as an integral part of project planning, the problems, the damages and the related costs of accelerated stormwater runoff can be alleviated.
CHAPTER TWO

RUNOFF MANAGEMENT

Philosophy

The basic philosophy of stormwater management in conjunction with urban development is currently undergoing change in many areas in Ohio and throughout the nation. Extensive damage has often resulted from past practices, indicating that stormwater has rarely been well managed, and, in fact, has often been mismanaged. Past philosophy sought maximum convenience at an individual site by the most rapid possible elimination of excess surface water after a rainfall. The cumulative effects of such an approach have been a major cause of accelerated downstream channel erosion and increased frequency and level of flooding downstream from urban development.

The entire concept of stormwater runoff management is undergoing a significant redirection. Briefly stated, the new philosophy emphasizes control of stormwater where it falls, on-site, through the use of detention, storage and other measures. Application of control measures on the individual development level can have beneficial downstream effects reducing both peak runoff and total short-term runoff. If fully applied throughout a drainage basin, runoff management would substantially reduce major investments for facilities required to
protect against increased flood hazards and accelerated channel erosion.

Of particular concern is the problem of increased channel erosion which results from changes in stormwater runoff from land being developed. Such changes include increases in peak rates, volume, duration or frequency of runoff, and decreases in sediment concentration of the runoff waters and in the time of concentration (the time required for stormwater falling on the most remote area of the site to reach the drainage system). While damages from gradual development go almost unnoticed for many years, a stream channel may erode very rapidly if a large portion of a watershed is suddenly covered with impervious surfaces.

Accelerated channel erosion as well as increased flooding could be controlled if the natural predevelopment drainage patterns could be maintained. However, it is usually not practical to retain the predevelopment rate of infiltration when a large part of the watershed is covered with impervious surfaces. The concept of reducing peak flows below those of predevelopment storms has been developed as an alternative to maintaining the predevelopment hydrograph. The logic behind this concept is to compensate for increased erosion due to:

(1) increased volume of runoff due to less infiltration.
(2) more frequent occurrences of the same flow. For example, a subdivision may now have the peak flow of a predevelopment, five-year storm occur once a year.
(3) less sediment in the runoff water because the watershed is paved with hard surfaces or good grass cover.
Criteria
The control criteria recommended by the Division of Soil and Water Districts, ODNR (see Appendix) are intended to hold the peak runoff from a developed area to pre-development rates, and compensate for any increase in volume of runoff water by reducing peak runoff rates to less than those prior to development for a selected design storm.

When agricultural cropland is converted to residential use with large lots, very little may need to be done to control accelerated runoff. With intense use, such as commercial development on well drained soils where most of the areas will be covered with impervious surfaces, the 50 or perhaps even the 100-year storm would need to be controlled to the pre-development, one-year frequency peak runoff rate.

Compliance with this criteria in all future development in a community should make long range planning for stormwater management easier. Storm sewers and stream channels could be designed to accommodate existing runoff knowing that upstream runoff rates will not be increased later as those areas are developed.

Design
Proper control of stormwater runoff does not occur by itself. Many factors influence the nature and quality of control, and they must all be brought together through imaginative design to achieve an effective program. Besides the technical aspects of hydrology and engineering, elements such as multiple use, maintenance, cost, safety and aesthetics must be integrated into the overall planning process for each individual development project. The purpose of the following section is to graphically illustrate these elements as the concept of stormwater management is explored.
CHAPTER THREE

CONTROL MEASURES

The control measures outlined here are intended to serve as basic models and perhaps to stir the imagination of both the earth changers — landowners, developers, contractors, engineers, architects, landscape architects — and the government officials involved in developing and implementing control programs. They are intended for use in planning an acceptable level of technically feasible and economically reasonable stormwater management.

Although the basic principles of stormwater control remain the same, each project presents slightly different problems. The many variations in climate, soils, topography, physical features and planned land use require site specific design. Some developments will be able to use several control methods in developing a total management system, while others may only be able to implement one or two. Whatever the case, it is imperative that the fundamentals of stormwater control be applied from the planning stages through construction and ultimate use of the project.

