PLANNING

CONTENTS

Section **Page PL-**

Photographs

1.0 THE DRAINAGE SUBSYSTEM

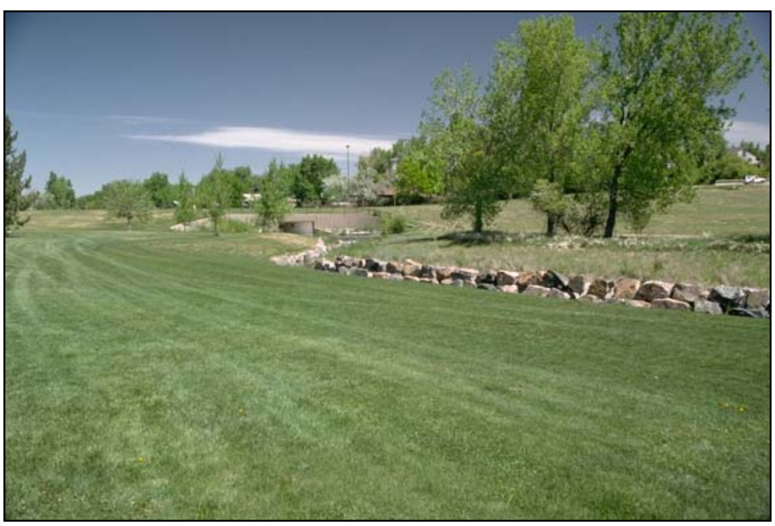
1.1 Planning

Planning of the urban storm runoff system is a very important step that requires a comprehensive understanding of city planning, drainage planning, and many of the social, technical, and environmental issues embedded in each watershed.

Urban storm runoff is a subsystem of the total urban system. It is an integral part of the urban community and should be planned as such. The drainage engineer must be included in all urban planning from the beginning. When drainage planning is done after all the other decisions are already made as to the layout of a new subdivision or commercial area or of the transportation network, drainage and urban space allocation problems often result that are costly and difficult to correct.

The city or county urban design team should think in terms of natural drainage easements and street drainage patterns and should coordinate efforts with the drainage engineers to achieve the policies and objectives presented in this *Manual*. Storm runoff will occur when rain falls or snow melts no matter how well or how poorly drainage planning is done. Drainage and flood control measures are costly when not properly planned. Good planning results in lower-cost drainage facilities for the developer and the community and a more functional community infrastructure (Jones 1967).

The drainage design team is encouraged to consider ways of creating additional benefits from drainage works such as recreation or open space.



Photograph PL-1—Bible Park with fully integrated drainage, flood control, recreation, and open space functions represents a partnership among engineers, landscape architects, planners and recreation professionals.

Consideration of multiple uses and multiple benefits in drainage planning and engineering can reduce drainage costs and increase benefits to the urban system. One way to ensure maximum consideration of these multiple uses is by preparing master plans for drainage so that the overall effort is coordinated with other predetermined objectives (ASCE and WEF 1992).

During the master planning phase, major decisions are made as to design velocities, location of structures, open space set-asides for drainage, integration with recreation, means of accommodating conflicting utilities, and potential alternate uses for open channels, detention, and water quality facilities. It is also at this time that decisions need be made on the use of downstream detention storage, either off-stream or channel ponds or reservoirs. Upstream storage and land treatment should also be evaluated.

1.2 Planning Philosophy

The planning of urban drainage should proceed on a well-organized basis with a defined set of drainage policies backed up with suitable ordinances. The policies presented in this *Manual* provide a basis upon which additional localized and specific policies can be built.

Planning of urban drainage facilities should be based upon incorporating natural waterways, artificial channels, storm sewers, and other drainage works into the development of a desirable, aesthetic, and environmentally sensitive urban community, rather than attempting to superimpose drainage works on a development after it is laid out, as is often done with water supply and sanitary sewer facilities. Surface drainage, unlike water and sanitation systems, must be integrated early into the fabric of the urban layout.

Urban drainage should be considered on the basis that two separate and distinct drainage systems exist. These are the initial drainage system and the major drainage system.

The *initial system,* as defined in the POLICY chapter, consists of grass and paved swales, streets and gutters, storm sewers, and smaller open channels. This is the system that, if properly planned and designed, will eliminate many "complaint" calls to the city or county. It provides for convenient drainage, reduces costs of streets, and directly affects the orderliness of an urban area.

A well-planned *major system* can reduce or eliminate the need for underground storm sewers, and it can protect the urban area from extensive property damage, injury, and loss of life from flooding. The major system exists in a community whether or not it has been planned and designed and whether or not development is situated wisely in respect to it. Water will obey the law of gravity and flow downhill to seek its lowest level whether or not buildings and people are in its way.

The planning process can best serve the community by making sure that nature's prescriptive easements are maintained along major drainage routes. Here, floodplain delineation and zoning are tools that should be used freely. Small waterways and gulches lend themselves to floodplain regulations in the same manner as larger creeks.

Reshaping channel areas along small waterways is often not required, except to provide grade control, protection of certain vulnerable areas (such as the channel toe and outer banks), or unless they are in a degraded or deteriorated condition. The practice of straightening, narrowing, and filling major drainageways such as gulches, dry streams, and other natural channels is not recommended for general use in drainageway master plans.

The urban stormwater planning process should attempt to make drainage, which is often a resource out of place, a “resource in place” which can contribute to the community’s general well being.

1.3 Drainage Management Measures

Urban drainage and flood control planning should consider the following management measures:

1. Appropriate measures to limit development of land that is exposed to flood damage including:
    a. Enacting floodplain management or other restrictive ordinances (i.e., building, subdivision, housing and health codes).
    b. Acquiring developed property in built-up areas.
    c. Preempting development of vacant flood fringe areas by public acquisition of land where appropriate for good drainage and community planning.
2. Appropriate measures to guide proposed development away from locations exposed to flood damage including:
    a. Developing floodplain regulations.
    b. Using warning signs.
    c. Limiting access to flood-prone areas.
    d. Using setbacks from channel banks.
    e. Withholding public financing from flood area development.
    f. Withholding utilities (electricity, water, sewers, etc.) from flood area development.
    g. Examining equivalent alternative sites.
    h. Maintaining low property assessment for tax purposes allowing flood-prone land to economically lie idle.
    i. Providing incentives for floodplain dedication to the public such as density credits.
3. Appropriate measures to assist in reducing individual losses by flooding including:
    a. Structural flood abatement devices.

b. Flood-proofing buildings.

c. Early warning systems.

d. Emergency preparedness plans (e.g., sandbagging, evacuation, etc.).

e. Ongoing maintenance of the minor and major drainage systems.

f. Disaster relief (funds and services).

g. Tax subsidies (i.e., ameliorating assessments).

