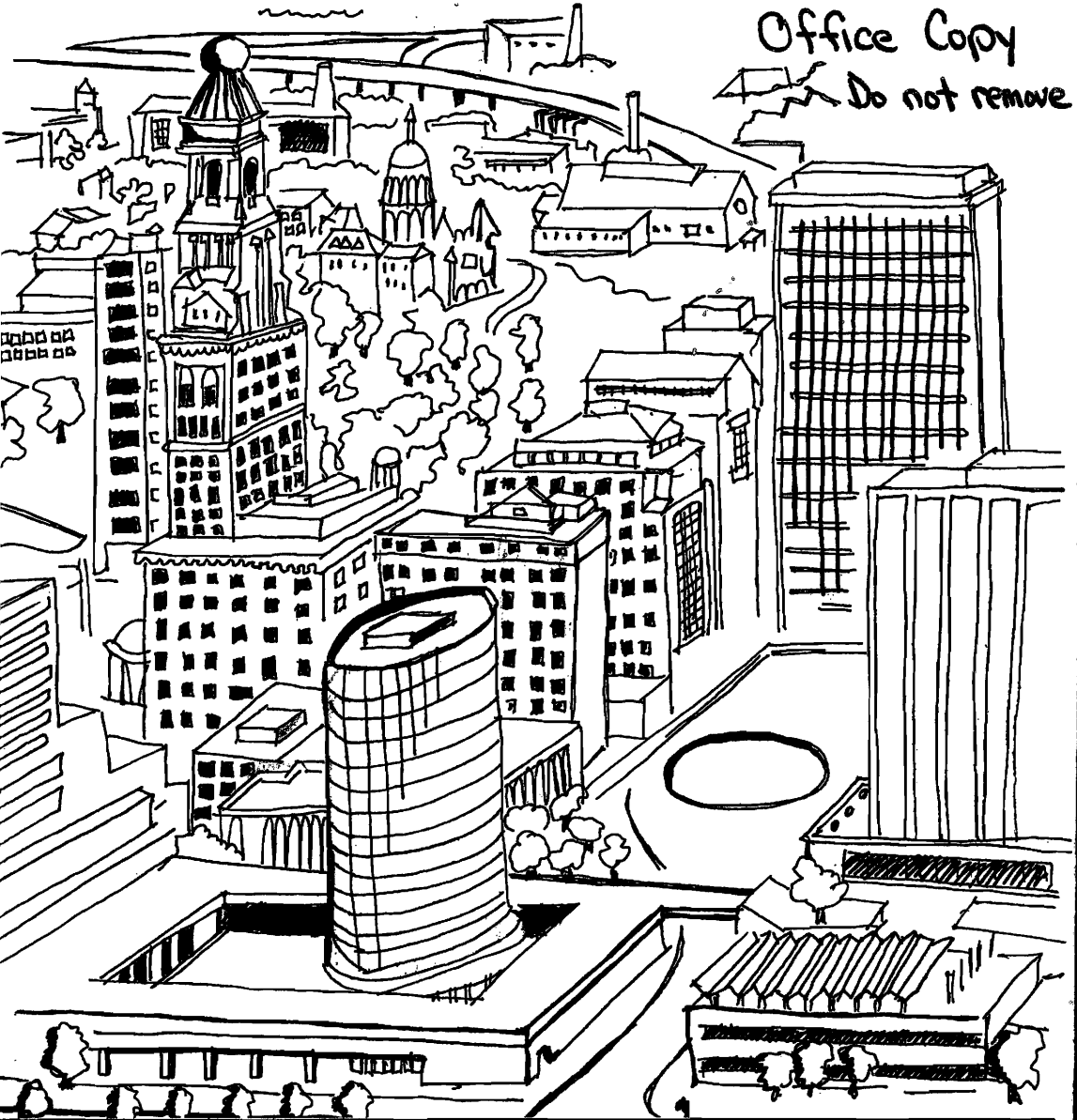


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Urban Water Runoff & Water Quality Control

by J. T. Wildrick, K. Kuhn, W. R. Kerns

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**URBAN WATER RUNOFF
AND
WATER QUALITY CONTROL**

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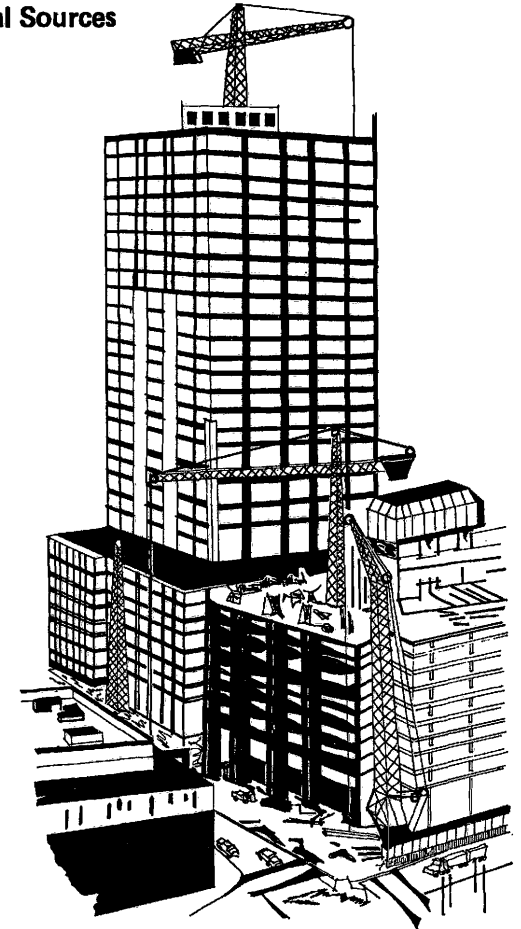
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INTRODUCTION

Reducing pollution in our nation's water has become a national objective of highest priority. Past efforts to control water pollution were primarily focused on point sources of water pollution such as discharges from municipalities and industries. In recent years, however, researchers have found that pollution from non-point sources may contribute as much or more to water pollution than do point sources. Urban runoff, for example, often is a more serious source of water pollution than municipal sewage discharges. This problem is a major obstacle in the attempt to attain higher water quality. Because of its seriousness, the 1972 Amendments to the Federal Water Pollution Control Act specifically require that non-point sources of water pollution be considered in the development of water quality management plans for both local and areawide planning.

The purpose of this manual is to explore the possibilities available to urban areas for reducing levels of pollution from urban runoff, thus reducing the need for expensive sewage treatment facilities. It does not give detailed information concerning engineering and implementation of specific control measures, but does make frequent references to sources containing more detailed information. The References section contains a list of the most useful of these information sources. Also not discussed in this publication are point sources of pollution that can be easily identified and controlled, or some non-point sources of pollution which are found only in rural areas, such as the pollution resulting from most agricultural and silvicultural activities.

This manual does contain an assessment of the seriousness of urban area non-point pollution, a survey of the control methods available for combating non-point urban pollution, and some planning guidelines for developing an integrated strategy of controls.

THE PROBLEM

Water pollution from non-point sources exists in essentially every urban area of the United States. The high concentration of people and the wastes they generate, plus the large proportion of impervious surfaces, combine to make this a serious situation.

The process through which stormwater becomes polluted begins with precipitation. As precipitation falls on urban areas, it picks up contaminants from the air, from land surfaces, and from sewer systems.

