Chapter 3
Planning

Contents

1.0 Importance of Drainage Planning

Planning the urban storm runoff system is fundamental for protection of public health, safety, welfare and the environment. The urban storm drainage system is a subsystem of the total urban infrastructure system and should be integrated with other subsystems including transportation, parks, open space, and utilities. When properly planned in concert with other subsystems, the storm drainage system can provide multiple benefits to urban communities. Effective planning requires an understanding of both urban and drainage planning, as well as the many social, technical, and environmental issues specific to each watershed.

Photograph 3-1. Bible Park with fully integrated drainage, flood control, recreation, and open space functions represents a partnership among engineers, landscape architects, planners, and parks and recreation professionals.

Drainage engineers should be included in urban planning from the beginning. Conducting drainage planning after decisions are already made regarding the layout of a new subdivision, commercial area or the transportation network often leads to costly and difficult drainage solutions and urban space allocation problems. When included early in the planning process, drainage engineers are able to work with the planning team to maximize benefits from drainage systems, including amenities such as recreation and open space. Consideration of multiple uses and benefits in drainage planning and engineering can reduce drainage costs and increase benefits to urban communities.

Urban Drainage and Flood Control District (UDFCD) has been engaged in drainage master planning for watersheds and streams in the metropolitan Denver area since the early 1970s. During the planning process, planners and engineers evaluate hydrology and identify important constraints, areas of open space preservation, needs for easements, opportunities for recreation and other multi-use opportunities, and means of accommodating utility conflicts. The team will develop design alternatives for locations and types of structures and facilities while also evaluating the suitability, type, and location of detention basins and water quality facilities. This is also a good time to identify opportunities and criteria to decrease the effective imperviousness of the built watershed through minimizing directly connected impervious areas. The planning process includes active participation by sponsoring municipalities, UDFCD and other regulatory stakeholders and includes public meetings and outreach to obtain community stakeholder input. Through public input and technical analysis, alternatives are vetted to make decisions and arrive at a conceptual plan for the system that is technically and politically feasible.

1.1 Planning Philosophy

> **A Resource in Place**
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> The urban stormwater planning process should attempt to make drainage, which is often a “resource out of place,” a “resource in place” that contributes to the community’s general wellbeing.

Urban drainage planning should proceed on a well-organized basis with a defined set of drainage policies supported by local ordinances. The policies, objectives and criteria presented in this manual provide a foundation on which additional local policies can be built. Many local ordinances and municipal stormwater permits incorporate the criteria in the Urban Storm Drainage Criteria Manual (USDCM) by reference.

Drainage must be integrated early into the fabric of the urban layout, rather than be superimposed onto a development after it is laid out. The planning and design team should think in terms of natural drainage easements and street drainage patterns and should coordinate efforts with the drainage engineers to follow the policies and achieve the objectives presented in the USDCM.

Urban drainage planning should address three key components:

1. Minor (Initial) Drainage System: As defined in the *Policy* chapter, the minor (or initial) drainage system includes conveyances such as grass swales, streets and gutters, storm drains, and roadside ditches. It may also include conveyance and storage-based water quality facilities. If the initial drainage system is properly planned and designed, complaints from the community related to localized flooding and drainage nuisance conditions will be reduced. A well-planned initial drainage system provides for convenient drainage, reduces costs of streets, and minimizes disruptions to the function of urban areas during runoff events.

2. Major Drainage System: A well-planned major system protects 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 regardless of whether development is situated wisely with respect to it. General principles that UDFCD has recognized in planning for the major drainage system include:

   - Water will obey the law of gravity and flow downhill regardless of whether buildings, roads and people are in its way.

   - Targeted stabilization (e.g., grade control, toe protection and other measures) before a stream begins to degrade is generally far more cost effective and environmentally beneficial than a reactive approach addressing channel stability/restoration after significant degradation has occurred.

   - The practice of straightening, narrowing, and filling natural watercourses comes at a high environmental cost. This practice also increases velocities and typically results in high maintenance costs.

> **Importance of Drainage Planning**
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> 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 more functional community infrastructure.—D. Earl Jones, 1967

3. Floodplain Management: Floodplain management is closely tied to major drainage systems. Nature's prescriptive floodplain easements along streams and rivers should be maintained using tools including floodplain/floodway delineation, floodplain regulation, open space preservation and zoning. Small waterways and gulches lend themselves to floodplain regulations in the same manner as larger creeks.

For all three of these components, drainage system planning that best serves the community follows natural drainage patterns.

Benefits of a Well Planned Drainage System

An urban area with well-planned drainage facilities is usually an area that experiences orderly growth and realizes benefits such as:

1. Fewer downstream constrictions and increased conveyance capacity for upstream property owners.
2. Better managed runoff, less pollution entering stormwater, and more 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 park and open space areas and more recreational opportunities.

1.2 Elements of Early Drainage Planning

The drainage engineer, planner, and the entire planning team should work in close cooperation, recognizing that good urban drainage planning is a complex process. Early drainage planning should include these elements and guiding principles:

1. Address fundamental drainage features and objectives, including the major drainage system, initial drainage system, stormwater water quality management, multi-use objectives, and the environment.