Furthermore, good urban drainage planning practices and management procedures should make it possible to initiate:

1. Land use planning that recognizes flood hazards and flood damage and the value of the riparian zones that often occupy natural major drainageway routes.

2. A plan for expansion of public facilities that recognizes the implications of flood hazards for:

   a. Sewer and water extensions.

   b. Open space acquisition.

   c. Transportation.

3. Implementation measures that demonstrate an existing or proposed floodplain management program including, where appropriate:

   a. Building codes, zoning ordinances, subdivision regulations, floodplain regulations, and map regulations with flooding encroachment lines. These should be consistent with land use recommendations discussed earlier, incorporating flood-proofing requirements and reserving areas used in accordance with flood control recommendations.

   b. Participation in regional land use planning.

   c. Participation in available floodplain management services, including flood warning systems.

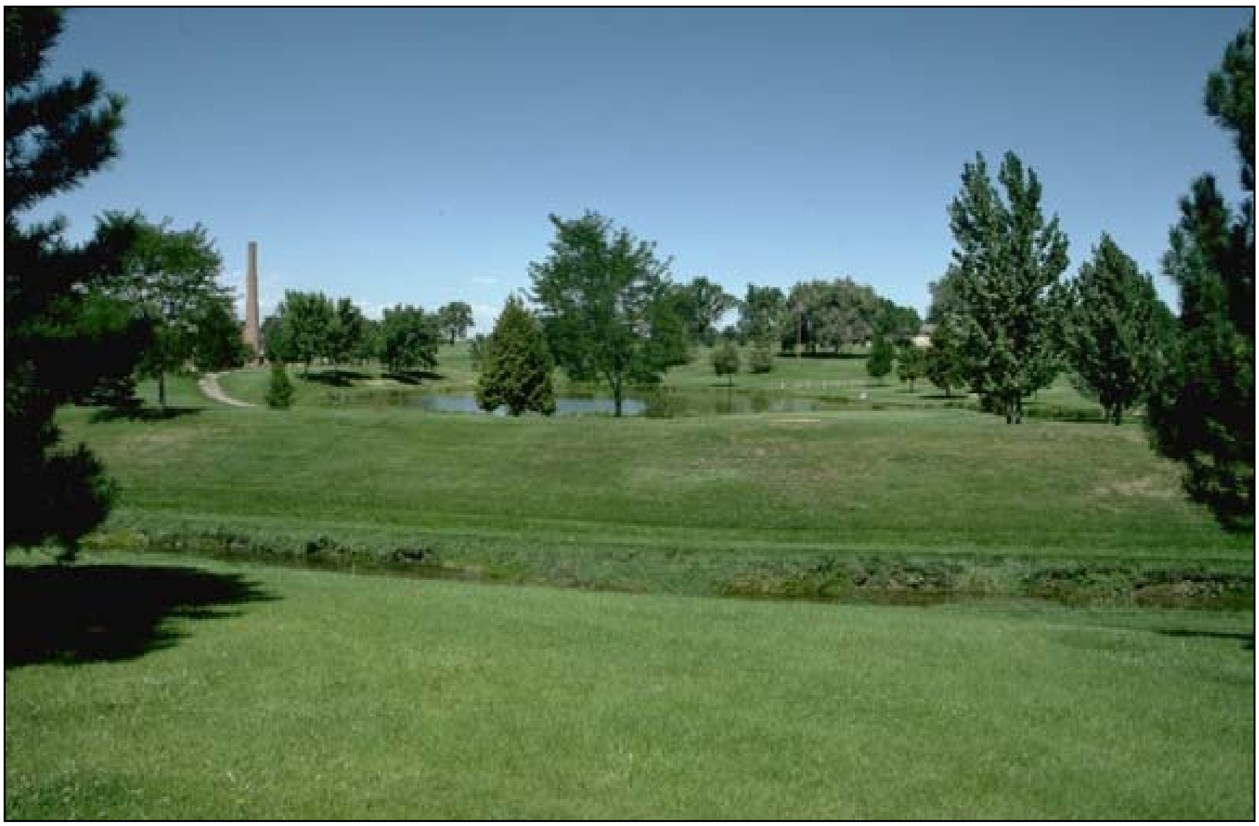
   d. Cooperation in flood damage data collection programs.

4. Use of major public programs that are available (e.g., urban renewal, public health, open space, code enforcement, highway programs and demonstration programs).

5. The administrative devices created to undertake and implement a floodplain management program including a commitment of personnel, financing, and other resources.

1.4 Water Quality

Drainage planning for quantity (rate and volume) should proceed hand-in-hand with planning for water quality management. Generally, in urban areas, water quantity and water quality are inseparable. There are a number of best management practices (BMPs) recommended in Volume 3 of this *Manual* for use in a newly developing area to mitigate the adverse effects of increased runoff rates and volumes and pollution, both during construction and after the occupancy permits have been issued. Another essential aspect of water quality protection is stream channel stability. Unstable channels can experience significant degradation and aggradation, both of which can damage aquatic life. Consequently, channel stability must be assured during the planning process.



Photograph PL-2—A stable channel coupled with wet detention for the outlet of a large storm sewer system provides Denver enhanced water quality in Harvard Gulch.

2.0 EARLY PLANNING ADVANTAGES

2.1 Advantages

There are many advantages to the developers, residents, and local governmental agencies when drainage planning is undertaken early. These advantages include lower-cost drainage facilities and facilities that provide integrated benefits to the community. The drainage engineer, planner, and the entire design team should work in close cooperation to achieve maximum urban benefits.

Good urban drainage planning is a complex process. Basic planning considerations that should be taken up early include planning for the major drainage system, the initial drainage system, and the environment.

2.2 New Development

When planning a new subdivision for residential purposes, various drainage concepts should be evaluated before decisions are made as to street location and block layout. It is perhaps at this point in the development process where the greatest impact can be made as to what the drainage facilities will cost and how well they will do their job. When flood hazards are involved, the planning consultant should take these hazards into consideration in land planning to avoid unnecessary complications with local planning boards and governments.