The most significant urban air pollutants are oxides of sulfur and nitrogen, fine particulate matter (dust), carbon monoxide, and volatile hydrocarbons. Particulates that have settled on city surfaces are much more significant than the pollutants picked up in the atmosphere by precipitation. These particulates fall at annual rates of 500 to 900 tons per square mile in most metropolitan areas.³

Precipitation passing over urban surfaces is exposed to a wide variety of contamination sources. Accumulated debris, animal droppings, eroded soil, tire and vehicular exhaust residue, air pollution fallout, heavy metals, deicing compounds, pesticides, decayed vegetation, and hazardous material spills are among the most significant sources of contamination carried by stormwater in metropolitan areas.⁹ Other contaminants may be introduced to storm and combined sewers through openings in the sewer system. Street drains often are used as convenient receptacles for automobile crankcase oil, dog droppings, leaves, and yard trimmings. Excess lawn watering and rinse water from home car washing introduce additional contaminants into storm drains. Most of the contaminants that can be found in urban runoff are listed in *Table 1* along with their potential effects.²

After passing through the urban environment, stormwater is usually treated slightly or simply discharged directly into a receiving water body, such as a lake, a stream, an estuary, or the ocean. There the remaining pollutants are decomposed, accumulated, or transported downstream. Although all waters have a natural self-purifying capacity for assimilating contaminants, an urban environment may overwhelm this capacity due to the vast amounts of contaminants entering the waters from a centralized source. Certain receiving waters are more capable of assimilating a small volume of highly polluted water.

The magnitude of the non-point pollution problem is shown by many recent findings. Under normal conditions, the bacterial contamination of surface runoff is two to four orders of magnitude lower than untreated sewage. However, these pollution concentrations are still two to five orders of magnitude higher than those considered safe for water contact activities.³

Usually the most significant pollution load in urban runoff occurs during the first part of a storm. This is called the "flush effect." Calculations based on a typical U.S. city indicate that the pollution load of street surface runoff during the first hour of a moderate-to-heavy storm would be many orders of magnitude greater than the same city's untreated sewage during the same time period.²

TABLE 1
Common Urban Runoff Contaminants

BOD ₅	<u>Biochemical Oxygen Demand</u> —Indicates amount of organic matter present by determining the amount of oxygen required by bacteria in a five-day period to decompose organic matter under aerobic conditions.
COD	<u>Chemical Oxygen Demand</u> —Another means of indicating amount of organic material present, in which a sample is "completely" oxidized by chemical methods rather than the incomplete bacterial oxidation of the BOD ₅ test.
OPO ₄	<u>Orthophosphate</u> —Total inorganic phosphate, which is an important nutrient to plants but which, in excessive amounts, can cause algal blooms in water if the right conditions prevail.
TPO ₄	<u>Total Phosphorous</u> —All types of phosphorus occurring in a water system; a good indication of the potential biological productivity of the water.
NO ₃	<u>Nitrate</u> —A form of nitrogen which is an essential plant nutrient but which can cause algal blooms if all other nutrients are present in sufficient quantities.
NH ₄	<u>Ammonia Nitrogen</u> —A form of nitrogen which is an essential plant nutrient but which can cause algal blooms if all nutrients are present in sufficient quantities; a product of natural decomposition of fecal matter, urea, and other animal protein.
OrgN	<u>Organic Nitrogens</u> —The "original" form of nitrogenous nutrients which, under aerobic conditions, gradually is converted to ammonia nitrogen and to nitrites and nitrates. An indication of water's algal activity potential.
Cd	<u>Cadmium</u> —An element of high toxic potential when taken by mouth; has possible association with renal arterial hypertension at sublethal levels.
Cr	<u>Chromium</u> —A toxic element when present in the hexavalent chromium ion form.

Cu	<u>Copper</u> —An essential and beneficial element in human metabolism, but quantities above 1 mg/l tend to impart an undesirable taste to drinking water.
Fe	<u>Iron</u> —An element that imparts a bitter taste to water and a brownish color to clothing laundered in such water.
Pb	<u>Lead</u> —A highly toxic heavy metal when ingested for either brief or prolonged periods; a cumulative poison.
Mn	<u>Manganese</u> —An element which produces a brownish color in laundered goods and impairs the taste of beverages, including coffee and tea.
Ni	<u>Nickel</u> —An element very toxic to plants (especially agricultural crops) but less so to animals.
Sr	<u>Strontium</u> —The radioactive form of this element, Strontium 90, has a tendency to accumulate in bone structures and is a well-recognized health hazard.
Zn	<u>Zinc</u> —An essential element in human health which, when present in excess, can impart a milky appearance and metallic taste to water supplies; toxic to many organisms in large quantities.
TCOLI	<u>Total Coliforms</u> —Bacterial indicators of less recent pollution and/or the existence of defects in water treatment or distribution; usually originate in the soil and are not fecal.
FCOLI	<u>Fecal Coliforms</u> —Pathogenic bacteria indicating recent fecal pollution in water supplies, expressed as number of organisms per gram of solids of street surface material.

Source: U.S. Environmental Protection Agency, 1974. *Water Quality Management Planning for Urban Runoff*. EPA-440/9-75-004, Washington, D.C.

A study by the American Public Works Association² shows the magnitude of the accumulation of street litter for various land uses.

single-family residential	0.7 lb/day/100 ft. of curb
multi-family residential	2.3 lb/day/100 ft. of curb
commercial areas	3.3 lb/day/100 ft. of curb

Results of a recent study of the entire Potomac River Basin³ indicate that the Washington Metropolitan Area produced 25 percent of the sediment in the river while occupying only two percent of the land in the basin.

Although the effects of heavy metals in urban runoff usually are not as significant as the extreme oxygen demand caused by organic contaminants, a recently completed EPA study showed that copper, cadmium, lead, and zinc may cause toxic effects to certain aquatic organisms. The effects of heavy metals are more severe when runoff discharges into quiescent water and accumulates to toxic concentrations.²

Finally, soil erosion, although very minor in developed areas, can be quite significant in areas under construction. Studies have shown that erosion from construction sites can contribute from 50 to 40,000 times the erosion of either undeveloped or developed land.⁴

Pollution from these non-point sources is a problem that every urban community should examine closely in order to understand the harmful effects and the means available for their reduction.

CONTROL METHODS

In approaching the problem of controlling urban area pollution from non-point sources, two basic aspects concerning the process by which water becomes polluted from these sources must be considered. First, the initial source of the pollution must be identified. The fact that a source is non-point in nature does not necessarily mean it cannot be controlled at the source. Second, the principal method by which water becomes polluted from urban surfaces is by stormwater runoff. Therefore, measures which reduce the quantity of stormwater runoff also will have a beneficial effect on water quality. Understanding this important basic concept is necessary in determining the most effective approach for control practices.

Source Control

Source control refers to methods of reducing non-point pollution in an urban drainage basin before it enters the sewerage system. Methods include processes which control both the quantity and quality of urban runoff. Since these techniques usually reduce the need for more costly treatment facilities in downstream areas, they can provide considerable savings in both construction and operation costs.³ Methods which slow the flow of stormwater may have the extra benefit of allowing additional recharge of groundwater by percolation. For this discussion, five major methods of source control are examined.