2. Street conveyance is an important part of the minor (initial) drainage system. For new subdivision planning, evaluate various conceptual drainage alternatives before decisions are made regarding street location and layout.

3. Consider the level of flood hazard in the planning area. Protect public safety and avoid unnecessary complications with local planning boards and governments.

4. Don't compromise on drainage in a new development to increase short-term profits. Long-term community interests will suffer as a result. Both governmental and private planners are encouraged to confer and work with drainage engineers.

5. Address federal, state and local regulatory requirements early in the planning process. Drainage projects will frequently trigger the need for environmental permits required under federal, state and/or local water quality regulations (e.g., disruption of wetlands, riparian setback ordinances). For some

Nature's Floodplain Easement

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.—Gilbert White, 1967 permits and approvals (e.g., CLOMRs, individual 404 permits, threatened and endangered [T&E] species), the review period can be lengthy. A solid understanding of applicable regulatory permits and requirements is imperative because these requirements can significantly affect the design, construction and long-term maintenance of channels, ponds, wetlands, and other facilities.

2.0 Minor (Initial) Drainage System Planning

Photograph 3-2. UDFCD drainage criteria are aimed at respecting the needs of safe, unimpeded traffic movement. This intersection represents a long-standing drainage problem needing a solution.

For the area served by UDFCD, the minor (initial) storm is defined to have a return frequency of once every 2- to 10-years. The minor drainage system is needed to convey flows from the initial design storm to reduce inconvenience, frequently recurring damages, and street maintenance costs, and to help create an orderly urban system with a multi-functional drainage system. The initial system may include a variety of features such as swales, curbs and gutters, storm drain pipes, on-site detention, runoff reduction (e.g., minimized directly connected impervious areas) practices, and water quality BMPs. Generally, the initial drainage system drains a tributary no larger than 130 acres, as the runoff from this area would be in excess of the typical capacity of these features within a street section. The initial system exists with or without storm drains. Storm drains are needed when the other parts of the initial system no longer have capacity for additional runoff. A good major drainage system coupled with wise layout of streets can often significantly reduce the need for storm drains. The *Policy* chapter and the *Streets, Inlets and Storm Drains* chapter of this manual provide policies, criteria and procedures for designing the initial drainage system, including criteria related to streets as part of the initial drainage system. The discussion in the remainder of this section is limited to planning-level considerations.

The preliminary layout of a storm drainage system should consider urban drainage objectives, hydrology, and hydraulics. The preliminary layout of the system has more effect on the success and cost of the storm drains than the final hydraulic design, preparation of the specifications, and choice of materials. For this reason, preliminary work on the layout of the storm drains should occur prior to finalizing street layout in a new development. Once the street layout is set, options 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 that street flow can be kept from concentrating in one street, the further gutters or swales can be used for conveyance. This will reduce the length of pipe required. In storm drain design, it is important to remember that small-diameter laterals represent a large part of the total construction cost. A key planning objective should be the design of a balanced system in which all portions will be used to their full capacity without adversely affecting the drainage of areas served by the system. See the *Streets, Inlets, and Storm Drains* chapter for limitations of street flow.

Another fundamental planning consideration for the initial system is the runoff or rainfall return period for designing a storm drain system required by local governments. Whenever the system crosses jurisdictional boundaries, differences in sizing policies for the initial system must be coordinated so that a consistent design is achieved for the entire system. Once the overall design return period has been established, the system should be reviewed for points where deviation is justified or necessary. A drainage area must be reviewed on the basis of both the initial and the major storm occurrence. When analysis implies that increasing the storm drain capacity is necessary to help convey the major storm, the basic system layout of the major drainage should be analyzed and changed, as necessary. For example, in a sump area that has no other method of drainage, it may be necessary to plan for a storm drain to receive more than the initial runoff.

3.0 Drainage Master Planning Process

3.1 General

Drainage master plans provide guidance for drainage and flood control related improvements for all or part of an evolving watershed, often crossing jurisdictional boundaries and incorporating public participation. Drainage master plans are most effective when sound hydrologic and hydraulic engineering analysis is coordinated with planning for open space, recreation, transportation, water quality, urban wildlife, and other considerations. Master plans are important tools to help identify capital projects for construction by local governments. Master plans also help guide new land development projects to be consistent with regional drainage and stormwater quality needs and help to identify and acquire land and rights-of-way for future capital improvements, drainageway maintenance, and floodplain preservation. Master plan recommendations can be remedial (correcting existing problems) and/or preventive. The drainage master planning process is based on a two-pronged approach:

1. Preserve: Where development has not yet occurred, preservation of existing drainage features and associated floodplains in a manner that preserves natural flow paths, ecological benefits and natural floodplains is preferred.

2. Mitigate: Both historic and future development may require mitigation of the impacts of urbanization through improvements that stabilize or restore stream channels, detain increased runoff volumes, and improve conveyance.