Many of the control measures presented here can also be effectively implemented in existing urbanized areas to correct existing problems and, in some cases, provide new visual and recreational amenities.

Although these measures are discussed individually, the reader should be aware that very often they work together as part of a total system, and that the primary effect or result of one measure may also be a secondary effect of another.
Friction Control

One of the problems with stormwater runoff from developed areas, besides the increase in quantity due to impervious surfaces, is the increased velocity of runoff as it enters the drainage system. Historically, the approach to managing stormwater was to remove it from the site where it fell as quickly as possible, usually through underground systems that directly collected both surface water and roof water. As a result, the increased runoff reached the natural drainage system (streams and waterways) sooner and with much greater velocity than before development. The resulting downstream damage from this increased volume and velocity has already been described.

Various techniques of friction control provide pathways for stormwater flows which reduce the velocity of runoff — a necessary factor in the alleviation of channel erosion and resulting sedimentation. This reduction in velocity also provides an opportunity for natural infiltration of stormwater into the groundwater supply system. Additionally, friction control techniques can extend the time of concentration of stormwater runoff, thereby contributing to the ultimate goal of maintaining the rate of runoff at the levels existing prior to development.
Accelerated flooding and channel erosion in the downstream sections of a drainage basin are directly related to the rate at which stormwater runoff reaches the receiving streams from developments in the basin. The applications of vegetative cover, rock channels and diversions in contributing to a reduction in runoff rate and volume are discussed below.

**Vegetative Cover**

Vegetative cover plays an important role in stormwater control in several ways. Vegetation:

1) absorbs the energy of falling rain,
2) maintains the soil's capacity to absorb water,
3) slows the velocity of runoff.

Friction control techniques which utilize the properties of vegetative cover include (but are not limited to) overland sheet flow, grassed swales and channels, and grassed discharge or flow areas for roof drainage. These measures are particularly suited to residential, transportation and recreational developments, but can be used in the design of commercial and industrial sites as well.
Overland sheet flow can be a significant factor affecting the peak rate of runoff reaching the first collecting channel. Overland flow distances should be as long as possible and should be over and through turf or other flow retardants such as ground cover or forest litter. This is one very good reason why natural woods should be preserved whenever possible. Slopes should be as flat as practical, with a minimum of 1-2 percent in areas of poorly drained soils to prevent swampy conditions. However, maintaining natural topography and vegetative cover should take precedence over regrading to achieve flat slopes, especially where good existing topsoil acts as a sponge in soaking up stormwater.

The type of vegetative cover is, of course, related to its effectiveness in controlling flow, as well as the overall land use with which it is associated. While many situations require the crisp appearance of mowed grass, areas within some developments may be suited to a naturalized appearance. In the proper setting, the trees, tall grasses and wildflowers of a naturalized landscape not only increase the retarding effect on runoff flow, but also decrease the need for maintenance.

Grassed swales and channels (other vegetative covers could be used) should be wide and shallow with a dense vegetated cover and on as flat a grade as topography and soils will permit (care should be taken to provide enough slope to avoid any standing water). The channel sides should be gently rounded at the top to produce an attractive green space when not in use and minimize any hazards to pedestrians.

Channels and swales should harmonize with the natural features of the site. Generally, street and development patterns and grades should recognize the natural drainage patterns of the area. Wherever possible, trees and existing vegetation should be maintained.

Maintenance requirements for swales and channels will not be significantly greater than those for a normal lawn. Keeping the system free of debris and non-biodegradable substances is, however, an important consideration.
Two unique applications of vegetative cover friction control involve roadway drainage swales and discharge areas for roof drains. Using grassed swales in place of curb and gutter, where feasible, has several advantages:

- less expensive
- slows runoff
- reduces size of underground storm sewer lines needed
- allows for infiltration of runoff in channels
- blends with natural topography.

However, this technique should only be used where the land use and site characteristics permit. Considerations such as on-street parking requirements and small lots requiring numerous driveway culverts may be a limiting factor. On the other hand, parkways, boulevards, collector streets and streets in large-lot subdivisions may all benefit from the technique of grassed swales.