Planners, both governmental and private, are encouraged to confer and work with the drainage engineer. The earlier drainage problems are identified and planned for, the better the final resulting plan will be. Compromising on drainageways in a new development may appear to have short-term benefits, but long-term urban interests suffer as a result. Good drainage policy and practices should be uniformly and consistently applied.

2.3 Get the Facts

The importance of obtaining the facts, including technical and community-based information that affects the drainage program, cannot be overemphasized even in the early planning stages of development. With the aid of the collected facts, defining the objectives of the drainage system, as well as the problems that will be encountered in implementing the drainage plan, can be the most important step in the planning process. As the planning process progresses, the defined objectives will need to be reevaluated for affordability and practicability of implementation, sometimes requiring adjustment of the initial set of objectives.

2.4 Regulatory Considerations

One of the essential elements of early planning is to address regulatory requirements at the federal, state and local level. Drainage projects will frequently trigger the need for environmental permits related to (for example): wetlands and “Waters of the United States;” stormwater discharges; dewatering discharges;

and local water quality, wetland or other protection ordinances. A solid understanding of these and other regulatory programs is imperative, as they can significantly affect the design, construction and long-term maintenance of channels, ponds, wetlands, and other facilities.

Photograph PL-3—An engineered wetland channel can serve as a filter for low flows and yet carry the major flood event without damage.

3.0 CONSIDER DRAINAGE BENEFITS

3.1 Benefits

The planner should be cognizant of the additional benefits that can be derived from a good urban drainage plan. It is generally recognized that an urban area that has well-planned drainage facilities is usually an area that experiences orderly growth.

Some of the additional benefits that are derived from good urban drainage systems are:

1. Benefits to upstream property owners resulting from elimination of downstream constrictions and increased conveyance capacity.
2. Reduced problems to downstream property owners and receiving systems resulting from managed runoff and stable waterways.
3. Improved water quality.
4. Protection and enhancement of environmentally sensitive areas.
5. Reduced street maintenance costs.
6. Reduced street construction costs.
7. Improved traffic movement.
8. Improved public health and environment.
9. Lower-cost open space.
10. Lower-cost park areas and more recreational opportunities.
11. Development of otherwise undevelopable land.
12. Opportunities for lower building construction cost.
13. Controlled rising groundwater table after urbanization.

Professionals from other disciplines, including urban hydrologists, sociologists, economists, traffic engineers, civil engineers, public health professionals, attorneys, geographers, ecologists, landscape architects, and others can contribute to the formulation of plans for additional benefits.

4.0 MASTER PLANNING

4.1 Master Plan

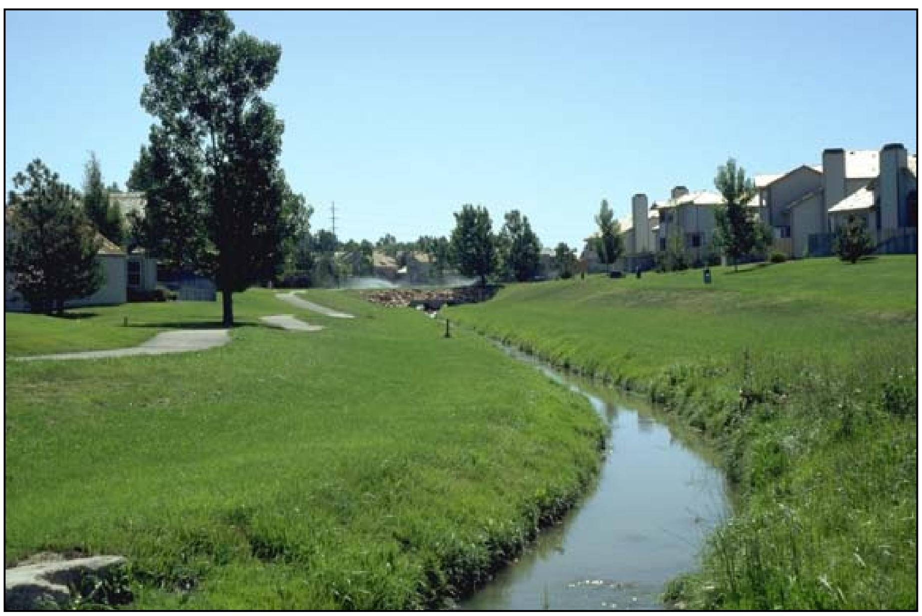
A master plan is an overall plan into which the details of other specific plans are fitted, providing overall guidance for future actions and improvements for all or part of an evolving watershed. It is generally a regionally conceived plan based on examination of the total system that, with the aid of public participation, bridges a variety of perspectives and jurisdictional boundaries. It is a road map for future drainage and flood control watershed actions, irrespective of political boundaries.

A drainage master plan for an urbanizing area is helpful to both the developer and the municipality. The drainage master plan must be based on good environmental design techniques and address the goals and needs of the urban area. It should not be prepared only on the basis of drainage hydraulics and not be limited to moving stormwater runoff from one location to another.

A master plan for drainage will only be effective if it is coordinated with planning for open space, transportation, water quality, urban wildlife, and other urban considerations.

4.2 Uniformity

A uniform approach to master planning of drainage in a region brings better results than when different approaches are utilized by each planning effort, depending upon the particular planning team's past experiences and training.



Photograph PL-4—Use of uniform design standards represents a reasonable standard of care for urban flood channels.

5.0 PLANNING FOR THE FLOODPLAIN

5.1 Floodplains

Planning addresses many issues that deal with floodplains and the necessity of floodplain zoning. It is necessary to understand the nature and concept of floodplain regulation before serious floodplain management planning can proceed intelligently. The planner must also consider the national flood insurance program, set forth in the National Flood Insurance Act of 1968, as amended (NFIA 1968).

5.2 Concept of Floodplain Regulation

On any floodplain, nature possesses, by prescription, an easement for intermittent occupancy by runoff waters. Man can deny this easement only with difficulty. Encroachments upon or unwise land modifications within this easement can adversely affect upstream and downstream flooding occurrences during the inevitable periods of nature's easement occupancy.

Government has a responsibility to protect the public's health and safety. Thus, it is implicit that government may permit unwise occupancy or use of the natural easement only at the risk of incurring liability.

Urbanization typically modifies the natural hydrologic and water quality response of its drainageways. Because urbanization usually proceeds in accordance with land use rules and land development regulations prescribed by local government and with the review and approval of detailed development plans, local government in effect becomes a party to the inevitable hydrologic modifications. It follows that a community cannot disclaim liability from consequences of such development, either upon the developed area itself or downstream there from.