An effective drainage master planning process typically begins with research and data collection, and

UDFCD's Master Planning Program

The Master Planning Program produces drainage master plans based on the following four key policy decisions which guide the program implementation:

1. Each master planning effort must be requested by the local governments and should have a multi-jurisdictional aspect;

2. Master plans are completed by consultants acceptable to all local project sponsors and UDFCD;

3. UDFCD will pay up to 50% of the study costs, with the local sponsors sharing the remainder of the costs; and

4. The master plan must be acceptable to all the affected local governments.

Master plan recommendations can be remedial or preventive and are important for identifying projects for construction. The master plans also provide valuable input to UDFCD's Five-Year Capital Improvement Program. They help new land development projects to be consistent with regional drainage and stormwater quality needs and help to identify and acquire land and rights-of-way for future capital improvements, for stream management, and for floodplain preservation.

ends with a solid conceptual design plan for future improvements that addresses multiple stakeholders' needs and can be used as a reference document for the future. The process includes technical analysis, engineering calculations, agency and public coordination, attention to the environment, and the use of sound judgment and common sense. The planning process generally includes the following tasks:

- Collection and evaluation of available reports and studies on existing drainage facilities, zoning and land ownership plans, current and future land use plans, soils information and other drainage related information.
- Coordination and meetings with the project sponsors and stakeholders.
- Performance of a site investigation to identify major drainage structures, existing problem locations and hydrologic and hydraulic parameters.
- Development of hydrology for the existing and proposed future watershed conditions, including runoff volumes and flow rates for various return periods of flooding along streams.
- Estimation of the flooding potential to properties throughout the watershed.
- Evaluation of the hydraulic capacity of the existing drainage system and facilities.
- Development of stormwater infrastructure alternatives that address stakeholders' future needs.
- Evaluation of alternatives based on criteria, estimated construction costs, potential flooding, planning constraints and/or other related issues.
- Providing a recommended plan to the project stakeholders and the affected communities.
- Determining a final selected plan for future improvements based on feedback from the stakeholders and communities.
- Preparation of the Major Drainageway Plan or Outfall System Plan and development of conceptual design documents.

Shelf Life

Drainage master plans typically have a shelf life of 20 to 30 years, gradually becoming outdated due to changes in philosophy, policy, and/or planning. They lay the foundation for development while allowing some flexibility for the design phase of developments within a watershed. Urban land development in general accordance with the master plan does not give cause to update the master plan.

3.2 Types of Drainage Plans

UDFCD works with local project sponsors to implement two types of drainage plans: Major Drainageway Planning Studies and Outfall Systems Planning Studies, as described below.

3.2.1 Major Drainageway Planning Studies

Major Drainageway Planning Studies (MDPs) are based on hydrologic analyses from CUHP and SWMM and on hydraulic analyses from HEC-RAS. These studies generally focus on the main stem of the stream, identifying a floodplain and making recommendations to mitigate the flood hazard, as well as to improve the safety and function of the stream. These studies are often completed in conjunction with a Flood Hazard Area Delineation (FHAD) studies. Improvements evaluated may include:

- Channel enlargement and/or stabilization of channel banks and bottom.
- Longitudinal grade control of channel invert.
- Crossing structure improvements.
- Floodplain preservation.
- Detention for flood mitigation.
- Acquisition of flood prone properties.
- Water quality protection strategies and treatment facilities.
- Restoration of a natural stream system.
- Maintenance access.

A benefit-cost analysis is performed for reaches where structures are identified in the 100-year floodplain to assist in the alternative selection process. The benefit is primarily measured in reduced flood damages to existing structures as a result of recommended improvements, though it is important to also identify other intangible (or at least difficult to valuate) benefits like improved water quality, reduction/elimination of street flooding, public safety, aesthetics, and recreation (either active recreation such as organized sports and individual exercise, or passive recreation which may simply entail being in the open space). Time spent in an urban open space for recreation offers the healthful benefit of an aesthetic and psychological reprieve from the urban environment.

3.2.2 Outfall Systems Planning Studies

Outfall Systems Planning Studies (OSPs) are also based on hydrology from CUHP and SWMM but utilize only limited hydraulic analyses (no HEC-RAS). These studies only rarely identify a regulatory floodplain. OSPs typically focus on a watershed tributary to a large waterway that may have its own MDP. Typical types of analyses and proposed improvements may include:

- Detention for flood mitigation.
- Water quality protection strategies and treatment facilities.

- Storm drain system improvements.
- Crossing improvements.
- Channel enlargement and/or stabilization.
- Floodplain preservation.
- Maintenance access.

3.3 Phases of Planning

UDFCD's planning process proceeds in a standardized, orderly sequence, which includes three phases: 1) Baseline Hydrology, 2) Alternatives Analysis and 3) Conceptual Design. UDFCD provides standardized checklists (see www.udfcd.org) for completion of each phase of the planning process, along with specific guidelines for electronic deliverables and mapping. Each of these phases is discussed below.

3.3.1 Baseline Hydrology

Baseline hydrology defines the storm runoff volumes and peak flow rates for the 2-, 5-, 10-, 25-, 50-, and 100-year storm events under existing and proposed future build-out conditions. These runoff volumes and peak flow rates are used to evaluate the sufficiency of existing drainage facilities, identify potential drainage problems, and evaluate alternative drainage improvements. Two computer models are typically used to estimate baseline hydrology:

1. The Colorado Urban Hydrograph Procedure (CUHP): This model is used to calculate runoff for each catchment in a watershed for the 2-, 5-, 10-, 25-, 50-, and 100-year storm events. CUHP considers physical characteristics of each sub-watershed including shape, slope, impervious area, and soil conditions. See the *Runoff* chapter for a full description of CUHP.