Water from roof surfaces is another source of accelerated runoff that could be controlled. Instead of dumping roof water into underground drains, the homeowner or developer could direct it away from the structure over the lawn, infiltration swales or a combined rock/lawn area. This would reduce the velocity of flow, encouraging infiltration and increasing the time of concentration.

In areas with well drained soils, another method to control roof water would be to carry it underground to a surface infiltration bed at a lower elevation than the structure.
Rock Channels

Rock-lined swales and channels have many of the same properties and characteristic effects on stormwater flow as grassed swales. The friction produced by the rough surface of the rocks reduces the velocity of runoff water. Careful alignment and channel design can produce an attractive and unique landscape element that provides aesthetic value in addition to stormwater management.

Both rock channels and vegetated waterways can be used to collect stormwater runoff and carry it to retention/detention facilities, underground systems or receiving streams. In this capacity they may be used in place of, or in conjunction with an underground pipe system.

Diversions

Another method for reducing the rate of stormwater flow is to lengthen the course that the water travels. One technique for doing this is to construct earth mounds, or diversions diagonally across the watershed slope. These mounds can be designed as landscaped features of unique visual quality and, at the same time, provide stormwater runoff control.
Grading Control

The concept of grading to control runoff is also based on reducing its velocity, thereby encouraging infiltration, reducing the potential for channel erosion and extending the time of concentration of stormwater runoff. Two methods of grading control are illustrated here: terraces and drop structures.

Terraces

The technique of terracing can be an extremely attractive control method in almost any area where a broad, sloping lawn is involved. Very simply, a terraced area is two or more sections of ground with very flat slope separated by narrow bands of moderately steep slope.

In a lawn area, a combination of grass and minimum slope of the flat sections substantially slows stormwater runoff and even reduces the quantity by allowing water to percolate into the soil. When the reduced flow arrives at the steeper sections, a coarser vegetative cover or stone wall is used to reach the next flat area. The combination of grass and ground cover (or low shrub masses) with careful grading can be an attractive design feature that requires nothing more than normal lawn care.
Drop Structures

Drop structures offer another method for reducing stream channel erosion. By placing them across the channel at intervals, the slope of the channel between drops can be reduced thereby controlling stream velocity and alleviating erosion potential.

This technique can be used in grassed or rock channels, roadside swales or even in the reshaping of natural streams. These drops can be constructed of natural materials such as timbers or rock enclosed in galvanized wire baskets (gabions) so that they blend with the landscape rather than detract from it.

Although somewhat high in initial cost, the gabion drop structure, if carefully placed and properly installed, can provide a permanent control measure requiring minimal maintenance. Its ability to flex, settle into place and allow water to drain through the rock often makes the gabion structure better than concrete.
Induced Infiltration

In an undeveloped area, infiltration is a natural part of the hydrologic cycle in which a certain portion of precipitation is absorbed into the ground. This water feeds trees and plants and replenishes the groundwater supply. The amount of infiltration depends, of course, on the characteristics of the soil. Course-grained soils, especially gravels or gravelly sand with no fines, have excellent infiltration capacity. As soils begin to have higher concentrations of clays and silts (fine-grained soils), their infiltration capacity diminishes until some (clays with high plasticity) are practically impervious.

The impervious pavement, building roofs and underground drainage systems of urban development drastically reduce the amount of natural infiltration. Additionally, heavy clay sub-soils from excavations, when spread over existing topsoil and then covered with a thin layer of sod, shed water almost like an impervious pavement. Control measures which address these problems and reinstate natural infiltration can contribute significantly to the overall objective of maintaining runoff rates at the levels prior to development.

In areas with well-drained soils, induced infiltration can be a valuable program element and control measures which provide
it should be encouraged. As already mentioned, secondary benefits of measures discussed under friction and grading control include the opportunity for increased infiltration. Other measures, as discussed here, are designed specifically for their infiltration properties.