Floodplain regulation is the government's response to limit its liability along natural drainageways and is an exercise of its health and safety protective function. The concept of the existence of a natural easement for the storage and passage of floodwaters is fundamental to the assumption of regulatory powers in a definable flood zone. Floodplain regulation, then, must define the natural easement's boundaries and must delineate easement occupancy that will be consistent with total public interests.

5.3 Tools

Key components of floodplain planning include reduction of the exposure to floods, use of development policies, disaster preparedness, flood proofing (see the FLOOD PROOFING chapter), flood forecasting, flood modification, and modification of the impact of flooding.

6.0 PLANNING FOR MAJOR DRAINAGE

6.1 Major Drainage

The major drainage system planning is the key to good urban drainage in newly developing areas. The general lack of good, open-surface major drainage in older urban areas often requires expensive storm sewer retrofit projects.

A major conduit or channel has an impact upon an urban area, and much depends upon its proper functioning. It is usually a box culvert, a large pipe, or an open channel. As an open channel, it may be a stabilized natural waterway, a modified natural channel, or an artificial channel with grass or other lining. The character of the major drainageway often changes from reach to reach to account for neighborhood needs and general environmental requirements.

The planner and designer have great opportunities when working on major drainageways to help provide a better urban environment for all citizens. The challenges and opportunities are particularly great for those having the opportunity to plan and design works in core areas of cities.

The conceptual design of a major drainageway channel or conduit is that portion of the engineer's job that is most important and that has the greatest effect on the performance and cost of the works. Imagination and general hydraulic experience of the engineer are the most important tools in the preliminary planning and design stage.

6.2 Initial Route Considerations

A preliminary estimate of the design rate of flow is necessary to approximate the channel's or conduit's capacity and size. This estimate can be made by comparisons with other similar basins where unit rates of discharge have been computed or by computing preliminary hydrographs.

Routing of the major drainageway is usually a straightforward matter of following the natural valley thalweg (i.e., the lowest point in the drainageway, sometimes also called channel invert) and defining it on a map. In many urbanized areas, however, there is no thalweg, or the thalweg has been filled and built upon. For these cases, it is necessary to determine many factors before the route is chosen. A meeting should be held with the owner and with the appropriate government officials to explain the routes studied, the conclusions, and the choice. At the same time, the types of channels or conduits being considered should be presented and suggestions or concurrence should be obtained. A dialogue with citizen groups is encouraged where various alternates can be explained.

6.3 The Master Plan

The major drainage master plan must be true to its name to be effective in urban drainage. It must be a team consensus with thorough attention to engineering concepts and details. The completed plan must be suitable for day-to-day use by local and regional governmental administrators.

The master plan portion of the planning phase is where major decisions are made as to design velocities, location of structures, means of accommodating conflicting utilities, approaches to minimize adverse environmental impacts and the potential alternate uses in the case of an open channel, among others.

The master plan is also where decisions need be made on the use of downstream detention storage, either off-stream or channel ponds or reservoirs. Upstream storage should also be evaluated along with BMPs for both quantity and quality.

6.4 Open Channels

Open channels for use in the major drainage system have significant advantages in regard to cost, capacity, multiple uses for recreational and aesthetic purposes, environmental protection/enhancement, and potential for detention storage. Disadvantages include right-of-way needs and the need for more frequent maintenance. Careful planning and design are needed to minimize the disadvantages and to increase the benefits.

Channel instability is a well-recognized problem in urbanizing areas because of the significant increase in low flows, storm runoff flow rates and volumes, and erosion along the waterways that cause increased sediment concentrations. The volume of storm runoff, peak discharge rate, and frequency of bankfull discharges from an urban area are usually significantly larger than under historic conditions (Leopold 1994; Urbonas 1980; ASCE and WEF 1992; and WEF and ASCE 1998). A natural channel must be studied to determine what measures are needed to avoid future bottom scour and bank cutting. Structural measures can be implemented that will preserve the natural appearance, minimize cost, and assure proper channel function during large events. These include features such as grade control structures, drop structures, and bank stabilization.

In cases of a meandering channel, it may be necessary to provide a buffer zone outside of the floodway or floodplain to account for future channel movement. Likewise, where a deep, incised channel exists, a buffer zone allowance should be provided for bank sloughing and future channel modification by creating a setback line computed at a bank slope of 4(H) to 1(V) measured from the channel bank's bottom.

The ideal channel is one shaped by nature over a long period of time. Unfortunately, urbanization changes the hydrology that has shaped the channel, which, in turn, destabilizes it. Providing for features to keep a natural channel from rapid degradation is an important part of any master plan. The benefits of a stabilized natural channel can include:

1. Lower flow velocities, resulting in longer concentration times and lower downstream peak flows.

2. Channel and adjacent floodplain storage that tends to decrease peak flows.

3. Lower maintenance needs.
4. Protection of riparian and aquatic habitat.
5. A desirable greenbelt and recreational area that adds significant social benefits.

While recognizing the need for at least some stabilization measures to address the hydrologic changes caused by urbanization, the closer an artificial channel character can be made to that of a natural channel, the greater the public acceptance.

In many areas about to be urbanized, the runoff has been so minimal that well-defined natural channels do not exist. However, subtle low areas nearly always exist that provide an excellent basis for location and construction of channels. Good land planning should reflect even these minimal drainageways to reduce development costs and minimize drainage problems. In many cases, wise utilization of natural water routes in the development of a major drainage system will eliminate the need for an underground storm sewer system.

A wide variety of channel types are available to the design team, depending on good hydraulic practice, environmental design, sociological impact, basic project requirements and other factors. However, from a practical standpoint, the basic choice to be made initially is whether or not the channel is to be a lined one for higher velocities, a wetland bottom channel, a grass-lined channel, a stabilized existing natural channel, or a bioengineered channel, all of which are discussed in the MAJOR DRAINAGE chapter.