2. The EPA Stormwater Management Model (SWMM): SWMM is used to route runoff from sub-catchments through the drainage system. Hydrograph routing considers the characteristics of conveyance elements, certain flood detention facilities, flow diversion conditions where existing storm drains cause flows to diverge from overland flow paths, and other factors.

Other models or techniques can be used to develop the baseline hydrology for MDPs and OSPs, but the CUHP and SWMM models are often preferred due to the size and complexity of study areas, degree of spatial variation in development and land-use within watersheds, and compatibility with UDFCD standards. Existing conditions used in these models are typically documented by a combination of field visits and Geographic Information System (GIS) analysis of data provided by local governments, such as imperviousness, land use, transportation infrastructure, soil types, slopes, and other features. Future conditions hydrologic analysis is completed based on future land use data from local governments, typically in the form of adopted zoning or comprehensive plans.

When developing existing and future hydrology, only detention facilities that are municipally-owned and operated and/or those with assurances for perpetual operation and maintenance are recognized in the modeling (i.e., most privately owned on-site detention and inadvertent detention are not considered in the modeling). This results in a model that conservatively bases runoff volumes and flow rates on only those flood control facilities that have a high probability of proper future maintenance and function.

Within the UDFCD planning area, master plans are often updated to reflect changes in development conditions, implementation of regional detention facilities and other factors. In these cases, a first step in hydrologic modeling is to compare results from the previous models being used to the hydrology from the study that is being updated. This is a critical step that is necessary due to changes in algorithms in CUHP and SWMM over time, as models have evolved. It is also a useful step for detecting and correcting input errors from earlier models where numeric input file formats made it more difficult to find input problems than current graphical user interfaces and GIS-based methods.[1] When there are differences in baseline hydrology results simply due to changes in model algorithms, the baseline hydrology is "calibrated" back to original model conditions.[2] Once the baseline hydrology model has been corrected and "calibrated" to the previous study, model inputs are adjusted based on current and future-projected changes in physical conditions such as revised imperviousness, regional detention, channel modifications, etc.

3.3.2 Alternatives Analysis

After completion of baseline hydrology, the alternatives analysis process is initiated based on stream reaches, sub-catchments, or other planning zones. These planning areas are typically defined based on geopolitical boundaries, changes in stream characteristics, roadway crossings and other major land features. The goal of the alternative development process is to identify problem areas within each planning reach and develop a range of alternatives that mitigate the problem. For purposes of evaluating improvements, UDFCD design criteria and guidance for improvements such as open channels, culverts, storm drains, grade control structures, stabilization measures, and detention basins (as well as the hydrologic methodologies used to size the facilities) are followed. Alternatives are then evaluated based on considerations such as right-of-way acquisition, cost, constructability, long-term maintenance issues, environmental impacts (and benefits), multiuse functionality, and public acceptance.

Although each watershed is unique and there is no standard formula that can be used for each planning study, alternatives considered typically include options such as these:

- "Status Quo" – the "do nothing" alternative that maintains the existing configuration. This alternative provides a baseline for comparison of other alternatives. There are costs associated with a "do nothing" alternative related to ongoing flooding issues, existing and future channel stability, maintenance and other factors.
- Floodplain preservation.
- Conveyance improvements including new channels and restoration/improvement of existing channels.
- Road crossings, including culverts and bridges.
- Channel stabilization – grade control structures to prevent vertical degradation and bank stabilization measures to prevent lateral migration.

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[1] This process is analogous to the Duplicate Effective and Corrected Effective modeling process that is used for FEMA floodplain modeling with HEC-RAS.

[2] This calibration exercise involves engineering judgment and familiarity with sensitivity of CUHP and SWMM to input parameters. The goal of the calibration is to obtain reasonable agreement between the previous and current studies in the context of overall hydrologic model uncertainty. Drainage engineers should exercise caution when adjusting inputs for calibration to be sure that parameters are physically realistic and within published ranges.

- Detention and/or water quality planned at the regional level. Detention and water quality are frequently planned conjunctively.
- Acquisition of flood-prone properties and other non-structural measures (e.g., easements).

Alternatives are evaluated based on many factors, including:

- The balance of detention and conveyance needed for flood mitigation.
- How the alternative fits into the existing area based on right-of-way acquisition and easements, transportation, general consistency in long-term floodplain and stormwater management along the corridor.
- Environmental considerations.
- Property rights considerations (e.g., detention is generally not proposed on private lands due to difficulty in future implementation without invoking the power of eminent domain).
- Benefit-cost analysis.
- Regulatory/permitting constraints.
- Public safety.
- Aesthetics.
- Public acceptance.
- Operation and maintenance requirements.
- Other feasibility issues.