Improved Stormwater Drainage

In the natural drainage process, large amounts of stormwater seep into the ground before entering streams and rivers. With urbanization, natural drainage patterns which have developed over hundreds of years often are disrupted and altered. Land in urbanized areas is increasingly covered with impervious structures which prevent much of the natural seepage into the ground and increase the runoff loads that nearby streams must carry. This sudden increase in flow volume often is more than streams and channels are able to handle, and "unnatural" flooding may occur. Besides increasing the amount of water a stream must handle, the urbanizing process often may change the path of existing streams. This means not only that the stream bed itself is changed, but that the entire estuary must adapt its drainage to the new course. In the process, additional erosion invariably occurs.

Whenever possible, natural drainage patterns should be preserved, or at least altered as little as possible. Although these management and planning alternatives usually exist only in areas where new development is occurring, some measures can be taken in built-up areas to restore natural drainage patterns. These include:

Elimination of Curb and Gutter—Although seldom used, elimination of curbs and gutters is feasible in many areas where sufficient land is available to handle the flows from nearby impervious areas. This practice can be an important contribution toward preserving or restoring natural drainage patterns. The method

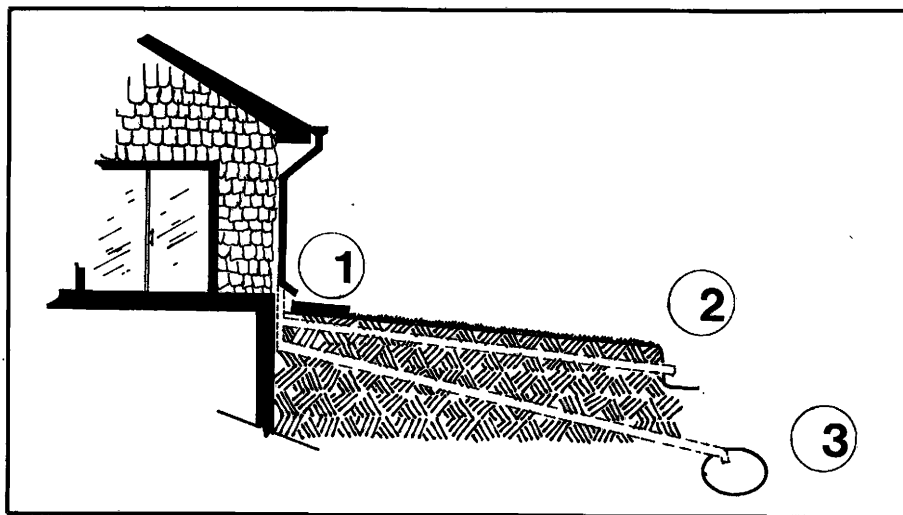
has the advantage of causing only minor inconveniences in most cases and is particularly important when the large amounts of pollutants which are washed from street surfaces can be reduced or eliminated.⁵

Disconnection of Drain Spouts—Another method of restoring natural drainage patterns is to disconnect drain spouts to eliminate their emptying into sanitary or separate sewers. Adding stormwater from drain spouts to the normal load of storm or sanitary sewers increases the size of facility required and quite often causes the systems to overflow. Simple splash blocks can be constructed at the point where the drain spout empties onto the ground (*Figure 1*).

These blocks prevent erosion from the force of the water and help disperse the water for infiltration. Another method is to construct infiltration areas at drain spout discharge points. These may be as simple as a trench filled with crushed stone, and may be constructed to accept the runoff from a splash block. To improve appearance, the crushed stones may be covered with a thin layer of previous soil sufficient for grass growth. If the area is not capable of accepting the runoff from drain spouts, they should be made to empty into separate storm sewers rather than sanitary sewers.⁴

FIGURE 1
Disconnection of Drain Spouts

One shows disconnection of drain spout and use of splash block. Alternatives Two and Three should be avoided wherever possible.



Porous Pavement—The method that has the greatest potential for restoring drainage patterns to a more normal state in urban areas is the use of porous pavements. Pavement for streets, sidewalks, and parking lots makes up a large percentage of the impervious area of any urban area. Porous pavements were originally developed for highway safety. They seem to have the most potential in areas of sandy soil where freezing is not a problem. Porous pavements also may be able to accept runoff diverted from other impervious areas, such as rooftops. Additionally, ground water recharge may be augmented by this process, provided that the runoff water is sufficiently treated by passage through the soil that contaminants from the street do not pollute ground water sources.

Stream Channel Storage—All runoff, of course, cannot be detained for absorption in natural ways. Other alternatives offer control possibilities. One method is stream channel storage. Detention areas can be dug in the sides of existing stream channels to accept and temporarily store excess runoff. The water can then be gradually released to the stream as the peak flow recedes.⁵

Aeration of Vegetative Strips—In areas where soils are somewhat impervious, perforation of lawns, golfcourses, and other open areas may increase infiltration and reduce the rate of runoff.

On-Site Detention

On-site detention involves collecting excess runoff before it enters the main drainage system. The goal is to reduce peak runoff flows caused by urbanization to as near predevelopment levels as possible, allowing minimum interference with the natural hydrologic cycle. This method often can help prevent pollution as well as flooding and soil erosion. The detained runoff sometimes can be used to augment water supplies and to serve multi-purpose uses such as recreation.⁴

Not all areas, however, are acceptable for on-site detention. Steep gradients, for instance, make on-site detention uneconomical. On-site detention also is costly when flat gradients are long distances from acceptable points of discharge.⁴ Locations that have been found to be most suitable for on-site detention measures include parking areas, parks, and playgrounds, open lands, rooftops, swamps or existing ponds, and golf courses.

FIGURE 2
Storage Depression and Constricted Drain
in Remote Corner of Parking Lot