The actual choice must be based upon a variety of multidisciplinary factors and complex considerations that include, among others:

1. Hydraulic Factors
   - Slope of thalweg
   - Right-of-way
   - Capacity needed
   - Basin sediment yield
   - Topography
   - Ability to drain adjacent lands
   - Permitting requirements
2. Structural Factors
   - Costs
   - Availability of material
   - Areas for wasting fill

3. Environmental Factors
    - Water quality
    - Neighborhood character
    - Neighborhood aesthetic requirements
    - Needs for new green and riparian areas
    - Street and traffic patterns
    - Municipal or county policies
4. Sociological Factors
    - Neighborhood social patterns
    - Neighborhood children population
    - Pedestrian traffic
    - Recreational needs
5. Regulatory Factors
    - Federal government permits, such as a Section 404 permit
    - State government permits
    - Local government permits

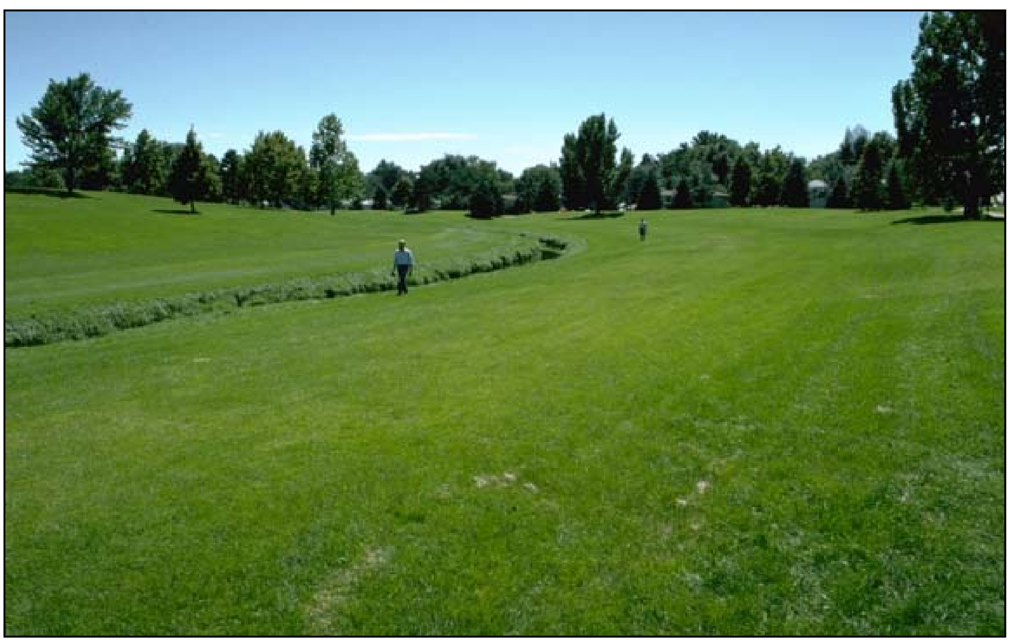
Prior to choosing the channel type, the designer should be sure to consult with experts in related fields in order that the channel chosen will create the greatest overall benefits. When practical, the channel should have slow flow characteristics, be wide and shallow, and be natural in its appearance and functioning.

Grass-lined channels, wetland bottom channels, and bioengineered channels with adequate structural enhancement may be the most desirable artificial channels. The channel storage, lower velocities, environmental benefits, and sociological benefits obtainable create significant advantages over other types. The design must give full consideration to aesthetics, sediment deposition, water quality, maintenance, scour, and hydraulics.

Many open waterways in the western and southern parts of the Denver region have experienced the effects of urbanization and are often steep-banked gulches that have erodible banks and bottoms. On the other hand, a number of natural waterways exist in the northern and eastern parts of the District that have milder slopes, are somewhat stable, and are not in an obvious state of degradation. However, for either type of channel, when it begins to carry storm runoff from an urbanized area, the changed runoff regime will result in new and highly active erosional tendencies. Careful hydraulic analysis of natural channels must be made to foresee and counteract these tendencies. In nearly all cases, some modification of the channel will be required to create a more stabilized condition so it can handle changes to surface runoff created by urbanization.

With most Denver area natural waterways, it is necessary to construct grade controls or drop structures at regular intervals to decrease the thalweg (channel invert) slope and control erosion. When site conditions are conducive, channels should be left in as near a natural condition as feasible, subject to the requirement of demonstrated stability during the major event. Extensive channel modifications should not be undertaken unless they are found to be necessary to avoid excessive erosion with subsequent sediment deposition downstream and water quality deterioration.

Because of the decided advantages that are available to a community by utilizing natural waterways for urban storm drainage purposes, the designer should consult with experts in related fields for the method of development. It is important to convene a design team to develop the best means for using a natural waterway. Sometimes it will be concluded that park and greenbelt areas should be incorporated into the channel works. In these cases the usual constraints of freeboard depth, curvature, and other rules applicable to artificial channels may be different or may not apply. For instance, there are significant advantages that may accrue if the designer incorporates relatively frequent (e.g., every five years) overtopping of the formal channel, thus creating localized flooding of adjacent areas that are laid out and developed for the purpose of being inundated during the major runoff peak.



Photograph PL-5—A wide-open waterway carries floodwater at modest depths while maintaining low velocities to inhibit erosion.

7.0 PLANNING FOR INITIAL DRAINAGE

7.1 Initial Drainage

Planning and design for urban storm runoff must be considered from the viewpoint of the regularly expected storm occurrence, which includes the initial storm and the major storm. The initial storm has been defined for the area served by the District to have a return frequency ranging from once in 2 years to once in 10 years. The major storm has been defined to have a return period of 100 years. The objective of major storm runoff planning and design is to reduce the potential for major damage and loss of life. The initial drainage system is necessary to reduce inconvenience, frequently recurring damages, and high street maintenance and to help create an orderly urban system with significant sociological benefits.

The initial system is sometimes termed the “convenience system,” “minor system,” “local system,” “collector system,” or “storm sewer system.”

The initial drainage system is that part of the storm drainage system frequently used for collecting, transporting, and disposing of snowmelt, miscellaneous minor flows, and storm runoff up to the capacity of the system. The capacity should be equal to the maximum rate of runoff to be expected from the initial design storm.

The initial system may include a variety of features such as swales, curbs and gutters, storm sewer pipes, open drainageways, on-site detention, “minimized directly connected impervious area” features, and water quality BMPs.

7.2 Streets

Streets serve an important and necessary drainage service, even though their primary function is for the movement of traffic. Traffic and drainage uses are compatible up to a point, beyond which drainage is, and must be, subservient to traffic needs.