Estimation of costs to implement improvements is a key component of the alternatives analysis. Costs for each alternative are developed based on approximate unit costs for each improvement. To assist with development of cost estimates, the UD-MP Cost workbook available at www.udfcd.org can be utilized. Typical costs considered include capital costs, land costs (e.g., ROW, permanent or temporary easement), engineering/legal/administrative costs, construction costs, maintenance costs and a contingency factor.

Regulatory constraints are also considered during the alternatives analysis phase. Implementation of drainage plans is affected by a variety of federal, state and local permit requirements. When developing drainage master plans, it is important to be aware of how these requirements can affect the feasibility of planned improvements. In particular, Section 404 permits and threatened and endangered (T&E) species issues can have significant effects on planned drainage improvements and should be considered during the planning process, not just prior to construction.

Because of the high quality wetland and riparian ecosystems associated with waterways, many species of wildlife spend part of their life cycle in these corridors. The U.S. Fish and Wildlife Service (USFWS) regulates T&E species, and if a T&E species, or habitat for a T&E species, is present in a project area, federal permitting will likely be required. Two of the most commonly encountered T&E species within the riparian areas of the Colorado Front Range are the Preble’s Meadow Jumping Mouse and the Ute Ladies'-tresses Orchid.

Section 404 Permits

Section 404 of the federal Clean Water Act regulates the discharge of dredged and fill material into waters of the United States, including wetlands. The USACE administers individual and general permit decisions, jurisdictional determinations and enforces Section 404 provisions. Prior to discharging dredged or fill material into the waters of the United States, a Section 404 permit must be obtained from the USACE. 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. Typical activities requiring Section 404 permits include:

1. Site-development fill for residential, commercial, or recreational construction.
2. Construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs.
3. Placement of riprap.
4. Construction of roads.
5. Construction of dams.
6. Any grading work affecting Waters of the United States.

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.

Other water quality permit-related requirements also apply with regard to erosion and sediment control practices during construction, as discussed further in Volume 3 of this manual.

3.3.3 Conceptual Design

Based on the Selected Plan that emerges from the alternatives analysis, the conceptual design is intended to provide guidance to the project sponsors for future planning and capital improvement projects along streams within the study area. The conceptual design typically provides reach-by-reach recommendations for improvements in terms of the problems being addressed, specific recommended actions, and expected costs (capital and long-term operation and maintenance). The conceptual design Plan includes plan and profile drawings for each reach, as well as details for typical channel sections, ditch crossings, drop structures, detention ponds, and other features. The conceptual design serves as the “roadmap” for future improvements to streams.

Major components of the conceptual design include:

- Plan Development Overview: Describes how the master plan will prevent or mitigate drainage problems and damages and documents the rationale for changes from the Selected Alternative (if any).

- Master Plan Description: Describes the Master Plan on a reach-by-reach basis, along with costs, mapping and profiles.

- Prioritization and Phasing: Discusses priority of improvements, specifically how they are interrelated to other improvements, which are independent, which need to be implemented first and which need to be implemented as a system to avoid transferring damage potential to other reaches. MS4 requirements should also be considered with phasing improvements.

- Water Quality Impacts: Describes how the plan addresses stormwater quality or mitigates stormwater quality impacts on the receiving system.

- Operations and Maintenance: Describes operations and maintenance aspects and costs of master plan.

- Environmental and Safety Assessment: Describes how the recommended alternative will affect the environmental character and public safety of each reach and how it will fit into the community being served.

3.4 Alternative Plan Components

Drainage plans typically address conveyance, channel stabilization, acquisition of flood-prone property or structures, stream crossings, detention (storage), and water quality. Each of these components is discussed further below. Although these components are discussed separately below, they are interrelated. For example, there are often tradeoffs between detention and conveyance (increasing detention storage can reduce conveyance needs and vice versa).

3.4.1 Conveyance

Conveyance alternatives consider channel improvements needed to convey large flood events (typically the 100-year flood, although lesser events may be considered to improve undersized systems). Conveyance-based alternatives can be cost effective and provide benefits to the community, especially when there is space available for integration with trails and open space. Depending on how the conveyance improvements are implemented, there can be potential for a loss or significant alteration of natural ecological resources, especially in areas with greater space constraints. As a result, the aesthetic and environmental concerns of conveyance alternatives must be carefully evaluated.

Photograph 3-4. An engineered wetland channel can serve as a filter for low flows and carry the major flood event without damage. Wetlands and vegetated overbank areas aid in providing transient storage that is beneficial for attenuating runoff.

Conveyance objectives can often be achieved by using stabilized, naturalized channels with improvements such as bridges or culverts at road crossings. In areas of existing development with flooding problems and undersized drainage systems, lined, engineered channels and/or closed systems that maximize conveyance within a limited right-of-way may be needed.

For the major drainage system, using open channels rather than closed conduits has significant advantages in regard to costs, capacity, multi-use potential, aesthetic purposes, environmental protection/enhancement, and potential for detention storage. A constraint for open channels relative to closed conduits is the greater right-of-way requirement (e.g., the inability for a roadway to be built atop the stream) for an open channel system. Careful planning and design are needed to minimize disadvantages and maximize benefits. See the *Open Channels* chapter for design principles.