The examples of control measures presented here illustrate the important point that stormwater management can and should be attractive. With imaginative design and proper installation, control measures can effectively meet the challenges of aesthetics, safety, and maintenance as well as effectiveness. But, as with any portion of a development project, good solutions do not happen by themselves. They must be planned as an integral part of the development process.

Vegetation

Besides the drainage characteristics of the sub-soil, the amount and nature of topsoil and vegetation are important factors affecting infiltration. Because of the penetrating action of roots, a thick layer of topsoil with dense sod provides an excellent medium for natural infiltration. Any area under development that is to be revegetated should receive an adequate layer of topsoil. Existing topsoil should be removed and stockpiled for reuse in providing a minimum of four inches over areas that have porous sub-soil. In areas where heavy clay, or other impervious sub-soils exist, six to eight inches of topsoil is desirable in providing proper plant growth and creating absorbent soil conditions.
Different vegetative covers have different effects on infiltration depending on the size and depth of root structure. This contribution to stormwater control through natural drainage makes areas of existing vegetation, whether open grassland or wooded areas, even more important to maintain wherever possible in the design of new developments. In addition, vegetated (or stone / rock covered) infiltration areas can be created as part of the overall landscape design in a project with suitable soils. Skillful design and grading can provide basins in lawn or shrubbery areas (with water tolerant shrubs) that temporarily detain stormwater, increasing the time for infiltration into the soil. The effectiveness of this technique can be improved by providing gravel fill to increase the infiltration capacity. As illustrated here (in a residential example), this same measure can be used in a linear form to assist infiltration in a natural low area and, at the same time, create a unique landscape element.

It should be emphasized, again, that these measures are most effective in soils which have adequate percolation rates.

In any situation where infiltration areas are created, provisions for emergency overflow must be made. An unobstructed pathway must be available to safely channel severe storm flows to the natural drainage system or permanent storage area with no danger to surrounding structures or facilities.
Porous Pavements

One of the new approaches to the problem of increased runoff from impervious pavements is the use of porous pavements in parking lots and low traffic volume roadways. Varieties of porous pre-cast concrete paving block with perforations have long been used in Europe, and are now found in this country. Another approach is the use of porous asphalt paving. (These solutions also require suitably permeable soils).

Perforated concrete block pavers are installed over a sand and gravel base and permit grass to grow in the perforations. Some of its obvious applications include intermittent or overflow parking areas, emergency stopping and parking lanes and service roads in parks or recreational areas.

Porous asphalt paving is achieved by eliminating the fine materials in the mix. If installed on a properly designed stone base, this pavement has the strength of ordinary non-porous asphalt and yet allows for stormwater infiltration and detention.

Although still being tested and studied, these two porous pavements show promise as effective tools for stormwater management.
Parking Areas

One of the major contributors to stormwater problems created by urban development is the impervious pavement of parking areas. By designing and implementing control measures which permit infiltration (where soils are suitable), stormwater is allowed to filter into the ground rather than flow into a sewer. This allows for recharge of groundwater supplies, reduction of peak flow quantities and an increase in the time of concentration.

The basic principle of parking infiltration control is to direct stormwater from the pavement surface, either by grading or underground pipe, into stone-filled infiltration areas. Here the water is stored temporarily as it filters into the ground. These infiltration areas can occur as linear areas between bays of parking, at the edge of a parking area or as a landscaped feature within the lot. In any location, these areas can be planned as an attractive and integral part of the overall parking design. Besides their stormwater functions, they can provide islands of landscape relief to break the monotony of parking pavements.

Although this approach to parking area drainage has many benefits (stormwater control, landscaped spaces, reduced storm sewer costs), there is a possible disadvantage. Oil and grease residues from parked cars may, in time, reduce the filtering capacity of the stone and require corrective maintenance. Also, to avoid possible contamination, such infiltration areas should not be located near wells supplying drinking water.
Detention/Retention Control

One of the primary considerations in stormwater runoff management is storage. Provision for storage can reduce peak runoff rates; aid in the replenishment of the groundwater supply; alleviate accelerated downstream channel erosion and flooding; reduce the size of storm sewers to be installed; and provide many desirable on-site benefits.