Gutter flow in streets or flow in adjacent swales is necessary to transport runoff water to storm inlets and to major drainage channels. Good planning of streets can substantially help in reducing the size of, and sometimes eliminate the need for, a storm sewer system in newly urbanized areas.

Design criteria for collecting and moving runoff water on or adjacent to public streets are based on a reasonable frequency of traffic interference. That is, depending on the character of the street and as discussed in the POLICY chapter of this *Manual*, certain traffic lanes can be fully inundated during the initial design storm return period, usually once each two years. However, during this design period, lesser storms occur that will produce runoff, which will inundate traffic lanes to some smaller degree.

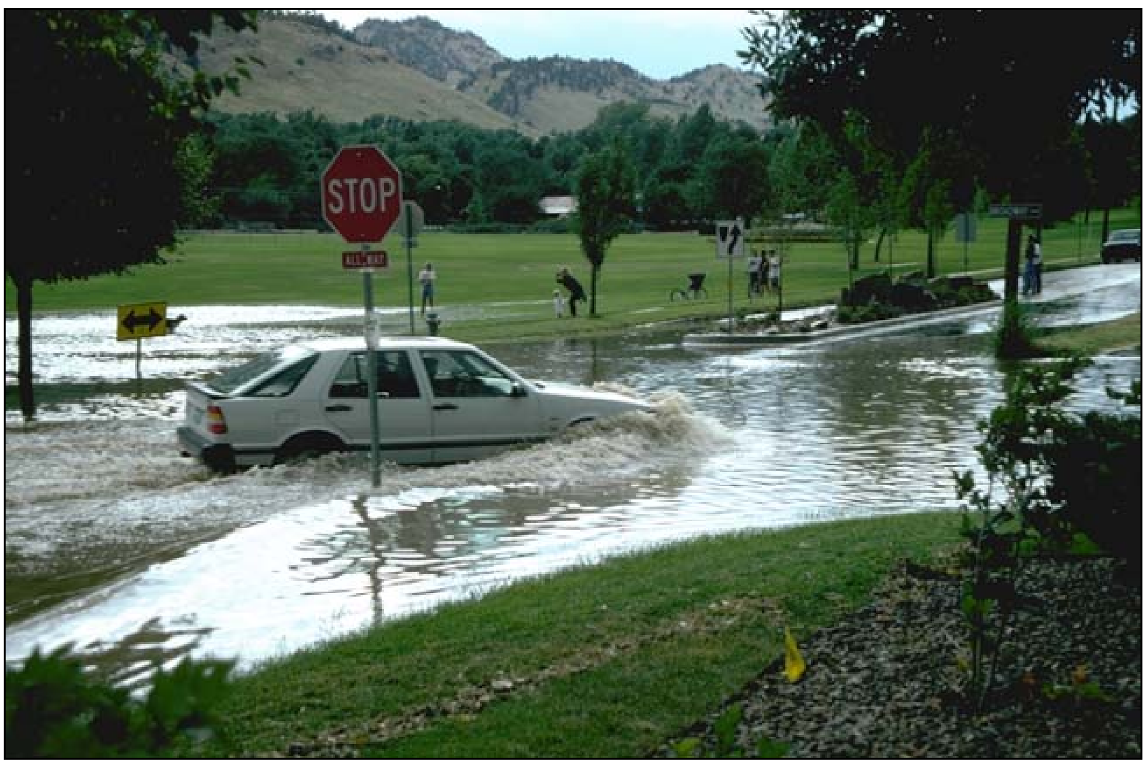
Drainage practices as related to streets are dependent on the type of street use and construction.

Classification of streets is based upon traffic volume, parking practices, design and construction, relationship to cross streets, and other criteria. The classification adopted for use herein includes:

- Local/residential.
- Collector.
- Arterial.
- Freeway.

Streets should be classified with respect to pedestrian traffic as well as vehicular traffic. As an example, streets that are classified as local for vehicles and located adjacent to a school are arterials for pedestrian traffic. The allowable width of gutter or swale flow and ponding should reflect this fact.

Inverted crown or “dished” streets shall not be utilized. The dished street design violates the basic function of a street: that of a safe vehicular traffic carrier.



Photograph PL-6—District drainage criteria are aimed at respecting the needs of safe, unimpeded traffic movement. This intersection represents a long-standing drainage problem needing a solution.

8.0 PLANNING FOR STORAGE

8.1 Upstream Storage

The drainage designer usually controls upstream storage utilization (sometimes called on-site detention) and land-shaping BMPs in the early stages of laying out a development. The architect, engineer, homebuilder, land developer, and governmental officials, however, all have a responsibility to work towards more upstream storage and effective land shaping. Upstream storage and land treatment, such as use of grass buffers and swales described in Volume 3 of this *Manual,* have the greatest potential for making good urban drainage less costly to the urban resident.

Many new urban area plans contain parks, both the neighborhood type and the large central type. Parks and recreational fields create little runoff of their own; however, they provide excellent detention potential for storage of runoff from adjacent areas. The use of parks for temporary detention of stormwater runoff can measurably increase benefits to the public, and the use of parks for such purposes is encouraged.

8.2 Downstream Storage

Downstream storage is defined as retention or detention storage situated in the downstream portions of the basin. Typically these are larger facilities that can include channel reservoirs, channel storage, and off-stream storage. The use of downstream storage to reduce storm runoff, and hence drainage costs, should be considered as supplementary to upstream storage. Benefits to be derived from downstream storage are significant and should be taken advantage of wherever possible.

The construction of pond embankments in the channel, generally where topography is favorable to the storage of stormwater runoff, can provide significant benefits in regard to reducing peak flows and settling sediment and debris, the latter helping to improve the quality of water downstream. Multiple benefits, including water quality, can be obtained by the use of on-stream storage ponds by planning and designing for a small permanent pool.

While upstream storage is usually the responsibility of upstream land developers, downstream storage is usually the responsibility of the local governmental unit because the water stored there is derived from a larger area representing many upstream tributary sources.

8.3 Channel Storage

The use of wide, slow-flow swales and natural-type channels also provides storage without constructing special embankments.

8.4 Other Benefits

Both upstream storage and downstream storage have significant multipurpose use potentials generally centered around recreational, water quality, aesthetic and, possibly, wildlife benefits. In regard to such multiple uses, it is necessary for the designer to work closely with the city planner and the recreational department of the local government.

Photograph PL-7—Urban stormwater detention basins can create neighborhood amenities that at the same time serve their flood control function.