Benefits of Open Conveyance

- Public Awareness – Visibility serves as a reminder to the community that stormwater quality is important and that potential for flooding exists, whereas a piped system diminishes the value of stormwater and streams and also hides the function of conveyance.
- Safety – Open channels offer eggress to escape flow when a person or animal unintentionally enters the water.
- Excess Capacity – The freeboard provided in an open channel will provide protection for a storm event higher than the design storm.
- Overbank Storage – Overbanks offer significant inadvertant detention that provides an extra level of protection that is not available when flows are conveyed underground.
- Water Quality – The natural bottom of a channel provides contact between the water and both soil and vegetation. This provides water quality benefit not available in a piped system.
- Habitat – Open channels provide opportunities for riparian vegetation and wildlife habitat.
- Education – A naturalized open channel can provide an outdoor classroom experience in an urban setting, bringing the public closer to nature.

3.4.2 Stabilization

Channel stabilization is typically needed in developing areas to mitigate the erosive impacts of urbanization. Grade control structures prevent downward incision of streams. When strategically positioned to reduce the longitudinal slope of channels, they help stabilize streams, thus protecting existing riparian zones, private and public property and urban infrastructure (DeGroot and Urbonas, 2000). The protection and/or establishment of wetland and riparian vegetation upstream of these structures is an added habitat benefit. Grade control structures also reduce silt deposits in downstream aquatic-habitat areas (Urbonas and Doerfer 2003).

Two categories of grade-control structures are typically considered in MDPs: drop structures and check structures. Drop structures are mitigation measures to raise the degraded bottom of a stream to return its elevation close to what was there before degradation occurred. Check structures are preventive and are installed as hard-points across the stream before degradation occurs. Planning for such structures is an important element in any master-planning project for urbanizing watersheds (Urbonas and Doerfer 2003).

Increasingly, other forms of channel restoration involving bioengineering methods, which go beyond traditional stabilization practices, are also being considered. See the *Open Channels* chapter for additional discussion of stream restoration techniques.

3.4.3 Acquisition of Flood-prone Properties or Structures

Acquisition of flood-prone properties and structures can be a very effective way to preserve floodplains and reduce flood hazards. Many municipalities have parks and open space programs that have acquired and continue to acquire land for this purpose, including large tracts of floodplains. When landowners develop along drainage corridors, the area within the floodplain is often dedicated to the municipality as an open space or park tract. The open space provides multiple benefits to the community including trails, recreation, wildlife and, most importantly, keeps development out of a hazardous location. Floodplain acquisition is also a major factor to consider in planning locations of detention and water quality facilities within or adjacent to the floodplain.

Acquisition is also an alternative considered in areas with frequent flooding due to undersized drainage systems, often in older neighborhoods developed before modern floodplain regulations. Although it is typically far more expensive to acquire developed lots in urban areas than undeveloped floodplain land, acquisition of flood-prone properties and structures may be necessary to upgrade undersized systems and reduce flood hazards in developed areas that have undersized drainage systems. Often the cost of infrastructure required to remove the flood hazard from one of these properties far outweighs the cost of acquiring the property when it is put up for sale.

3.4.4 Crossing Structures

Crossing structures often include transportation features that cross or run parallel to major channels and streams, along with major utilities and pedestrian bridges. Many existing flood problems are due to inadequate waterway openings (bottlenecks) under transportation facilities. These inadequate openings have resulted from lack of appropriate basic criteria or changes in criteria, lack of good planning, lack of proper hydraulic engineering, and lack of coordination between the various agencies. Many storm drainage problems can be avoided by cooperation and coordination between the various public agencies and public and private stakeholders in the very early stages of planning for storm drainage infrastructure associated with transportation features. This coordination is essential to providing proper drainage at a reasonable cost.

Transportation agencies often focus on drainage improvements needed for their specific projects; however, such planning should be integrated with drainage planning for the adjacent urban area. For example, in some cases, transportation-related drainage facilities may also need to be designed to intercept and convey storm runoff from a significant urban watershed. In design and construction of sound barriers along freeways, which can act as dams impeding conveyance, highway designers must account for the major drainage needs of the uphill land and provide a way for the water to pass under or around the sound barriers without backing up. A similar situation develops with the construction of crossings – roadway embankments or median barriers that impede flow. These can create costs that should be avoided. In such cases, cooperation between the transportation agency and the local government is particularly advantageous so that joint planning, design, and construction can result in a better urban environment.

See the *Culverts and Bridges* and the *Stream Access and Recreational Channels* chapters of this manual for specific guidance related to channel crossings that should be considered during the master planning process.

3.4.5 Detention (Storage)

Detention and retention storage for flood control are key components of drainage planning, as described in the *Policy* and *Storage* chapters of this manual. Although on-site, subregional and regional flood detention facilities all play a role in drainage and floodplain planning, only detention and retention facilities with assurances for construction and perpetual operation and maintenance are considered in master plans. For planning purposes, UDFCD adheres to the following policies when developing hydrology for the delineation and regulation of the 100-year flood hazard zones:

1. Hydrology must be based on fully developed watershed condition as estimated to occur, at a minimum, over the next 50 years.
2. No detention basin will be recognized in the development of hydrology unless:
    a) It serves a watershed that is larger than 130-acres or otherwise significantly reduces the downstream flow rate, and
    b) It provides a regional function, and
    c) It is owned and maintained by a public agency, and
    d) The public agency has committed itself to maintain the detention facility so that it continues to operate in perpetuity as designed and built.

Photograph 3-5. Urban stormwater detention basins can create neighborhood amenities that at the same time serve their flood control function.

Importance of Implementing Master Plan Recommendations

The success of any master plan depends upon whether or not it is implemented. The master plan provides a "roadmap" for the future and provides the basis for incorporating the facilities and practices it recommends as lands develop or when funds become available to design and build new facilities. It also provides coherence of function so that each stormwater management facility, whether a channel, culvert, storm sewer, or detention basin provides the needed function to make the entire system work. Site drainage cannot function in a vacuum; it is affected by what happens upstream and, in return, affects what happens downstream.

When implementing a master plan a certain amount of flexibility is warranted, however, the spirit of the plan and its major features must not be compromised if the community desires to have the system function as intended in the plan. Nevertheless, some modifications of the plan are expected over time. Any major omission of a critical plan element, such as a regional flood-detention basin, will render the plan ineffectual and create a potential for damage to public health, safety, and welfare.

Any master plan is a living document. It cannot remain static for too long without outliving its usefulness. Thus, as areas urbanize and facilities are installed, it becomes evident over time that the assumptions made when the plan was developed may have changed, or the community needs are not the same anymore. As a result, most master plans have to be updated over time.

(Urbonas and Doerfer, 2003)

Storage areas for detention and water quality can have significant multipurpose uses and benefits related to recreation, water quality, aesthetics, and wildlife. In order to maximize these benefits, early coordination among the engineer, planner, parks and open space staff, and others is needed.

As a part of local ordinances across the UDFCD region, flood detention is required for new development and redevelopment. In some areas, regional facilities provide detention while in others sub-regional and on-site facilities are common. Under certain circumstances flood detention facilities may not be needed, although volumetric water quality may still be required. This is typically only the case for onsite facilities that have all of the following characteristics:

- The area has a direct outfall to a major waterway and is a small fraction of the overall watershed area with a time of concentration that is much shorter than the watershed time of concentration. Theoretically, for a uniformly spatially-distributed design storm, the runoff peak from a small, undetained property under this condition would enter the major drainage system and flow downstream long before the peak from the overall watershed occurs. This theory it is often referred to as “beat the peak.”

- There are no benefits to be realized from detention in terms of sizing conveyance infrastructure from the property to the point of outfall.

- Undetained flows will not cause adverse impacts in terms of flooding, erosion and water quality to other structures or property, on the property or between the property and the point of outfall.

The decision on whether to grant a waiver from detention requirements typically rests with the local floodplain administrator.

3.4.6 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. Volume 3 of the USDCM provides design criteria for best management practices (BMPs) recommended to mitigate the adverse effects of increased runoff rates and volumes and pollution, both during and post-construction. Another essential aspect of water quality protection is stream stability. Unstable streams can experience significant degradation and aggradation, both of which can be detrimental to aquatic life. Consequently, channel stability must be addressed during the planning process.

Photograph 3-6. A wide, open waterway carries floodwater at modest depths while maintaining low velocities to inhibit erosion.

4.0 Floodplain Management

Urbanization modifies the natural hydrologic and water quality response of the watershed. Because urbanization usually proceeds in accordance with land use rules and land development regulations and with the review and approval of detailed development plans, the local government in effect becomes a party to the inevitable hydrologic modifications. It follows that a community cannot disclaim liability from the consequences of such development, either upon the developed area itself or downstream therefrom. Government has a responsibility to protect the public’s health and safety;

therefore, it is implicit that government is at the risk of incurring liability if it permits unwise occupancy or use of the natural floodplain easement. Floodplain regulation is the government's response to limit its liability 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 must define the natural easement's boundaries and must delineate easement occupancy consistent with total public interests.

Key components of floodplain planning include reduction of the exposure to floods, use of development policies, disaster preparedness, flood risk management (see the *Flood Risk Management* chapter). The administrative tools created to undertake and implement a floodplain management program require a commitment of personnel, financing, and other resources. Flood control planning should consider the following management measures:

- Appropriate measures to limit development of land that is exposed to flood damage including:
    - Enacting floodplain management or other restrictive ordinances (i.e., building, subdivision, housing and health codes).
    - Preempting development of vacant flood fringe areas by public acquisition of land where appropriate for good drainage and community planning.
    - Adhering to Colorado Water Conservation Board (CWCB) and/or Federal Emergency Management Agency (FEMA) higher regulatory standards (critical facilities, freeboard, minimum floor elevations, etc.).
- Appropriate measures to guide proposed development away from locations exposed to flood damage include:
    - Developing floodplain regulations.
    - Limiting access to flood-prone areas.
    - Requiring setbacks from channel banks.
    - Restricting the reconstruction without mitigation of properties damaged by floods.
    - Withholding public financing from development projects in the floodplain.
    - Withholding utilities (electricity, water, sewers, etc.) from flood-prone area development.
    - Examining equivalent or similar alternative sites.
    - Maintaining low property value assessment for tax purposes allowing flood-prone land to economically remain idle.
    - Providing incentives for floodplain dedication to the public such as density credits.
- Appropriate measures to assist in reducing individual losses by flooding in areas developed before flood damage exposure was identified include:

  - Structural flood abatement devices.
  - Flood-proofing buildings.
  - Early warning systems.
  - Emergency preparedness plans (e.g., sandbagging, evacuation, etc.).
  - Ongoing maintenance of the minor and major drainage systems.
  - Disaster relief (funds and services).
  - Tax subsidies (i.e., ameliorating assessments).
  - Floodplain acquisition.

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

- Land use planning that recognizes flood hazards and damage that values the riparian environment along streams.
- A plan for expansion of public facilities that recognizes the implications of flood hazards for sewer and water extensions, open space acquisition, and transportation.
- Implementation of measures that demonstrate an existing or proposed floodplain management program such as:
  - 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.
  - Participation in regional land-use planning.
  - Participation in available floodplain management services, including flood warning systems.
  - Cooperation in flood damage data collection programs.
- Use of major public programs that are available (e.g., urban renewal, public health, open space, code enforcement, highway programs and demonstration programs).

Finally, the planner and engineers should understand the underlying principles of floodplain regulation, the requirements of the National Flood Insurance Act of 1968 (as amended), and state and local floodplain regulations to effectively plan for flood risk management.

5.0 Multi-use Opportunities

Regional detention facilities, preserved floodplains, and naturalized streams with hydraulically connected floodplains provide a wealth of natural and beneficial functions (NBFs), as discussed in the UDFCD's "Good Neighbor Policy." The land along natural streams and gulches has already been chosen by nature as a storm runoff easement for intermittent occupancy. Nature will always exact some price for use of its floodplains, so use of this land for open space is a good choice.

Zoning land for floodplains and limiting the potential uses of such land provides for open space and greenbelts that enable preservation of riparian zones. Floodplain land acquisition costs should be lower because of the limited potential for development without costly improvements and permitting.

The design team should develop park and greenbelt objectives in conjunction with the master planning and floodplain zoning. Without this early coordination, opportunities for multipurpose benefits may be lost. Additionally, working across local government departments presents opportunities to leverage funding and achieve multi-use objectives associated with open space and regional trail master plans.

Good Neighbor Policy

In 2011, the UDFCD Board adopted a "Good Neighbor Policy," which recognized a variety of opportunities that arise from drainage planning and programs. Among these, the UDFCD Board recognized the Natural and Beneficial Functions (NBF) of floodplains; including trail corridors, parks, recreation, wildlife habitat, flood storage, and groundwater recharge, can serve as amenities to adjacent neighborhoods and entire communities. The Good Neighbor Policy states:

- The Master Planning Program will, during the preparation of storm drainage criteria, major drainage plans, outfall systems plans, and other master planning studies, identify and incorporate NBF and other opportunities.

- The Floodplain Management Program will continue to map the 1% and 0.2% floodplains in undeveloped areas in order to identify areas that are hazardous to develop, and areas of significant NBF; and to work with local governments in the management of future development in or near these hazardous areas to minimize future flood risks and maximize preservation of the NBF.

- The Design, Construction, and Maintenance (DCM) Program will, when feasible, include amenities in flood management projects that enhance neighborhoods and preserve NBF. As a result of including these amenities, the public will be drawn to the flood management projects; therefore, public safety is of paramount importance and will be included in all planning, design, construction, operation, and maintenance of these facilities.

- The DCM Program will participate with local government partners and others such as Great Outdoors Colorado and the Trust for Public Land to acquire and preserve areas of significant NBF and/or flood hazards.

- The Information Services and Flood Warning Program will continue adapting state-of-the-art information technologies to keep decision-makers, partners and other stakeholders informed concerning past, present and future flood threats; and will provide local governments, consultants, affiliates, and the general public with easy access to educational material, publications and other helpful information associated with UDFCD programs and activities.

Utah Park: A Multi-Use Success Story

Utah Park, located at the northeast corner of Peoria Street and Jewell Avenue in Aurora, is a recreational area heavily used by the surrounding community that also serves on rare occasions as a regional flood detention facility. Utah Park provides recreational amenities including tennis courts, ball fields, trails and open space. This park is the upper-most flood detention facility on the main stem of Westerly Creek. In 2006, Utah Park storage capacity was expanded from 135 acre-feet (roughly the volume of the 50-year flood) to 160 acre-feet, the estimated volume of the 100-year flood.

During the September 2013 flood, Utah Park exceeded its 100-year capacity, with water reaching a peak depth of over 2 feet above the 100-year level during the afternoon of September 12. Floodwaters exceeded the capacity of the overflow spillway and overtopped the western bank onto Peoria Street as designed. Despite the fact that conditions significantly exceeded the design storm (100-year event), spillway overflows caused only limited damage. In the absence of this facility, widespread catastrophic damage would have occurred from flooding.

Aerial view of Utah Park a few days after record rainfall in 2013. (Photo: David Mallory).

Utah Park providing critical flood detention during the September 2013 flood.

6.0 References

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