Storage occurs naturally on a small scale in most drainage areas. Natural storage is provided during overland flow in surface depressions and on wetted vegetation. Greater storage is possible where larger depressions and swales exist and where there are highly pervious recharge areas. Much natural storage is temporary, of small volume and can be lost through development. This volume can be restored and increased by using swales, by revegetation and by utilizing restricted inlets to create small areas of controlled ponding.

Large scale storage can be accomplished through the use of temporary detention methods which store water for a short time and release it at a controlled rate, or retention facilities that permanently store runoff water, or some combination of the two. Detention techniques include (but are not limited to) parking lot ponding, in-
ground storage facilities and dry vegetated basins; while ponds, lakes, reservoirs and even stream channels are examples of retention storage.

All too often in the past, inadequate or improper design and construction of storage areas have produced unsightly, unsafe facilities that do not perform well and quickly become maintenance problems. Public acceptance of such projects is understandably poor, and the entire concept of stormwater runoff management suffers as a result.

The careful design of stormwater management measures should be an integral part of the overall development planning process, and should consider opportunities within the open space and landscape plan for the creation of such facilities. Creative design can produce stormwater control techniques that not only function in a technically correct fashion, but also: provide an aesthetic amenity; reduce maintenance operations; control access and views; and provide the potential for recreation, wildlife habitat, irrigation and fire protection.
Retention

Retention facilities refer to storage areas that maintain a planned permanent level of water even after storm runoff has ceased. These permanent ponds and lakes, if properly constructed, provide multiple benefits including short-term and long-term enhancement of property values and the landscape; possibilities for boating, ice skating, fishing and swimming; water for irrigation and fire protection; and habitats for resident and migratory wildlife.

Technical design criteria for stormwater runoff storage in lakes and ponds are numerous and are thoroughly discussed in publications listed in the Appendix. General concerns critical to safe, efficient operation of storage facilities include: evaluation of runoff hydrographs for storms of various size and frequency; determination of level of control; rate of stormwater release to meet criteria established; provision for draining; provisions for maintaining minimum permanent water level; and provision for emergency overflow protecting adjacent and downstream properties.

In some retention ponds or lakes, evaporation losses, seepage into groundwater, and consumptive uses (irrigation, fire protection, cooling, flushing) between storms all remove water, providing storage capacity for retaining runoff water from the next rainfall. More frequently perhaps, these permanent storage areas are designed in combination with detention methods so that additional capacity is always available above the level of the permanent pond to temporarily store runoff and release it at a controlled rate.

Once the technical requirements such as capacity and rate of outflow have been established, they must be translated into physical reality through competent design and construction. The same set of technical requirements can be met through a pure engineering solution or through creative design with full appreciation of aesthetic, maintenance, safety and multiple use considerations.
The solution shown at right illustrates several important elements in the design of retention facilities. The pool of permanent water in this pond is bordered by a stone edge capped by a concrete coping, to give it a refined appearance that blends with its landscaped surroundings. The first level of runoff control capacity is provided within the borders of stone and concrete coping. For the storage capacity required by more intense storms, the lawn area surrounding the permanent pond is skillfully graded to contain additional runoff. The final level of control is provided by an emergency overflow swale designed to channel water from a very large, infrequent storm, more severe than the design storm, safely away from improvements susceptible to damage.

The entire appearance of this example is aesthetically pleasing, and has been skillfully integrated into the overall landscape design of this urban setting. Because of the rock and concrete edgings, bank erosion and maintenance are not problems, and the overflow area of the facility is simply maintained as lawn. An additional maintenance consideration provided in this design is the fact that the permanent pool is small enough to replenish its water with even a small rainfall, thereby preventing stagnant water conditions.
Retention facilities can be designed to fit almost any development: commercial, industrial, recreational, or residential. Depending on the nature of the land use, the retention ponds and lakes can be refined and sophisticated, or natural and somewhat wild.