9.0 PLANNING FOR STORM SEWERS

9.1 Storm Sewers

The term storm sewer system refers to the system of inlets, conduits, manholes, and other appurtenances that are designed to collect and convey storm runoff from the initial storm to a point of discharge into a major drainage outfall. Storm sewers are a portion of the initial drainage system that includes street gutters, roadside drainage ditches and swales, culverts, storm sewers, small open channels, and any other feature designed to handle runoff from the initial storm. Alternate terms for the storm sewer system are convenience or minor drainage system. These names are derived from the function of the storm sewers, which is to prevent inconvenience and frequently recurring damage caused by the more frequently occurring smaller storm events.

The initial drainage system, including storm sewers, is that portion of the total drainage system that often receives the most attention from engineers. It is what the average citizen considers to be the urban drainage system. It is what directly contributes to the orderly growth of a community by handling the storm runoff expected to occur once every two to ten years.

The initial system exists even without storm sewers. Storm sewers are needed only when the other parts of the initial system no longer have capacity for additional runoff. A good major system of drainage coupled with wise layout of streets can often significantly reduce the need for storm sewers. The more inadequate the major system is, the more costly the storm sewers are.

9.2 Function of Storm Sewers

Storm sewers belong to the initial drainage system, as do curbs and gutters, roadside swales and roadside ditches. The more distant the point of outfall for the storm sewer, the more extensive the system must be. It is for this reason that the major drainage system takes on importance in regard to the storm sewer system. Generally, the better the major system is, the shorter the storm sewers.

In older built-up urban areas, the storm sewer system may be the only existing planned drainage works. When the capacity of the storm sewers is exceeded, the excess water flows in an unplanned manner overland, often causing damage and loss. The intent of planning and designing for major drainage is to control and manage the large runoff, which exceeds the capacity of the initial system.

9.3 Layout Planning

The preliminary layout of a storm sewer system should consider urban drainage objectives, urban hydrology, and hydraulics. The preliminary layout of the system has more effect on the success and cost of the storm sewers than the final hydraulic design, preparation of the specifications, and choice of materials.

The ideal time to undertake early work on the layout of the storm sewers is prior to finalizing the street layout in a new development. Once the street layout is set, the options open to the drainage engineer to provide a more cost-effective system are greatly reduced. Various layout concepts should be developed and reviewed, and critical analyses should be done to arrive at the best layouts. For example, the longer street flow can be kept from concentrating in one street, the further the distance from the divide the storm sewer system can begin. In storm sewer design remember that small-diameter laterals represent a large part of the construction cost. Planning a storm sewer system should have as its objective the design of a balanced system in which all portions will be used to their full capacity without adversely affecting the drainage of any area.

9.4 System Sizing

The runoff or rainfall return period to be utilized for designing a storm sewer system is a choice local governments must make. Whenever the system crosses jurisdictional boundaries, differences in sizing policies for the initial system must be worked out between these jurisdictions so that a consistent design is achieved for the entire system serving two or more communities.

The suggested design return periods to be used by local jurisdictions in the Denver region for storm sewer design for all land uses is 2- to 10-years. This is a departure from the policy of recommending different return periods for different land uses. Experience has shown that it is not practical to vary storm sewer design by land use because a single system often serves multiple land uses. Instead, greater attention is necessary to ensure that the major system is adequate to protect the public and property within all areas, regardless of land use.

Once the overall design return period has been set, the system should be reviewed for points where deviation is justified or necessary. For example, it may be necessary to plan a storm sewer to receive more than the initial runoff from a sump area that has no other method of drainage. The sewer might be planned to receive only necessary initial runoff both upstream and downstream of this particular area.

An area must be reviewed on the basis of both the initial and the major storm occurrence. When an analysis implies that increasing the storm sewer capacity is necessary to help convey the major storm, the basic system layout of the major drainage should be analyzed and changed, as necessary.

9.5 Inlets

A stormwater inlet is an opening into a storm sewer system for entrance of surface storm runoff. There are four typical categories of inlets:

1. Curb opening inlets

2. Grated inlets

3. Combination inlets

4. Multiple inlets

In addition, inlets may be further classified as being on a continuous grade or in a sump. It is recommended that curb opening and combination inlets generally be utilized in the design of storm sewer systems, particularly when a sump condition exists. Although these inlets will not guarantee against plugging, they are the most dependable.

9.6 Alternate Selection

The best alternate is chosen on the basis of numerous considerations, one of which is cost. Cost, however, should not be overemphasized. The choice should be based, in part, upon the total benefit-cost ratio, taking into consideration other community benefits and needs.

Photograph PL-8—Planning for storm sewers is aimed at maintaining an orderly urban area where stormwater street flow is limited to predetermined levels.

10.0 PLANNING FOR OPEN SPACE

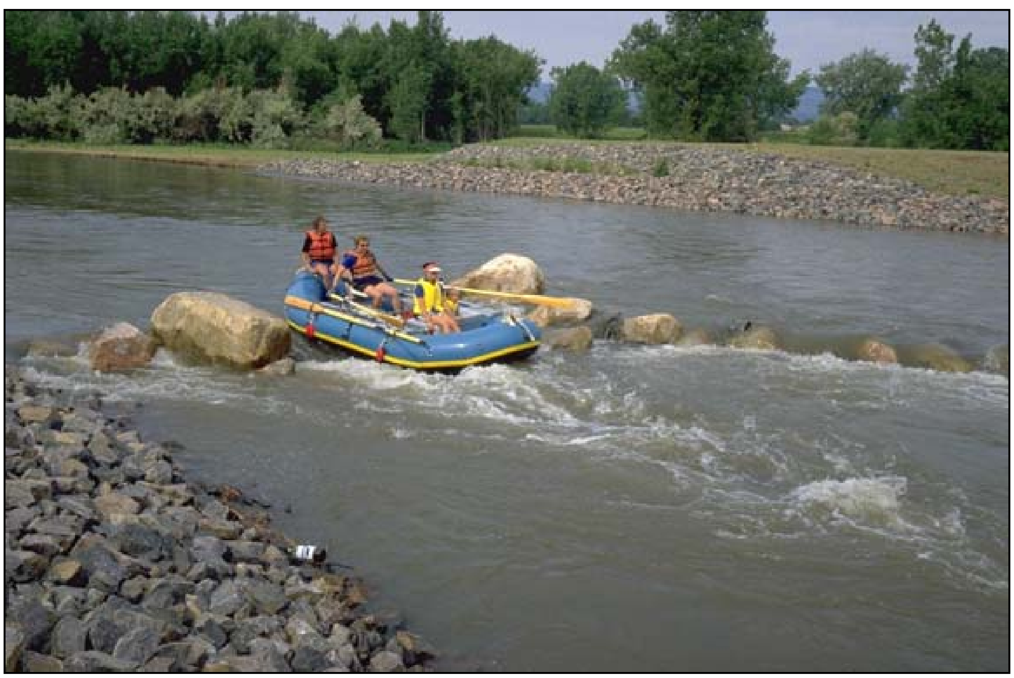
10.1 Greenbelts

Waterways can make excellent greenbelts and riparian zones because the needs for drainage and the needs for greenbelts and riparian zones are often compatible.