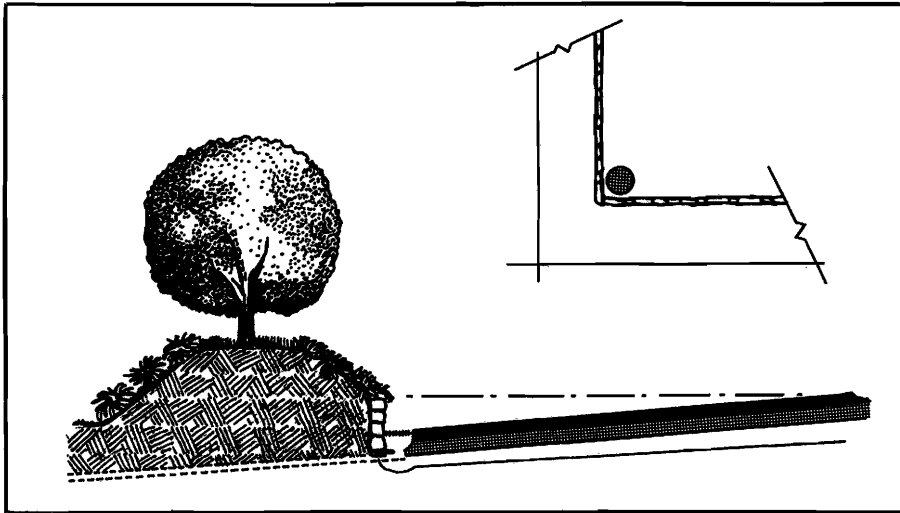
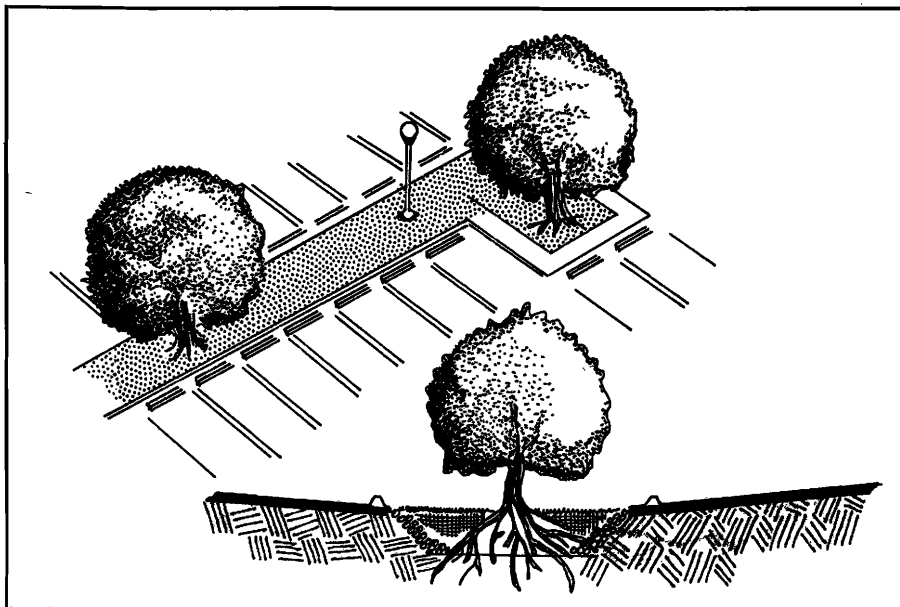


FIGURE 3
Water Channeled into Grassy Area of Parking Lot



Parking Lot Storage—The construction of parking lots serving shopping centers, office buildings, apartment complexes, and industrial parks characteristically changes large areas of land to impervious areas. In such parking lots stormwater detention usually is feasible with little maintenance required. Two general types of detention designs are used. The first involves storage in depressions constructed at drain locations (*Figure 2*). Water is then allowed to drain slowly into the sewer system by a restriction in the drain. To cause the least inconvenience, these ponding areas are usually placed in seldom-used areas of a parking lot. The second type of design involves channeling runoff across the paved areas of the lot into a grassy area or a gravel-filled seepage pit (*Figure 3*), where it infiltrates into the ground.⁴ Many variations of these two basin designs are possible and generally offer aesthetic values (*Figure 4*).

Rooftop Detention—Stormwater may be temporarily stored on flat or slightly sloping roofs by equipping them with detention drains to regulate the release of water. The extra structural load exerted on the building must be considered, but existing buildings often have been designed with sufficient structural strength to carry the added load. Additionally, the drains can be designed to overflow before excessive structural loads are reached. Several types of roof drain detention rings have been designed (*Figure 5*). The simplest is a perforated circular ring which is placed around the drain inlet.⁴ Various styles are available commercially with both fixed and variable capacity.

An alternate method of detaining stormwater on roofs is by a simple gravel dam that causes water to collect behind it but still allows it to flow through at a reduced rate.⁴

Detention Ponds—In areas where excess runoff is a problem and sufficient open land is available, detention ponds serve as ideal holding areas for stormwater. The major design consideration for a detention pond is the volume of storage needed and the maximum release rate. Other design considerations include topography, space availability, climate, soil type, and other local factors. A detention pond may be designed to serve as a recreational pond for boating and fishing.⁴ Beautification of the area around a detention pond should be considered an integral part of its design. Planting of trees and other valuable vegetation can change a detention pond from an eyesore to an attractive aesthetic asset.

FIGURE 4
Detention Storage May Offer Aesthetic Benefits

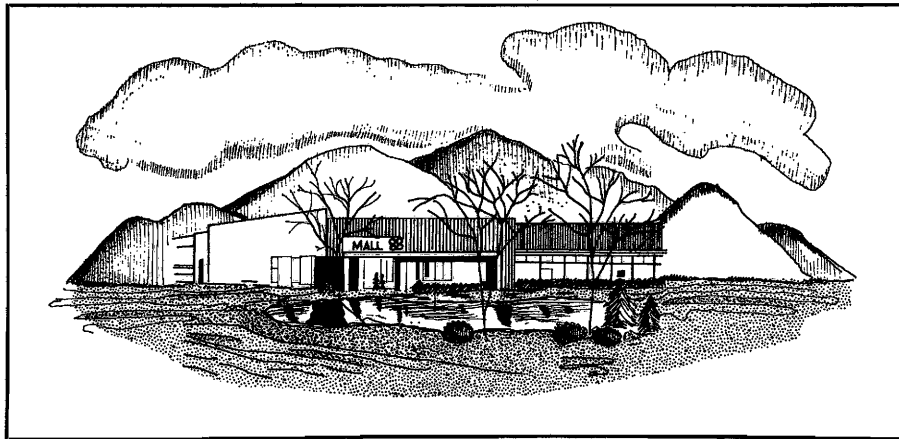
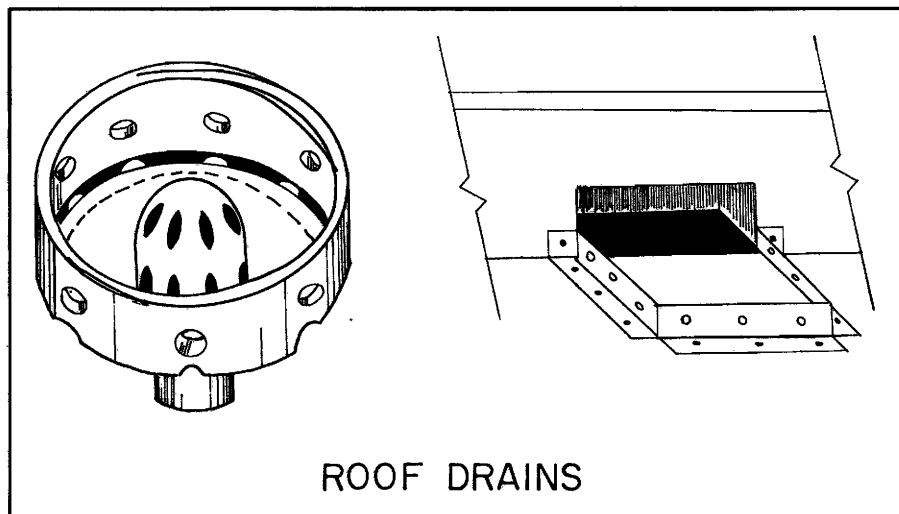


FIGURE 5
Rooftop Water Detention Devices

A. Commercial Detention Ring

B. Homemade Detention Device



Maintenance of detention ponds should be a consideration in their acceptance and design. Although the specific maintenance measures are beyond the scope of this text, the general categories of maintenance and operation include:

- algae and aquatic vegetation control
- mosquito control
- debris removal
- sediment removal
- safety features
- maintenance of hydraulic facilities such as pipes, channels, control gates and pumps
- general maintenance⁴

A special report by the American Public Works Association, *Practices in Detention of Urban Stormwater Runoff*,⁴ gives information on how to minimize or eliminate many of these maintenance problems.

Holding Tanks—Holding tanks either above or below ground are an alternative when space is not available or conditions not favorable for ponds. They usually have a predetermined release rate and may be arranged for temporary storage prior to treatment.⁵

Economics of On-Site Detention—In many instances on-site detention is less costly than traditional drainage systems. In the construction of a trucking terminal in St. Louis, for example, it was found that the use of detention ponds on the parking lot reduced the size of the required storm sewers and thereby lowered construction cost from \$150,000 to \$115,000.⁴

Another example is in the planned community of Earth City, Missouri, where a system of lakes serving as detention ponds reduced the cost of the originally planned conventional system from \$5 million to \$2 million plus the value of the 51 acres needed for the lakes. In addition, the lakes will add value to the surrounding property.⁴

Generally, the economics of on-site detention can be quite appealing, provided there is sufficient space available. If the facility also can be used for recreation, the economics become more attractive because a part of the cost can be allocated to recreation.⁴

Erosion Control

In highly developed urbanized areas, soil erosion is usually only a minor problem. But land under development, which is characteristic of newer urbanizing areas, can contribute large amounts of pollution in the form of sediment from erosion.⁴ The greatest erosion problem occurs during the transition from rural or agricultural use to urban use. During this period, land is normally stripped of its protective cover and left exposed until final construction and restabilization.⁵ Erosion control methods serve one or more of the following functions: (1) minimize soil exposure; (2) control runoff; (3) shield the soil; and/or (4) bind the soil.⁵

There are numerous methods of accomplishing these functions. A recent publication prepared for the U.S. Environmental Protection Agency identifies 42 methods of control.⁴ Only a few of the simpler and more effective means of erosion control will be covered here to provide a general understanding of the principles and methods of erosion control.

Site Planning—Forethought in site planning can do much in the way of preventing erosion problems before they start. The site should be developed so that a minimum of land grading is required. New streets should follow the contours of the existing topography. Existing vegetation should be preserved wherever possible, particularly on steep slopes. Development should take place in staged increments so that the period of exposure is greatly reduced and will diminish the possibility of serious damage by erosion during construction. Temporary vegetation may be established in areas that will not be built upon within 60 days, but permanent vegetation should be established immediately after final grading. Storm drainage facilities should be made operational as soon as possible.⁴

Selection of Vegetation Covers—The following is a list of the major considerations in choosing an appropriate vegetative cover.

1. Suitability for the time of year, soil conditions of the site, and environmental conditions of the area.
2. Resistance to heat, cold, insects, and diseases
3. Potential for rapid growth

4. Capacity for compact growth
5. Potential for nitrogen fixation
6. Maintenance requirements
7. Draught resistance⁵

A good principle is that most native grasses, trees, and shrubs grow well with little or no maintenance. The *Virginia Erosion and Sediment Control Handbook*⁶ contains lists of many types of vegetation that are suitable for these various conditions.

Mulching—One of the most effective temporary erosion control measures is the application of mulch. It not only helps retard erosion but holds seed and fertilizer in place, retains soil moisture, and helps maintain temperatures conducive to germination when vegetation is being established. Among materials successfully used as mulch are straw, wood chips, asphalt emulsion, jute matting, and similar materials.⁶

Surface Roughening—Another erosion control measure that can be applied quite easily is "surface roughening." For example, the verticle movement of a cleated bulldozer roughens a graded slope and produces horizontal grooves that spread the runoff and slow its movement. Additionally, the compacted surface helps prevent water from loosening the soil.⁵

Filters—Filters are generally placed around inlet drains or are constructed as berms on slopes. They may be made of coarsely crushed stone, straw bales, or sandbags (*Figures 6 and 7*), and are effective in trapping coarser sediment.⁵

Stream Channel Erosion—An important but often unnoticed type of erosion is that which occurs in stream channels when increased demands are placed on them from urban runoff. Establishment of vegetation should be considered a first possibility for this type of erosion control. Where this is not possible, a protective layer of crushed stones along stream banks may prove effective. Occasionally, when slopes are too steep or the stream is too swift, more rigid structures made of concrete or metal may be necessary.⁵

FIGURE 6
Crushed Stone Filter at a Drain Outlet

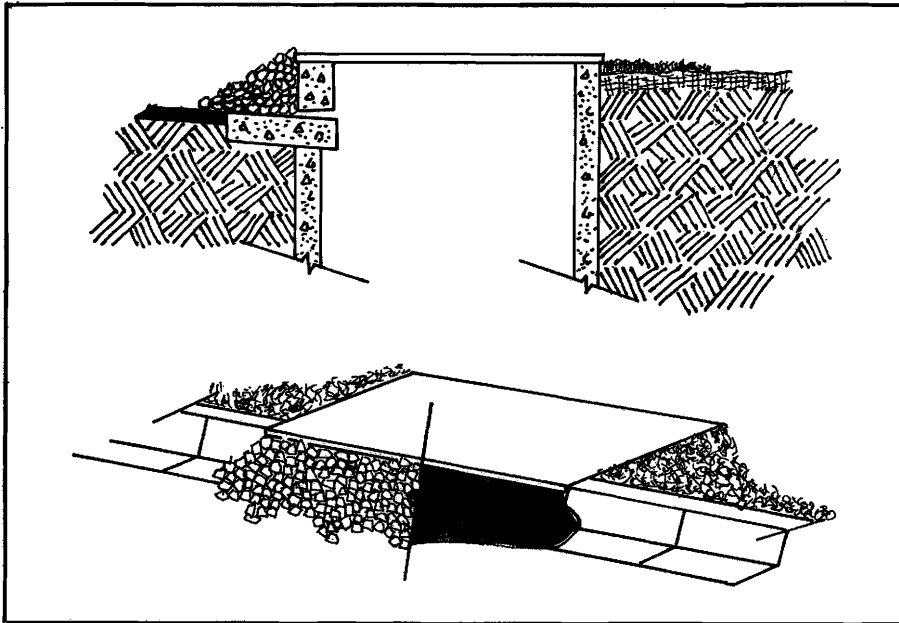
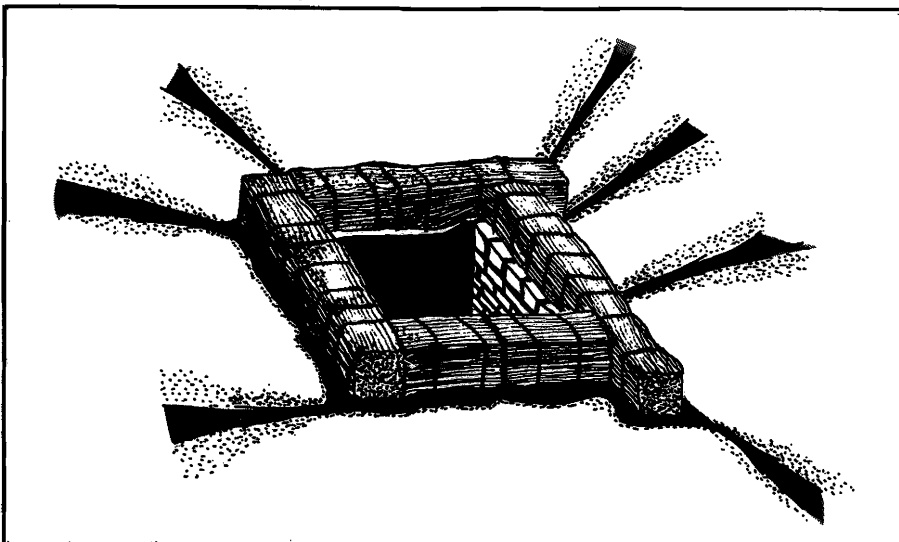


FIGURE 7
Hay Bales Used as a Filter



Public Works Practices

A city or community may take a number of measures in its public works practices to prevent water pollution. They include street cleaning, catch basin cleaning, refuse and litter collection, proper use of de-icing salts, sewer cleaning, and the use of separate sewers.

Separate Sewers—Treatment of stormwater runoff separately from sanitary sewage often is more desirable than the treatment of combined wastes. One reason is that the pollutants in stormwater runoff are of a different type and usually must be treated differently. Where their use is practical, separate sewers may avoid the necessity of a large treatment facility capable of treating both stormwater runoff as well as sanitary sewage wastes. Another advantage of separate treatment is that when overflows occur due to heavy storms, raw sewage will not be carried into the streams.

Reducing Combined Sewer Overflows—While it is desirable to have separate sewers so that urban runoff can be treated separately, it is a gigantic task to separate existing combined systems and the undertaking would probably be unrealistic. For instance, to separate the systems in Detroit or Chicago would cost over \$2 billion and take over 40 years to accomplish.⁹ An alternative to sewer separation is the modification of existing combined sewer systems so they are able to handle peak loads and therefore reduce the incidence of overflows.

During a storm every effort should be made to contain as much flow and treat as much sewage as possible. If hydraulic loading becomes a problem, then primary treatment plus disinfection should be considered as an alternative. Remotely stationed rain gauges are used in some locations to warn operators ahead of time of possible peak flows. This allows the operator enough time to increase the treatment plant pumping and thus treat more sewage during intense storms.

Many overflows occur simply due to clogged orifices or malfunctioning devices. Regular inspection and maintenance can minimize these occurrences. Periodic cleaning of catch basins and sewer lines can prevent overflows due to obstructions as well as reduce excess solids loading during a storm.

Controlling infiltration and extraneous inflow is another method

of reducing combined sewer overflows. Concern about infiltration should first take place during sewer pipe installation. New methods of sewer sealing and lining should be fully considered and proper installation should be ensured. Special attention should be given to the installation of building connections to street sewers since they are a major source of infiltration. There are many techniques for detecting infiltration, including use of television, smoke tests, and various flow techniques.

Finally, when there is insufficient carrying capacity in the sewer lines, polymer addition may reduce fluid friction. Tests have shown that this may increase the flow capacity by as much as 2.4 times. Of course, all of the source control techniques that reduce the volume of runoff will reduce the problem of combined sewer overflows as well.

Waste Containers—It is common practice for many people to dispose of waste materials on city streets. These materials become street litter and commonly include containers from food and drink, cigarettes, newspapers, floor sweepings, and many other items. These materials will end up in stormwater discharges unless they are removed by street cleaning equipment. Enforcement of anti-litter laws and convenient location of sidewalk waste-disposal containers are measures that can help reduce street litter.³

Street Cleaning—Despite the best efforts at prevention, a certain amount of litter will inevitably collect in streets and gutters. Street sweeping can be an effective means of removing this litter. A good deal of the pollution potential from street debris is due to the very fine siltlike particles which account for only 5.9 percent of the total by weight.² An EPA study³ has shown that conventional street sweeping operations are relatively ineffective in removing this fine material. However, tests by the American Public Works Association³ have shown that vacuum-type street sweepers are effective in removing 95 percent or more of this fine material. These vacuum sweepers have been used in Europe for some time. They use a broom to loosen debris and a vacuum system to pick it up.⁵

Deicing Salts—Some of the ill effects from the use of deicing salts and chemicals have been mentioned earlier. Snow and ice removal remains a problem which cannot be ignored in urban areas. The easiest way to minimize the adverse effects from deicing salts is by using

less of them. This can often be accomplished without any loss of safety. Straight, flat sections of the road may not need salt. Cab monitoring devices can be installed in salt application trucks which allow the essential amount of salt to be applied and prevent excesses.³ Drivers of these trucks need to be instructed in such economy techniques.

Salt storage areas frequently are sources of ground and surface water contamination. Covering these storage areas can help to prevent the spread of contamination.⁹ Another measure is to simply prohibit use of highly toxic substances such as cyanide and chromium compounds which are added to deicing salts. In light of their high toxicity, their use as anti-caking agents and corrosion inhibitors cannot be justified.

An alternative to salt is the use of such abrasives as sand or cinders. This decision must be weighed carefully, since these abrasives also present problems. Although they do not cause the same pollution problems as salt, they do contribute significant amounts of suspended solids to runoff. They also may clog sewers and add to the costs of street cleaning. Sand and cinders are more expensive than salt, but their use should be weighed against the damage done by salt and the cost of correcting that damage.

Legal Remedies

Legislation often is useful in solving the problem of urban stormwater quality. Legislation can clearly delineate responsibility for controlling runoff and it can protect the health, welfare, and safety of the public.⁴

When proposing legislation, the question of the appropriate level of government is extremely important. Because drainage networks do not respect political boundaries, a regional approach may be most desirable. Solutions proposed in one community might easily become problems for another community. Therefore, a drainage district or a sanitary district might be most suitable for implementing legislation.⁴ However, laws and regulations can be enacted by a local municipality (county, city, village, etc.) or even a state as well as a drainage district. The state of Minnesota, for instance, incorporates stormwater drainage regulations in its state building code.⁴ Among the types of legislation that have been used to control runoff from new land developments and urban renewal projects are: (a) subdivision

regulations ordinances; (b) zoning ordinances; (c) building code ordinances; (d) plumbing and sewer ordinances; (e) water pollution control ordinances; (f) flood control ordinances, and (g) drainage fee assessments.

Several of these types of legislation may be used simultaneously. The last type, drainage fee assessment, is particularly interesting. It usually provides for a reduction in the assessment if detention facilities are installed. If they are not installed, the full drainage fee can be used to pay for the construction of drainage facilities. Such legislation should be structured so it is site-specific and relates to the normal stormwater runoff rates.

A similar practice is to require the developer to put cash in escrow for erosion and sediment control practices. If the developer does not comply with the ordinances satisfactorily, the money in escrow can be used to install controls.⁴

Zoning laws normally are structured to specify the minimum amount of drainage protection needed in various areas. Floodplain zoning regulations prohibit any permanent development that would interfere with the natural storage of flood waters in the floodplain.⁴ Local building codes may require new buildings to have rooftop storage incorporated into the design. The Building Officials and Code Administrators, International, a national building code, contains standards for detention on roofs.⁴

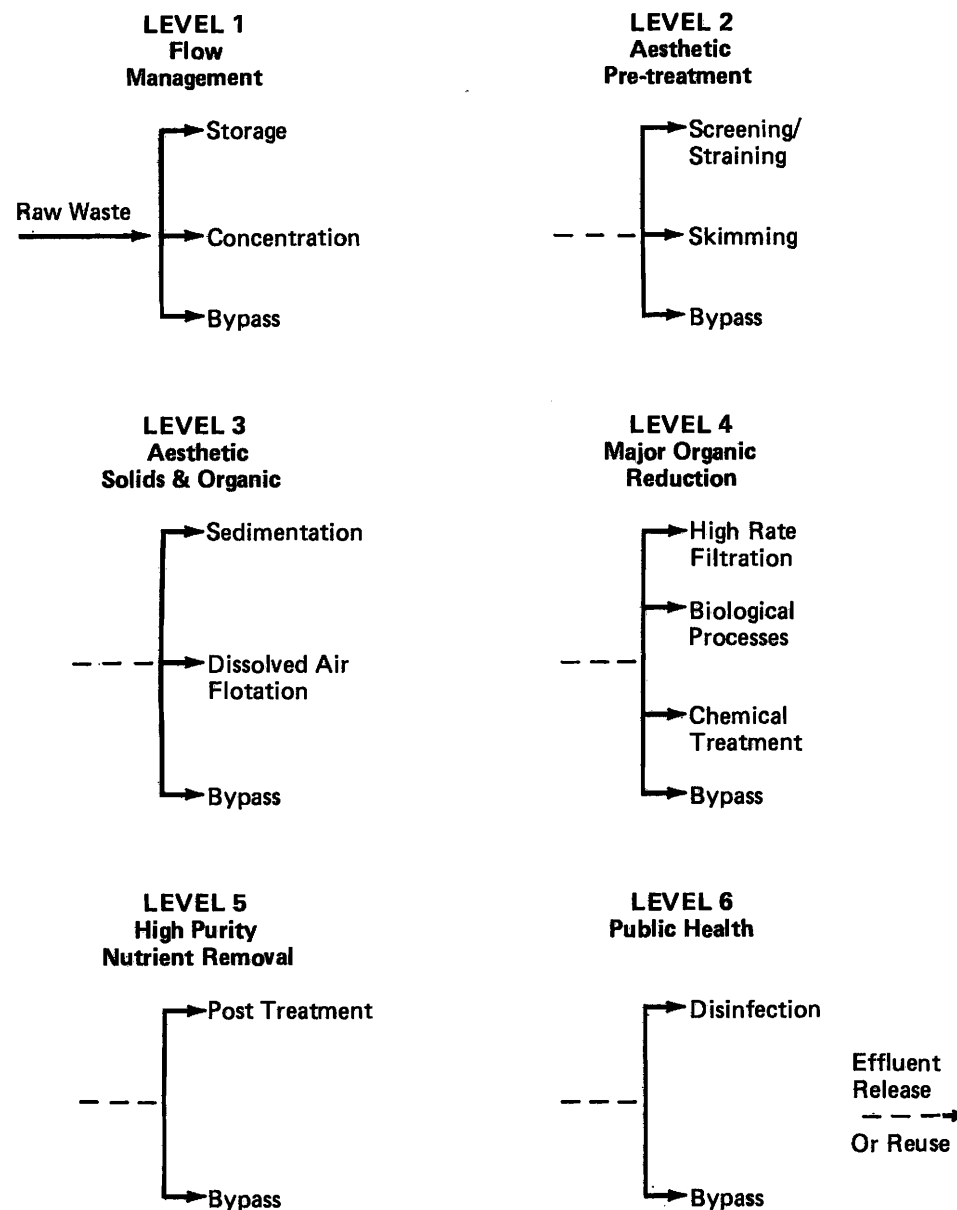
Other uses of legislation for the control of pollution in runoff include the regulation of leaf disposal, control of fertilizer and pesticide use, and prevention of sanitary sewer use for disposal of undesirable substances.⁵

Enforcement of the various types of legislation usually includes inspections, approval of construction where applicable, and provision for penalties.⁴

Stormwater Treatment Processes

When pollution resulting from stormwater becomes a problem, source controls may not always be adequate to improve water quality to an acceptable level. If this is the case, selected stormwater treatment

FIGURE 8
Stormwater Treatment Decision Choices



Source: Reference 8

processes may be necessary. The possible treatment decision choices are shown in *Figure 8*. A different degree of treatment is indicated for each level. The first level provides for constraints on flow rates and separation into a concentrate stream or a relatively clear stream. The second level offers a modest pre-treatment of the waste. The third level provides further upgrading which approximates conventional primary treatment. The fourth and fifth levels correspond to secondary and tertiary levels in conventional treatment. The sixth level, disinfection, is the most thorough treatment and is a major undertaking. The "bypass" notations on the figure indicate the option to end the treatment at any level or to skip any of the levels depending upon the objectives of the treatment. Our purpose is merely to point out the availability of these various treatment processes.⁸ The EPA publication, *Urban Stormwater Management and Technology: An Assessment*,³ does a thorough job of explaining these various treatment options and how they work.

PLANNING FOR WATER QUALITY

This final section examines the use of urban planning alternatives to obtain higher water quality. These alternatives usually involve some aspect of land-use planning and assume that more is required than simply providing relief from the problems created by society. It also involves eliminating or minimizing the sources of those problems. Many advances have been made in the technological treatment of urban stormwater; however, long term effects on the pattern and distribution of land use and the rate of growth may be more efficient alternatives than new treatment processes.⁸

Most of the previous discussion has been concerned with land that has already been urbanized. To that extent, many of the methods suggested have been corrective in nature and very high levels of water quality may be difficult and costly to achieve. However, in undeveloped or developing areas where man has had little effect on the hydrology and where control can be exercised on land development patterns, a unique opportunity exists to achieve optimal water-land use relationships.¹⁰

Critical Water-Land Interfaces

Four important water-land interfaces are particularly sensitive and should be given careful treatment when considering land uses. They are watersheds, shorelands, estuarine wetlands, and floodplains.¹⁰

Watersheds

A watershed is all the land area from which the water at a particular point has drained.¹⁰ When development of a watershed area is inevitable, precautions should be taken to preserve the natural drainage patterns and provide adequate open space. Land acquisition of critical areas, zoning controls, and many of the methods previously mentioned might be employed depending on the terrain and nature of development.

Shorelines

Shorelines, as we will define them, include the land area adjacent to a stream or lake that has significant effects on its quality.¹⁰ Since shorelines are inevitably part of a watershed, the precautions mentioned above apply. However, shorelines have special problems of their own. Among these problems are pollution from septic tanks, erosion from land clearing, loss of aesthetic quality, and disruption of the natural ecology.¹⁰ Because of these problems, shoreline ordinances should include building-permit systems which control minimum lot sizes, setbacks from the water, tree cutting, filling, draining, dredging, and septic tank installation.¹⁰

Estuaries

An estuary occurs when water from streams or rivers mixes with salt water from the oceans. Estuaries and the adjacent wetlands are significant biological areas. Intrusion by man in estuaries and wetlands can cause serious disruption of ecologic processes. These processes depend on a number of factors, including fresh water inflow, temperature, sediment load and level of nutrients. Some activities of man common to urban development that may significantly effect an estuarine area are damming streams that feed the estuary, filling in the wetlands and estuary, dredging stream bottoms and wetlands for boating, diversions of the fresh water supply, waste discharge, the use of water for cooling, and the use of pesticides. Planning to protect the processes that occur

in estuaries involves a balance among three broad development categories: (1) *Preservation*—those areas which should be protected from further development; (2) *Conservation*—areas set aside for recreation, forestry, wildlife management, agriculture, and other limited land uses; and (3) *Development*—areas suitable for urban development.¹⁰ The particular estuary being considered will dictate the balance among these three categories. Legal controls may help accomplish those ends.

Floodplains

A floodplain is the relatively flat and lowland area adjacent to a stream or river. Restrictions that should be enforced in a floodplain have been discussed in previous sections of this report.

Specific Planning Techniques

Several methods exist for determining which land should be developed and which should be left in open space to enhance water quality. Two techniques will be presented that can be useful in the planning process. The first presents a method of determining the land that has the fewest constraints to development, and the second details a basis for restricting the coverage of a development once the land-use decisions have been made. Following the description of these two techniques, some outlines of planning alternatives will be provided.

Composite Overlay

Ian McHarg of the University of Pennsylvania has demonstrated a technique of environmental determinism to locate the best places for various land-use activities. Water resources and water pollution potential receive strong consideration in his analysis. He considers surface water, marshes, floodplains, aquifer recharge areas, and aquifers as being unsuited to urban development. The result of his analysis is a map showing the best and worst areas for development as well as intermediate levels of unsuitability. This technique might be used to good advantage in planning the path of future growth to minimize the potential of non-point pollution. McHarg's book, *Design With Nature*, contains detailed information on this technique.¹²

Determining Maximum Allowable Impervious Cover

A method has been developed which regulates the amount of impervious surfaces allowed in new developments in accordance with a site's natural capacities.¹¹ First, determine the quantity of runoff of a given area, the amount of precipitation, and the water retention potential of the soil and vegetative cover. Next, determine to what extent new development will be permitted to increase the quantity of runoff. From this information, the allowable amount of impervious surfaces in houses, driveways, and streets is calculated. These calculations form the basis for zoning and sub-division regulations which restrict the amount of impervious surfaces based on the capacities of the site. This technique has been demonstrated using a computer and four-acre cells. The end product is a graphic output showing the recommended impervious cover limit for each cell.

Outline of Planning Alternatives

The strategies outlined in *Figure 9* are presented as a potpourri of ideas for consideration in achieving water quality goals. They have the potential of achieving high water quality standards by reducing the amount of pollutants, by balancing the discharges with the assimilative capacity of the receiving waters, and by the conservation of natural features which protect water quality and quantity. Since land-use planning demands a "regional approach" and planning for the control of non-point pollution does not occur in a vacuum, these strategies and techniques include the control of rural and point sources of pollution as well as urban non-point pollution.

In *Figures 10 and 11*, specific implementation techniques are identified with each of the strategies in *Figure 9*. It is assumed that most of these techniques are familiar to planners.

Finally, in *Figure 12*, the strategies are assessed and those which are most effective are identified in terms of their potential reduction of water pollution and ease of implementation. As shown, the most effective strategies generally are those implemented directly by public regulation or through traditional capital budget expenditures.

FIGURE 9

Role of Land Use Planning and Control in Water Quality Management

GOALS		
Balance and Reduce Point Discharges	Reduce and Balance Non-Point Discharges	Conserve Natural Features
STRATEGIES		
Regional Strategies	Site Development Strategies	Land Management Strategies
<ul style="list-style-type: none"> ■ Modify Growth Rates ■ Modify Growth Distribution ■ Conserve Environmentally Sensitive Areas & Open Space ■ Control Siting of "Critical Uses" 	<ul style="list-style-type: none"> ■ Modify Site Location Practices ■ Modify Project Size & Mix ■ Improve Site Planning & Development 	<ul style="list-style-type: none"> ■ Control Construction Related Erosion ■ Utilize Agriculture & Silviculture Conservation Practices ■ Manage Floodplain & Shoreline Uses ■ Control Resource Extraction Activities

Source: Reference 8

FIGURE 10

Regional Strategies and Techniques in Water Quality Management

Strategy	Implementation Techniques
Modify Growth Rate	<ul style="list-style-type: none"> ■ Policy Recommendations and Decisions by Governmental Leaders ■ Zoning ■ Public Service Policy ■ Building Moratoria
Modify Growth Distribution and Density	<ul style="list-style-type: none"> ■ New Town Assistance Programs ■ Locational Decisions for Major Public Facilities Such as Sewage Lines and Treatment Plants and Location of Major Highways ■ Zoning ■ Local Moratoria on Sewage Taps or Extensions ■ Regional Planning and Adoption of Policy and Controls by Member Jurisdictions ■ A-95 Review: Environmental Impact Statements ■ Tax Abatement for Open Space ■ Large Lot Zoning ■ Negotiate Densities Proposed in Impact Areas
Preserve Environmentally Sensitive Areas and Open Space	<ul style="list-style-type: none"> ■ Acquisition of Special Zones Requiring Use Permits ■ Zoning ■ Private or Public Compacts ■ Tax Incentives and Disincentives
Control Location of Critical Uses	<ul style="list-style-type: none"> ■ Collaborative Regional Planning and Funding ■ Zoning ■ A-95 Review: Environmental Impact Statements ■ Federal or State Regulation of Certain Uses

Source: Reference 8

FIGURE 11

Site Development and Land Management Strategies in Water Quality Management

Strategy	Implementation Techniques
Encourage Proper Site Selection	<ul style="list-style-type: none"> Zoning, Subdivision, Building, and Other Regulations
Modify Project Size and Mix	<ul style="list-style-type: none"> Site Plan Review
Exercise Sound Site Planning Principles	<ul style="list-style-type: none"> Permit to Construct
Control Construction-Related Erosion	<ul style="list-style-type: none"> Erosion and Sedimentation Control Ordinances Soil Conservation Service Advice
Utilize Conservation Practices in Agriculture	<ul style="list-style-type: none"> Regulations Requiring Conservation Plan Implementation Laws Regulating Application of Fertilizer, Pesticides & Disposal of Annual Waste Conservation Plans Advisory Services Regarding Pesticide and Fertilizer Application, Feedlot Management
Utilize Conservation Practices in Flood-plains Shorelines	<ul style="list-style-type: none"> Zoning Subdivision and Other Regulations Acquisition, in Fee or Easement Building Permits Fill and Dredge Laws
Control Resource Extraction	<ul style="list-style-type: none"> Require Plan for Water Quality Protection Performance Bonds Prior to Permitting Use Zoning Permit Systems

Source: Reference 8

FIGURE 12
Assessment of Implementation Requirements in Water Quality Management

Planning Strategy	Implementation Techniques											
	Zoning	Sub. Regs.	Bldg. Codes	Discharge Permit Systems	Spec. Ordinances, Statutes	Incentive Programs	State Land Use Regs.	Acquisition Programs	Pub. Fac. Devel. & Service	Grant Program	Gov't Reviews	Private Agreements
Modify Growth Rates	1			2	2	1						
Modify Growth Distribution	1				1	2	1	1	2			
Preserve Environmentally Sensitive Areas and Open Space	1	2			1	1	1	1	1	1	2	
Control Siting of Critical Uses	1			1	1	2		2		1		
Control Construction-Related Erosion		1	2	1	2						2	2
Utilize Agriculture and Silvaculture Conservation Practices						2					2	
Manage Floodplain and Shoreline Use	1	2	2	2	1	2					2	
Control Resource Extraction Activities	2			2	1	2						1
Improve Site Planning and Development	1	1	2	2	2	2						2

1 indicates primary implementation techniques.
2 indicates secondary implementation techniques.

Source: Reference 8

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