Careful attention to detail is important regardless of the design characteristic. The visual aspect of inlet and outlet structures should be considered. The edge of the permanent pond should be stabilized (formal or naturalized). Depths and slopes of pond edges should be carefully designed depending on surrounding uses (close-in residential areas may have children), desirability of vegetation (cattails can be appropriate in certain landscapes), and capacity requirements.

Many stormwater runoff storage facilities have been constructed in connection with new (and some existing) urban land developments. As illustrated by the examples presented here, the problems of safety and maintenance as well as the considerations of aesthetic quality and multiple use can be effectively controlled through sound planning and careful design. In addition to the site amenities and stormwater control provided, many developments have found that the incorporation of on-site storage facilities has resulted in appreciable cost savings through the reduction in diameter and length of storm sewers required.
Detention

As was defined earlier, detention control measures store water for a short period and release it at a controlled rate. They may remain dry when not in use or may be used in combination with permanent retention pools. They can easily be designed into parking lots, and swales, lawns or general open space and are suitable for all types of development — residential, recreational, commercial or industrial. Since they are frequently designed to remain dry when not in use, detention areas can function as parking lots, recreation areas or blend inconspicuously into the overall landscape design when not performing stormwater duties. Many are even buried in the ground and thus completely out of site.

Parking Lot Storage

The large areas covered by many parking lots serving shopping centers, office buildings, apartment complexes and industrial facilities make these areas extremely attractive for stormwater detention. Two general approaches are possible and are often used together. One involves the storage of runoff in depressions constructed at drain locations, or in the case of curbed islands between bays of parking, ponding against the curb leading to a drain. The stored water is drained away slowly either through undersized pipe or through a restriction in the pipe. Proper design of such a system restricts ponding to areas that will cause a minimum of inconvenience to users of the parking facility. In most cases the ponded water should not exceed a depth of 8-10 inches, or the height of the retaining curb.
The other type of parking lot detention involves collecting the stormwater runoff, either through drain pipes or surface grading, in grassed or gravel filled areas. By using restricted outflow drains, these areas act as small detention ponds, releasing stored water slowly into the sewer system, while also permitting some infiltration. As illustrated on the preceding page, these areas can be incorporated as attractive elements in the overall design and landscaping of the parking facility. Both types of parking lot detention are easily and inexpensively maintained with standard equipment.

**Underground Storage**
A different approach to utilizing parking areas, as well as lawns, sidewalks and certain other site elements is to excavate space under them for concrete vaults or pipes which temporarily store stormwater while safely accommodating parking or other uses on the surface. Such underground storage is particularly appropriate when space for surface storage on site is limited.

**Dry Basins**
Nearly every land use in a developing area can integrate on-site stormwater detention into its overall design effectively and economically.

On a small scale, individual lawn areas can store water for short periods and release it either to the sewer system through a restricted drain inlet or through tiled swales and grassed channels. Some detention areas can be designed as landscaped rock gardens or picturesque dry creek beds.

On a larger scale, detention areas can be designed into the open space system of an entire residential development or park system. A series of storage areas can be connected by swales to a natural drainage outlet or can be associated with an existing stream.

Proper design of these detention facilities can insure successful, useful, and attractive results. During dry periods, large detention basins can also serve as community recreation areas for soccer, volleyball, basketball, and baseball.

When intended for multiple use, the side slopes should be gentle enough to mow
and properly shaped to blend with the surrounding topography and provide an amphitheater for spectator seating on the grassy banks. Banks can also serve to contain balls in the playing area in place of chain link fence.

Proper drainage and good vegetative cover are extremely important in the design and development of multiple use detention/recreation facilities. The basin floor must be properly graded (2 percent slope — more on poorly drained soils) to provide adequate surface drainage after the controlled release of stormwater is complete, and proper outlets should be provided to accommodate any residual flow entering the basin between storms. By eliminating the possibility of standing water, maintenance can be simplified, problems of weeds, algae and mosquitoes can be avoided and the multiple uses of the facility can be realized.