The land along natural streams and gulches has already been chosen by Mother Nature as a storm runoff easement for intermittent occupancy. Only humans, based on cost and difficulty, can deny this easement. Nature will always extract some price for use of its floodplains.

Zoning land for floodplains and limiting the potential use of such land provide ideally situated open space, greenbelts and potential riparian zones. Acquisition cost of the land for greenbelts and riparian zones should be lower because of the limited potential of the land for development without costly works and major federal regulatory constraints. In appraisal work, adjustments are made to comparable sales to make them equal to the subject property. One adjustment is typically the risk factor for flooding and whether or not the subject property is in a floodplain or a floodway.

The design team should develop the park and greenbelt needs in conjunction with the master planning of the major drainage channels and floodplain zoning. To wait means that a good opportunity may be lost.



Photograph PL-9—Open space, stable channels and recreation go hand-in-hand towards creating urban amenities.

11.0 PLANNING FOR TRANSPORTATION

11.1 Coordination Needed

The planning, design, and construction of transportation facilities including local, state, and federal highways, railroads, utilities involving conduits, and airports often involve crossing or paralleling major channels and streams. Many of the flood problems presently existing are created by inadequate waterway openings (bottlenecks) under transportation facilities. These inadequate openings have been a result of various deficiencies, including lack of appropriate basic criteria, lack of good planning, lack of proper hydraulic engineering, and lack of coordination between the various agencies involved with drainageways.

Many storm drainage problems can be avoided by special cooperation and coordination between the various governmental, state, county, local, and publicly owned agencies in the very early stages of planning for storm drainage works. This is absolutely essential if proper drainage is to be provided at the lowest reasonable cost. Proper coordination will make it possible to solve many of the inherent initial design and monetary problems connected with storm drainage.

Transportation agencies often get involved in constructing drainage works that are necessary for draining their own facilities. Planning such drainage facilities should be integrated with the total urban system and the drainage subsystem of the adjacent urban area in question. At times this will indicate that the drainage facilities constructed for a transportation facility, for instance, should intercept and convey storm runoff from a significant urban drainage basin. In design and construction of sound barriers along freeways, which in essence can act as dams across drainageways, it is possible for the highway designers to neglect the major drainage needs of the uphill land, sometimes creating flooding problems upstream of the sound barrier. A similar situation develops when a roadway embankment or a median barrier is constructed across a drainageway. These can create community costs that should be avoided. It is in these cases that cooperation with the local governmental entity is particularly advantageous so that joint planning, design, and construction can result in a better urban environment.

12.0 CLEAN WATER ACT SECTION 404 PERMITTING PROCESS

12.1 Purpose of the 404 Permit

The stated purpose of the U.S. Army Corps of Engineers (USACE) Section 404 program is to insure that the physical, biological, and chemical quality of our nation's water is protected from irresponsible and unregulated discharges of dredged or fill material that could permanently alter or destroy these valuable resources.

12.2 Activities Requiring Permit

Section 404 of the Clean Water Act requires approval from the USACE prior to discharging dredged or fill material into the waters of the United States. Typical activities within the waters of the United States (which include adjacent wetlands) requiring Section 404 permits are:

- Site development fill for residential, commercial, or recreational construction
- Construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs
- Placement of riprap
- Construction of roads
- Construction of dams
- Any grading work affecting waters of the United States

12.3 Who Should Obtain a Permit

Any person, firm, or agency (including federal, state, and local government agencies) planning to work, dump, or place dredged or fill material in waters of the United States, must first obtain a permit from the USACE. Other permits, licenses, or authorizations may also be required by other federal, state, and local agencies, and the issuance of a 404 permit does not relieve the proponent from obtaining such permits, approvals, licenses, etc.

12.4 Definition of Waters of the United States

Waters of the United States include essentially all surface waters such as all navigable waters and their tributaries, all interstate waters and their tributaries, all wetlands adjacent to these waters, and all impoundments of these waters.

"Wetlands" are areas characterized by growth of wetland vegetation (e.g., bulrush, cattails, rushes, sedges, willows, pickleweed, andiodine bush) where the soil is saturated during a portion of the growing season or the surface is flooded during some part of most years. Wetlands generally include swamps, marshes, bogs, and similar areas.

12.5 Pre-Application Meetings

Pre-application meetings with the USACE and other regulatory agencies are encouraged by the USACE to facilitate the review of potentially complex or controversial projects, or projects that could have significant impacts on the human environment. Pre-application meetings can help streamline the permitting process by alerting the applicant to potentially time-consuming concerns that are likely to arise during the evaluation of their project.

13.0 REFERENCES

American Society of Civil Engineers and Water Environment Federation (ASCE and WEF). 1992. *Design and Construction of Urban Stormwater Management Systems*. American Society of Civil Engineers Manuals and Reports of Engineering Practice No. 77 and Water Environment Federation Manual of Practice FD-20. New York: ASCE.

Jones, D.E. 1967. Urban Hydrology—A Redirection. *Civil Engineering* 37(8):58-62.

Leopold, L.B. 1994. *A View of the River*. Cambridge, MA: Harvard University Press.

National Flood Insurance Act. 1968. *U.S. Code*. Vol. 42, secs. 4001-4129.

Urbonas, B. 1980. Drainageway Erosion in Semi-arid Urbanizing Areas. *Flood Hazard News* 10:1-2, 8.

Water Environment Federation and American Society of Civil Engineers (WEF and ASCE). 1998. Urban Runoff Quality Management. American Society of Civil Engineers Manuals and Reports of Engineering Practice No. 87 and Water Environment Federation Manual of Practice FD-23. Alexandria, VA: Water Environment Federation.