In designing any storage facility, detention or retention, the natural properties of the site must be respected and utilized. In many situations, the appropriate appearance of control measures will be crisp and clean with a certain quality of sophistication. In other instances, such as parks or residential developments, detention areas can effectively be created in naturalized or wooded areas, further reducing maintenance considerations.

With sensitive placement, careful grading and appropriate landscaping, these facilities, whatever their location, can be a meaningful and aesthetically satisfying part of the community environment.
Maintenance

The ultimate success of a stormwater management program is dependent upon proper maintenance. If not properly maintained, the potential for facility failure and subsequent downstream damage from normal rainfall is very real; sooner or later, damage will result and the investment in management facilities will have been wasted.

Continuing maintenance should be a major factor in the planning and design of a stormwater management system. Along with the consideration of ultimate maintenance responsibility, design decisions concerning safety, soil conditions, topography, watershed size, land use, slope of vegetated banks and proper drainage all have a bearing on facility maintenance. Proper handling of these elements during design and implementation can minimize maintenance activities and costs associated with stormwater management.

Historically, well designed and constructed facilities on industrial and institutional sites generally have been well maintained. This seems to be especially true of multiple purpose facilities. One reason for this is that the entity responsible for planning, design and construction is also responsible for maintenance. These facilities are often intended to provide a major site amenity and, as such, require maintenance on a regular basis as do lawn and building care.

If developers and builders of commercial and residential areas are given the proper guidance (standards to meet), they should be expected to design and build safe, efficient stormwater management facilities. They cannot, however, be expected to assume ultimate maintenance responsibility. These facilities should be selected (as to type), designed and constructed to allow as much owner maintenance as possible, but the final responsibility for major on-going maintenance must be assumed by the local governmental entity.

Proper easements for all stormwater management facilities must be required, granted and recorded to insure adequate access for maintenance operations.

Finally, methods to finance required maintenance must be identified as part of the overall planning process. The potential for major downstream damage from uncontrolled, accelerated stormwater runoff makes financing the maintenance of control facilities as important to the community as street, road and bridge maintenance or sanitary and safety services.
Conclusion
Properly designed stormwater management is a practical, feasible and desirable element in urban development and redevelopment. Stormwater runoff can be adequately controlled in conjunction with the development of almost any site. The control program should be tailored to fit the requirements of the individual project by sound selection of alternative control methods, good technical and aesthetic design, and quality construction and maintenance. This guidebook has presented a variety of approaches to controlling accelerated stormwater runoff. It is hoped they will serve as a resource of ideas, and stimulate imaginative new solutions to this urban development problem.
APPENDIX

The following criteria have been adopted by the Ohio Department of Natural Resources, Division of Soil and Water Districts, and are recommended to alleviate accelerated stream channel and flood plain erosion caused by increased stormwater runoff from developed urban areas.

Stream Channel and Flood Plain Erosion

To control pollution of public waters by soil sediment from accelerated stream channel erosion and to control flood plain erosion caused by accelerated stormwater runoff from development areas, the increased peak rates and volumes of runoff shall be controlled such that:

(a) The peak rate of runoff from the critical storm and all more frequent storms occurring on the development area does not exceed the peak rate of runoff from a one year frequency storm (of 24 hours duration) occurring on the same area under pre-development conditions.

(b) Storms of less frequent occurrence than the critical storm, up to the one hundred year storm, have peak runoff rates no greater than the peak runoff rates from equivalent size storms under pre-development conditions.

The critical storm for a specific development area is determined as follows:

(a) Determine by appropriate hydrologic methods the total volume of runoff from a one-year frequency, 24-hour storm occurring on the development area before and after development.

(b) From the volumes determined in (a), determine the percentage increase in volume of runoff due to development, and using this percentage, select the 24-hour critical storm from this table.

If the percentage of increase in volume of runoff is:

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<th>Equal to or greater than</th>
<th>and less than</th>
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<td>10</td>
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The critical storm for peak rate control will be

- 10 year
- 2 year
- 5 year
- 10 year
- 25 year
- 50 year
- 100 year
FOR FURTHER READING

Sources of additional information on stormwater management:


