Drainage Criteria Manual

Greenwood Village

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ABBREVIATIONS

AASHTO	American Association of State Highway & Transportation Officials
ACPA	American Concrete Pipe Association
ASTM	American Society for Testing & Materials
BMP	Best Management Practices
CAD	Computer Aided Design
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CLOMR	Conditional Letter of Map Revisions
CMP	Corrugated Metal Pipe
COE	US Army Corps of Engineers
CUHP	Colorado Urban Hydrograph Procedure
CWCB	Colorado Water Conservation Board
DRCOG	Denver Regional Council of Governments
EGL	Energy Grade Line
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
HDPE	High Density Polyethylene Pipe
HGL	Hydraulic Grade Line
LOMR	Letter of Map Revision
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic & Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
PVC	Polyvinyl Chloride Pipe
RCP	Reinforced Concrete Pipe
SCS	Soil Conservation Service
TMAL	Total Mass Annual Load
UDFCD	Denver Urban Drainage & Flood Control District

UDSWM	Urban Drainage Stormwater Model
USGS	United States Geological Survey
WIR	Wetlands Impact Report
WQCV	Water Quality Control Volume

DEFINITIONS

Base Flood - The flood having a one percent (1%) chance of being equaled or exceeded in any given year. Also known as the 100-year flood.

Base Flood Elevation - The elevation shown on a FEMA Flood Insurance Rate Map for Zones AE, AH, A1-A30, AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO, V1-V30, and VE that indicates the water surface elevation resulting from a flood that has a one percent chance of equaling or exceeding that level in any given year. Basement - That portion of a building that is partly or completely below grade.

Conditional Letter of Map Revision (CLOMR) - FEMA's comment on a proposed project, which does not revise an effective floodplain map, that would, upon construction, affect the hydrologic or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodplain.

Critical Facilities - Means a structure or related infrastructure, but not the land on which it is situated, that if flooded may result in significant hazards to public health and safety or interrupt essential services and operations for the community at any time before, during and after a flood (For further information, see Rule 6, Rules and Regulations for Regulatory Floodplains in Colorado).

Energy Grade Line (EGL) - The total energy level of the water in a conveyance, being the sum of the depth of flow, the velocity head, and the elevation of the invert.

Flood or Flooding - A temporary condition of partial or complete inundation of normally dry land from the unusual and rapid accumulation or run-off of surface water from any source.

Flood Insurance Rate Map (FIRM) - The official map on which the Federal Emergency Management Agency (FEMA) delineated the Special Flood Hazard Areas.

Flood Insurance Study (FIS) - The official report provided by (FEMA) that includes flood profiles, the Flood Boundary Map, and the water surface elevation of the base flood.

Flood Profile - A longitudinal profile showing the water elevation of a flood event.

Floodplain - The relatively flat or lowland area adjoining a creek, gulch, drainageway, or other body of standing water which has been or may be covered temporarily by floodwater.

Floodplain Easement - That area which has been dedicated for the Special Flood Hazard Area.

Floodway - The channel of a river or other watercourse and the adjacent areas that must be kept free of obstructions in order to discharge the base flood without cumulatively increasing the water surface elevation more than one (1) foot or EGL elevation more than six (6) inches, whichever is less. Land Development - Any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, dredging, filling grading, paving, excavation, and drilling operations.

Letter of Map Revision (LOMR) - An official revision to the currently effective FEMA map. It is issued by FEMA and changes flood zones, delineations, and elevations.
Letter of Map Revision Based on Fill (LOMR-F) - FEMA's modification of the Special Flood Hazard Area (SFHA) shown on the Flood Insurance Rate Map (FIRM) based on the placement of fill outside the existing regulatory floodway.
Local Drainage System - The Local Drainage System consists of curb and gutter, ditches, swales, storm sewer inlets, storm sewers, culverts, bridges, detention areas, and all other drainage facilities used to convey the minor storm and major storm runoff to the Major Drainageways.

Lowest Floor - Means the lowest floor of the lowest enclosed area (including basement)

Major Drainageway - Any channel with a tributary area of 130 acres or more.

Mean Sea Level - Means, for purposes of the National Flood Insurance Program (NFIP), the National Geodetic Vertical Datum (NGVD) of 1988 or other datum, to which base flood elevations shown on a community's Flood Insurance Rate Map are referenced.

New Construction - Structures for which the start of construction commenced on or after December 16, 1980, the date of publication of the initial FIRM map for the Village.

One Hundred Year Flood - The flood having a one percent (1%) chance of being equaled or exceeded in any given year assuming ultimate development conditions throughout the tributary basis.

Pre-Development Conditions - The condition of the land in a natural state prior to any development.

Regional Drainage Facilities - Regional Drainage Facilities include swales, ditches, culverts, storm sewers, Major Drainageways, detention facilities, water quality control features, and other drainage facilities designed to manage stormwater from more than one property.

Special Flood Hazard Area - - Area subject to flooding by the one percent (1%) annual chance flood. The one percent annual chance flood (100-year flood), also known as the base flood is the flood that has a one percent chance of being equaled or exceeded in any given year.

Start of Construction - Includes substantial improvement, and means the date the building permit was issued, provided the actual start of construction, repair, reconstruction, placement, or other improvement was within 180 days of the permit date. The actual start means the first placement of permanent construction of a structure on a site, such as the pouring of slab or footings, the installation of piles, the construction of columns, or any work beyond the stage of excavation; or the placement of manufactured home on a foundation. Permanent construction does not include land preparation, such as clearing, grading and filling; nor does it include excavation for a basement, footings, piers, or foundations or the erection of temporary forms; nor does it include the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure.

Structure - A walled and roofed building that is principally above ground.

Substantial Damage – Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial Improvement – Any reconstruction, rehabilitation, addition or other improvements of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before start of construction of the improvement. This includes structures which have incurred substantial damage, regardless or the actual repair work performed. The term does not include any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications identified by the local code enforcement official which are the minimum necessary conditions or alteration of a historic structure, provided that the alteration will not preclude the structure's continued designation as a historic structure.

Violation - Means the failure of a structure or other development to be fully compliant with this Drainage Criteria Manual. A structure or other development without an approved Final Drainage Study, approved Construction Drawings, or other evidence of compliance with this Drainage Criteria Manual or NFIP standards is presumed to be in violation until such time as that documentation is provided.

Water Surface Elevation - Means the height, in relation to the NGVD of 1988 (or other datum, where specified) of floods of various magnitudes and frequencies in floodplains or in any drainageway.

Wetlands - Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas, though in the Village it can also include gulches, washes, Major Drainageways, and other areas that are not wet year round. The federal regulations defining wetlands and limiting activities which affect wetlands are found in 33 CFR Parts 320 through 330 and 40 CFR Part 230.

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1.0 Drainage Policies

1.1 Background and Purpose

The City of Greenwood Village (Village) has adopted a series of policies for the integration of its major drainage systems into the overall planning policies of the Village. The Village's Major Drainageways have become a focus for the development of an extensive parks and trails system. These parks are "passive" in nature and include a series of pedestrian and equestrian trails, wetlands, terrestrial and avian wildlife protection areas, and aquatic habitat.

The purpose of this Drainage Criteria Manual is to describe acceptable criteria for the construction of drainage improvements in the Village. It also provides guidance for the applicant in regard to the review procedures to be used by the Village for the approval of stormwater management plans. Many of these criteria rely upon the extensive successful experience of the Urban Drainage and Flood Control District (UDFCD) and the latest editions of its published Drainage Criteria Manuals, Volumes 1, 2 and 3. The criteria and analysis and design procedures presented in the UDFCD Drainage Criteria Manuals are implicitly incorporated into this Drainage Criteria Manual by reference herein. The Village's drainage management requirements; however, are more extensive and include numerous policies not addressed in the UDFCD Drainage Criteria Manuals. Thus, by necessity, this Drainage Criteria Manual requires consideration of several factors not addressed in the UDFCD Drainage Criteria Manuals. In some instances, these criteria are more stringent than, and may be in conflict with, the criteria of the UDFCD Drainage Criteria Manuals. Wherever conflicts exist among the criteria, the criteria of this Drainage Criteria Manual shall apply in the Village.

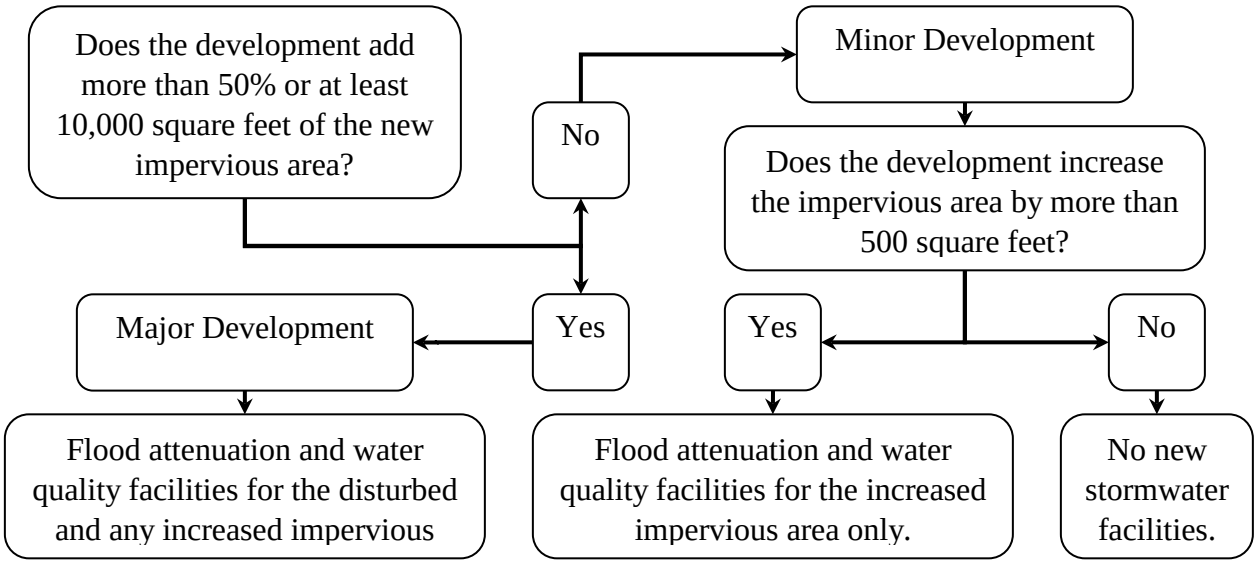
The stormwater management policies of the Village are summarized in the following Sections.

1.2 General Policies

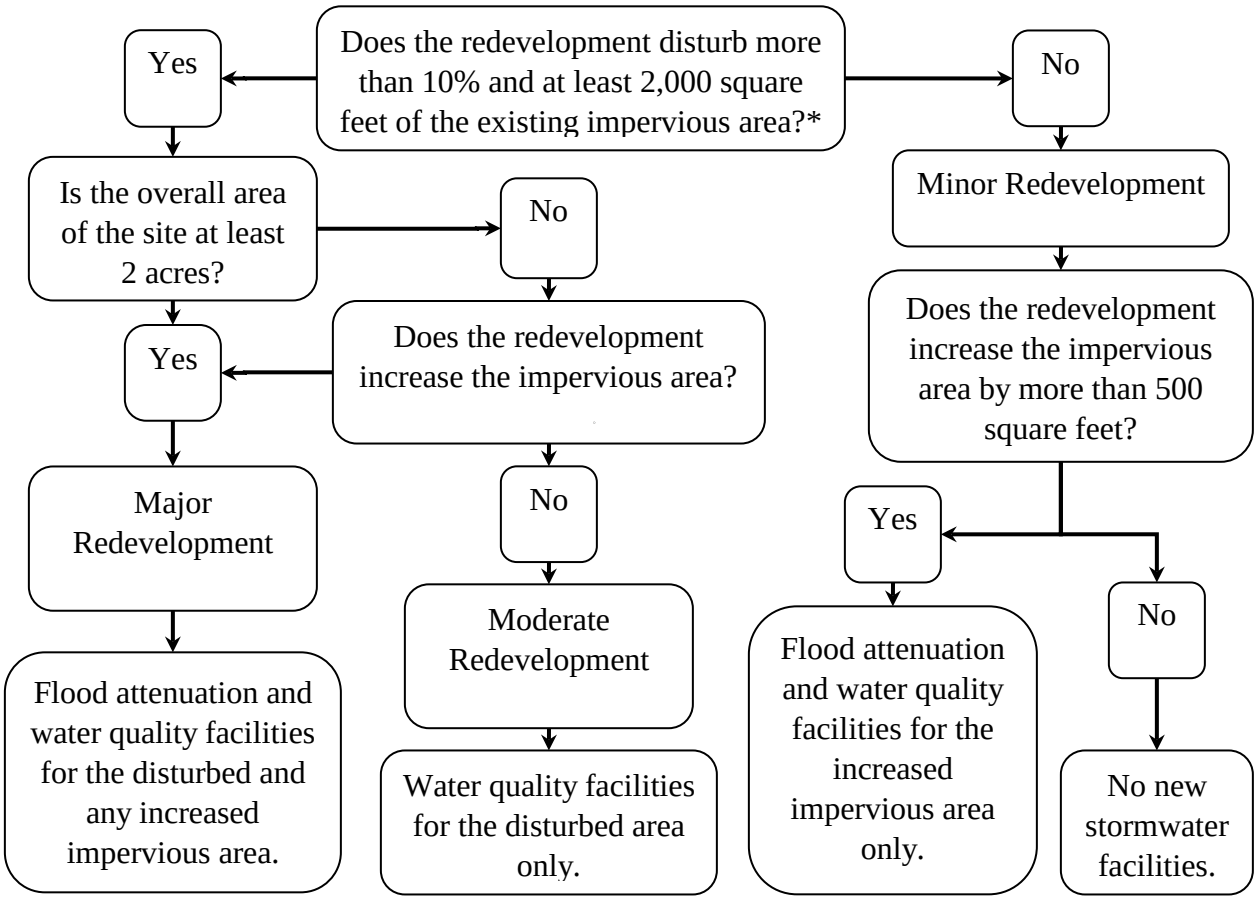
1) For purposes of this Drainage Criteria Manual, any land development project that will increase the amount of impervious area on a property is classified as Development. Any land development project that disturbs the existing impervious area on a property is classified as Redevelopment. The thresholds for Development and Redevelopment are shown in Figure 1-1 and defined as follows:
   a. Development
      i. Minor: A Development that increases the amount of impervious area by:
         (1) Less than 10,000 square feet, and
         (2) Less than 50% of the existing impervious area.
      ii. Major: A Development that increases the amount of impervious area by:
         (1) More than 10,000 square feet, or
         (2) More than 50% of the existing impervious area.

Figure 1-1

Flowchart for Development Criteria



Flowchart for Redevelopment Criteria



*Note: Sites greater than one acre of disturbance that increase the imperviousness by more than 500 SF shall provide permanent water quality facility(ies).

b. Redevelopment
   i. Minor: A Redevelopment that disturbs the existing impervious area by:
      (1) Less than 2,000 square feet, or
      (2) Less than 10% of the existing impervious area.
   ii. Moderate: A Redevelopment that disturbs the existing impervious area, without increasing the impervious area, by:
      (1) At least 2,000 square feet, and
      (2) At least 10% of the existing impervious area, and
      (3) The overall size of the site is less than 2 acres.
   iii. Major: A Redevelopment that disturbs the existing impervious area by:
      (1) At least 2,000 square feet and increases the amount of impervious area, and
      (2) At least 10% of the existing impervious area and increases the amount of existing impervious area, or
      (3) At least 2,000 square feet and 10% of the existing impervious area and the overall size of the site is at least 2 acres.

Maintenance activities on impervious areas, including removal and replacement, that do not impact the layout or function of the impervious area are not classified as redevelopment. The existing impervious area is defined as the impervious area in existence when the property was initially developed or the area shown on the 1998 aerial photography, whichever is later. Any impervious areas added to the existing impervious area shall be considered as new impervious areas for all calculations.

2) The stormwater management that is required by the different categories of Development and Redevelopment are shown in Figure 1-1 and discussed below:
   a. Minor Developments and Redevelopments shall meet the flood attenuation and water quality requirements of this Drainage Criteria Manual for the increased impervious area only if the increase in impervious are is more than 500 square feet. The Simplified Method may be used to meet the flood attenuation and water quality requirements as described in Section 13.4.2. It provides a consistent, but simplified approach for calculating the retention volume for the increased impervious areas.
   b. Moderate Redevelopments shall only meet the water quality requirements of this Drainage Criteria Manual for the disturbed area only. The existing levels of flood attenuation that are present at the time of Redevelopment must be maintained. Because Moderate Redevelopments maintain or reduce the amount of impervious area, the average annual total phosphorus produced by the property shall be based on the amount of existing impervious area. Therefore, reducing the amount of impervious area reduces the amount of phosphorus that will need to be removed.
   c. Major Development shall meet the flood attenuation and water quality requirements of this Drainage Criteria Manual for the entire property. Major Redevelopment shall meet the flood attenuation and water quality requirements of this Drainage Criteria Manual for the disturbed area and increased impervious

area only. Major Development projects increase the amount of impervious area; therefore, the average annual total phosphorus produced by the property shall be based on the amount of total proposed impervious area. Because Major Redevelopment projects may reduce the amount of impervious area, the average annual total phosphorus produced by the property shall be based on either the amount of existing or total proposed impervious area, whichever is greater. Reducing the amount of impervious area reduces the amount of phosphorus that will need to be removed. Major Development or Redevelopment projects that consist of a single family residential lot may use the Retention Method to meet the flood attenuation and water quality requirements of this Drainage Criteria Manual. The Retention Method is described in Section 13.4.5. It provides a consistent, but simplified approach for calculating the retention volume for the entire property.

d. Sites greater than one acre of disturbance that increase the imperviousness by more than 500 SF shall provide permanent water quality facility(ies).

3) Any drainage study or drawing, except the Simplified and Retention Methods, submitted by an applicant to the Village for approval shall be certified by a professional engineer licensed in the State of Colorado as discussed in Section 3.1.

4) The responsibility for compliance with the policies and criteria of the Village rests entirely with the applicant. Any review or approval by the Village of drainage studies or drawings submitted by an applicant does not relieve the applicant of the responsibility of meeting the requirements of this Drainage Criteria Manual.

5) Any Development or Redevelopment that adversely impacts off-site areas because of modifications to drainage patterns or facilities shall mitigate the impact to the area.

6) Whenever work is being performed contrary to any provision of this Drainage Criteria Manual, the City Manager or designee may order the work stopped by notice in writing served on any person engaged in doing or causing such work to be done. Any such person shall forthwith stop such work until authorized by the City Manager or designee in writing to proceed with the work. It is unlawful to do or perform any work in violation of such stop order.

7) The Village benefits from the creation and preservation of wetlands. The Village will approve only those drainage studies and drawings which fully preserve the function and values of wetlands. This is known as the “no net loss of wetlands” goal.

8) Drainage easements shall be provided for all drainage improvements including storm sewers, inlets, roadside ditches, swales, culverts, floodplains, open channels, flow areas outside of streets, storage facilities, and stormwater quality treatment facilities. The easements shall be sufficiently large to accommodate the 100-year flood, provide public access, and allow proper maintenance of the facilities. The drainage easements shall be clearly shown in all drainage studies, construction drawings and plats.

9) Where this Drainage Criteria Manual and any other drainage criteria manual, ordinance, plat, or development plan overlap or conflict, whichever imposes the more stringent restrictions as determined by the City Manager or designee shall prevail.

10) Any development or redevelopment that disturbs an acre or more of land shall be required to obtain a State CDPS Stormwater permit and adhere to the requirement set forth in this manual and the Greenwood Village Construction Site Management Manual for erosion control during construction.

1.3 Floodplain Management Policies

1) The Village will not approve uses of or modifications to Special Flood Hazard Areas, which could adversely impact the public health, safety, and general welfare of the Village.
2) The Flood Insurance Rate Maps (FIRM) approved by the Federal Emergency Management Agency (FEMA) will be used to delineate floodplains. The Flood Hazard Delineation as provided in the basin master plans prepared by the UDFCD and adopted by the Colorado Water Conservation Board (CWCB) shall also be considered. Whenever there is a conflict among sources in the delineation of the floodplain, the most restrictive (widest) delineation shall be used.
3) The applicant is responsible for securing the appropriate revisions to floodplain maps at its own expense for any alterations to the 100-year floodplain.
4) UDFCD has prepared Major Drainageway Planning for most of the Major Drainageways within the Village showing recommended channel and bank improvements to stabilize the drainageways. The latest edition of the Major Drainageway Planning is hereby adopted as a guideline for improvements to the Major Drainageways within the Village. Major Development and Redevelopment projects that are located on properties adjacent to the Major Drainageway will be responsible for implementing the recommended improvements.
5) Appeals to decisions by the City Manager or designee related to the regulation of Special Flood Hazard Areas must follow the procedures outlined in Section 3.4.

1.4 Flood Flow Attenuation Policies

1) One of the most fundamental requirements of drainage systems is to control flood discharges so that flood flows are released at pre-developed discharge rates to downstream properties. The pre-developed discharge rate is the rate at which stormwater was discharged when the property was in a natural condition prior to development. The most promising, and historically, the most effective, ways to manage flood discharges has been to avoid the artificial channelization of Major Drainageways and to construct stormwater flood attenuation facilities. The Village requires the attenuation of the peak stormwater discharges to pre-developed conditions from developed areas for the 5-year and 100-year frequency storms events.
2) The flood discharges from any modification of any landform, Development, or Redevelopment in the Village must be reduced to pre-development conditions. Unless compelling evidence is presented by the applicant to the contrary, the pre-

development condition shall be presumed to be as shown in Table 1-1 for each of the major soil type areas in the Village:

Table 1-1: Allowable Peak Discharge (cfs per ac)

Soil Type	5 year	100 Year
I. Clays	0.17	1.00
II. Clay Loams	0.13	0.85
III. Sands and Gravel	0.07	0.50

3) The Village strongly encourages the use of grass-lined swales and ditches, wetlands, minimization of impervious areas, and extended detention and retention facilities to meet the flood attenuation policies of the Village.
4) The flood attenuation requirements shall be met prior to discharge of stormwater to a Major Drainageway, wetland, or across the property line of the applicant.
5) The Village may waive the requirements to attenuate the peak flood flows at the locations specified above and approve the substitution of regional facilities following the procedures outlined in Section 3.3. The Village will encourage regional detention facilities if on-site detention is impractical due to previous development conditions and it is in the best interest of the health, safety, and welfare of the Village.

1.5 Stormwater Quality Management Policies

1) Stormwater quality control is an integral part of any stormwater management system in the Village. The Major Drainageways, reservoirs, and wetlands in and near the Village are valuable resources, which must be protected against the potentially adverse water quality effects of stormwater discharges.
2) The Colorado Water Quality Control Commission has adopted stream classifications and in-stream water quality standards for Cherry Creek Reservoir and all of the perennial streams in the Village. These standards will protect the aquatic, recreation, wildlife, and water supply resources of the Village. The Village supports these classifications and standards.
2) Colorado and federal regulations require the adoption of stormwater management plans capable of maintaining the applicable water quality standards. This Drainage Criteria Manual provides the minimum requirements for maintaining water quality standards. Data from ongoing stream and reservoir monitoring programs and site-specific conditions may warrant drainage criteria more stringent than presented in this Drainage Criteria Manual.
3) All drainage studies and drawings for Developments and Redevelopments that require water quality treatment shall demonstrate the attainment of the goal to remove 60 % of the average annual total phosphorus in stormwater runoff prior to discharge to any Major Drainageway, wetland, or across the property boundary of

the applicant, whichever is the most stringent.

4) The Village may waive the requirements to meet the water quality requirements of this Drainage Criteria Manual and approve the substitution of regional facilities following the procedures outlined in Section 3.3.

1.6 Local Drainage Systems

1) All new Development and Redevelopment projects shall include the planning and construction of the Local Drainage System within the development in accordance with the requirements presented in this Drainage Criteria Manual.
2) When soils reports or excavation indicate the presence of sub-surface water conditions requiring foundation drains or sump pumps, the outlet must be discharge to a Major Drainageway, storm sewer, ditch, swale, or flood attenuation or water quality facility.

1.7 Maintenance of Drainage Facilities

1) All drainage studies and drawings shall include a maintenance program designed to maintain the flood attenuation and water quality management requirements of this Drainage Criteria Manual. Public access shall be provided to maintain the facilities.
2) The applicant and its successors are responsible for maintaining the drainage improvements.
3) The Village shall inspect the drainage facilities and determine whether or not the flood attenuation and water quality management requirements of this Drainage Criteria Manual have been maintained. If the Village notes any deficiencies it shall notify the owner of the deficiencies and the owner shall submit to the Village a proposal to correct the deficiencies within thirty days. The City Manager or designee will review and comment upon the proposed plan and approve or reject the proposed plan in writing.
4) If an approved plan has not been completed within the proposed timeframe in the plan, the Village reserves the right to correct the deficiencies at it’s own expense and collect it’s expenses from the owner and to file a lien on the property which relies upon the drainage facilities and to use other lawful means of collection of it’s expenses if they are not paid by the owner in a timely manner.

2.0 Inventory of Resources

2.1 Village Mapping Systems

Topographic mapping is available for most of Greenwood Village (Village) with a 2-foot contour interval. The topographic mapping was completed in 1998 and includes an inventory of landscaping, structures, streets, and various other planimetric features. The horizontal control for the mapping is the Colorado State Plane Coordinate system, and vertical control is NGVD 1929. This vertical datum is different from the NGVD 1988 that is used for floodplain mapping. Although the difference varies somewhat by location, for the Village the NGVD 1929 is approximately 3 feet lower than the NGVD 1988. Each section quarter corner has a designated control point. The mapping is available electronically or in hardcopy form in quarter sections. Figure 2-1 is an index for the mapping system.

Updated aerial photography is also available and can be used in conjunction with the topographic mapping. The date of the aerial photography is 2002 and it is ortho-corrected to minimize horizontal distortions in the photography. The aerial photography is available electronically and/or in hardcopy.

The Department of Community Development maintains a list of sources from which the maps and aerial photography can be purchased.

2.2 Perennial Streams and Lakes

The Village has 6 perennial streams within its corporate boundaries. They are:

1) Big Dry Creek
2) Little Dry Creek
3) Greenwood Gulch
4) Prentice Gulch
5) Goldsmith Gulch
6) Cottonwood Creek

In addition, several areas drain directly into Cherry Creek Reservoir. Figure 2-2 shows the locations of the above listed drainageways that are located in the Village. This mapping is available from the Village in electronic and hardcopy forms.

2.3 Wetlands

The Village has mapping available of inventoried wetlands within the corporate boundaries. Typically, the wetlands are located in the Major Drainageways. The inventoried wetland boundaries have been superimposed on the aerial photography of the Village and provided on Figure 2-3. This mapping should only be used for planning purposes and does not constitute an

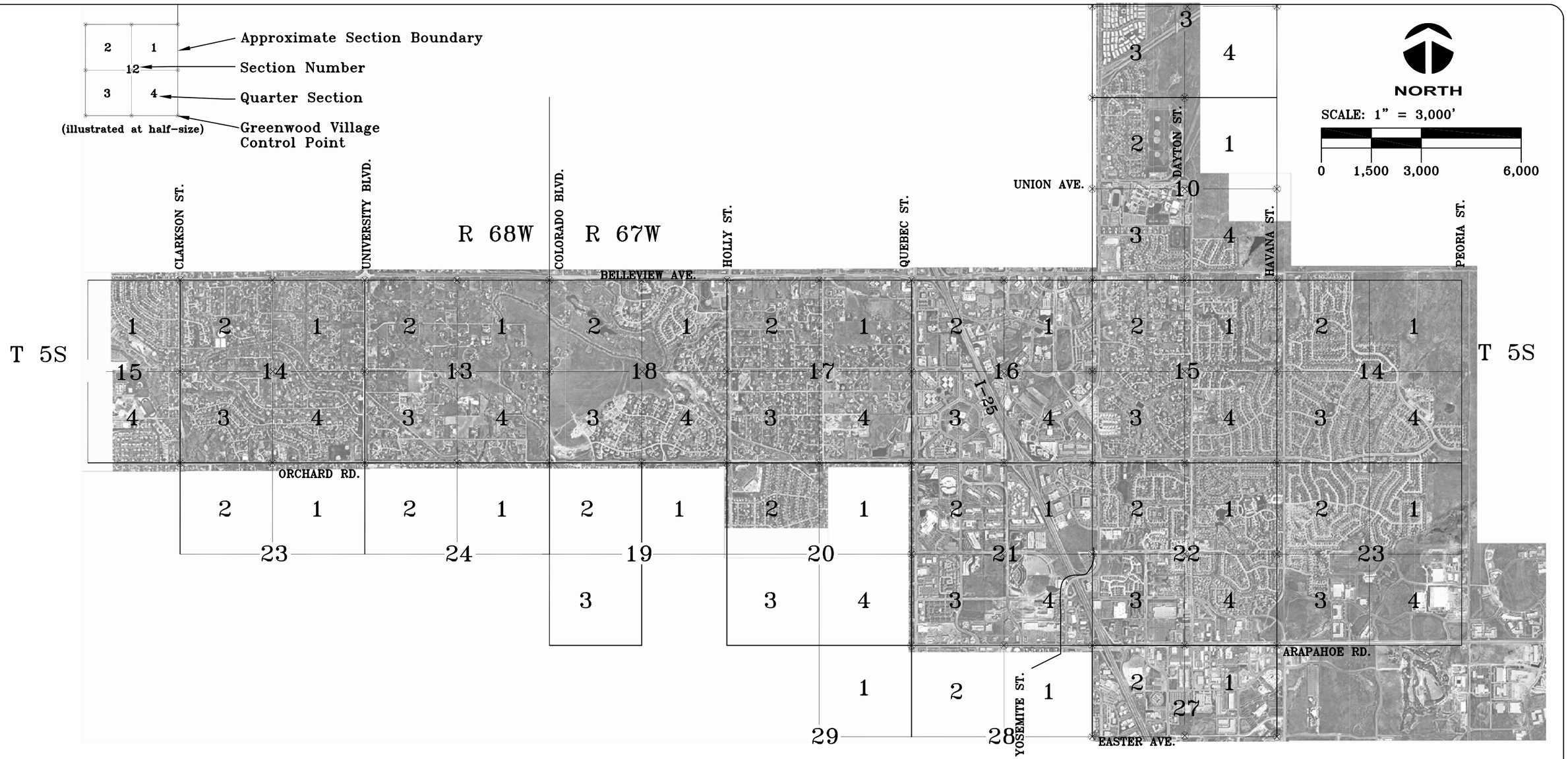
official wetland delineation. Chapter 14.0 of this Drainage Criteria Manual specifies the requirements for proper wetland delineation. This mapping is available from the Village in electronic and hardcopy forms.

2.4 Soils Mapping

The soil types of the Village have been classified by the Soil Conservation Service and are presented in the Soils Survey of Arapahoe County. For convenience, the soil series in the Village have been grouped into three general soil types. Figure 2-4 shows the individual soil classifications and the composite classifications. This mapping should be used for planning purposes and can be referenced for design information unless the Village requires site-specific classification of soil type. Chapter 6.0 of this Drainage Criteria Manual provides additional information regarding soil types and their relationship to runoff. This mapping is available from the Village in electronic and hardcopy forms.

2.5 Urban Drainage and Flood Control District

Urban Drainage and Flood Control District (UDFCD) is an important resource for completing drainage designs for the Village. UDFCD has authored the Urban Storm Drainage Criteria Manual Volumes 1, 2, and 3. The UDFCD Drainage Criteria Manual should be used concurrently with this Drainage Criteria Manual. However, when there are differences between the two manuals, this Drainage Criteria Manual shall be used. Copies of the UDFCD Drainage Criteria Manual are available from UDFCD.



Greenwood Village
Inventory of Resources
October 2003

Figure 2-1
City Mapping System Index

FIG0201.DWG TIF: GREEM-BW.TIF

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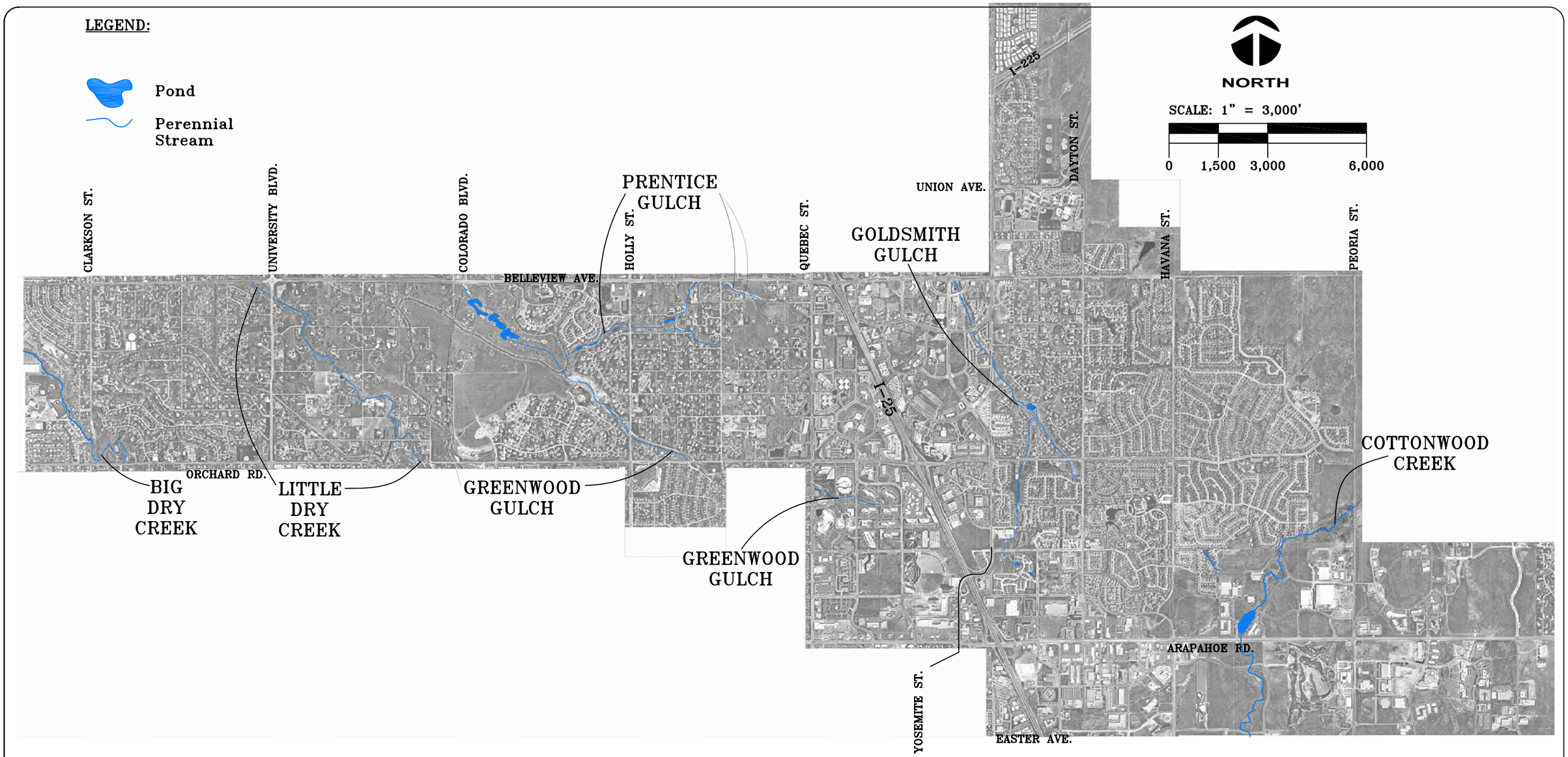

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Figure 2-2
Perennial Streams and Ponds

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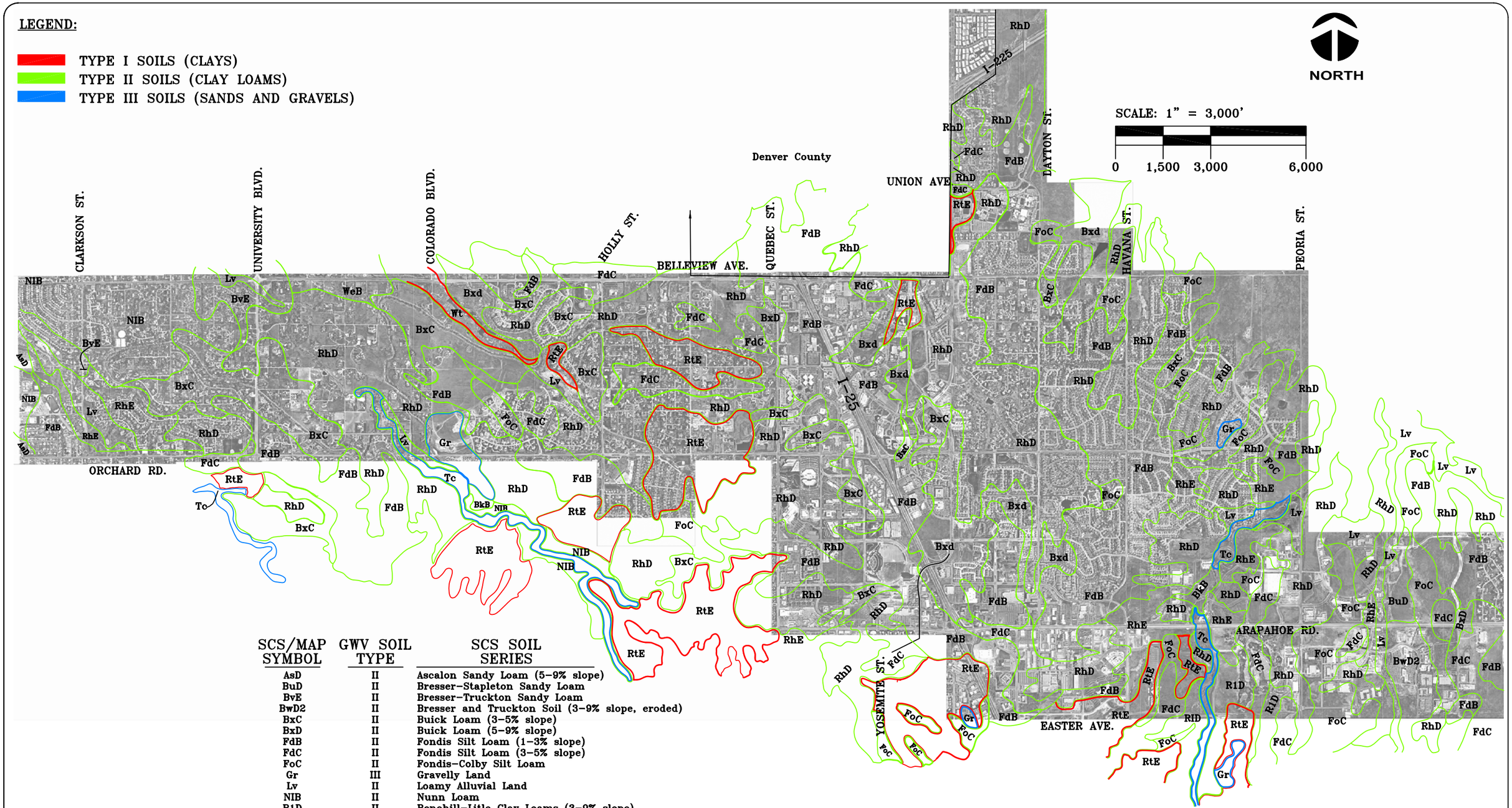

SCS/MAP SYMBOL	GWV SOIL TYPE	SCS SOIL SERIES
AsD	II	Ascalon Sandy Loam (5–9% slope)
BuD	II	Bresser–Stapleton Sandy Loam
BvE	II	Bresser–Truckton Sandy Loam
BwD2	II	Bresser and Truckton Soil (3–9% slope, eroded)
BxC	II	Buick Loam (3–5% slope)
BxD	II	Buick Loam (5–9% slope)
FdB	II	Fondis Silt Loam (1–3% slope)
FdC	II	Fondis Silt Loam (3–5% slope)
FoC	II	Fondis–Colby Silt Loam
Gr	III	Gravelly Land
Lv	II	Loamy Alluvial Land
NIB	II	Nunn Loam
R1D	II	Renohill–Litle Clay Loams (3–9% slope)
RdD	II	Renohill Loam (3–9% slope)
RhD	II	Renohill–Buick Loams (3–9% slope)
RhE	II	Renohill–Buick Loams (9–20% slope)
RtE	I	Renohill–Litle–Thedalund
Tc	III	Terrace Escarpments (nearly vertical)
WeB	II	Weld Silt Loam
Wt	I	Wet Alluvial Land

Greenwood Village
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Figure 2–4
Soil Classifications Map

FIG0204.DWG TIF: GREEM-BW.TIF

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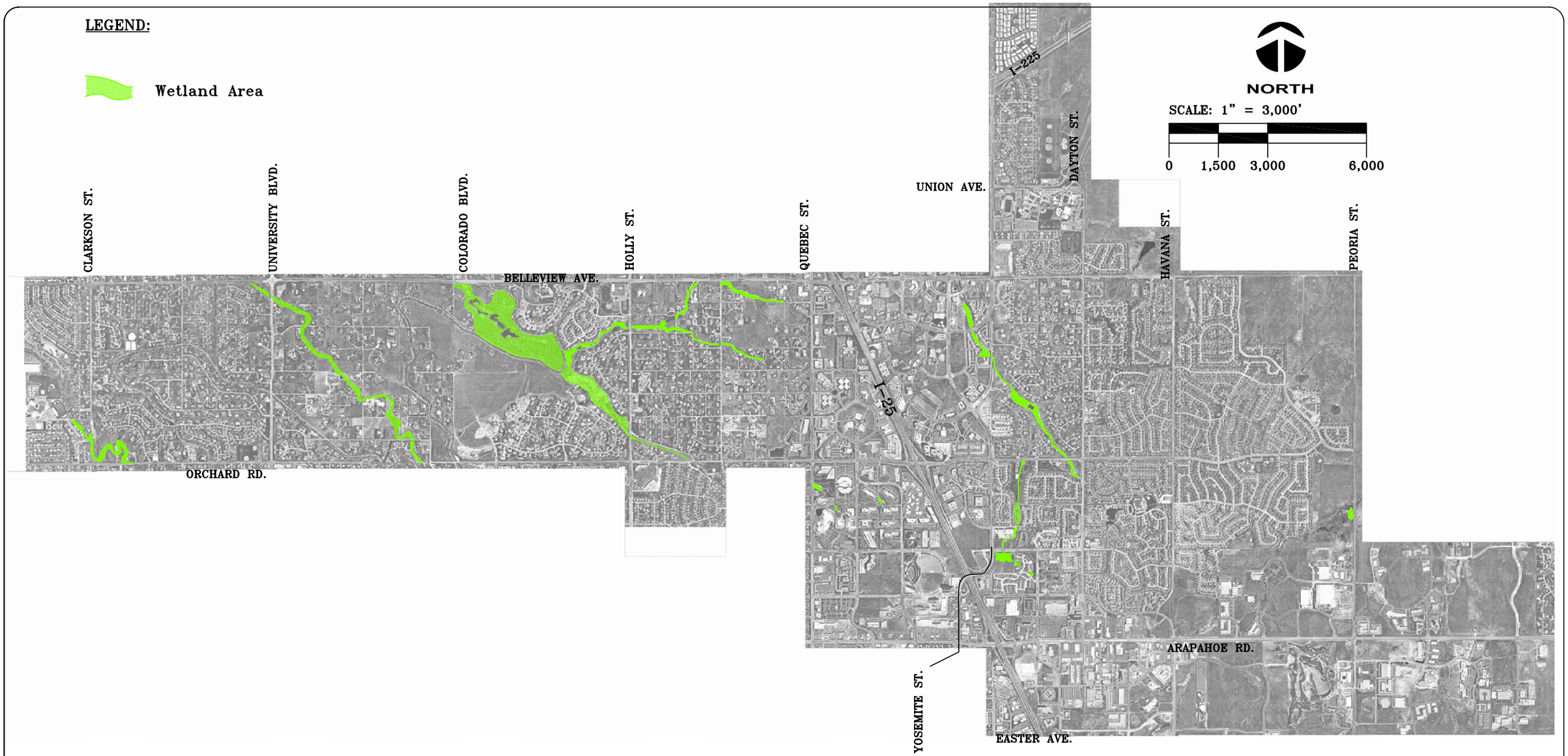

Greenwood Village
Inventory of Resources
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Figure 2-3
Inventoried Wetland Areas

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3.0 Planning and Submittal Requirements

3.1 Drainage Studies and Drawings

The City of Greenwood Village (Village) requires the planning and construction of adequate drainage facilities. This Chapter of the Drainage Criteria Manual sets forth the requirements for the studies and drawings submitted to the Village.

The applicant for each proposed land development project shall make submittals in accordance with Table 3-1 depending on the type of application or level of Development or Redevelopment for review and approval by the City Manager or designee.

Table 3-1: Submittal Requirements

Type of Development	Type of Drainage Study		
	Conceptual	Preliminary	Final
Rezoning/Master Plan	Yes	No	No
Preliminary Plat	Optional	Yes	No
Final Plat	Optional	Optional	Yes
Amended Plat	Optional	Optional	Yes
PUD/FDP/Site Plan	Optional	Optional	Yes
Major Development	Optional	Optional	Yes
Moderate Redevelopment	Optional	Optional	Yes
Major Redevelopment	Optional	Optional	Yes
Minor Dev/Redevelopment	No	No	No

The optional submittal of a Conceptual or Preliminary Drainage Study is allowed during the initial phases of the review by the Village for the types of application or level of Development or Redevelopment shown in Table 3-1. However, the land development project can not be approved until the Preliminary or Final Drainage Study has been submitted and approved.

Minor Development and Minor Redevelopment may use the Simplified Method to meet the requirements as described in Section 13.4.2. Major Development and Redevelopment that consists of a single family residential lot may use the Retention Method to meet the requirements as described in Section 13.4.5.

3.1.1 Conceptual Drainage Study

The purpose of the Conceptual Drainage Study is to identify and define conceptual solutions to the problems which may occur on-site and off-site as a result of the development. In addition,

those problems that exist on-site prior to development must be addressed during the conceptual phase. The Conceptual Drainage Study shall include, as a minimum, the information shown in Table 3-2.

3.1.2 Preliminary Drainage Study

The purpose of the Preliminary Drainage Study is to identify and define solutions to the problems which may occur on-site and off-site as a result of the development. In addition, those problems that exist on-site prior to development must be addressed during the preliminary phase. When a Conceptual Drainage Study was previously approved, the Preliminary Drainage Study will update the information in the Conceptual Drainage Study. The Preliminary Drainage Study shall include, as a minimum, the information shown in Table 3-2.

3.1.3 Final Drainage Study

The purpose of the Final Drainage Study is to identify and define solutions and to present the design details for the drainage facilities. The final drainage design, erosion control measures, non-point source pollution control measures, and wetlands preservation and mitigation measures must be presented. When a Conceptual or Preliminary Drainage Study was previously approved, the Final Drainage Study will update the information in the Conceptual Preliminary Drainage Study. The Final Drainage Study shall include, as a minimum, the information shown in Table 3-2.

Table 3-2: Drainage Study Checklist

Item	Conceptual	Preliminary	Final
Engineer's Certificate	X	X	X
Owner's Certificate	X	X	X
1) General Location and Description	X	X	X
a. Location	X	X	X
i. Streets within and adjacent to the development.	X	X	X
ii. Township, range, section, and ¼ section.	X	X	X
iii. Major Drainageways, drainage facilities, and wetlands near the development.	X	X	X
iv. Names of surrounding developments.	X	X	X
b. Description of Property	X	X	X
i. Area in acres.	X	X	X
ii. Ground cover (type of trees, shrubs, and vegetation).	X	X	X

Item	Conceptual	Preliminary	Final
iii. Major Drainageways, drainage facilities, and wetlands within the development.	X	X	X
iv. General project description.	X	X	X
2) Major Drainage Basins and Sub-basins	X	X	X
a. Major Basin Description	X	X	X
i. Reference to major drainageway planning studies such as flood hazard delineation reports, major drainageway planning reports, and flood insurance rate maps.	X	X	X
ii. Major drainage basin characteristics.	X	X	X
iii. Identification of all nearby irrigation facilities within 100-feet of the property boundary, which will influence or will be influenced by the local drainage.	X	X	X
b. Sub-basin Description	X	X	X
i. Discussion of historic drainage patterns of the property.	X	X	X
ii. Discussion of off-site drainage flow patterns and impact of development.	X	X	X
3) Drainage Design Criteria	X	X	X
a. Regulations	X	X	X
i. Discussion of compliance with or deviation from this Drainage Criteria Manual.	X	X	X
b. Development Criteria Reference and Constraints.	X	X	X
i. Discussion of previous drainage studies (i.e., project master plans or other approved drainage study) that influence or are influenced by the drainage design and how the previous drainage study will affect drainage design for the site.	X	X	X
ii. Discussion of the drainage impact of site constraints such as streets, utilities, light rail rapid transit, existing structures, and development or site plans.	X	X	X
c. Hydrological Criteria	X	X	X
i. Identify the source of design rainfall information for all storm events.	X	X	X
ii. Identify runoff calculation method.	X	X	X

Item	Conceptual	Preliminary	Final
iii. Identify flood attenuation discharge and storage calculation method.	X	X	X
iv. Identify design storm recurrence intervals.	X	X	X
v. Discussion and justification of other criteria or calculation methods used that are not presented in or referenced by this Drainage Criteria Manual.	X	X	X
d. Hydraulic Criteria	X	X	X
i. Identify capacity references.	X	X	X
ii. Identify facility outlet design method.	X	X	X
iii. Identify hydraulic structure criteria used.	X	X	X
iv. Discussion of other drainage facility design criteria used that is not presented in or referenced by this Drainage Criteria Manual.	X	X	X
4) Drainage Facility Design	X	X	X
a. General Concept	X	X	X
i. Discussion of existing drainage patterns.	X	X	X
ii. Discussion of proposed drainage patterns.	X	X	X
iii. Discussion of compliance with off-site runoff considerations.	X	X	X
iv. Discussion of the content of tables, charts, figures, or drawings.	X	X	X
b. Specific Details	X	X	X
i. Discussions of drainage problems encountered and solutions.	X	X	X
ii. Discussion of detention storage and outlet design.	X	X	X
iii. Discussion of maintenance access to facilities.	X	X	X
iv. Discussion of impacts of concentrating the discharge from facilities on the downstream properties.	X	X	X
5) Environmental Protection Criteria	X	X	X
a. Stormwater Quality Management Plan	X	X	X
i. Include items in the Table 16-1 from Chapter 16.0, if a separate Stormwater Quality Management Plan is not prepared.	X	X	X

Item	Conceptual	Preliminary	Final
b. Wetlands Preservation	X	X	X
i. Complete Wetlands Impact Report, if necessary, in accordance with Chapter 14.0 or discuss no impact on wetlands within or adjacent to the property.	X	X	X
6) Maintenance Plan	X	X	X
a. Maintenance Activities	X	X	X
i. Description of routine maintenance activities, including frequency, to maintain flood attenuation of the facilities.	X	X	X
ii. Description of extraordinary maintenance activities following minor and major storm to maintain the flood attenuation functions of the facilities.	X	X	X
b. Estimated Maintenance Costs	X	X	X
i. Cost estimate for each routine and extraordinary maintenance activity.	X	X	X
ii. Description of the methods by which maintenance costs will be paid, including assurances that sufficient funds will be available at all times.	X	X	X
7) Conclusions	X	X	X
a. Compliance with Standards	X	X	X
i. Drainage Criteria Manual.	X	X	X
ii. Major Drainageway Planning Studies or other previously approved drainage studies.	X	X	X
iii. UDFCD Drainage Criteria Manuals.	X	X	X
b. Drainage Concept	X	X	X
i. Effectiveness of drainage design and facilities to control damage from storm runoff to either public and private improvements or adjacent property.	X	X	X
ii. Influence of proposed development on the recommendations from the Major Drainageway Planning Studies or other previously approved drainage studies.	X	X	X
8) References	X	X	X
a. Reference all criteria and technical information used.	X	X	X

Item	Conceptual	Preliminary	Final
9) Appendices	X	X	X
a. Hydrologic Calculations	X	X	X
i. Runoff coefficients.	X	X	X
ii. Times of concentration.	X	X	X
iii. Pre-developed and post-developed runoff for both the minor and major storm events at specific design points.	X	X	X
iv. Hydrographs for both the minor and major storm events at specific design points, if required.	X	X	X
b. Hydraulic Calculations	X	X	X
i. Culvert capacity.		X	X
ii. Storm sewer capacity, including hydraulic grade line (HGL) and energy grade line (EGL).		X, No HGL & EGL	X
iii. Street capacity.		X	X
iv. Storm inlet capacity.		X	X
v. Open channel design.		X	X
vi. Hydraulic structure design.		X	X
vii. Flood attenuation facility volume capacity and outlet configuration.	X	X	X
c. Water Quality Computations	X	X	X
i. Include calculations in the Table 16-1 from Chapter 16.0, if a separate Stormwater Quality Management Plan is not prepared.	X	X	X
10) Maps	X	X	X
a. General Location Map	X	X	X
i. A general location map showing the general drainage patterns around the property. The map should be at a scale of 1” = 1000’ or 2000’ and show the path of all drainage to and from any off-site basins. The map shall identify any development or drainage facilities (i.e., irrigation ditches, existing flood attenuation and water quality facilities, culverts, and storm sewers) along the entire path of the off-site and on-site drainage.	X	X	X

Item	Conceptual	Preliminary	Final
b. Drainage Plan	X	X	X
i. Plan of the proposed development shall be provided at a scale of 1” = 20’ to 1” = 200’ on 24” x 36” sheets.	X	X	X
ii. A topographic map shall be provided with two-foot existing and proposed contours tied to the Greenwood Village “Control Diagram” (Figure 2-1). The topographic map shall extend a minimum of 50-feet beyond the property lines.	X	X	X
iii. Property lines, easements and purposes of easements.	X	X	X
iv. Streets.	X	X	X
v. Existing drainage facilities and structures, irrigation ditches, Major Drainageways, and existing wetlands. All pertinent information such as materials, size, shape, slope, and location shall also be included.	X	X	X
vi. Overall drainage area and sub-area boundaries.	X	X	X
vii. Proposed type of street flow, roadside ditch, gutters, and cross pans.	X	X	X
viii. Proposed drainage structures and open channels.	X	X	X
ix. Proposed outfall point for runoff from the development and facilities to convey flows without damage to downstream properties.	X	X	X
x. Routing and accumulation of flows at specific design points for the minor storm.	X	X	X
xi. Routing and accumulation of flows at specific design points for the major storm.	X	X	X
xii. Details of storage facilities and outlet works.	X	X	X
xiii. Location and elevations of all floodplains affecting the property.	X	X	X
xiv. Location and elevations of all existing and proposed utilities affected by or affecting the drainage design.	X	X	X
xv. Routing of off-site drainage flow through the development.	X	X	X

3.1.4 Submittal Requirements

All studies shall be typed on 8-1/2" x 11" paper and bound. The drawings, figures, and tables shall be bound with the study or included in a pocket attached inside the study. The study shall be certified by a professional engineer licensed in the State of Colorado using the following form:

> I hereby certify that this (type of study) for (name of site) was prepared by me or under my direct supervision in accordance with the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

The study shall also be certified by Owner of the property using the following form:

> I hereby certify that the drainage facilities proposed for (name of site) shall be constructed and maintained in accordance with the design presented in this (type of study). I understand that the City of Greenwood Village does not and will not assume liability for the proposed drainage facilities.
>
> _____
> Signature
>
> _____
> Date

3.1.5 Construction Drawings

The construction drawings shall be submitted on paper and submitted with the permit application for review and approval prior to construction. The construction plans shall be certified by a professional engineer licensed in the State of Colorado using the following form:

> I hereby certify that these construction drawings for (name of site) were prepared by me or under my direct supervision in accordance with the approved Final Drainage Study and the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

The construction drawings for the site shall address all the improvements required by the approved Final Drainage Study, including, but not limited to:

1) Storm sewers, inlets, and outlets.
2) Culverts, end sections, and inlet/outlet protection.
3) Channels, ditches, and swales.
4) Checks, structures, channel drops, and other hydraulic facilities.
5) Stormwater facility grading, trickle channels, outlets, and landscaping.
6) Other drainage related structures and facilities.
7) Maintenance access considerations.
8) Erosion control measures.
9) Water quality control facilities.
10) Wetland mitigation measures.
11) Floodplain boundaries.
12) Drainage easements.

3.1.6 Record (As-Built) Drawings

One reproducible set of as-constructed drawings for all drainage improvements shall be certified by a professional engineer licensed in the State Colorado using the following form and submitted to the Village before the Village will accept the improvements:

> I hereby certify that these record drawings for (name of site) were prepared by me or under my direct supervision. The changes in the as-constructed conditions will not materially adversely affect the performance of the drainage facilities approved in the construction drawings and as required by the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

Red-line or cloud mark-ups of the approved construction drawings are the preferred method for the initial submittal of the record drawings. All changes shall be legible and representative of actual as-built conditions. After the record drawings have been approved by the City Manager or designee, corrected electronic versions shall be submitted.

3.2 Village Review and Approval

The City Manager or designee will review the studies, construction drawings, record drawings, and applications for waivers and provide written review comments or approval.

It should be specifically noted that the review comments or approval of any studies or drawings shall not relieve the applicant of their responsibility to comply with the requirements and regulations of the federal government, the state of Colorado, or the Village. The review and approval by the Village is offered only to assist the applicant's understanding of the applicable requirements.

3.3 Waivers of Requirements

The City Manager or designee may waive one or more requirements of this Drainage Criteria Manual. The applicant shall initiate the waiver procedure by submitting an application for a waiver to the City Manager or designee. The application shall include a description of the waiver with specific reference to the applicable Sections of this Drainage Criteria Manual. The applicant shall also provide an analysis, certified by a professional engineer licensed in the State of Colorado, in accordance with the following:

1) Cumulative impacts of the proposed waiver and similar potential waivers for similar properties on the achievement of the water quality protection and flood attenuation requirements of this Drainage Criteria Manual in the same Major Drainage Basin and within the Village.
2) Availability and cost of off-site and/or regional drainage facilities to meet the water quality protection, wetland protection, and flood attenuation requirements of this Drainage Criteria Manual.
3) Potential adverse impacts of the proposed waiver on the Major Drainageways and downstream public and private property.
4) Potential advantages of regional drainage facilities to achieve the goals and requirements of this Drainage Criteria Manual where the retrofit of drainage facilities could be disruptive and expensive.
5) Enforceable commitment from the applicant to pay for the pro rata share of the construction and maintenance costs of the off-site or regional drainage facilities required to mitigate the adverse water quality, wetlands and flood discharge impacts of the proposed waiver.

Upon receipt of a complete application for a waiver, the City Manager or designee shall prepare a rationale statement recommending approval or disapproval of the proposed waiver. The rationale statement shall consider the analysis of the above required items. The City Manager or designee shall then approve, disapprove, or request modifications of the proposed waiver.

3.4 Appeals

The applicant or any citizen of the Village materially affected by the proposed waiver may appeal the decision of the City Manager or designee. Any appeal from an order, requirement, decision, or determination of the City Manager or designee made pursuant to this Drainage Criteria Manual shall be taken within (10) ten days following the date of such order, requirement, decision, or determination by the filing of a written notice of appeal with the City Manager or designee . The notice of appeal shall state in detail the action appealed from, the grounds for the appeal, and the relief sought. The City Manager or designee shall forward the notice of appeal to the Planning and Zoning Commission (Commission). The Commission shall, within thirty (30) days following the filing of the notice of appeal, review the record of the action taken by the City Manager or designee, and make any recommendation to the City Council in writing. The matter shall thereupon be placed on a City Council agenda for action. The City Council may either review the matter on the record or schedule a public hearing, at its discretion. At the conclusion of the review or hearing the City Council may reverse or affirm wholly or partly the order, requirement, decision or determination appealed from and shall enter such order as it deems appropriate under the circumstances.

4.0 Floodplain Criteria

4.1 Introduction

The Special Flood Hazard Areas in the City of Greenwood Village (Village) are subject to periodic inundation which could result in loss of life and property, health and safety hazards, disruption of commerce and government services, extraordinary public expenditures for flood protection and relief, and impairment of the tax base. All of these impacts, singularly or collectively, could adversely affect the public health, safety, and general welfare of the Village. These flood losses could be caused by the cumulative effect of obstructions in Special Flood Hazards Areas which would increase flood heights and velocities, and when inadequately anchored, could cause obstructions to move and to damage uses downstream. Structures that are inadequately floodproofed, elevated, or otherwise protected from flood damage also contribute to the flood loss

The purpose of the floodplain management criteria is to promote the public health, safety, and general welfare, and to minimize public and private losses due to flood conditions in specific areas by provisions designed to:

1) Protect human life and health.
2) Minimize expenditure of public money for costly flood control projects.
3) Minimize the need for rescue and relief efforts associated with flooding that are generally undertaken at the expense of the public.
4) Minimize prolonged business interruptions.
5) Minimize damage to public facilities and utilities located in Special Flood Hazard Areas.
6) Maintain a stable tax base by providing for the use and development of Special Flood Hazard Areas so as to minimize future flood blight areas.
7) Alert potential property buyers that a property is in a Special Flood Hazard Area.
8) Ensure that those who occupy the Special Flood Hazard Areas assume responsibility for their actions.
9) Protect the storage capacity of floodplains and assure retention of sufficient floodway area to convey flood flows which can reasonably be expected to occur.
10) Protect the hydraulic characteristics of the small watercourses, including gulches, streams, and artificial water channels used for conveying floodwaters.
11) Reduce continuing Major Drainageway operations and maintenance costs.

In order to accomplish these purposes, this section includes methods and provisions for:

1) Restricting or prohibiting uses which are dangerous to health, safety, and property due to water or erosion hazards, or which result in damaging increases in erosion, flood heights or velocities.

2) Requiring that uses vulnerable to floods, including facilities which serve such uses, be protected against flood damage at the time of initial construction.
3) Controlling the alteration of natural floodplains, stream channels, and natural protective barriers, which help accommodate or channel floodwaters.
4) Controlling the filling, grading, dredging, and other development which may increase flood damage.
5) Preventing or regulating the construction of flood barriers which will unnaturally divert floodwaters, or which may increase flood hazards in other areas.

4.2 Floodplain Mapping

The Federal Emergency Management Agency (FEMA) has published Digital Flood Insurance Rate Maps (DFIRMS) that delineate floodplains. The Urban Drainage and Flood Control District (UDFCD) has published Flood Hazard Area Delineation (FHAD) maps as a part of adopted Major Drainageway Planning. These maps delineate areas flooded by the base flood and many have been adopted by the Colorado Water Conservation Board (CWCB). Proposed development that may have an effect on or be effected by these floodplains shall use the flood delineations adopted by the CWCB or the DFIRM, whichever is more restrictive. Floodplain maps are available from the Village or on line at the FEMA Map Service Center at FEMA.GOV.

Floodplain limits shall be determined by scaling distances from the maps and by plotting the flood elevation based on existing topography. Where a conflict exists between this information and actual field conditions, the City Manager or designee will make the necessary determination.

Whenever a development alters a Major Drainageway, the developer is responsible for making revisions to the floodplain maps at their expense. All plans, details, calculations, and other requirements must be submitted through the Village to UDFCD in accordance with FEMA criteria. The Village shall notify the CWCB as required. In areas where the floodplain has not been mapped, the developer will be required to provide the initial mapping prior to beginning any work within the estimated floodplain.

The Village will issue building permits based on approval of drainage design plans as well as compliance with all other Village requirements. A Conditional Letter of Map Revision (CLOMR) must be issued by FEMA prior to the Village issuing a building permit. “As-Built” surveys must be submitted for construction in or near the floodplain prior to issuance of a certificate of occupancy. All necessary documentation must also have been approved by the Village for submittal to UDFCD.

When construction is completed, the developer shall, at their expense, prepare and submit through the Village to UDFCD all required documents to obtain FEMA’s approval and issuance of a Letter of Map Revision (LOMR).

4.3 General Provisions

4.3.1. Special Flood Hazard Areas

The Special Flood Hazard Areas prepared by the UDFCD and adopted by the CWCB, and the flood areas identified in the FEMA report entitled "The Flood Insurance Study Report for Arapahoe County, Colorado and Incorporated Areas", dated December 17, 2010, with an accompanying updated Digital Flood Insurance Rate Map, are hereby adopted by reference and declared to be a part of this Drainage Criteria Manual. The Flood Insurance Study Report is on file at the City Hall, 6060 South Quebec Street, Greenwood Village, Colorado 80111-4591, with the City Clerk. Areas not included in the federally designated floodplains, but within the Major Drainageways, shall be considered as Special Flood Hazard Areas if they are inundated by the base flood assuming ultimate development conditions in the basin. Major Drainageways are drainageways with at least 130 acres of tributary area. Areas removed from the floodplain by the issuance of a FEMA Letter of Map Revision Based on Fill (LOME-F) shall be considered as Special Flood Hazard Area.

4.3.2 Compliance

No structure shall be constructed, extended, converted, or altered within a Special Flood Hazard Area without full compliance with the requirements of this Drainage Criteria Manual

4.3.3 Abrogation

Where this Drainage Criteria Manual and another ordinance, plat, or other approved plan conflict or overlap, whichever imposes the more stringent restrictions as determined by the City Manager or designee shall prevail.

4.3.4 Interpretation

In the application of this Chapter, all provisions shall be considered as minimum requirements, liberally construed in favor of the Village and deemed neither to limit nor repeal any other powers granted under the State of Colorado Statutes.

4.3.5 Disclaimer

The degree of flood protection required by this Drainage Criteria Manual is considered reasonable for regulatory purposes and is based on scientific and engineering considerations. Larger floods can and will occur on rare occasions. Flood heights may be increased by man-made or natural causes. This Drainage Criteria Manual does not imply that land outside the Special Flood Hazards Areas or uses permitted within such areas will be free from flooding or flood damages. This Drainage Criteria Manual shall not create liability on the part of the Village, any officer or employee thereof, or FEMA for any flood damages that result in reliance on this Drainage Criteria Manual or any administrative decision made thereunder.

4.4 Administration

4.4.1 Permit Application

All permit applications must be approved by the City Manager or designee before construction or development begins within a Special Flood Hazard Area. Application for a permit shall be made on forms furnished by the Village and shall include, but not be limited to, plans in duplicate drawn to scale and certified by a professional engineer licensed in the State of Colorado showing the following:

1) Location, dimensions, uses, and USGS elevations of the area in question.
2) Existing or proposed structures.
3) Existing and proposed contours and drainage facilities.
6) Elevation in relation to mean sea level of the lowest floor (including basement) of all structures. All elevations shall be related to the Greenwood Village Control Diagram.
7) Elevation in relation to mean sea level to which any non-residential structure has been floodproofed and the method of such floodproofing.
8) Description of the extent to which any watercourse will be altered or relocated as a result of proposed development.
9) Evaluation of the cumulative effect of the proposed development, when combined with existing and anticipated development within the floodplain, on the energy grade line elevation of the base flood.

4.4.2 Duties and Responsibilities of the City Manager or Designee

The City Manager or designee shall implement and administer this Drainage Criteria Manual by granting or denying permit applications in accordance with the provisions of this Chapter. Duties of the City Manager or designee shall include, but are not limited to, the following:

1) Permit Review
   a. Review all permit applications to determine that the requirements of this Drainage Criteria Manual have been satisfied.
   b. Review all permit applications to determine that all necessary permits have been

obtained from those federal, state, or local governmental agencies.

c. Review all permit applications to determine if the proposed development is located in the Special Flood Hazard Area.

2) Use of Other Base Flood Data
   a. When base flood elevation data has not been provided in accordance with Section 4.3, the applicant shall provide accurate base flood elevation and floodway data to the City Manager or designee in order to administer Section 4.5.
3) Information to be Obtained and Maintained
   a. Obtain and record the actual elevation in relation to mean sea level of the lowest floor (including basement) of all new or substantially improved structures, which are positioned within Special Flood Hazard Areas.
   b. For all new or substantially improved floodproofed structures:
      i. Verify and record the actual first floor elevations (in relation to mean sea level).
      ii. Maintain the floodproofing certifications required in Section 4.5.3.
   c. Maintain for public inspection all records pertaining to the provisions of this Drainage Criteria Manual and in accordance with the provisions of the current edition of the International Building Code and Uniform Plumbing Code as referenced by the Village.
4) Alteration of Watercourses
   a. Notify adjacent communities and the CWCB prior to any alteration or relocation of a watercourse and submit evidence of such notification to the UDFCD.
   b. Require that maintenance be provided within the altered or relocated portion of said watercourse to preclude diminishing the flood carrying capacity.
5) Interpretation of Flood Boundaries
   a. Make interpretations where needed, as to the exact location of the boundaries of the Special Flood Hazards Areas (for example, where there appears to be a conflict between a mapped boundary and actual field conditions). The person contesting the location of the boundary shall be given a reasonable opportunity to appeal the interpretation as provided in Section 3.4.

4.4.3 Nonconforming Uses

The existing lawful use of a structure or premises which is not in conformity with the provisions of this Drainage Criteria Manual may be continued subject to the following conditions:

1) No such use shall be expanded or enlarged except in conformity with the provisions of this Drainage Criteria Manual.
2) No structure alteration, addition, or repair to any nonconforming structure over the life of the structure shall exceed fifty percent (50%) of its assessed value at the time of its becoming a nonconforming use unless permanently changed to a conforming use.

3) If such use is discontinued for twelve (12) consecutive months, any future use of the building or premises shall conform to this Chapter.
4) Any alteration, addition, or repair permitted to any non-conforming non-residential structure shall be protected by floodproofing measures in accordance with Section 4.5.3.

4.4.4 Permitted Uses

The permitted uses in Special Flood Hazard Areas are horizontal construction including but not limited to roads, sports fields (without fences), golf courses, and hiking/biking trails that will not impair the capacity of the drainageway to convey water, cause the water surface or the velocities of the base flood to increase, and cause the energy grade line to increase by more than 6 inches. Parking lots and sport courts with fences or netting are not permitted uses in Special Flood Hazard Areas. In addition, stormwater storage and water quality treatment facilities are not permitted uses in Special Flood Hazard Areas unless the facility controls the drainageway.

4.5 Special Flood Hazard Areas

4.5.1 General Provisions

Encroachments in areas flooded by the base flood are restricted. This restriction includes fill for roads and levees, obstruction, storage of materials, or other floodplain uses which acting alone or in combination with existing or future floodplain uses adversely affects the efficiency, the capacity of the floodway, increases flood heights, or decreases the storage capacity of the floodplain based on the assumption that there will be “equal degree of encroachment” extending for a significant “reach” on both sides of the stream.

No floodplain uses shall adversely affect the efficiency of or unduly restrict the capacity of the channels or floodways of Major Drainageways, ditches, or any other drainage facilities.

No permit shall be issued for the construction of a new structure on a property removed from the floodplain by issuance of a FEMA Letter of Map Revision Based on Fill (LOMR-F) with the lowest floor elevation placed less than one foot above the adjacent base flood elevation or less than one foot above the prior base flood elevation, whichever base flood elevation is greater.

4.5.2 Floodways

Floodways are special zones within the Special Flood Hazard Areas as established in Section 4.3.1. Since the Floodway is an extremely hazardous area due to the velocity of floodwaters which carry debris, potential projectiles, and erosion potential, the following provisions apply:

1) All encroachments, including fill, new construction, substantial improvements, and other development are prohibited in the Floodway.

2) If Provision 1 is satisfied, all new construction and substantial improvements shall comply with all applicable flood hazard reduction provisions of Section 4.5.3.

4.5.3 Provisions for Flood Hazard Reduction

Within the areas flooded by the base flood, the following standards are required:

1) Anchoring
   a. All new construction and substantial improvements shall be anchored to prevent flotation, collapse, or lateral movement of the structure and to withstand hydrodynamic loads. Fences, logs, railroad ties, and the like are included.
2) Construction Materials and Methods
   a. All new construction and substantial improvements shall be constructed with material and utility equipment resistant to flood damage.
   b. All new construction and substantial improvements shall be constructed using methods and practices that minimize flood damage.
3) Utilities
   a. All new and replacement water supply systems shall be designed to minimize or eliminate infiltration of floodwaters into the system.
   b. New and replacement sanitary sewage systems shall be designed to minimize or eliminate infiltration of floodwaters into the system and discharges from the system into floodwaters.
   c. On-site waste disposal systems shall be located to avoid impairment to them or contamination from them during flooding.
   d. Electrical, heating, ventilation, plumbing, and air-conditioning equipment and other service facilities shall be designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.
4) Subdivision Proposals
   a. All subdivision proposals shall be consistent with the need to minimize flood damage.
   b. All subdivision proposals shall have public utilities and facilities located and constructed to minimize flood damage.
   c. All subdivision proposals shall have adequate drainage provided to reduce flood damage.
   d. Base flood elevation data shall be provided for all subdivision proposals and other proposed developments which contain at least forty (40) lots or five (5) acres or more.
5) Residential Construction
   a. New construction and Substantial Improvements of any residential structures shall have the lowest floor, including basement, elevated at least one (1) foot above the base flood elevation.
   b. Manufactured homes, recreational vehicles and enclosures are prohibited in the

Special Flood Hazard Area.

6) Nonresidential Construction
   a. New construction and substantial improvement of any commercial, industrial, or other nonresidential structure shall either have the lowest floor, including basement, elevated to one (1) foot above the base flood elevation or-
      i. Be flood proofed one foot above the base flood elevation the structure is watertight with walls substantially impermeable to the passage of water and,
      ii. Have structural components capable of resisting hydrostatic and hydrodynamic loads and effects of buoyancy and,
      iii. Provide that where a non-residential structure is intended to be made watertight one foot above the base flood elevation: (1) a licensed professional engineer or architect shall develop and/or review structural design, specifications, and plans for the construction, and shall certify that the design and methods of construction are in accordance with accepted standards of practice for meeting the applicable provisions of Section 4.5.3 and (2) a record of such certification which includes the specific elevation (in relation to mean sea level) to which such structures are floodproofed shall be maintained with the City Manager or designee.
7) All new and substantially improved Critical Facilities and new additions to Critical Facilities shall be located outside the Special Flood Hazard Area.

5.0 Rainfall

5.1 Introduction

Rainfall patterns have a strong influence on the volume and rate of stormwater runoff in a drainage system. The Urban Drainage Flood Control District (UDFCD) has maintained an ongoing study of rainfall patterns in the Denver Region since the publication of the UDFCD Drainage Criteria Manual in 1969. These studies have confirmed the accuracy and reasonableness of the rainfall maps published in 1973 by the National Oceanic and Atmospheric Administration (NOAA) for Colorado. As a result, the UDFCD has adopted the NOAA maps as a starting point for the procedures for determining the different rainfall patterns that are likely to occur throughout the Denver region.

The highest rainfall tends to occur in the higher elevation areas such as the foothills in Jefferson County, Douglas County near Sedalia, and the eastern parts of Aurora. The rainfall depths in the City of Greenwood Village (Village) tend to be very similar to the rainfall depths within the City and County of Denver.

The stormwater management policies of the Village strongly encourage the use of local on-site detention, grass-lined swales, and stormwater infiltration systems to attenuate peak flood discharges and improve stormwater quality. As a result, many of the facilities are designed for drainage basins smaller than 90 acres with times to the peak rate of discharge that are less than 30 minutes. This requires the use of rainfall patterns in the design of facilities that are shorter than one-hour duration.

The Village recognizes the methodologies developed by the UDFCD as the standard method of practice for determining design rainfall patterns for design storms equal to or larger than one hour duration. These methods shall be used in the preparation of any drainage study or drawings submitted to the Village.

5.2 Flood Control Design Storms

Storms used in the design of flood control facilities are selected on the basis of

1) A temporal distribution that reflects the regional climatological and meteorological conditions.
2) A duration that produces the highest peak rate of runoff consistent with the size, shape, slope, and proposed development characteristics of the basin.

Flood control facilities are typically designed for storms with 1, 2, 3 or 6–hour durations. The selection of the proper storm duration depends on the size, shape, slope and development

characteristics of the basin. The proper storm duration for flood control purposes is the storm which produces the highest peak rate of runoff for the proposed development conditions in the study area. The proper duration is usually equal to the time of concentration when using the Rational Method or the closest standard duration (1, 2, 3 or 6-hour) when using the Colorado Unit Hydrograph Procedure (CUHP) for calculating runoff. For unusual shaped basins (e.g. length to width ratio greater than four to one), the basin should be divided into smaller sub-basins and a trial and error method should be used to determine the storm duration which produces the highest peak rate of runoff.

The rainfall depths for the 1, 2, 3, and 6-hour storms in the Village are summarized in Table 5-1. The depths were taken from the UDFCD Rainfall Depth-Duration-Frequency Maps found in the Rainfall Chapter, Volume 1 of the UDFCD Drainage Criteria for the 2, 5,10, 50 and 100-year return periods. The 2-hour and 3-hour rainfall depths were interpolated from the 1-hour and 6-hour depths using the methodology described in the Rainfall Chapter, Volume 1 of the UDFCD Drainage Criteria Manual.

Table 5-1: Rainfall Depths for Greenwood Village

	Duration			
Frequency (years)	1-hr (in)	2-hr (in)	3-hr (in)	6-hr (in)
2	0.97	1.18	1.28	1.44
5	1.34	1.58	1.73	1.96
10	1.55	1.82	2.02	2.29
50	2.24	2.79	2.79	3.09
100	2.58	2.88	3.17	3.46

The methodologies for estimating the runoff coefficient for the Rational Method and effective rainfall for CUHP are described in detail in Chapter 6.0. The Time-Intensity-Frequency curves for storms less than one hour duration were developed using the methodology described in the Rainfall Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. The factors used for calculating the intermediate rainfall depths after 5, 10, 15 and 30 minutes were taken from the NOAA Atlas 2, Volume III, 1973 as reported in the Rainfall Chapter, Volume 1 of the UDFCD Drainage Criteria Manual.

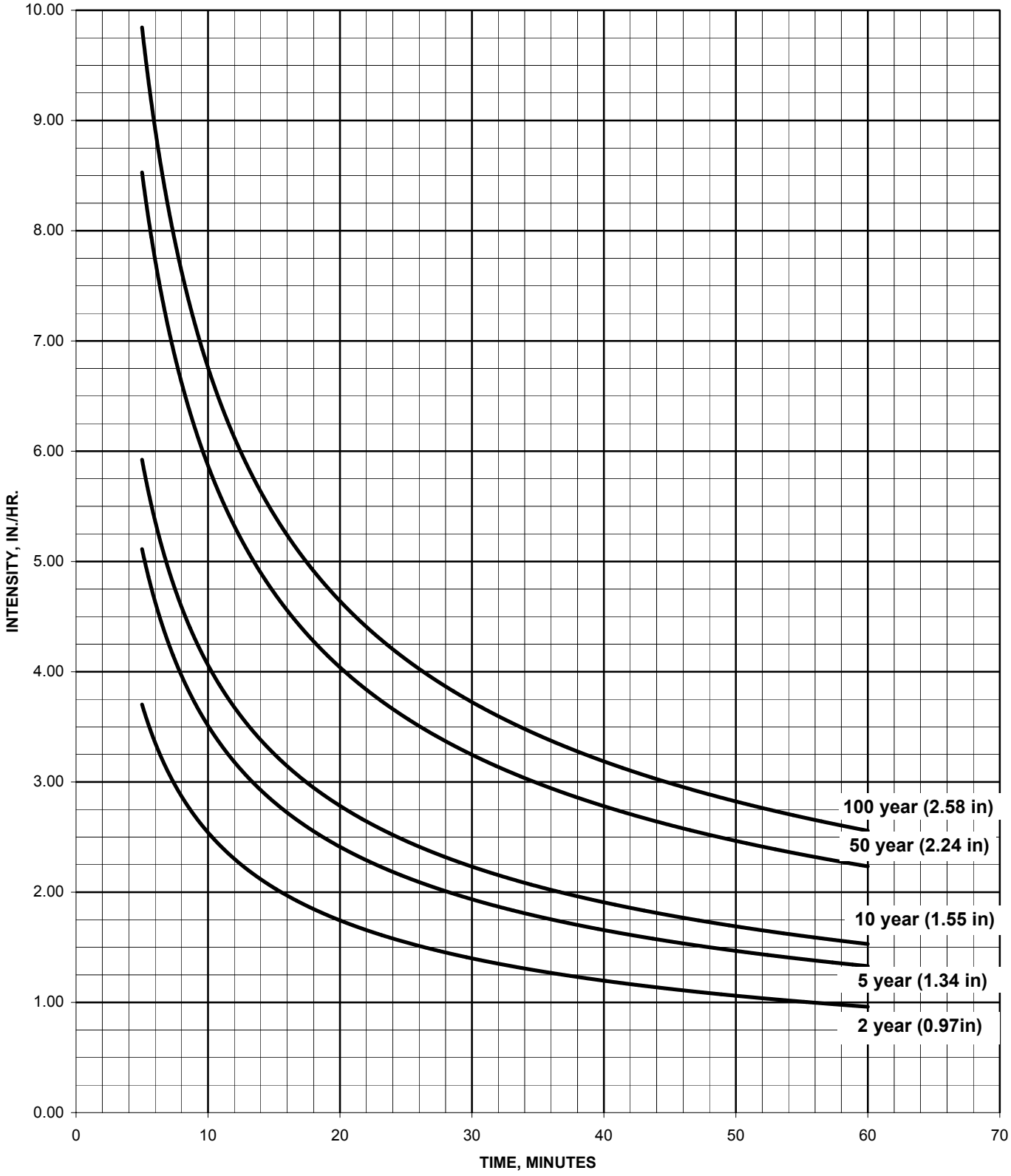
Figure 5-1 is a plot of the Flood Flows – Time-Intensity-Frequency curves. The curves were developed according to the methodologies provided in the Rainfall Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. These curves shall be used to estimate rainfall intensity as needed for the Rational Method Formula when calculating peak rates of runoff.

5.3 Water Quality Design Storm

For reasons to be discussed in Chapter 6.0 Runoff, it is likely that stormwater quality

management facilities in the Village will be designed to capture and treat storms that are around the 2-year event.

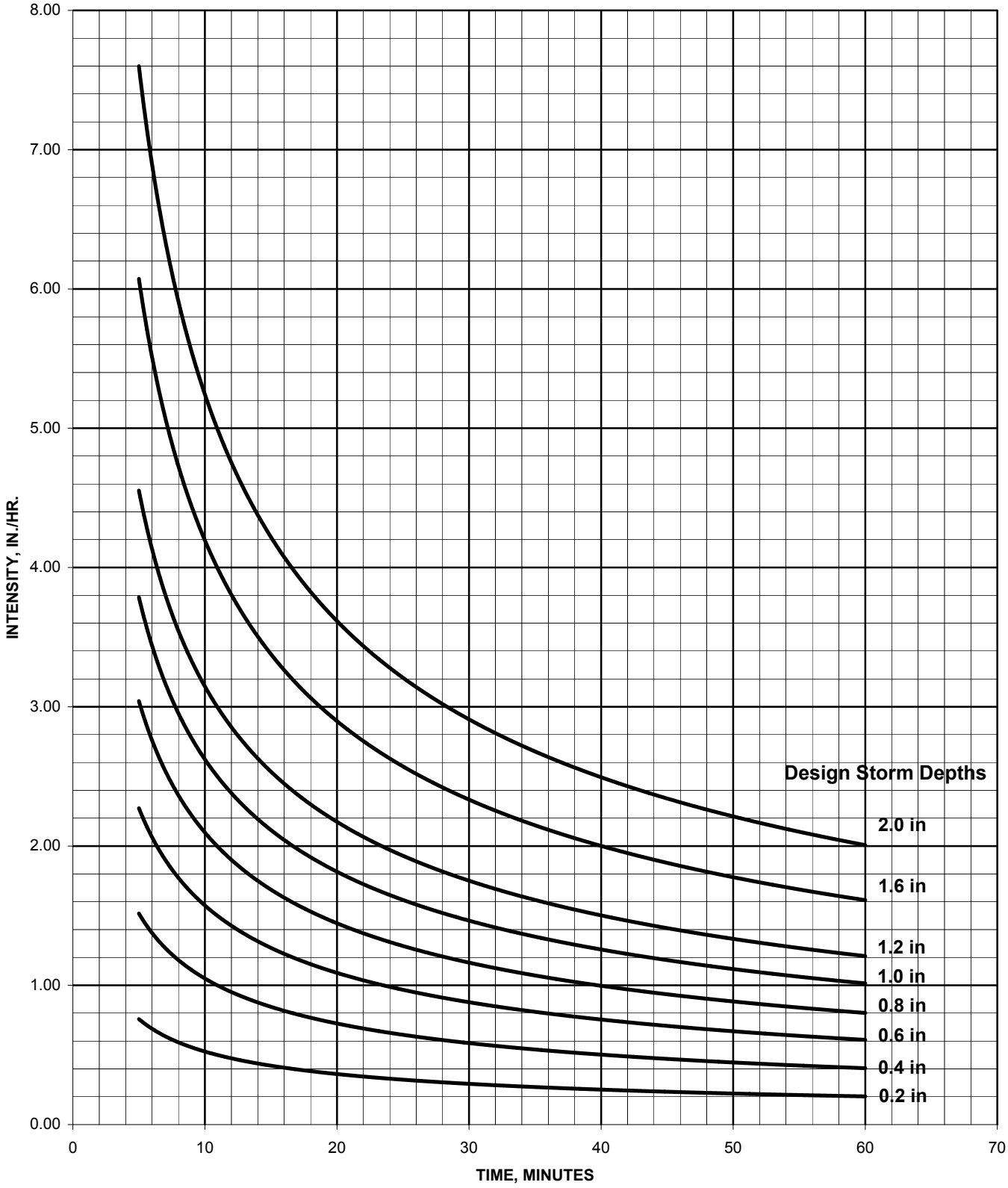
Figure 5-2 contains the Water Quality – Time-Intensity-Depth curves for several storms that may be selected as the water quality design storm for the Rational Method. Values can be interpolated for design storm depths that are not plotted in Figure 5-2. If the CUHP is used, the same temporal distributions discussed in Sections 5.2.1 can be used to estimate the effective rainfall for the selected design rainfall.



Greenwood Village
October 2003

Figure 5-1
Flood Flows
Time-Intensity-Frequency Curves

FIG 5-1,5-2.xls\Figure 5-1



Greenwood Village
October 2003

Figure 5-2
Water Quality Design Storm
Time-Intensity-Depth Curves

FIG 5-1,5-2.xls\Figure 5.2

6.0 Runoff

6.1 Introduction

The timing, peak rates of discharge, and volume of stormwater runoff are the primary considerations in the design of drainage facilities for the management of flood discharges and water quality in drainage systems. The purpose of this Chapter is to provide a dependable and consistent methodology for estimating storm runoff in the City of Greenwood Village (Village). It depends to a great degree on the general methods developed by the Urban Drainage Flood Control District (UDFCD) that are applicable to the entire region. This Chapter includes refinements that are necessary to address the local physical conditions, including soil types and typical drainage basin size, and water quality goals of the Village. The methodologies for estimating storm runoff described in this Chapter are to be used for all drainage studies submitted to the Village. Whenever there is a conflict between the methodologies described in the UDFCD Drainage Criteria Manual and this Drainage Criteria Manual, the methodologies described in this Drainage Criteria Manual shall be used.

6.2 Flood Control Design Runoff

6.2.1 Basin Size Criterion

The Rational Method and the Colorado Unit Hydrograph Procedure (CUHP) are the two methods that have been widely adopted as the preferred methods for estimating runoff patterns in the Denver metropolitan region. The Rational Method is a simplified approach that has proven to be reliable for the design of storm sewers and determining runoff from small drainage basins. The CUHP is a more sophisticated approach and is generally recommended for larger basins with more complex design needs. The UDFCD recommends the use of CUHP for basins larger than 90 acres. For smaller basins, the UDFCD has developed a modified CUHP method that can be applied to basins in the 10 to 90 acre range.

Most of the drainage basins within the Village are in the range of 10 to 90 acres and require relatively sophisticated drainage improvements to meet the land use, recreation, flood control, and water quality goals of the Village. The optimum design of these facilities requires significantly more study, thought, and judgment than can be obtained using the Rational Method. For these reasons, the Village requires the use of the more sophisticated CUHP for estimating runoff from any basin larger than 10 acres.

The CUHP provides a higher degree of dependability for estimating the peak runoff rates and the time of distribution of runoff. Both of these parameters can have a significant impact on the design of a flood control facility such as a detention facility or grass-lined drainage channel. The requirement to use CUHP for all drainage basins larger than 10 acres is a reasonable

application of this technology. It is likely that the critical rainfall pattern for determining the peak rate of runoff for basins in the 10 to 90 acre range will be the 1-hour storm because the times of concentration for basins this size in the Village are typically between 10 and 45 minutes.

Use of the Rational Method for storm sewer design is a well-established local and regional practice that is appropriate for drainage design with multiple, small basins. The Village will continue to permit use of the Rational Method for estimating runoff in storm sewer design.

6.2.2 Application of Design Methods

The first step in applying the various analysis and design methods is to obtain a representative topographic map of the drainage basin and to define the boundaries of all the relevant drainage basins. Basins to be defined include all basins tributary to the area of study and sub-basins in the study areas. Field checks and possibly field surveys should be completed for each basin. At the preliminary stage of planning, the possibility of the diversion of transbasin waters into the study basin should be investigated. Such imports of drainage water could be a result of drainage improvements by others or overflows from irrigation canals such as the Highline Canal.

Transbasin diversions out of the study area should also be kept in mind. The engineer should be very cautious when reducing a design flow due to a transbasin export, particularly for the major storm analysis. This approach could cause significant drainage problems in the basin receiving the exported flows.

The boundaries of the major storm drainage basin frequently, but do not always, coincide with the boundaries of the minor storm drainage basin. This is often the case in urban areas where low flows from the minor storm will remain contained by the curb and gutter and follow the grade, but when a large flow occurs, the water will be deep enough to cause part of the water to overflow street crowns and flow into a new sub-basin.

When analyzing the major runoff event occurring on an area that has a storm sewer system sized for the minor storm, care must be used when determining the time of concentration. Normally, the design of storm sewers assumes that all of the runoff is collected by the storm sewer or gutter. For the minor storm design, the time of concentration is, in part, dependent upon the flow time in the storm sewer. However, during the major runoff event, the storm sewers are likely to be at capacity and cannot accept all the runoff flowing to the inlets. This additional runoff then bypasses the inlets and continues overland, generally at a significantly lower velocity than the runoff in the storm sewers. This requires an analysis of different times of concentration between underground flow and overland flow.

This difference in travel times allows for the storm sewer to continue flowing full for a longer period and, in effect, carry significant portions of the major runoff. The basis for this increased benefit is that the excess runoff from one inlet will flow to the next inlet downhill, using the overland route. If that inlet also at capacity, the runoff will often continue on until capacity is

available in the storm sewer. The analysis of this aspect of the interaction between the storm sewer system and the major storm runoff is complex. The most useful procedure for this analysis is the routing of the major and minor storm runoff hydrographs through the overland and storm sewer routes concurrently.

6.2.3 Rational Method

As discussed in Section 6.2.1, the Rational Method can only be used for drainage studies in the Village with basins smaller than 10 acres. The Rational Method is based on the Rational Formula as presented in the Runoff Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. The assumptions and limitations presented in the UDFCD Drainage Criteria Manual should be reviewed to ensure that the use of the Rational Method is appropriate.

6.2.3.1 Time of Concentration

The UDFCD provides a methodology for estimating the times of concentration for both urban and rural areas in the Runoff Chapter, Volume 1 of its Drainage Criteria Manual. This method shall be used to estimate times of concentration for use with the Rational Method in the Village. The initial flow time shall be used for sheet flow conditions only. Once the flow becomes concentrated by a swale, ditch, gutter, or storm sewer, then the travel time equations shall be used.

The minimum time of concentration shall be 5 minutes for urban areas and 10 minutes for rural areas. The maximum time of concentration for urbanized areas shall not exceed that discussed in the UDFCD Drainage Criteria Manual.

6.2.3.2 Intensity

The intensity, I, is the average rainfall rate, in inches per hour, for the period of maximum rainfall of a given frequency having a duration equal to the time of concentration.

After the design rainfall has been selected (i.e., 2-yr, 5-yr, or 100-yr frequency occurrence) the intensity can be determined for the selected time of concentration using Figure 5-1.

6.2.3.3 Runoff Coefficient

The runoff coefficient, C, represents the integrated effects of infiltration, evaporation, retention, flow routing, and interception all of which effect the time distribution and peak rate of runoff. Determination of the runoff coefficient requires judgment and understanding by the engineer.. The coefficients presented in the Runoff Chapter, Volume 1 of the UDFCD Drainage Criteria Manual shall be used. Because the coefficients vary with frequency, no further adjustments are needed for large storms.

The determination of the percent of impervious area is an important parameter for determining the runoff coefficient. Surface area is either considered pervious or impervious. Pervious areas are those surface areas where water can readily infiltrate into the ground. Impervious areas are those surface areas where the infiltration of water into the ground is restricted. Examples of impervious areas are parking lots, sidewalks, roads, pool deck areas, and structures. As an area is developed, i.e., the land use changes from undeveloped to commercial, industrial, and/or residential use, the amount of impervious area typically increases. As the percent of impervious area increases, generally less water infiltrates into the ground. This will cause the stormwater runoff volumes to increase, the time to the runoff peak to decrease, and the stormwater peak runoff rates to increase.

The proposed development conditions shall be used to estimate the percent impervious area. The estimated imperviousness presented in the Runoff Chapter, Volume 1 of the UDFCD Drainage Criteria Manual provides general guidance for estimating the percent impervious area during the early planning stages for a project. The estimates present typical values for the Denver region. For lots greater than ½ acre, Figure 6-1 shall be used. Figure 6-1 is based on a survey of actual percent impervious area for modern low-density residential subdivisions in the Village and Lakewood, Colorado. The estimates on probable impervious area are to be used in the early stages of planning for a project and can be used only for a Conceptual and Preliminary Drainage Study. As soon as a site layout has been prepared by the applicant, a more accurate estimate of the impervious area for the project will be required to be used. Impervious area estimates based solely on the information contained in UDFCD Drainage Criteria Manuals and Figure 6-1 will not be acceptable for inclusion in a Final Drainage Study.

6.2.4 CUHP Method

As discussed in Section 6.2.1, the CUHP shall be used for all drainage studies in the Village with basins larger than 10 acres.

6.2.4.1 CUHP Rainfall Patterns

The CUHP was designed to be used with the NOAA 1-hour rainfall depths for the Denver region. The temporal distribution to be used in the Village can be derived using the Village's rainfall depths and the methodology described in the Rainfall Chapter, Volume 1 of the UDFCD Drainage Criteria Manual.

6.2.4.2 CUHP Effective Rainfall

Effective rainfall is that portion of precipitation which runs off land into a drainageway closely following a precipitation event. Those portions of precipitation that do not result in runoff are called abstractions. Abstractions include interception by vegetation, evaporation, infiltration, storage in all surface depressions, and long-time surface retention.

The abstractions for pervious areas tend to be substantially larger than those for impervious areas. Any reasonable estimate of effective rainfall must be based on a reasonably accurate estimate of the impervious area. Refer to Section 6.2.3.3 for a discussion of impervious area and the acceptable methods for estimating impervious area.

Precipitation that is collected and held in small surface depressions and does not become a part of general surface runoff is called depression storage. Most of this water is eventually infiltrated or evaporated. The CUHP method requires values for retention losses as input in calculating effective rainfall. The actual input to the CUHP can be an area-weighted average for the basin.

Infiltration is the flow of water into the soil surface. Soil type and soil moisture content are the most important factors for determining infiltration rates. Fine-grain soils, clays and clay loams, exhibit slower infiltration rates and coarse-grained soils, sands, exhibit faster infiltration rates. As soil moisture increases, the rate of infiltration decreases. If the soil has several layers or horizons, the least permeable layer will control the maximum infiltration rate. Vegetation, lawn grass in particular, tends to increase infiltration by loosening the soil on the surface. Other factors that affect infiltration rates include slope of land, quality of water, age of lawn, and soil compaction.

As the rainfall continues, infiltration rates decrease. When a rainfall event occurs on dry soil, the infiltration rate is higher than if it occurs on a wet soil, such as irrigated lawn grass. This changing rate of infiltration is more important for small rainfall events which carry a majority of the stormwater pollution than it is for larger rainfall events such as the 100-year storm.

The UDFCD uses Horton's Equation for estimating infiltration abstractions for the CUHP. The CUHP Method described in the Runoff Chapter, Volume 1 of the UDFCD Drainage Criteria Manual shall be used for estimating runoff hydrographs in the Village.

6.3 Water Quality Control Design Runoff

Urbanization typically leads to a decrease in pervious land areas. This, in turn, causes an increase in the volume of runoff and typically allows accumulated pollutants to more easily wash off the surface quickening their conveyance through the watershed. Human activities such as lawn fertilization, use and disposal of chemicals, and ice control on streets also increases the potential pollutant loads on receiving streams during a storm.

The concept of a "first flush" of stormwater pollutants has been studied for a number of years with mixed conclusions. The first flush refers to the initial higher concentrations of pollutants contained in the runoff at the beginning of a rainfall event. Although there is a high degree of certainty that the concentrations of pollutants in the runoff are higher at the beginning of the storm, there is less certainty concerning the relative importance of this first flush when compared with the lower concentrations of pollutants which occur as the storm continues. Understanding these differences can be important if a stormwater quality management facility is designed to focus only on the treatment of the first flush.

The Village requires the design of stormwater quality management systems for an entire design storm. The focus of the design effort then shifts to the consideration of the size of the runoff event to be included. The following Sections define a procedure for selecting the size of the storm to be managed by the water quality-related improvements in a drainage system. Chapter 16.0 defines the procedures for estimating the effectiveness of alternative control measures for removing pollutants from the selected design storm. Based on an analysis of the relative annual contribution of pollutants for the design storm conditions and the effectiveness of the proposed improvements to remove the pollutants for the design storm, the overall effectiveness of the proposed system can be evaluated and compared with the stormwater quality goals of the Village.

6.3.1 Precipitation Patterns

The UDFCD has studied precipitation patterns for the Denver region based on many years of record at Stapleton Airport. Based on that analysis, it was concluded that the average storm in the region has an 11-hour duration with an average time interval between storms of 11.5 days. It was further noted that only about 30 storms per year are large enough, with more than 0.1 inches total precipitation, to cause significant runoff. Of these runoff events, approximately 75 percent or 22 events are the result of storms with a total depth of 0.1 to 0.5 inches. Thus, it was concluded that facilities designed to treat runoff from a 0.5-inch event would be “very effective.”

Later, more detailed studies, considered the effects of impervious areas, time intervals between storms, and alternative sizes for capture volumes. These studies concluded that facilities designed to capture the 80th percentile runoff event would remove 80 % to 90 % of the annual total suspended solids load in the stormwater, while doubling the capture volume was estimated to only increase removal rates by 1% to 2 %.

The determination of an optimum design storm for water quality management will depend upon a number of factors, including but not limited to:

1) Type of land use,
2) percent impervious areas,
3) effectiveness of the selected water quality control measures, and
4) water quality goals of the receiving stream.

With this wide range of factors, it is not possible to determine a design storm for water quality control purposes without considering site specific conditions.

To assist in this analysis, the Village has studied in detail the precipitation and runoff patterns that are likely to occur within the Village. Table 6-1 summarizes the precipitation patterns recorded at the Cherry Creek Reservoir gauge from 1952 through 1997. The total average annual precipitation is 16.37 inches and the average number of runoff events, with precipitation greater than 0.1 inches, is 35.

Table 6-1: Average Annual Precipitation Patterns in Greenwood Village

Precipitation Event Rage (in)	Average Event (in)	Events Per Year (number)	Annual Precipitation (in)	Accumulative Annual Precipitation (in)	Accumulative Annual Precipitation (%)	Accumulative Annual Measurable Events (number)	Accumulative Annual Measurable Events (%)
0.00				0.00	0.00	0.00	0.00
	0.00	294.71	0.00				
0.01				0.00	0.00	0.00	0.00
	0.05	35.39	1.77				
0.10				1.77	10.81	35.39	50.38
	0.15	12.50	1.88				
0.20				3.65	22.30	48.89	68.17
	0.25	6.41	1.60				
0.30				5.25	32.07	54.30	77.30
	0.35	3.85	1.35				
0.40				6.60	40.32	58.15	82.78
	0.45	3.26	1.47				
0.50				8.07	49.30	61.41	87.42
	0.55	2.00	1.10				
0.60				9.17	56.02	63.41	90.26
	0.65	1.50	0.98				
0.70				10.15	62.00	64.91	92.40
	0.75	1.33	1.00				
0.80				11.15	68.11	66.24	94.29
	0.85	0.90	0.77				
0.90				11.92	72.82	67.14	95.57
	0.95	0.62	0.59				
1.00				12.51	76.42	67.76	96.46
	1.05	0.43	0.45				
1.10				12.96	79.17	68.19	97.07
	1.15	0.35	0.40				
1.20				13.36	81.61	68.54	97.57
	1.25	0.28	0.35				
1.30				13.71	83.75	68.82	97.96
	1.35	0.22	0.30				
1.40				14.01	85.58	69.04	98.28
	1.45	0.22	0.32				
1.50				14.33	87.54	69.26	98.59
	1.55	0.20	0.31				
1.60				14.64	89.43	69.46	98.88
	1.65	0.17	0.28				
1.70				14.92	91.14	69.63	99.12
	1.75	0.13	0.23				
1.80				15.15	92.55	69.76	99.30
	1.85	0.10	0.19				
1.90				15.34	93.71	69.86	99.44
	1.95	0.07	0.14				
2.00				15.48	94.56	69.93	99.54
	2.125	0.07	0.15				
2.25				15.63	95.48	70.00	99.64
	2.375	0.07	0.17				
2.50				15.80	96.52	70.07	99.74
	2.625	0.04	0.11				
2.75				15.91	97.19	70.11	99.80
	2.875	0.04	0.12				
3.00				16.03	97.92	70.15	99.86
	3.25	0.08	0.26				
3.50				16.29	99.51	70.23	99.97
	3.75	0.02	0.08				
4.00				16.37	100.00	70.25	100.00
Total		364.96	16.37				

Based on total precipitation records at US Army Corps of Engineers gage at Cherry Creek Reservoir (1952 - 1997).

6.3.2 Determination of Runoff for the Water Quality Design Storm

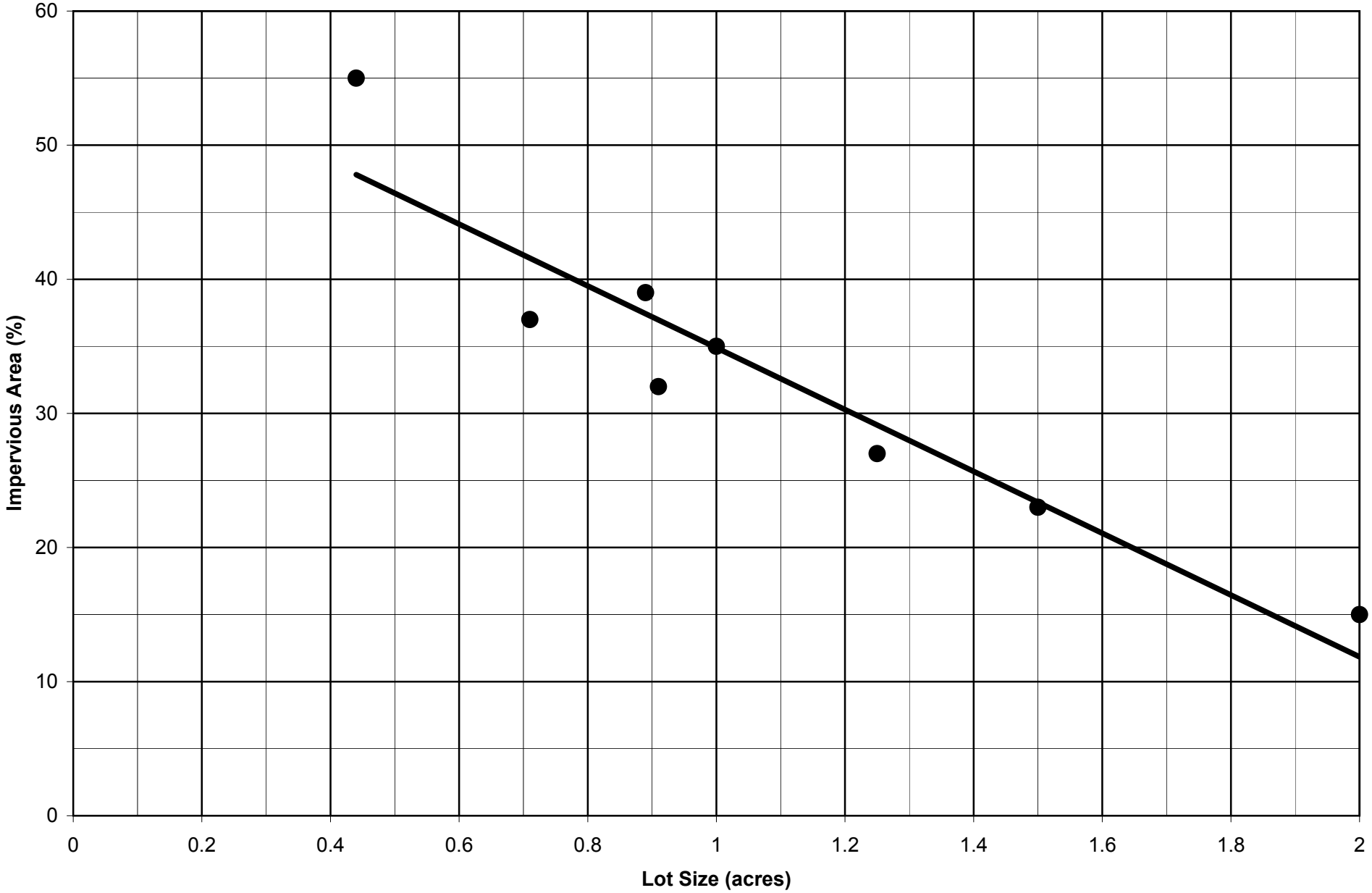
The runoff for each precipitation event will depend primarily upon the percent imperviousness and the soil type. The runoff for various size precipitation events were estimated for different ranges of percent imperviousness for the three major soil types in the Village using the CUHP Method described in Section 6.2.4. Figures 6-2 and 6-3 show the runoff results from a selected design storm for different soil types and percent imperviousness conditions. These curves shall be used to estimate the runoff volume for a selected water quality design storm.

The peak rate of runoff for the selected design storm shall be based on the Rational Method for basins smaller than 10 acres and the CUHP Method for basins larger than 10 acres as described in Section 6.2.

6.3.3 Determination of Design Storm Runoff for Calculating Annual Phosphorus Loads

The phosphorus removal rate will be estimated based on the design storm conditions used to design the water quality control facility. For storms larger than the selected design storm, it can be reasonably assumed that a well-designed facility will remove at least the same mass of phosphorus that was removed for the design storm condition. It can also be assumed that the total phosphorus loading in a given storm is proportional to the volume of runoff. This is a conservative assumption that essentially ignores the higher concentrations of phosphorus that occur during the first flush.

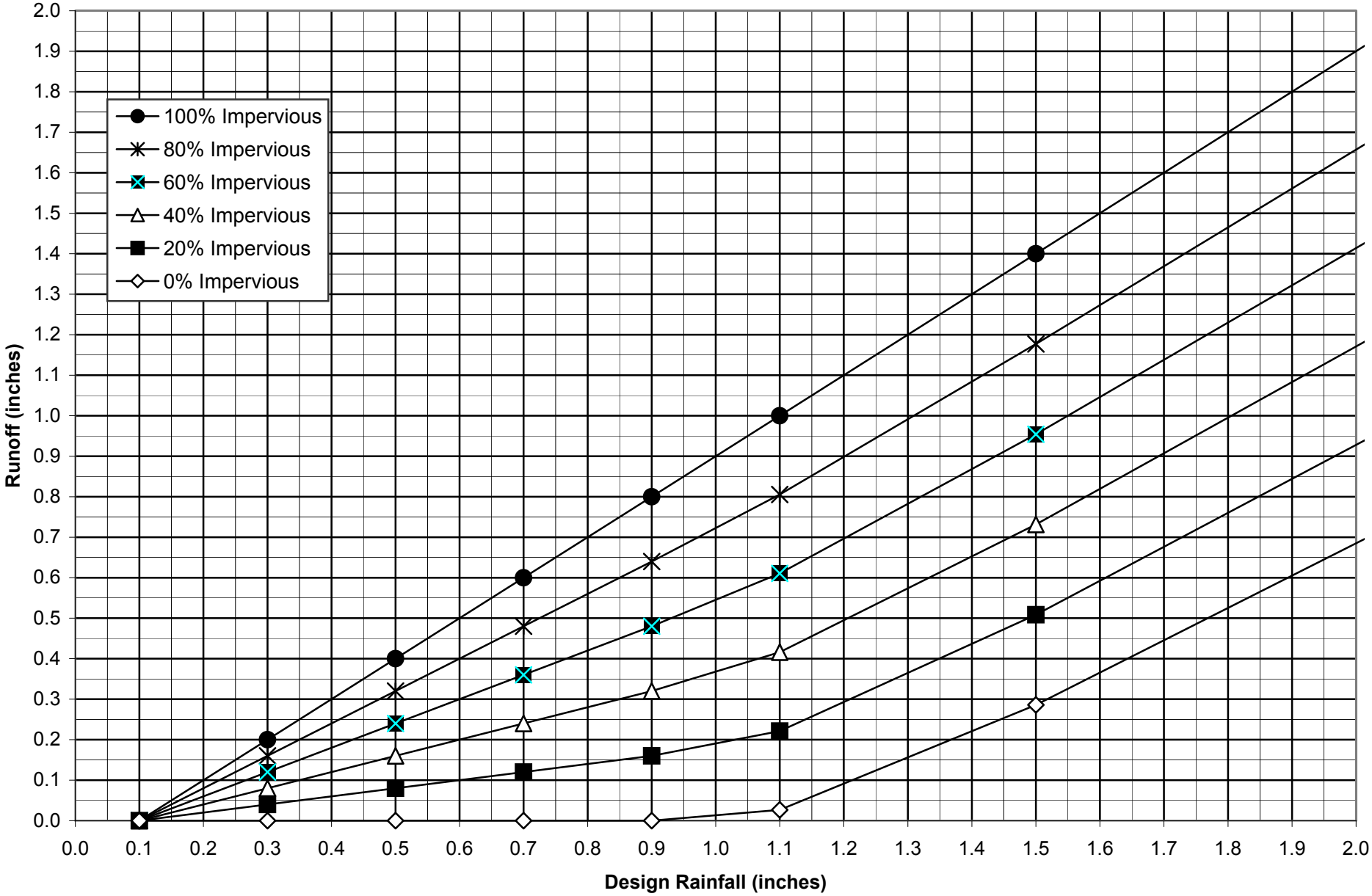
Figures 6-4 and 6-5 provide the percent captured in a facility based on the assumptions presented above, the percent imperviousness of a site, and the soil type of the site. These figures shall be used to estimate the percent captured in a facility for a selected design storm. This percent captured and the effectiveness of the selected control measure as calculated following the procedures described in Chapter 16.0, shall be used to estimate the phosphorus removal efficiency of the proposed facility.



Greenwood Village
October 2003

Figure 6-1
Percent Imperviousness for
Low Density Residential Housing

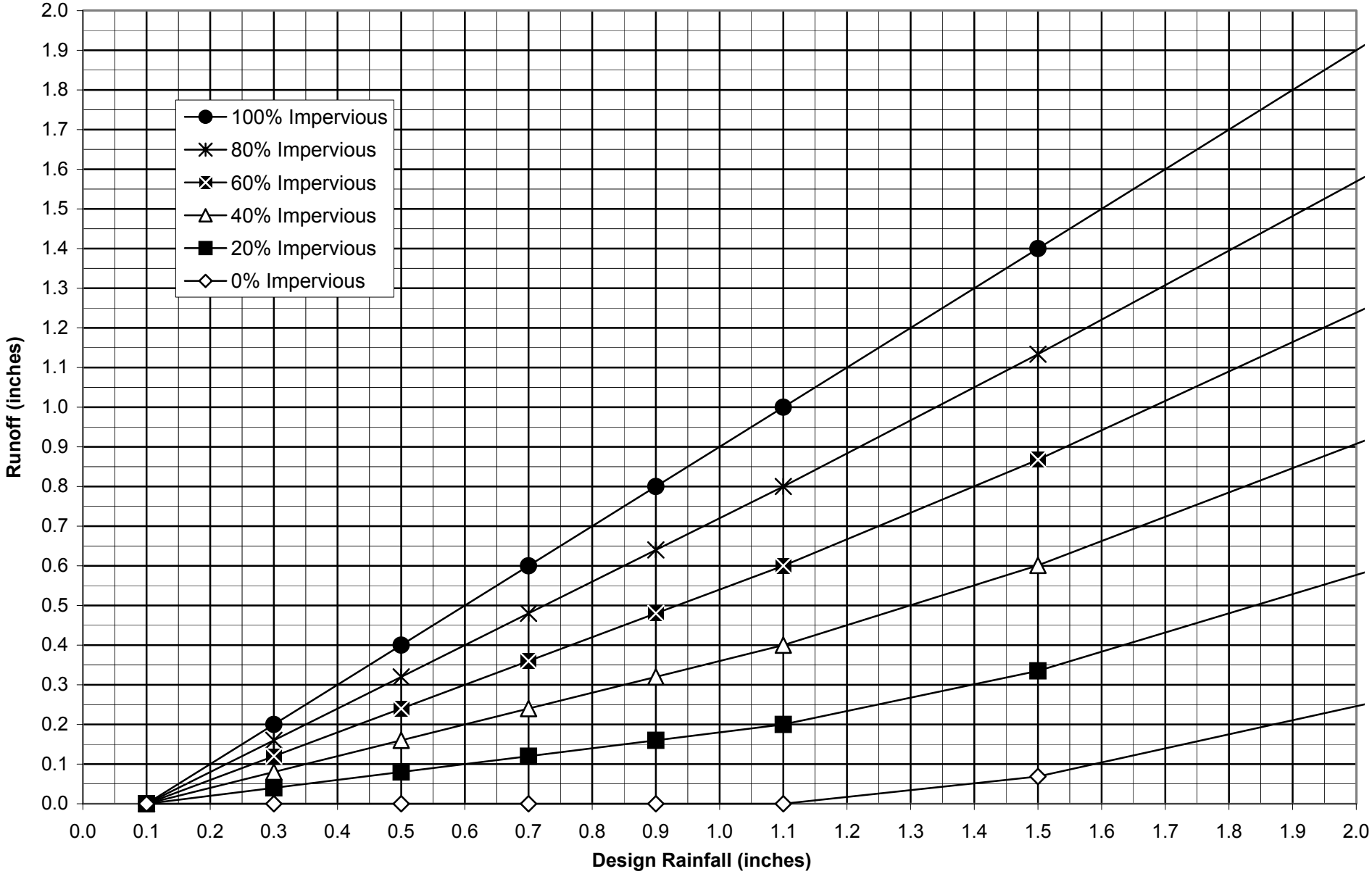
2003 Figures 6-1 to 6-3.xls-Figure 6.1



Greenwood Village
October 2003

2003 Figures 6-1 to 6-3.xls-CLAY&LOAMS WQ fig6.2

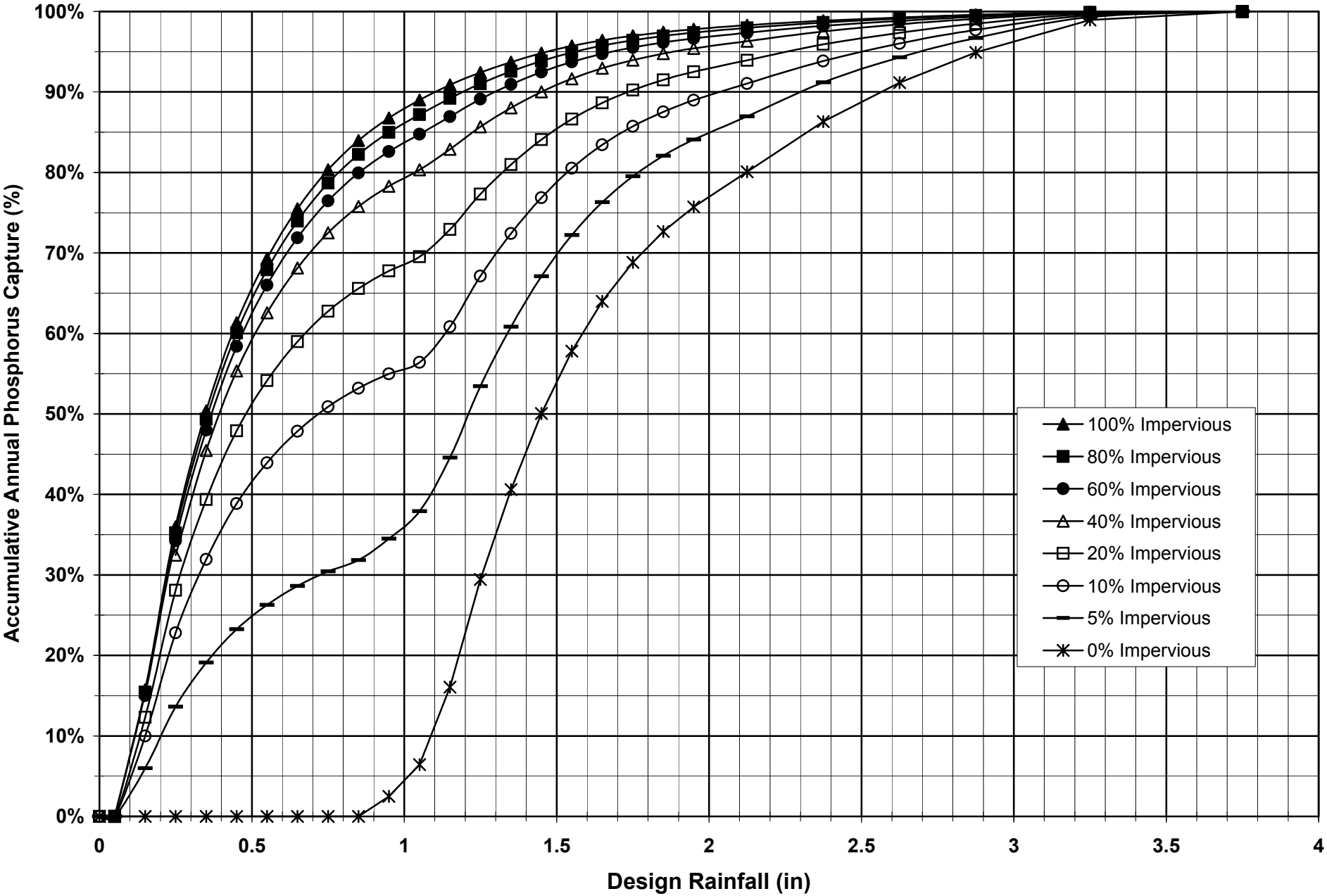
Figure 6-2
Rainfall-Runoff-Imperviousness for
Type I and II Soils - Clays and Clay Loams



Greenwood Village
October 2003

Figure 6-3
Rainfall-Runoff-Imperviousness for Type III Soils - Sand and Gravels

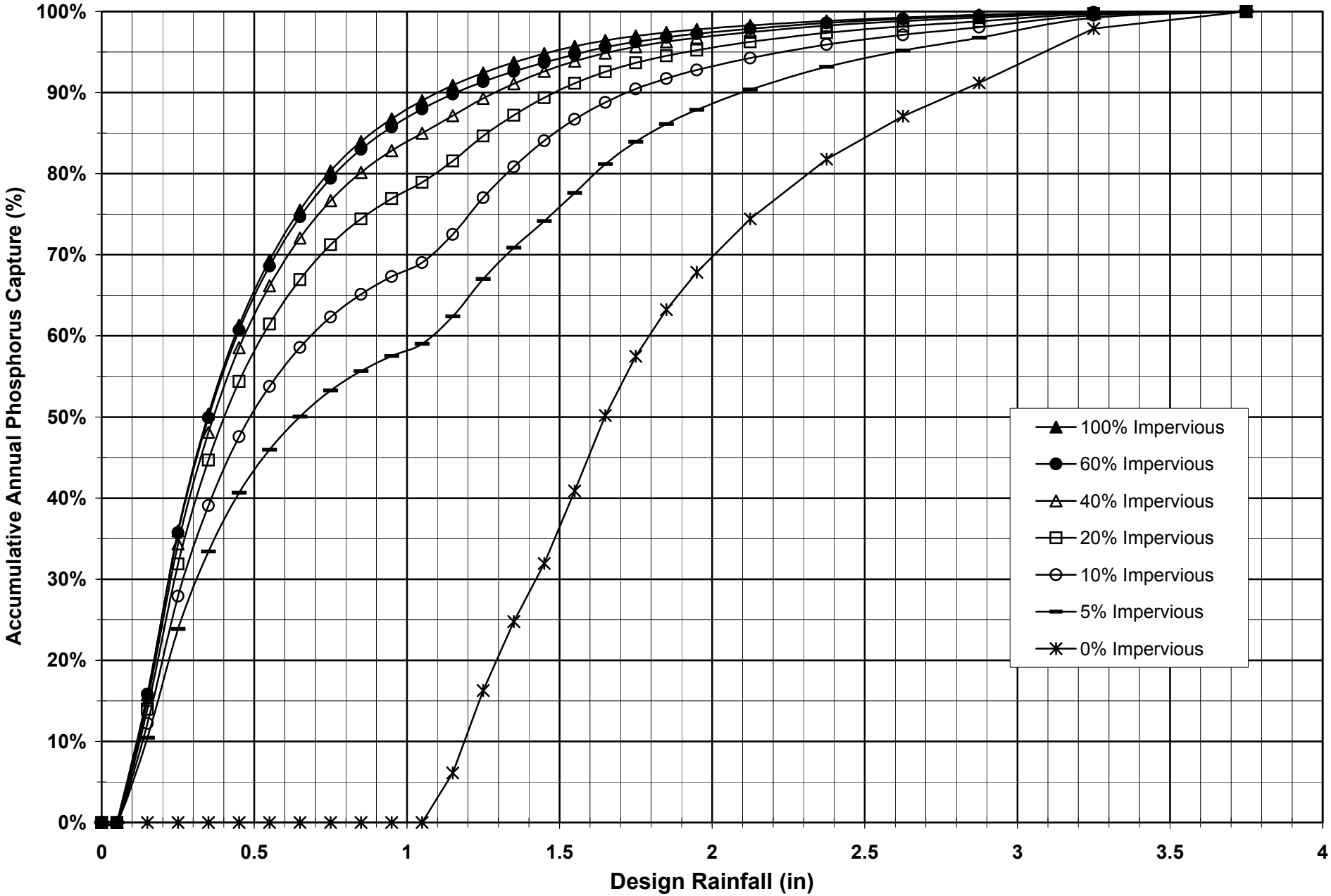
2003 Figures 6-1 to 6-3.xls-S&GR WQ fig6.3



Greenwood Village
October 2003

Figure 6-4
Percent Annual Stormwater Phosophorus Capture
Type I and II Soils (Clay and Clay Loams)

2003 Figures 6-4 to 6-5.xls-FIG 6_4



Greenwood Village
October 2003

Figure 6-5
Percent Annual Stormwater Phosophorus Capture
Type III Soils (Sand and Gravel)

7.0 Open Channels

7.1 Introduction

Open drainage channels are the most common components of drainage systems. The well-established hydraulic design principles of channeled flow must be integrated into the recreation, aesthetic, water quality, and aquatic habitat preservation goals of the City of Greenwood Village (Village).

The City Manager or designee shall review and approve the drainage analysis and design of all proposed development projects that will potentially impact the Major Drainageways and other natural channels within the Village limits. The City Manager or designee shall review and approve any proposed channel modifications, including but not restricted to, erosion and grade control structures, realignment, outfalls, and crossings.

7.2 Channel Types

Open channels are defined in terms of origin as artificially constructed or naturally occurring. Artificial channels are generally prismatic with a constant cross sectional geometry along the length of the reach. Natural channels generally do not exhibit these characteristics. Traditional artificial channels include all designed and constructed watercourses such as the Highline Canal, irrigation canals and flumes, roadside ditches, and vegetated channels. Natural channels are formed by concentration of sheetflow into erosion-incised channels and include within the Village limits, named channels such as Big Dry Creek, Little Dry Creek, Greenwood Gulch, Prentice Gulch, Goldsmith Gulch, and Cottonwood Creek.

7.2.1 Natural Channels

Natural channels are formed by erosion and exist in a state of equilibrium regulated by the dynamic interaction between soil and water. A proposed development can change flow rates for both base and flood flow conditions. This can cause significant changes in the sediment erosion and deposition patterns of the channel, significantly changing its appearance and capacity. These changes can have significant adverse effect on property, aquatic habitat, and wetlands.

The most common and the most difficult design issue that arises when incorporating natural channels into a proposed drainage system is destabilization of the sediment-water equilibrium by development induced changes in velocity. Urbanization can potentially degrade the channel bed by increasing both the peak discharge and runoff volume. Conversely, a reduction in peak discharge and runoff volume can decrease the sediment carrying capacity of the channel and increase the potential for deposition. Both alterations may require localized design modification of the channel to ensure a stabilized hydraulic flow condition and to protect wetland areas as well as the water quality and aquatic habitat of receiving streams.

7.2.2 Vegetation-Lined Channels

Vegetation-lined channels provide multiple-use benefits not available from smooth-lined channels. Vegetation stabilizes the channel perimeter, provides in-line storage to attenuate peak discharge rates, reduces erosion potential by stabilizing the soil mass of the bed, and provides a visually pleasing and aesthetically integrated form of drainage conveyance.

The Village strongly encourages use of vegetation-lined channels designed with a meandering alignment to reduce levels of phosphorus contained in runoff from developed watersheds. A meandering alignment increases the contact time between the vegetated perimeter and the pollutant load by reducing the velocity. The channel hydraulic analysis must ensure that design modifications to provide or improve water quality treatment do not adversely impact the sediment transport capacity of the channel.

7.2.3 Smooth-Lined Channels

Concrete and other smooth-lined channels, such as roller-compacted concrete, soil cement, and shotcrete, can adversely impact the integrated hydraulic performance of regional drainage facilities. Smooth-lined conveyance channels concentrate and accelerate flow which alters the temporal characteristics of surface runoff in a regional context and can result in larger downstream peak rates of discharge which may, in turn, adversely impact downstream channels and floodplains.

Within the Village, concrete and other smooth-lined channels will be permitted only where restrictions within the drainage easement within existing development prohibit use of vegetation-lined channels.

7.2.4 Rock-Lined Channels

Rock-lined channels, including ordinary riprap, grouted riprap, and wire enclosed riprap (gabions), are typically designed for higher flow velocities with the same potential adverse impacts on downstream channels and floodplains, as described for smooth-lined channels.

Design criteria for rock-lining are typically derived from field experience or computer modeling because failure modes and preventative design mechanisms are stochastic. Individual rock is designed for collective hydraulic function. Performance of rock as a protective lining against the hydraulic force of flowing water depends on achieving an optimal design balance between the rock gradation and the thickness of the rock layer and the thickness of the granular bedding and the number of increasingly finer granular layers.

Use of rock as a construction material requires careful oversight to ensure the rock to be used conforms to gradation design specifications within acceptable tolerance limits.

The long term hydraulic performance of the rock-lining requires intensive maintenance, relative to less structural forms of conveyance such as vegetation-lined channels. Rock-lined channels must be maintained to ensure preservation of the physical integrity of the constructed rock lining that is consistent with design assumptions for gradation and layer thickness.

The specifications for rock-lined channels require careful calibration of the design to the specific hydraulic constraints of the project. This requires consideration of the base flow conditions, minor storm flood events and major storm flood events.

Rock-lined channels will be permitted only where restrictions within the drainage easement within existing development prohibit use of vegetation-lined channels. The Village will consider this option only in very limited circumstances where it has been demonstrated that there are no feasible alternatives. This design will typically be limited to erosion control at channel alignment discontinuities such as outfalls, confluences, sharp bends, and steepened bed slopes.

7.2.5 Revetment Mattresses

Revetment mattresses consist of synthetic flexible fabric that is structurally reinforced by pressure injecting a fine-aggregate concrete mix to form a stable lining for erosion control on embankments. The fabric is prefabricated to project specifications and dimensions and placed over minimally graded terrain before pressure injecting with concrete mix. Controlled bleeding of the mixing water through the porous fabric produces all the desirable features of concrete mix with a low water to cement ratio, including rapid setting, high strength, and exceptional durability.

Cost effectiveness, performance characteristics, and ease of installation make revetment mattresses a viable form of slope stabilization for diverse applications, including shorelines, levees, dikes, canals, holding basins, slopes with limited access for rock placement, and slopes with a permanent pool that cannot be easily dewatered.

Within the Village, revetment mattresses will be permitted only where restrictions within the drainage easement within existing development prohibit vegetation-lined channels.

7.2.6 Composite Channels

The Village encourages open channel design that is in accordance with the policies as presented in Chapter 1.0, responsive to the site-specific constraints of the project and the criteria presented in this Drainage Criteria Manual, environmentally integrated with the ambient urban, rural, and geographical characteristics, and developed for the purpose of balancing multiple use benefits and economic constraints with limited easement availability.

7.3 Design Criteria

The analysis and design of open channels shall be in accordance with the criteria presented in the Major Drainage Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects..

Alternate cross-sections can be proposed that are appropriate to the project constraints and in accordance with this Drainage Criteria Manual. The feasibility of alternate designs shall include an economic analysis performed in accordance with sound and reliable techniques for estimation of project construction and long-term maintenance costs.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

7.3.1 Natural Channels

7.3.1.1 Hydraulic Design Criteria

Frictional Resistance. Channel conveyance shall be computed using a Manning roughness coefficient (n) selected from Table MD-1 from the UDFCD Drainage Criteria Manual. Maximum flow depths shall be determined using a high n-value to represent unmaintained channel conditions. Maximum limiting velocities shall be determined using a low n-value to represent maintained channel conditions.

Grade Control Structures. Grade control structures to reduce erosive velocities shall be landscaped and designed in accordance with criteria presented in Chapter 12.0.

7.3.1.2 Floodplain Criteria

The applicant shall prepare plan and profile drawings of the floodplain showing existing and proposed conditions, including proposed bridge or culvert crossings that may modify the flow conditions. Any such modifications shall be consistent with the criteria in Chapter 4.0.

7.3.2 Vegetation-Lined Channels

7.3.2.1 Hydraulic Design Criteria

Frictional Resistance. Channel conveyance shall be computed using a Manning roughness coefficient (n) selected from Figure 7-1. Maximum flow depths shall be determined using an n-value from Retardance Curve C which represents unmaintained channel conditions. Maximum

limiting velocities shall be determined using an n-value from Retardance Curve D which represents maintained channel conditions.

Flow Velocity. Where vegetation-lined channels are used to control phosphorus loading or where wetlands are located within the proposed alignment, the maximum normal depth velocity for the water quality design storm discharge shall meet the criteria in Chapter 16.0.

Grade Control Structures. Grade control structures to reduce erosive velocities shall be landscaped and designed in accordance with criteria presented in this Chapter 12.0.

7.3.2.2 Cross-Section

The channel cross section shall be designed to provide the required hydraulic conveyance within easements in a manner that maximizes the aesthetic integration with the ambient environment.

Low Flow Channel. The Village strongly encourages use of vegetation-lined low flow channels to minimize degradation of the aquatic habitat and to maximize water quality treatment benefits. Smooth-lined low flow channels are prohibited unless required by existing site development and unless approved by the City Manager or designee. The minimum low flow design capacity shall be 3% of the 100-year peak flow, but not less than 1.0 cfs.

Bottom Width. The minimum bottom width shall be 4 feet where low flow channels are provided. Where low flow channels are not provided, the minimum bottom width shall be consistent with sound hydraulic design and maintenance requirements.

Side Slopes. Side slopes shall be 4 (horizontal) to 1 (vertical) or flatter. Designs with channel side slopes steeper than 4:1 are prohibited unless approved by the City Manager or designee.

Freeboard. Freeboard shall be required for all channels where localized overflow is not permitted for ponding benefits or other reasons. The minimum freeboard height shall be 1.0 foot. Freeboard height shall be provided in accordance with Equation 7-1.

$$H_{FB} = 0.5 + \frac{V^2}{2g} \qquad (7\text{-}1)$$

where H_{FB} = freeboard height (feet)
V = average channel velocity (fps)
g = acceleration of gravity = 32.2 ft/sec^2

Easement Width. The minimum easement width shall include the top width at the freeboard elevation and the width of the maintenance access.

7.3.2.3 Maintenance Requirements

Vegetation-lined channels shall be designed to minimize long-term maintenance requirements by including design features that minimize deterioration by velocity-induced scour.

7.3.3 Concrete-Lined Channels

Concrete-lined channels shall be designed in accordance with the criteria presented in the UDFCD Drainage Criteria Manual. Channels constructed of other smooth linings, such as roller-compacted concrete, soil cement, and shotcrete, shall be designed in accordance with applicable manufacturer's criteria and shall require approval by the City Manager or designee.

7.3.3.1 Hydraulic Design Criteria

Frictional Resistance. Channel conveyance shall be computed using a Manning roughness coefficient (n) selected from Table MD-1 from UDFCD Drainage Criteria Manual. Maximum flow depths shall be determined using a high n-value to represent unmaintained channel conditions. Maximum limiting velocities shall be determined using a low n-value to represent maintained channel conditions.

7.3.3.2 Structural Design Criteria

1) All concrete lining for drainage channels shall be designed to withstand the hydrostatic and hydrodynamic forces of the design discharge. The minimum thickness shall be no less than 7 inches.
2) All concrete-lined side slopes shall be 2:1 or flatter. Use of steeper slopes shall require structurally reinforced retaining wall design.

7.3.3.3 Bedding Compaction

Compaction. Minimum compaction requirements shall be 90% of maximum density, in accordance with ASTM D-1557, Modified Proctor, and shall pertain to all fill material, all bedding material, the top 12 inches of the maintenance access road, and the top 12 inches of finish grade within 10 feet of the edge of the channel.

Geotextiles. The use of geotextile fabrics shall require approval by the City Manager or designee.

7.3.3.4 Maintenance

Maintenance and public access shall be as required by the City Manager or designee. Ladder-type steps shall be installed at maximum intervals of 400 feet and staggered on both sides of the channel. The bottom rung shall be no more than one-foot vertical above the channel invert.

7.3.4 Rock-Lined Channels

Rock-lining is typically most cost effective when applied as a localized form of erosion control for short channel reaches, less than 0.25 mile, where site constraints dictate a change in flow velocity, alignment, or cross section. Rock-lining may also be used for low flow channels.

The ease of placement, construction, and installation of various types of rock linings must be balanced with increased long-term maintenance required for sustaining hydraulic conveyance and visual esthetics. Channels lined with gabions or light riprap are susceptible to degradation by erosion and destruction by vandalism.

Rock lining is classified for design purposes as ordinary riprap, grouted riprap, or wire-enclosed rock, also known as gabions.

7.3.4.1 Hydraulic Design Criteria

Frictional Resistance. Channel conveyance shall be computed using a Manning roughness coefficient (n) selected from Table MD-1 from UDFCD Drainage Criteria Manual. Maximum flow depths shall be determined using a high n-value to represent unmaintained channel conditions. Maximum limiting velocities shall be determined using a low n-value to represent maintained channel conditions.

7.3.4.2 Maintenance Requirements

Maintenance and public access shall be as required by the City Manager or designee.

7.3.4.3 Ordinary Riprap

Ordinary or loose riprap consists of a layer of large rock that meets specified material properties and placed by machine to achieve the design specifications. Material design properties of riprap include the size, weight, and shape of the individual rocks, the composite gradation, thickness, and slope of the rock layer, and the type of bedding. Hydraulic design properties include velocity, direction of flow, and localized turbulence due to eddies and vortices.

Riprap smaller than 18 inches must be mixed with soil, covered with topsoil, and revegetated in order reduce vandalism and improve the aesthetics of the installation. The Village strongly encourages similar treatment of installations with larger riprap.

Riprap failures typically result from undersized or rounded rock or rock with an improperly specified gradation, all of which can reduce the protection provided by interlocking of the individual rock pieces and improperly designed bedding which permits leaching of channel particles through the riprap layer.

7.3.4.4 Grouted Riprap

Grouted riprap provides a relatively impervious channel lining that is subject to less vandalism and is typically less maintenance intensive than loose riprap when properly designed and constructed. Structural failure and aesthetic deterioration result from improper design, construction, and/or maintenance. The Village discourages use of grouted rock as a construction material for channel linings or grade control structures unless required by existing site constraints. All grouted riprap designs shall require approval by the City Manager or designee.

All grouted riprap designs shall minimize to the maximum extent practical, including the selection of larger riprap and the volume and thickness of the grout in the design.

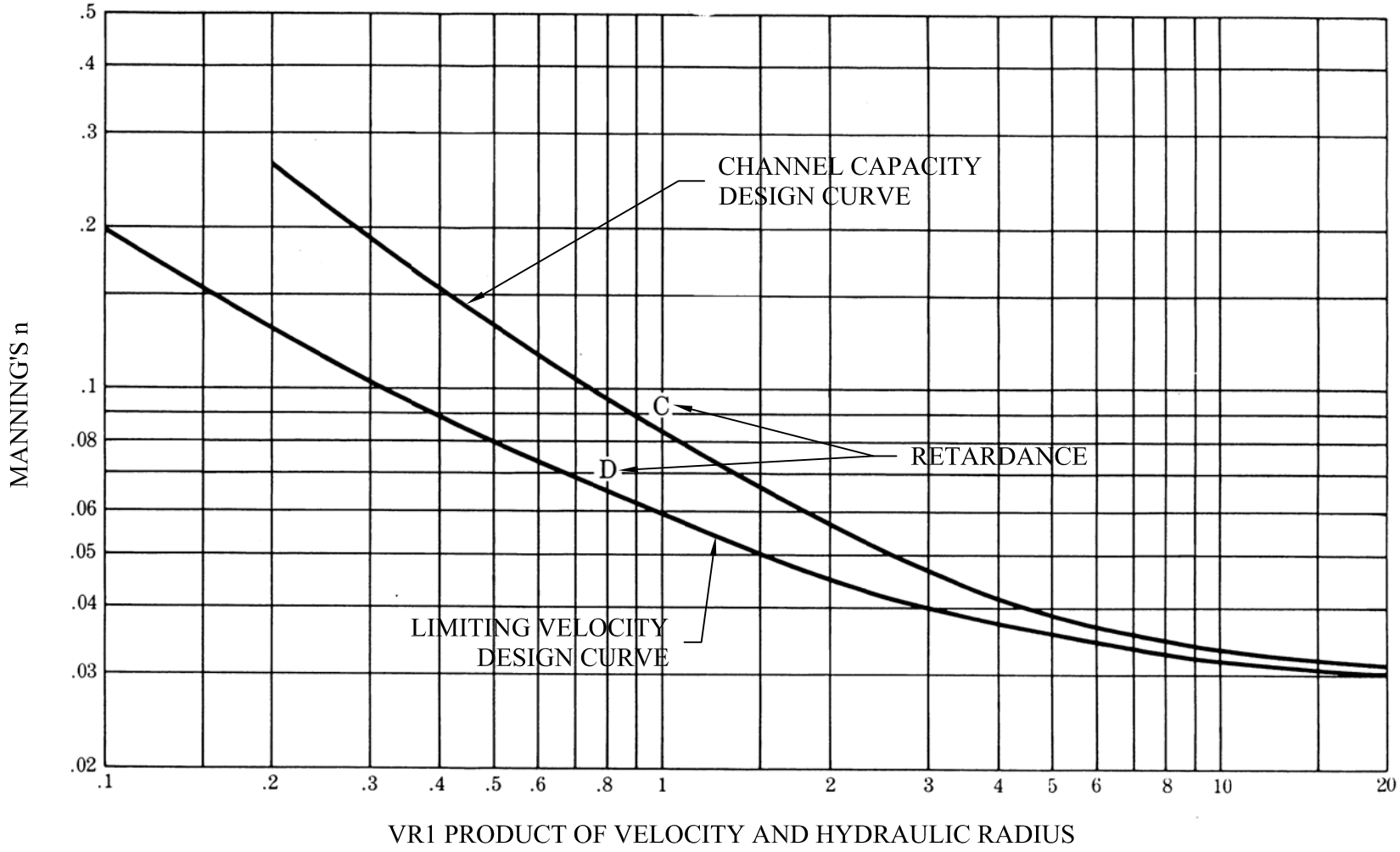
7.3.4.5 Wire-Enclosed Rock

Wire enclosed rock refers to a protective layer formed by enclosing rock in a wire basket, or gabion, which functions as a single structural unit. Wire enclosed rock provides a structurally stronger alternative for designs requiring individual rock larger than commercially available and having greater geometric versatility.

Wire-enclosed riprap shall be used as a construction material for channel linings, erosion protection, and grade control structures only as a last resort and shall require approval by the City Manager or designee. Wire enclosed riprap shall not be used in areas exposed to annual flooding.

7.3.5 Composite Channels

Composite channels shall be designed in accordance with the UDFCD Drainage Criteria Manual and the manufacturer’s criteria applicable to the selected channel lining materials. The applicant shall include any applicable manufacturer’s data and design specifications in the drainage studies.



Greenwood Village
Open Channels
October 2003

Figure 7–1
Manning Roughness Coefficient (n)
for Grass Lined Channels

FIG 7–1.dwg TIFF: fig0701.tif

P:\97003\027 Drainage Code Update 2003\Figures\FIG0701.dwg, Layout1, 10/15/2003 08:40:50 AM, 1:1

8.0 Streets

8.1 Introduction

Streets are designed to function as transportation corridors. Conveyance of stormwater drainage is a secondary function and must be designed to maintain the safety of the transportation corridor. A second objective of street drainage design is protection of the pavement and subgrade from deterioration due to stormwater runoff.

Streets can be included as parts of both the minor and the major drainage conveyance systems. The street can function as a conveyance corridor as part of the minor drainage system and will quickly remove nuisance flows from the more frequent storm events consistent with the safety criteria for the transportation function of the street. As part of the major drainage system, the street functions as an emergency flow corridor conveying large flows to minimize the damage to the ambient environment.

Street conveyance of stormwater runoff consists of two hydraulic phases. Precipitation impacting the street is directed by street grades as sheet flow into the curb and gutter system or a roadside ditch where runoff is concentrated and conveyed as open channel flow. Depending on the magnitude of the design storm, the curb and gutter or roadside swales may discharge into a storm sewer system or other designated outfall. Streets designed to efficiently convey stormwater runoff can reduce long-term maintenance costs of repairing deterioration caused by surface runoff.

Hydraulic analysis of street conveyance capacity and design of streets as drainage corridors requires determination of the allowable gutter and roadside swale flow capacity. When the allowable capacity is equaled or exceeded, a storm sewer system is required to reduce the storm runoff in the streets to depths in accordance with regulatory criteria governing transportation safety.

8.2 Street Classifications and Allowable Drainage Encroachments

The integration of planning concepts, theoretical design, and long-term maintenance of streets as drainage corridors is consistent with the criteria presented in the Streets/Inlets/Storm Sewer Chapter, Volume 1 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual, but is organized with reference to street classifications specific for the City of Greenwood Village (Village). Streets within the Village are classified for drainage purposes as local, collector, or arterial streets. The allowable drainage encroachment into the driving lanes becomes more restrictive with increasing transportation capacity, as described in Table 8-1 for both the minor and major storm events.

Table 8-1: Allowable Use of Streets for the Local Drainage System

	Minor Storm Runoff[1]			Major Storm Runoff		
Street Classification	Design Storm (Recurrence Interval) [1]	Maximum theoretical Street Encroachment[2]	Maximum Depth of cross street flow	Design Storm (Recurrence Interval)	Maximum Theoretical Depth [2]	Maximum depth of cross street flow
Local	2-yr or 5-yr	No overtopping of curb or backside of roadside ditch. Flow may spread to crown of street.	6 inches depth in cross pan	100-yr	Residential dwelling, public, commercial, and industrial buildings should be no less than 12" above the 100-yr flood at the ground line, unless buildings are floodproofed. The depth of water at the gutter flowline shall not exceed 12 inches. Drainage easements shall be provided for all areas flooded by the major storm runoff.	18 inches of depth at gutter flowline.
Collector	2-yr or 5-yr	No over topping of curb or backside of roadside ditch. Flow spread must leave at least a 10-foot width free of water in each direction.	Where cross pans are allowed, depth of flow shall not exceed 6 inches	100-yr	(same as Local)	18 inches of depth at gutter flowline.
Arterial	2-yr or 5-yr	No overtopping of curb or backside of roadside ditch. Flow spread must leave at least a 10-foot width free of water in each direction.	None	100-yr	Residential dwelling, public, commercial, and industrial buildings should be no less than 12" above the 100-yr flood at the ground line, unless buildings are floodproofed. To allow for emergency vehicles, the depth of water shall not exceed the street crown or 12 inches at the gutter flowline. Drainage easement shall be provided for all areas flooded by the major storm runoff.	12 inches or less over crown.[3]

(1) The2-year design storm shall apply to residential areas. The 5-year design storm shall apply to commercial, business, and industrial areas.

(2) The maximum allowable street flow shall be the product of the flow calculated at the "Maximum Theoretical Street Encroachment" and the required correction factor.

(3) Cross street flow is only allowed when the flow in a drainageway exceeds capacity of a road culvert and subsequently overtops the crown of the streets.

8.3 Design Criteria

The hydraulic analysis and design of streets for drainage conveyance shall be in accordance with the criteria presented in the Streets/Inlets/Storm Sewer Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

The Village requires grading of property along the edge of streets to minimize flooding of areas beyond the street right-of-way. The initial 15 feet behind a curb must slope towards the street at a minimum 2% grade. For streets with roadside ditches, the ground 15 feet from the edge of the pavement must be 9 inches higher than the elevation of the edge of the pavement.

8.3.1 Curb and Gutter

All curb and gutter designs shall be in accordance with Village standards. Use of other curb and gutter designs requires prior approval by the City Manager or designee.

8.3.2 Roadside Ditches

The Village strongly encourages the use of grass-lined roadside ditches for stormwater conveyance. Roadside ditches shall be designed in accordance with the criteria in this Section.

8.3.2.1 Hydraulic Design Criteria

Conveyance Capacity. Roadside ditches in residential developments shall be designed to convey the 2-year design discharge in accordance with criteria given in Table 8-2. Roadside ditches in non-residential developments shall be designed to convey the 5-year design discharge in accordance with criteria given in Table 8-2. A pipe conveyance system shall be required when the design discharge exceeds the ditch capacity.

Frictional Resistance. The conveyance shall be computed using the Manning roughness coefficient (n) given in Figure 7-1. Maximum flow depths shall be determined using an n-value from Retardance Curve C which represents unmaintained channel conditions. Maximum limiting velocities shall be determined using an n-value from Retardance Curve D which represents maintained channel conditions.

Flow Velocity. Roadside ditches shall conform to the specifications for a Type I ditch shown in Figure 8-1. Use of a Type II or a Type III ditch is discouraged and requires approval by the City Manager or Designee. The maximum allowable velocity as a function of ditch type is presented in Table 8-2 for flood conveyance purposes. Refer to Chapter 16.0 for velocity limits for water quality control purposes.

Table 8-2: Roadside Ditch Capacities [(1) (2) (3)]

	DITCH TYPE I		DITCH TYPE II		DITCH TYPE III	
Slope (%)	VEL (fps)	Q (cfs)	VEL (fps)	Q (cfs)	VEL (fps)	Q (cfs)
0.5	0.7	6	0.7	6	2.8	22
1.0	1.6	14	1.6	14	3.9	31
1.5	2.4	22	2.4	22	4.9	39
2.0	3.2	29	3.2	29	Not Permitted	
2.5	Not Permitted		4.0	36	Not Permitted	

[(1)]Water Resources Consultants, Inc.
[(2)]See Figure 8-1 for geometry of roadside ditch.
[(3)]Velocity and capacity are based upon Figure 7-1 in full flow conditions.

Vertical Alignment. The maximum allowable velocities will limit the longitudinal slope. Drop structures may be required where slopes exceed 2.5%. Steeper longitudinal slopes may be allowed when the ditch is flowing partially full. However, the maximum velocity and Froude numbers shall meet the limits specified in the UDFCD Drainage Criteria Manual.

Horizontal Alignment. The minimum radius of curvature shall be 25 ft.

Freeboard. Freeboard is not required for roadside ditches that conform to the cross sections shown in Figure 8-1.

Driveway Culverts. Driveway culverts in residential developments shall be sized to pass the 2-year design discharge without overtopping of the driveway. Driveway culverts in non-residential developments shall be sized to pass the 5-year design discharge without overtopping of the driveway. The minimum culvert size shall be 12 inch circular pipe, or the equivalent arch pipe, with flared end sections or headwalls.

8.3.2.2 Maintenance Requirements

Roadside ditches shall be designed to minimize long-term maintenance requirements by including design features that minimize deterioration from velocity-induced scour, sediment deposition at low velocity, and ponding of runoff.

Maintenance within public rights-of-way shall be performed by the Village. Maintenance within private street rights-of-way and in drainage easements on private property shall be performed by the owner of the property unless otherwise specified.

8.3.3 Drainage Easements

Drainage easements shall be provided for any areas inundated by the major storm runoff. These easements shall be shown on all drawings and plats.

8.4 Design Procedures

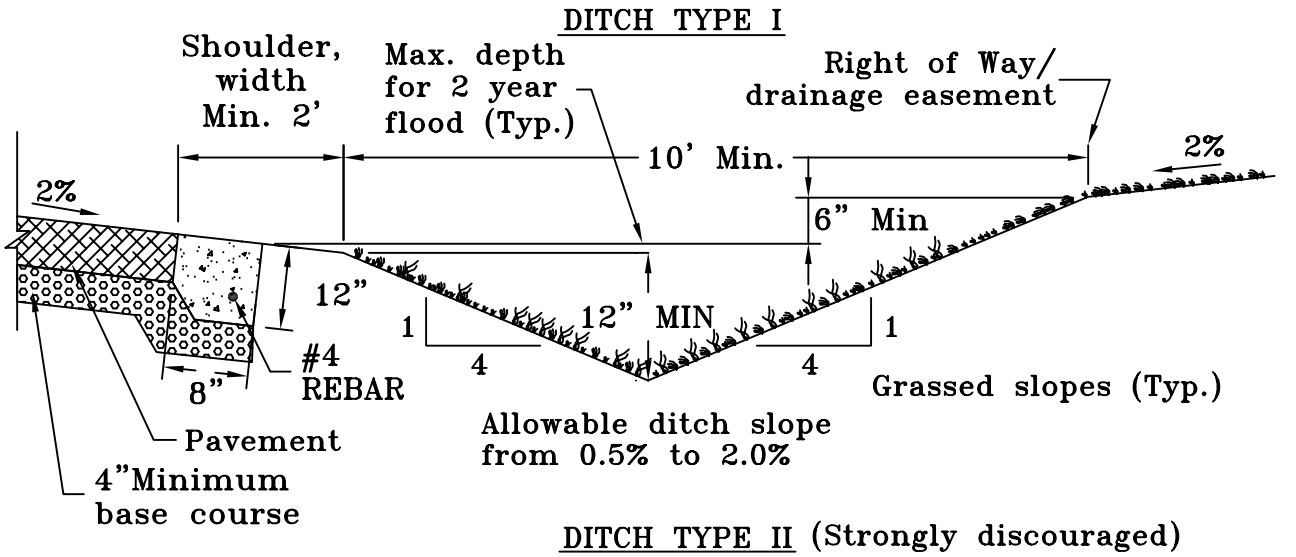
An effective street design integrates both the transportation and drainage functions. The philosophy of the Village is that street drainage design criteria should complement the transportation design criteria. The Village shall review street design projects from the dual perspective of transportation and drainage.

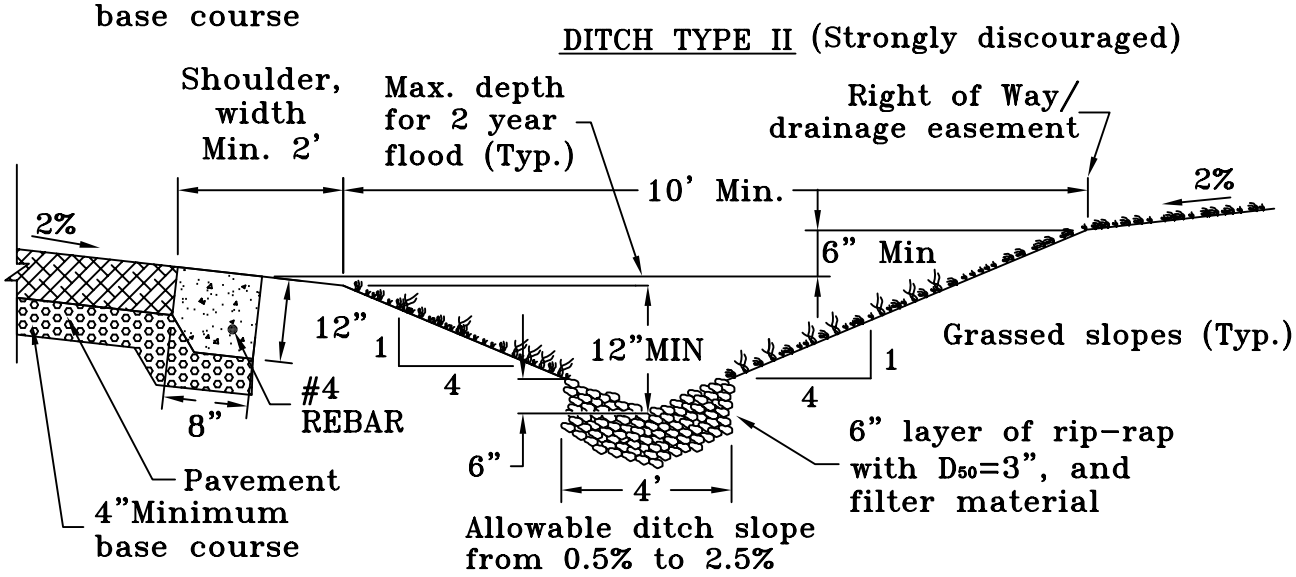
8.4.1 Minor Storm

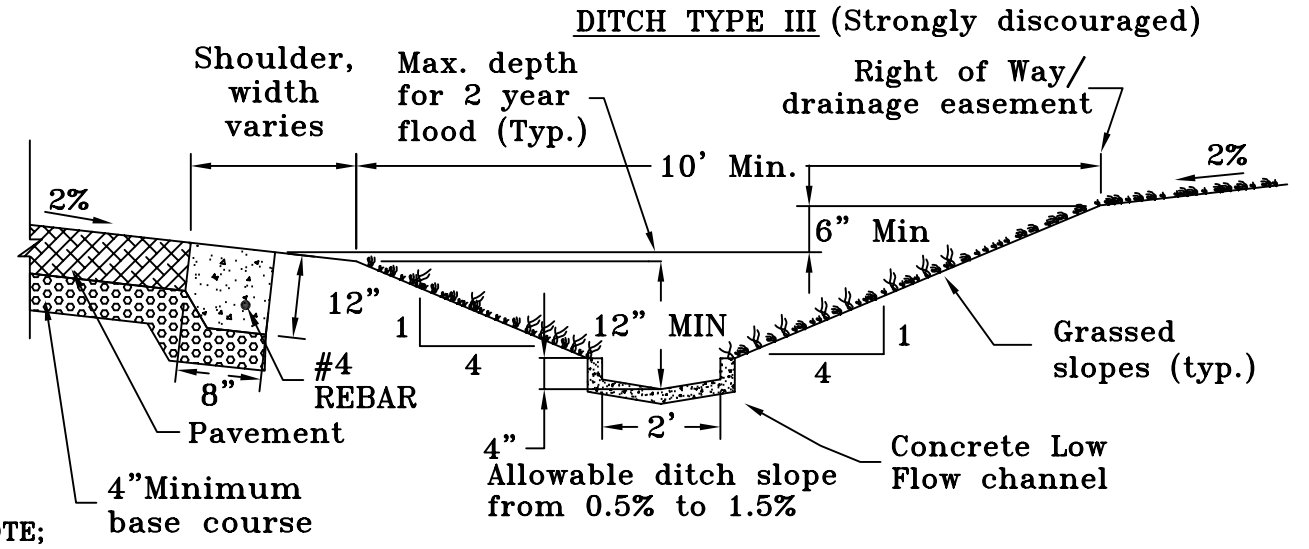
The theoretical allowable street capacity for minor storm events shall be determined using the Manning Equation that has been modified for triangular gutter flow. A nomograph solution is given in Figure 8-2. A Manning's roughness coefficient (n) of 0.015 shall be used for paved surfaces. The theoretical gutter capacity shall be modified using reduction factors to account for random obstructions to gutter flow.

8.4.2 Major Storm

The theoretical allowable street capacity for major storm events is determined by applying the Manning Equation to the composite cross section consisting of the street, sidewalk, landscaped areas, and adjacent structural features that will confine the flow. A composite roughness coefficient (n) shall be derived by weighting the roughness coefficient for each section. A roughness coefficient of 0.015 shall be used for pavement and sidewalk areas, 0.025 for roadside ditches, and 0.050 for uncontrolled landscape areas.







NOTE;

1. For street slopes greater than maximum allowed, landscaped check drops (2 ft maximum height) will be required.

Greenwood Village
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Figure 8-1
Roadside Ditch Sections
Types I, II, & III

FIG 8-1.dwg

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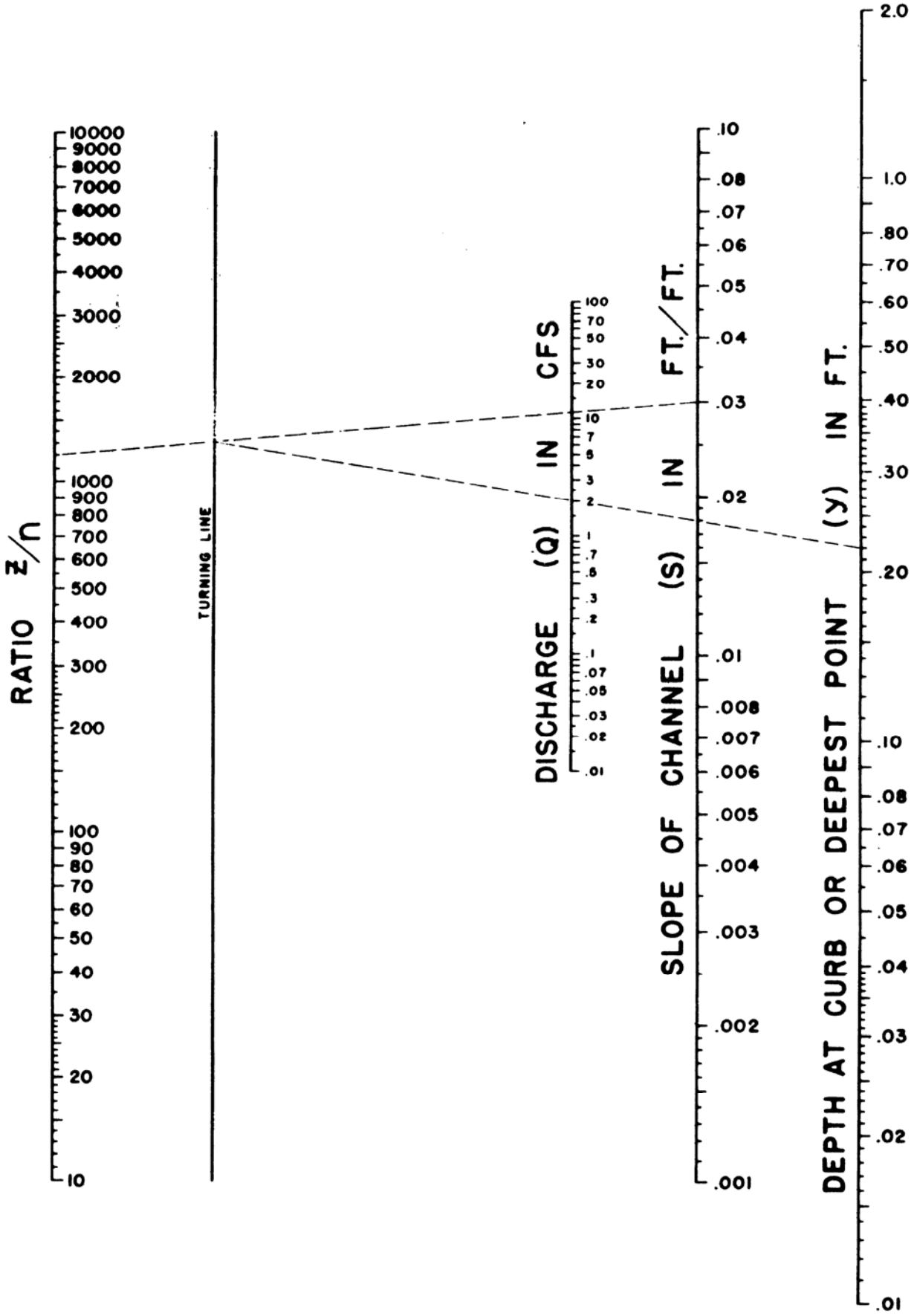

Greenwood Village
Street Drainage Design
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Figure 8-2
Nomograph for Flow
In Triangular Gutters
Sheet 1 of 2

FIG 8-2,SHEET1.DWG TIFF:FIG0802.TIF

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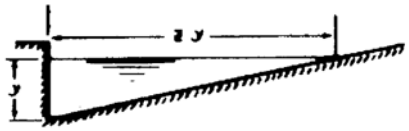


EQUATION: $Q = 0.56\left(\frac{z}{n}\right) S^{1/2}\, y^{8/3}$

n IS ROUGHNESS COEFFICIENT IN MANNING FORMULA APPROPRIATE TO MATERIAL IN BOTTOM OF CHANNEL

z IS RECIPROCAL OF CROSS SLOPE

REFERENCE: H. R. B. PROCEEDINGS 1946, PAGE 150, EQUATION (14)

EXAMPLE (SEE DASHED LINES)

GIVEN: $S = 0.03$

$z = 24$, $n = .02$; $z/n = 1200$

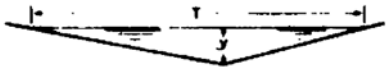
$y = 0.22$

FIND: $Q = 2.0$ CFS

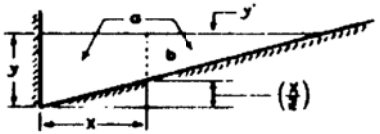
INSTRUCTIONS

1. CONNECT z/n RATIO WITH SLOPE (S) AND CONNECT DISCHARGE (Q) WITH DEPTH (y). THESE TWO LINES MUST INTERSECT AT TURNING LINE FOR COMPLETE SOLUTION.

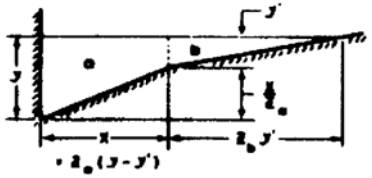
2. FOR SHALLOW V-SHAPED CHANNEL AS SHOWN USE NOMOGRAPH WITH $z = \frac{T}{y}$



3. TO DETERMINE DISCHARGE Q_x IN PORTION OF CHANNEL HAVING WIDTH X: DETERMINE DEPTH y FOR TOTAL DISCHARGE IN ENTIRE SECTION a. THEN USE NOMOGRAPH TO DETERMINE Q_b IN SECTION b FOR DEPTH $y' = y - \left(\frac{x}{z}\right)$



4. TO DETERMINE DISCHARGE IN COMPOSITE SECTION:- FOLLOW INSTRUCTION 3. TO OBTAIN DISCHARGE IN SECTION a AT ASSUMED DEPTH y; OBTAIN Q_b FOR SLOPE RATIO z_b AND DEPTH y' THEN $Q_T = Q_a + Q_b$



Greenwood Village
Street Drainage Design
October 2003

Figure 8–2
Nomograph for Flow
In Triangular Gutters
Sheet 2 of 2

FIG 8-2,SHEET 2.DWG TIFF:FIG0802.PCX

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9.0 Storm Sewer Inlets

9.1 Introduction

Storm sewer inlets are structural openings in a curbside or a swale that collect surface runoff for conveyance in a pipe system. Inlets are a critical component in the drainage system because efficient inlets will minimize ponding and flooding of streets and other areas. Inlet design must be conservative, not only to ensure performance as a critical component of the drainage system, but to adequately address hydraulic flow characteristics that are based primarily on empirical data. The Village strongly encourages that all inlets be labeled to warn against dumping anything into the inlet because of sensitive downstream areas.

9.2 Standard Inlet Classifications

Storm sewer inlets are classified by type of opening and grade-dependent hydraulic inlet conditions. The City of Greenwood Village (Village) allows use of curb inlets (non-grated), grated curb inlets, and combination inlets. Hydraulic inlet conditions are classified as inlets located on a continuous grade with by-pass flow or inlets located in a sump condition that function under ponding head.

Standard inlets permitted for use in the Village are given in Table 9-1 as a function of street classifications as defined in Chapter 8.0 of this Drainage Criteria Manual.

Table 9-1: Storm Sewer Inlet Design

Inlet Type	Grade Permitted	Use Permitted
Curb Opening Inlet Type R	Collector and Arterial streets with standard 6-inch vertical curb & gutter	Continuous or Sump
Grated Inlet Type C	Local streets only, with a roadside ditch	Sump only
Grated Inlet Type 16	Local streets only, with a valley gutter	Continuous or Sump
Combination Inlet Type 16	All street types with standard 6-inch vertical curb & gutter	Continuous or Sump

The standard details for the inlets listed in Table 9-1 are provided in the Colorado Department of Transportation Standard Drawings.

9.3 Design Procedures

The hydraulic analysis and design of storm sewer inlets shall be in accordance with the criteria presented in the Streets/Inlets/Storm Sewer Chapter, Volume 1 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

The reduction factors shown in Table 9-2 shall be used for all inlets designed in the Village.

Table 9-2: Storm Sewer Inlet Reduction Factors (1)

Hydraulic Inlet Condition	Inlet Type	Percentage of Theoretical Inlet Capacity Allowed
Sump	Curb opening, only	80%
Sump	Grated, only	50%
Sump	Combination	65%
Continuous Grade	Curb opening, only	80%
Continuous Grade	Grated only	50%
Continuous Grade	Combination	110% of that listed for type of grate utilized

[1] Reference: Urban Storm Drainage Criteria Manual UDFCD, 1969.

9.3.1 Continuous Grade Condition

Inlet capacity on a continuous grade depends on many factors including gutter slope and flow depth, street cross slope, height and length of curb opening, and the amount of depression at the inlet. Inlets on a continuous grade are subject to bypass or carryover flow that must be included in the design of the inlet as well as the downstream storm sewer.

9.3.2 Sump Condition

Inlet capacity in a sump depends on many factors including gutter slope and flow depth, street cross slope, height and length of curb opening, and the depth of ponding at the inlet. The design procedure typically requires estimating the number of inlets and the ponding depth required to intercept a selected percentage of the design flow.

9.3.3 Inlet Spacing

The optimal spacing of storm inlets depends on several factors, including traffic requirements, contributing land use, street slope, and distance to the nearest outfall system. The interception rate of inlets in a continuous grade condition varies from less than 50% to as much as 100% of the allowable street capacity. Therefore, the optimal inlet spacing cannot be achieved in all instances, and the applicant should carefully analyze the spacing requirements.

The suggested sizing and spacing of the inlets based upon an interception rate of 70% to 80% is typically more economical than a spacing based upon a 100% interception rate. Using the suggested spacing, only the most downstream inlet in a development would be designed to intercept 100% of the flow. Inlet spacing design should consider the improvements in overall inlet system efficiency that can be achieved if inlets are located in the sumps created by street intersections.

10.0 Storm Sewer Systems

10.1 Introduction

A storm sewer system consists of a system of inlets, pipes, manholes, junctions, cleanouts, outlets, and other appurtenant structures that collect and convey minor storm runoff. Storm sewer systems must be conservatively designed to function with a level of reliability that maximizes safety and minimizes the inconveniences of inadequate control for frequent storm events.

10.2 Classifications

Pipe conveyance systems are hydraulically classified by type of flow condition. Storm sewer systems are typically designed for gravity flow and operate, under design conditions, as partial flow conduits with a free water surface. Storm sewer systems are less typically designed to operate as full flow conduits under pressurized flow conditions. Operational flow conditions are not restricted to design assumptions. For instance, gravity storm sewers may convey pressurized flow during major storm events and pressurized storm sewers may function as gravity flow conduits during low-flow events.

10.3 Design Criteria

The hydraulic analysis and design of storm sewer systems shall be in accordance with the criteria presented in the Streets/Inlets/Storm Sewer Chapter, Volume 1 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the City of Greenwood Village (Village) are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. These guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

10.3.1 Design Storm Frequency

A storm sewer system is required when the allowable street capacity is exceeded by runoff from the design storm. The design storm recurrence interval is given in Table 8-1 as a function of street classification.

The design of the storm sewer system shall include appropriate capacity modifications at all locations where deviation from the design storm is required, for example, at sump inlets with no

alternative drainage outlet for the major storm. The design of the storm sewer system shall include hydraulic analysis of both the minor and the major storm events.

10.3.2 Construction Materials

Pipe materials acceptable for use in storm sewer construction include the following:

1) Reinforced concrete pipe (RCP), in accordance with the criteria specified in ASTM C-76, C-506, C-507, with Class II pipe being the minimum acceptable standard;
2) Corrugated polyvinyl chloride (PVC) pipe, in accordance with the criteria specified in ASTM D-3034 and ASTM F-679; and
3) Corrugated dual wall high-density polyethylene pipe (HDPE), in accordance with the criteria specified in ASTM D-1248.

In areas of high abrasion potential and under collectors and arterials, the Village may limit acceptable pipe materials only to RCP. The use of other storm sewer materials shall require approval of the City Manager or designee.

10.3.3 Vertical Alignment

Manholes are required at all locations of hydraulic discontinuity, including junctions and changes in pipe size or alignment. The maximum spacing between manholes shall be in accordance with criteria presented in Table 10-1.

Table 10-1: Maximum Manhole Spacing

Vertical Dimension of Pipe (in)	Maximum Allowable Distance Between Manholes and/or Cleanouts
36 and smaller	400 feet
42 and larger	500 feet

The storm sewer grade shall be sufficient to provide minimum cover required for H-20 loading conditions as specified in the American Association of State Highway and Transportation Officials (AASHTO) “Standard Specifications for Highway Bridges”. The minimum cover shall not be less than one foot at any point along the pipe.

10.3.4 Horizontal Alignment

Storm sewer alignment between manholes shall be straight, except when approved in writing by the City Manager or designee. Storm sewers may be constructed with curvilinear alignment using the pulled-joints, pipe bends, or radius pipe. The maximum allowable joint pull shall be ¾ inch. The radius requirements for pipe bends shall be in accordance with the manufacturer’s specifications.

10.3.5 Pipe Diameter

The minimum allowable pipe size for storm sewers is dependent upon maintenance considerations. The length of the storm sewer also affects maintenance. The minimum pipe size for storm sewers is given in Table 10-2.

Table 10-2: Minimum Storm Sewer Size

Vertical Dimension of Pipe (in)	Minimum Equivalent Pipe Diameter	Minimum Cross-Sectional Area
Main Trunk	18 in	1.77 ft^2
Lateral from Inlet	15 in	1.23 ft^2

Private systems that serve a single family residential lot or business can reduce the minimum allowable pipe size to 12 inches.

10.3.6 Storm Sewer Outlets

Selection of an outfall location is an important and sometimes critical design issue. Isolated sites or other project constraints may require design and construction of an intermediate surface water drainage facility to convey site runoff to an acceptable outfall, or existing outfalls may require substantial improvements to convey the increased flows from the developed site. Erosion control requirements may vary from rock-lined protection to stilling basins, depending on the magnitude of the discharges, the extent of the existing surrounding development, and the relationship of site hydraulics relative to receiving water hydraulics.

All storm sewer outlets that discharge into open channels shall be constructed with a headwall and wingwalls or a flared-end section. Erosion protection shall be provided at the outlet in accordance with the criteria presented in Chapter 12.0.

10.3.7 Hydraulic Design Criteria

The hydraulic analysis shall include calculation of the hydraulic and energy grade line to ensure that the storm sewer system is capable of conveying the design discharge without surcharge for the minor storm. The hydraulic grade lines must be at least 6 inches below the top of any storm sewer structures or the ground surface during the major storm. The energy grade line for the design discharge shall be at or below final grade during the major storm.

Total hydraulic losses, including friction losses and form losses due to expansions, contractions, bends, and junctions, shall be computed in accordance with the criteria presented in the UDFCD Drainage Criteria Manual or manufacturer’s criteria. Use of other hydraulic loss criteria shall require approval by the City Manager or designee.

10.4 Design Procedures

Design of many storm sewer systems can be adequately addressed by manual application of the computational procedures described herein. The Village, however, recognizes the efficiency of using computerized applications, including spreadsheets and other technical software, to design larger and more complicated systems.

Storm sewer systems can be sized using the Rational Method as presented in the Streets/Inlets/ Storm Sewer Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. The Colorado Urban Hydrograph Procedure (CUHP) and Urban Drainage and Storm Water Management (UDSWM) model may also be used for basins larger than 10 acres.

10.4.1 Gravity Flow Design

The design of a gravity flow storm sewer system shall be in accordance with the criteria presented in the UDFCD Drainage Criteria Manual. Storm sewers not flowing full are hydraulically equivalent to open channels and are analyzed using the Manning equation for uniform open channel flow.

The computation of hydraulic properties for conduits under partial flow conditions is arithmetically complex. Pipe manufacturers have, therefore, condensed the computation into charts for convenience of application. The full flow capacity of the storm sewer is computed using the Manning Equation. The partial flow values are estimated from the charts. The applicant shall consult the manufacturer for partial flow charts pertaining to other pipe flow geometries.

10.4.2 Pressurized Flow Design

The design of a pressurized storm sewer system shall be in accordance with the criteria presented in UDFCD Drainage Criteria Manual.

11.0 Culverts

11.1 Introduction

A culvert is defined as a conveyance conduit for surface water drainage beneath a driveway, street, highway, railroad, canal, or other embankment. The hydraulic analysis of culvert flow is complicated by the variety of discharge-dependent flow conditions that can occur. Culvert conveyance capacity is a function of both inlet and discharge flow conditions.

11.2 Culvert Classifications

Culverts are classified hydraulically by the type of flow control that exists at the design discharge. Culverts functioning under inlet control are limited in conveyance capacity by entrance losses. Culverts functioning under outlet control are limited in capacity by the material properties, geometry of the conduit, and downstream flow conditions. Culverts designed for inlet control require analysis of the entrance headloss at the inlet. A well-designed inlet can dramatically increase the hydraulic performance of the culvert. Culverts designed for outlet control require analysis of the hydraulic properties of the conduit, such as slope, roughness, shape, and diameter. The possible backwater conditions at the point of discharge of the culvert must also be considered and may decrease the capacity of the culvert.

11.3 Design Criteria

The hydraulic analysis and design of culverts shall be in accordance with the criteria presented in the Culverts Chapter, Volume 2 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the City of Greenwood Village (Village), are highlighted in the following Sections.

Additional design procedures for concrete culverts are described in Concrete Pipe Design Manual, American Concrete Pipe Association. Additional design procedures for corrugated metal conduits are described in the Handbook of Steel Drainage and Highway Construction Products, American Iron and Steel Institute.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and are not intended to replace site-specific analysis and design requirements of individual projects. For instance, the presence of corrosive soils may prevent the use of corrugated steel pipe.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Section 17.0.

11.3.1 Construction Material and Pipe Size

Conduit materials acceptable for use in culvert construction include reinforced concrete (RCP), corrugated metal (CMP), and high density polyethelene pipe (HDPE). The use of CMP shall require a soil analysis to ensure that the corrosivity of the soil will not shorten the design life of the culvert. The Village will consider use of other construction materials. The minimum size for culverts is provided in Table 11-1.

Table 11-1: Minimum Culvert Size

Shape of Culvert	Minimum Equivalent Pipe Diameter (in^2)		Minimum Cross-Sectional Area (ft^2)	
	Streets	Driveways	Streets	Driveways
Circular	24	12	3.1	0.75
Arch	24	12	2.8	0.70
Elliptical	24	12	3.3	0.82

11.3.2 Inlet and Outlet Configuration

All culverts shall be designed with headwalls and wingwalls or flared-end sections at the inlet and outlet. Erosion protection shall be provided at the outlet in accordance with the criteria presented in Chapter 12.0. All culverts shall be designed and installed to be resistant to damage from errant vehicular traffic.

11.3.3 Hydraulic Design Criteria

11.3.3.1 Frictional Losses

Culvert capacity and velocity shall be computed using the Manning roughness coefficient (n) in accordance with the manufacturer's criteria.

11.3.3.2 Velocity

Culverts are designed for both a minimum and a maximum allowable velocity. A minimum cleansing velocity of 3 fps is required for the minor storm. The maximum allowable velocity is 15 fps for the major storm.

11.3.3.3 Headwater Criteria

The maximum headwater for the major storm flow shall be 1.5 times the culvert diameter or rise dimension.

11.3.4 Structural Criteria

As a minimum, all culverts shall be structurally designed to withstand a minimum H-20 loading condition in accordance with AASHTO "Standard Specifications for Highway Bridges" or in accordance with the pipe manufacturer's recommendations.

11.3.5 Trash Racks

The use of trash racks at culvert inlets and outlets reduces long-term maintenance requirements of the conduit and increases public safety. Field experience has demonstrated, however, that trash racks routinely become blocked with sediment and debris, requiring regular maintenance to ensure adequate conveyance capacity of the conduit during storm events. Use of trash racks shall be evaluated with respect to project-specific constraints. All trash racks shall be designed and installed to be resistant to damage from errant traffic. Breakaway designs are acceptable to the Village and will be reviewed on a case by case basis consistent with generally accepted culvert and trash rack manufacturer's recommendations.

11.4 Design Procedures

The culvert is sized in accordance with minor and major storm design criteria governed by allowable street inundation. Culverts shall be sized in accordance with the criteria presented in Table 8-1. In addition, street overtopping is not allowed for the minor storm. Private driveways crossing roadside ditches shall be designed to prevent overtopping during the minor storm.

The following procedure shall be used as a minimum design standard for culvert street crossings and modified, as required in response to site-specific constraints. For example, removal of structures from the 100-year floodplain may require increasing the size of the culvert by increasing the design frequency of the storm to lower the floodplain elevation.

1) The allowable street overtopping shall be determined from overflow rating curves developed for the street profile assuming proposed conditions of development and drainage for the major storm. Design shall be in accordance with criteria governing allowable street inundation for major storm events, as shown in Table 8-1.
2) The culvert is sized to convey the difference between the major storm peak discharge and the allowable street overtopping.
3) If the resulting culvert is smaller than that required to pass the minor storm peak discharge without overtopping, the culvert shall be increased in size to pass the minor storm peak discharge.

12.0 Hydraulic Structures

12.1 Introduction

Hydraulic structures are used in stormwater management systems to ensure the long-term integrity of drainage facilities and to protect the environment by controlling the direction and velocity of channelized runoff. The energy of flowing water can damage channel linings, destabilize the hydraulic equilibrium of unlined channels leading to erosion or deposition, and physically damage drainage structures and other constructed features through repetitive hydraulic action.

The analysis and design of hydraulic structures shall be in accordance with the criteria presented in Hydraulic Structures Chapter, Volume 2 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the City of Greenwood Village (Village) are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

12.2 Types of Hydraulic Structures

12.2.1 Conduit Outlet Structures

Turbulence induced by high-energy transitions from conduit flow to open channel flow is a common source of scour in stormwater management systems requiring a degree of protection depending on the magnitude of the outlet velocity. Erosion protection design shall be in accordance with the criteria presented in the Major Drainage Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. Rock-lined erosion protection shall be provided at all outlets for conduit discharges with a velocity greater than 5.0 fps in erosive soils and greater than 7.0 fps in non-erosive soils. Concrete or other lined energy dissipation structure shall be provided for conduit discharges with a Froude Number exceeding 2.50 in accordance with the Hydraulic Structures Chapter, Volume 2 of the UDFCD Drainage Criteria Manual.

The Village prefers the use of the United States Bureau of Reclamation (USBR) Type VI impact stilling basins when greater flow control is required.

12.2.2 Hydraulic Drop Structures

Reducing the channel invert slope using hydraulic drop structures is a common method of controlling flow velocity. Design of hydraulic drop structures shall be in accordance with the criteria presented in the Hydraulic Structures Chapter, Volume 2 of the UDFCD Drainage Criteria Manual.

The Village strongly encourages the use of boulder designs for drop structures. Typical designs for boulder drop structures are shown in Figures 12-1 and 12-2. Typical grouted boulder designs are shown in Figure 12-3. These designs are more adaptable to the parks, recreation, and trail usage of the Major Drainageways in the Village. The Village also strongly encourages designs which rely on larger boulders rather than the use of grout to provide the structural stability.

12.2.3 Bridges

Bridge hydraulic design shall be in accordance with the criteria presented in the Hydraulic Structures Chapter, Volume 2 of the UDFCD Drainage Criteria Manual.

Bridge hydraulic capacity shall be designed in accordance with the following criteria:

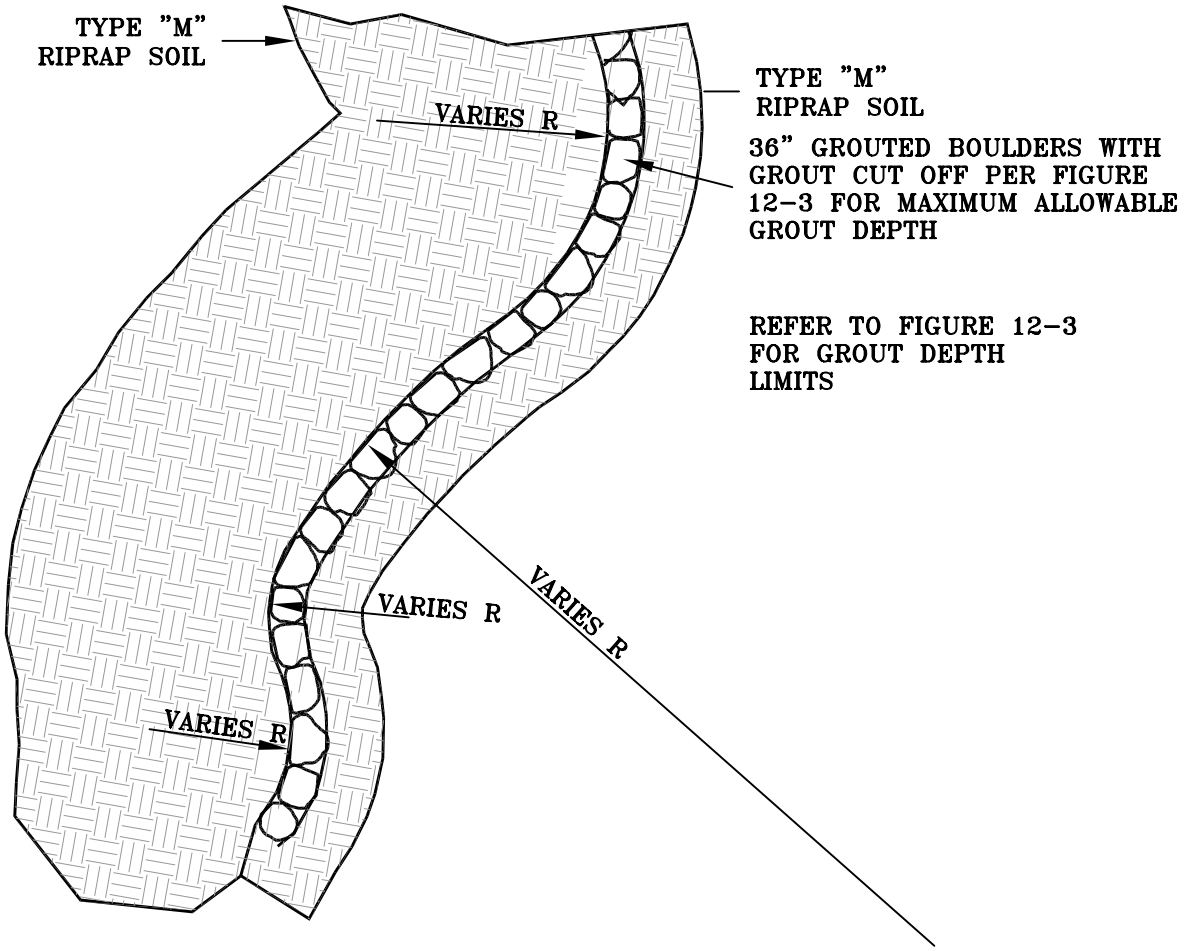
1) Flow through the bridge constriction shall be modeled using backwater analysis to establish the water surface profile.
2) The Village prohibits supercritical flow through bridge openings. For sub-critical flow, the low chord of the bridge shall be a minimum of one foot above the 100-year water surface elevation or the energy grade line, whichever is greater.
3) Maximum allowable velocities shall be consistent with the constraints of the abutment lining material and the potential for scour. The Village recommends that velocities not exceed 18 fps.

12.2.4 Transitions, Bends, and Confluences

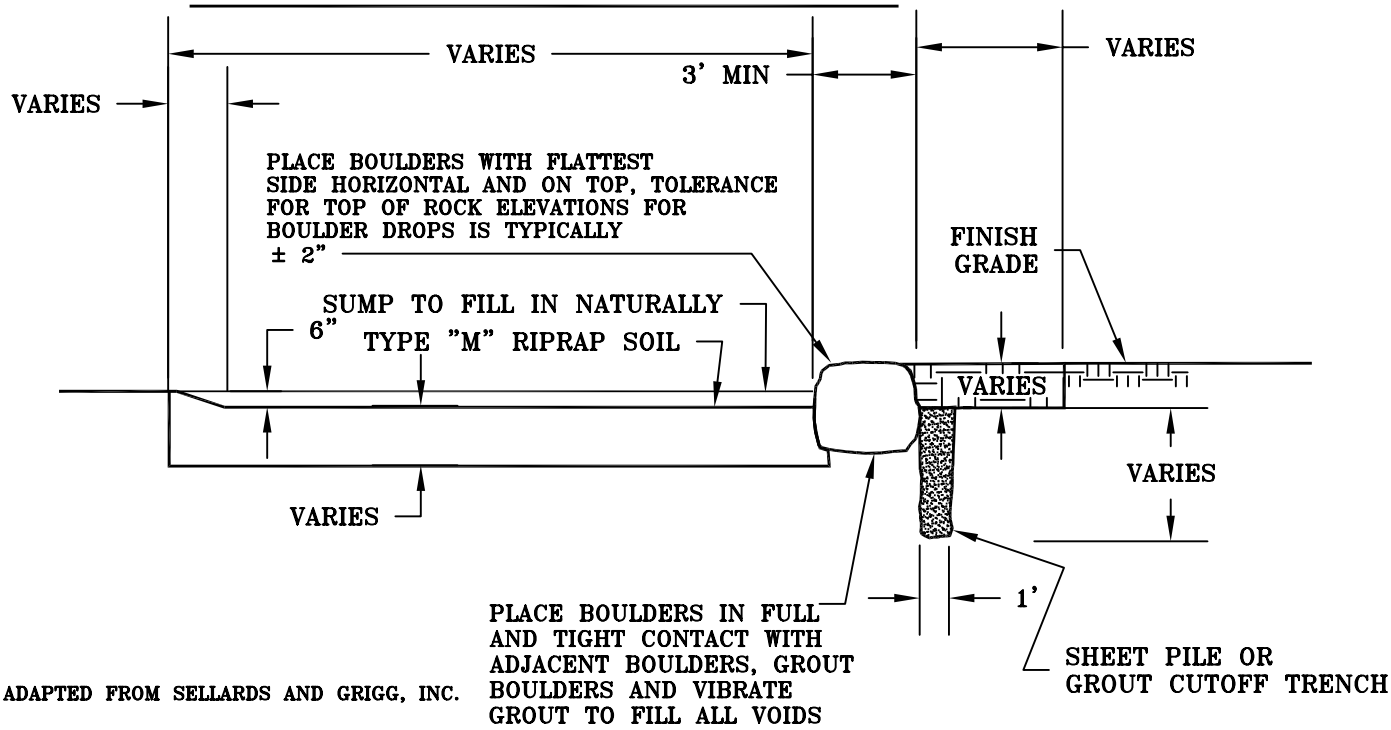
The design of hydraulic structures as erosion protection for transitions, bends, and confluences shall be in accordance with the criteria presented in the Hydraulic Structures Chapter, Volume 2 of the UDFCD Drainage Criteria Manual.

12.2.5 Crossings and Discharges into Irrigation Ditches

The Village is divided by the Highline Canal, which crosses Greenwood Gulch, Prentice Gulch, and Little Dry Creek within the Village boundaries, as shown in Figure 2-2. The Highline Canal is owned and operated by the Denver Board of Water Commissioners (Denver Water Board). Documentation of approval by the Denver Water Board is required for any discharges into the Highline Canal. By a separate document, the applicant shall indemnify the Village for any claims against the Village as a result of activities of the applicant adjacent to the Highline Canal.



TYPICAL LANDSCAPED SINGLE BOULDER DROP



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Greenwood Village
Hydraulic Structures
October 2003

Figure 12-1
Typical Landscaped Single
Boulder Drop Structure

FIG 12-1.dwg

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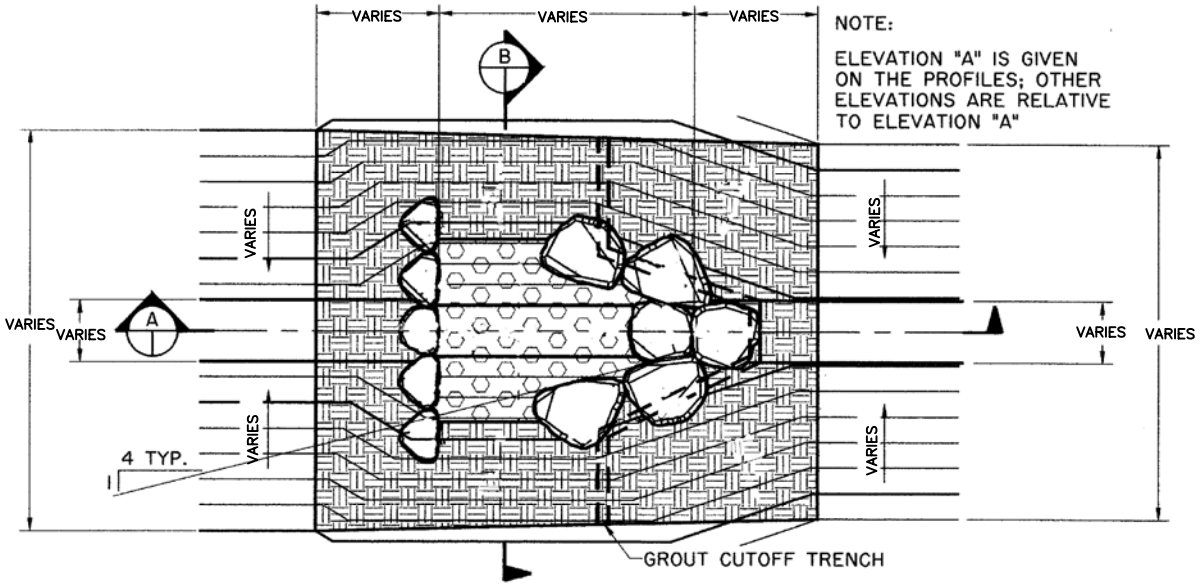

TYPICAL LANDSCAPED DOUBLE BOULDER DROP

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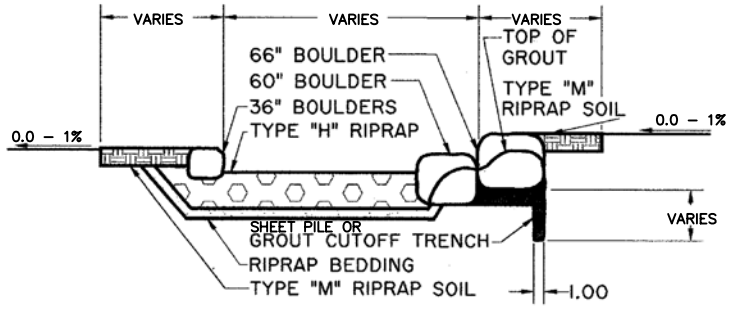
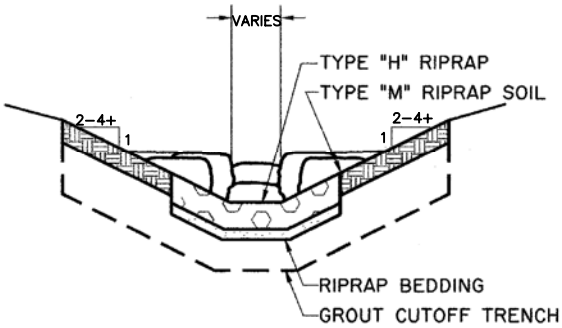


SECTION A

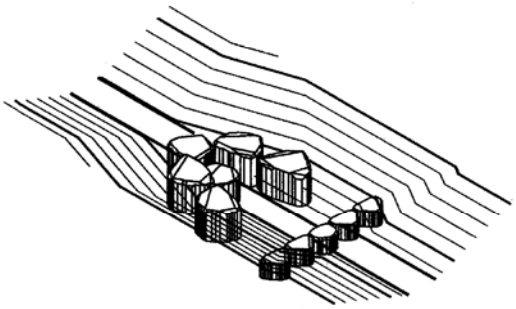
N.T.S.

NOTE: REFER TO FIGURE 12–3 FOR THE MAXIMUM ALLOWABLE GROUT DEPTH BETWEEN LANDSCAPED BOULDERS



SECTION B

N.T.S.



ISOMETRIC VIEW

NTS

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Greenwood Village
Hydraulic Structures
October 2003

Figure 12–2
Typical Landscaped Large
Double Boulder Drop Structure

FIG12–2.dwg TIF:FIG1202.TIF

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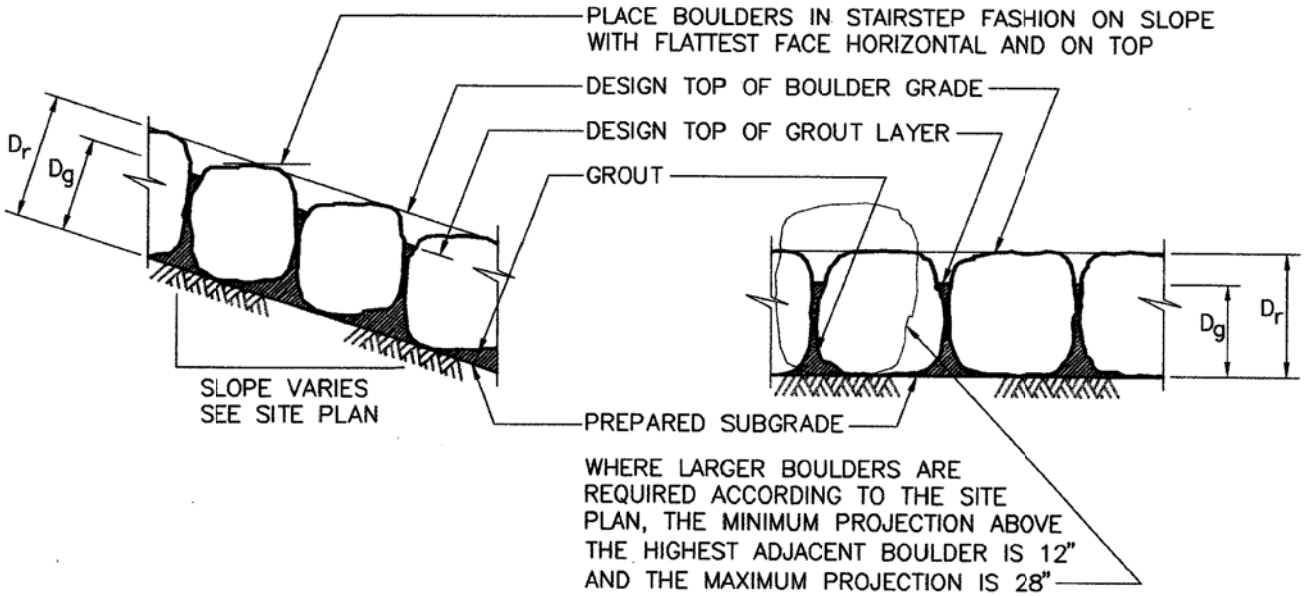


BOULDER SIZE (D_r)	D_g
DIMENSIONS IN INCHES	
12	6
24	18
30	22
36	27
42	31
60	45
66	49
72	54

Dr = DEPTH OF ROCK LAYER WHICH IS EQUIVALENT TO MINIMUM BOULDER SIZE – SEE TABLE ABOVE

Dg = DEPTH OF GROUT LAYER – SEE TABLE ABOVE

1. THE TOPS OF BOULDERS MAY VARY FROM THE DESIGN GRADE BY 4"±. AT A DROP CREST NO BOULDER SHALL VARY FROM THE DESIGN GRADE BY MORE THAN 1" OR AS INDICATED ON THE DRAWINGS. THE ENGINEER MAY REQUEST GREATER VARIATION AT SELECT LOCATIONS.
2. BEFORE GROUTING, CLEAN FROM THE BOULDERS ALL DIRT AND MATERIALS THAT COULD PREVENT THE GROUT FROM BONDING TO THE BOULDERS. FINAL PLACEMENT OF THE BOULDERS TO BE APPROVED BY THE ENGINEER PRIOR TO GROUTING.
3. INJECT GROUT BETWEEN BOULDERS TO FILL VOIDS UNDER AND BETWEEN BOULDERS. USE CONCRETE VIBRATOR TO CONSOLIDATE THE GROUT. THE CONTRACTOR SHALL CONTROL GROUT PLACEMENT TO ACHIEVE THE REQUIRED DEPTH OF GROUT. CLEAN EXCESS GROUT FROM ALL SURFACES TO BE EXPOSED. TROWEL THE GROUT SURFACE TO ACHIEVE A SMOOTH SURFACE BETWEEN BOULDERS WITHOUT PUDDLES.
4. SPACING BETWEEN BOULDERS SHALL BE KEPT TO MINIMUM REQUIRED FOR PLACEMENT OF GROUT AND TO MINIMIZE VISUAL APPEARANCE OF GROUT

ADAPTED FROM SELLARDS AND GRIGG, INC.

Greenwood Village
Hydraulic Structures
October 2003

Figure 12–3
Typical Landscaped Grouted Boulder Placement

FIG 12-3.dwg tif:fig1203.tif

P:\97003\027 Drainage Code Update 2003\Figures\FIG12-3.dwg, Layout1, 10/15/2003 11:03:21 AM, 1:1

13.0 Flood Attenuation

13.1 Introduction

One of the most fundamental requirements of stormwater management systems is to control flood discharges so that flood flows are released at pre-developed discharge rates to downstream properties. The pre-developed discharge rate is the rate at which stormwater was discharged when the property was in a natural condition prior to development. The most promising, and historically, the most effective, ways to manage flood discharges have been to avoid the artificial channelization of Major Drainageways and to construct stormwater flood attenuation facilities. The City of Greenwood Village (Village) requires the attenuation of the peak stormwater discharges to pre-development conditions from developed areas for the 5-year and 100-year frequency storms events.

The Village strongly discourages the artificial channelization of its Major Drainageways. Artificial channelization tends to accelerate velocities, increase peak flood discharges, and increase the costs for proper flood management for downstream property owners. The channelization of Major Drainageways is also inconsistent with the well-established policies of the Village to encourage recreation and the enhancement of the aquatic, terrestrial, and avian wildlife habitat along the Major Drainageways.

The Village strongly encourages the minimization of impervious areas to the maximum practical extent and the construction of on-site flood attenuation to minimize the inevitable increases in flood discharges caused by development. On-site flood attenuation also provides for sediment and debris collection near the source and away from the recreation areas along the Major Drainageways.

The Village will also consider and encourage regional detention facilities when it has been determined by the City Manager or designee that on-site detention is impractical or not in the best interest of the health, safety, and welfare of the Village. The City Manager or designee will prepare a rationale statement evaluating any proposal for regional detention. The rationale statement shall consider the same factors described in Section 3.3. The recommendations of the City Manager or designee may be appealed by the applicant or a resident of the Village in accordance with the procedures presented in Section 3.4.

13.2 Types of Stormwater Storage

Several types of stormwater storage can be constructed to meet the flood attenuation requirements of the Village.

13.2.1 Upstream Storage

The storage of runoff at the point of rainfall occurrence is known as "upstream storage." Upstream storage may take the form of rooftop storage, parking lot storage, and ponding in landscape areas. Upstream storage is particularly amenable to high-density commercial developments with large rooftop and parking areas. It is also amenable to parks and open space areas where short-term ponding does not excessively infringe upon the intended use of the property.

A well-designed upstream storage system can significantly reduce the requirements for the construction of stormwater facilities and flood-control improvements. It can also substantially enhance stormwater quality if the upstream storage area is landscaped with grasses or wetland vegetation and the stormwater is infiltrated into the ground.

13.2.2 Offstream Storage

Offstream storage usually occurs in depressed open areas outside of the main channel of the drainageway. Offstream storage can occur in constructed reservoirs or low-lying recreational fields where only storm hydrograph peaks are routed to the facility. These facilities usually require a side channel spillway or overflow from the main channel.

13.2.3 Underground Storage

Storage facilities can be built underground using large diameter pipes or other structures. These facilities tend to be expensive and are therefore usually used only for controlling runoff from commercial facilities with tight site limitations. A carefully designed access and maintenance program is a key element for the long-term success of these facilities.

13.2.4 Channel Storage

Low flow channels with wide bottoms can provide effective storage as an inherent part of their hydraulic characteristics. Wetland vegetation is particularly effective in slowing down peak discharge rates, thereby effectively providing storage and flood attenuation.

13.2.5 Retention Storage

The storage of runoff for a significant period of at least seven days is known as retention storage. Retention storage is frequently referred to as "wet storage" because of the relative permanence of the storage pool. A properly designed retention storage system can provide recreation and esthetic uses as well as providing for some enhancement of stormwater discharges from the retention storage basin.

13.2.6 Detention Storage

Detention storage is probably the most common form of stormwater storage. The flood discharges are typically held in a detention storage facility for several hours. Detention storage facilities are sometimes known as "dry ponds."

Detention storage facilities are frequently designed to provide the multi-purpose functions of flood attenuation and water quality enhancement. A portion of the detention facility can be designed to include wetlands or an extended detention basin that slowly releases runoff over a few days. The extended detention time provides treatment for the water quality design storm. The water quality design storm is typically smaller than the design storm for flood attenuation.

13.3 Design Criteria

The analysis and design of storage facilities for flood attenuation purposes shall be completed in accordance with the criteria presented in the Storage Chapter, Volume 1 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

13.3.1 General Criteria

All flood attenuation facilities shall be designed in accordance with the following criteria:

1) Existing drainage courses shall be preserved.
2) All flood attenuation facilities shall be designed to provide control for the 5-year and 100-year design storms.
3) Unless otherwise specified, local detention shall be provided to control on-site runoff. Off-site runoff from upstream drainage areas shall be diverted around any proposed detention facility or the detention facility shall be designed to control the off-site runoff as if it were on-site runoff.
4) Flood attenuation storage volume shall be provided to reduce the peak discharge rate for developed site conditions to the peak discharge rate for pre-development site conditions. Developed site conditions shall include all anticipated future development that will impact the site drainage basin. Pre-development site conditions are defined as undisturbed natural conditions.

5) Channel conveyance facilities shall be designed with adequate hydraulic capacity to convey the combined off-site and on-site runoff through the property. The off-site peak discharge rate shall be determined in accordance with the most recent land-use planning maps or at the direction of the Village.
6) Drainage facilities shall incorporate design features to minimize, maintain, and enhance the physical aesthetics of the site. Design features may include proposed grading that mimics or improves the existing site profile and use of construction materials that visually integrate with the ambient environmental textures and patterns.
7) Properties served by an existing regional detention facility may only utilize the existing facility if the following conditions are met:
   a. Calculations shall be provided that show that the regional facility is adequate to mitigate the runoff from the property. The entire basin that drains to the facility shall be included in the calculations. The facility shall meet the requirements of this Drainage Criteria Manual.
   b. Calculations shall be provided that show that the drainage system between the property and the regional facility is adequate to convey the runoff from the property. The entire basin that drains to the drainage system shall be included in the calculations. The drainage system shall meet the requirements of this Drainage Criteria Manual.
8) Non-residential redevelopment. Non-residential redevelopment projects are encouraged to use regional solutions to meet the flood attenuation requirements of this Drainage Criteria Manual.

13.4 Design Procedures

Design procedures specific for the Village, which deviate from those presented in the UDFCD Drainage Criteria Manual are highlighted in the following Sections.

13.4.1 General

The construction of a swimming pool may or may not increase the effective impervious area on a site. If the pool is covered in such a way that it sheds runoff, the pool acts as if it was a new impervious surface and will increase the runoff from the site. If the pool is not covered, it will reduce runoff from the site. Because of the variation in the design of pool covers and the likelihood that a pool cover will be replaced with a different design sometime during the life of the pool, it is impractical to assign a specific permanent impervious area to a pool.
Therefore, it shall be assumed that the surface area of the pool will not create a change in the impervious area for the site. However, the impervious area created by the pool deck area shall be considered as new impervious area for the site.

Minor Development and Redevelopment projects will have minimal impact on stormwater runoff patterns and water quality. Minor Development and Redevelopment projects may submit a

design in accordance with the Simplified Method as described in Section 13.4.2. The Simplified Method includes both the flood attenuation and water quality management requirements for the increased impervious area.

Major Development and Redevelopment projects will have significant impact on stormwater runoff patterns and water quality. Major Development projects shall provide both flood attenuation and water quality management for the entire site. Major Redevelopment projects shall provide both flood attenuation and water quality management for the disturbed and increased area. Major Development and Redevelopment projects shall use one of the following methods:

1) To establish a hydraulically consistent and region-specific detention design, UDFCD adopted a set of empirical relationships to simplify sizing of detention facilities that provide flood attenuation. Required detention storage for projects with tributary areas smaller than 10 acres may be determined using the empirical relationships in accordance with the criteria presented in Section 13.4.3 Equation Detention Method.
2) The Colorado Urban Hydrograph Procedure (CUHP), a computer program written for the UDFCD, is widely used and accepted in the Denver region. The synthetic hydrograph parameters represent statistical precipitation averages derived from the historical period of record for watersheds of various sizes. Chapter 6.0 provides a detailed discussion of the applicability of the CUHP program in designing drainage facilities in the Village. Required detention storage for drainage areas larger than 10 acres in size shall be determined by routing through CUHP in accordance with the criteria presented in Section 13.4.4 Hydrograph Detention Method.
3) Major Development and Redevelopment projects that consist of a single family residential lot may submit a design in accordance with the Retention Method as described in Section 13.4.5.

13.4.2 Simplified Method

Minor Developments and Redevelopments can fulfill the requirements of this Drainage Criteria Manual using the Simplified Method. Projects using the Simplified Method must also meet the no net loss wetlands requirement of this Drainage Criteria Manual. The Simplified Method is based on the following assumptions:

1) All runoff calculations are based on impervious area and total lot size.
2) Stormwater flows are not separated into multiple downstream drainage basins.
3) The stormwater retention volume requirements are based on the Equation Detention Method (Table 13-1) for Type II (clay loam) soils.
4) The 60% phosphorus removal can be achieved with the retention of 0.45 inches of rainfall on-site based on Figures 6-2 and 6-4 for Type II (clay loam) soils.
5) A retention facility will be used. If a detention facility is used, then the facility shall be designed by a professional engineer licensed in the State of Colorado.

Figure 13-1 shows the required retention volume based on lot size and amount of impervious area, with sufficient volume for both flood attenuation and water quality control, using the Simplified Method.

13.4.3 Equation Detention Method

The Equation Detention Method shall be used to size detention for drainage areas smaller than 10 acres in size. The equations presented in Table 13-1 shall be used to determine the minimum required detention volume and the maximum allowable release rates.

Table 13-1: Equation Detention Method

Design Storm Recurrence Interval	Minimum Detention Volume $V=KA^{(1)}$	Maximum Release Rates (cfs/ac) by Soil Type		
		I	II	III
5-yr	$K_5 = (0.77\ I - 2.65)/1000$	0.17	0.13	0.07
100-yr	$K_{100} = (1.78\ I - 0.002[I]^2 - 3.56)/1000$	1.00	0.85	0.50

where: V = minimum required storage volume (ac ft)
I = developed basin imperviousness (%)
A = tributary drainage area (ac)

13.4.4 Hydrograph Detention Method

The Hydrograph Detention Method shall be used to size detention for drainage areas larger than 10 acres in size using the CUHP as described in Chapter 6.0.

The applicant shall include sufficient documentation to clearly identify the design parameters. The maximum release rate shall be the rate specified in Table 13-1 or a rate approved by the Village determined based on an engineering analysis of site-specific pre-development conditions.

13.4.5 Retention Method

Major Development and Redevelopment projects that consist of a single family residential lot can fulfill the requirements of this Drainage Criteria Manual using the Retention Method. The Retention Method utilizes either full retention of the runoff or a combination of retention and detention. Developments using the Retention Method must also meet the no net loss wetlands requirement of this Drainage Criteria Manual. The Retention Method is based on the following assumptions:

1) All runoff calculations are based on impervious area and total lot size.
2) Stormwater flows are not separated into multiple downstream drainage basins.
3) The stormwater retention volume requirement is based on 1.5 times the volume of runoff generated by a 24-hour, 100-year storm event using Type II (clay loam) soils.
4) The stormwater detention volume requirements are based on the Equation Detention Method (Table 13-1) for Type II (clay loam) soils.
5) The 60% phosphorus removal can be achieved by the retention of the runoff.

13.4.5.1 Full Retention with No Discharge

The goal of a pond designed for full retention with no discharge would be to retain all of the runoff from the site. This often creates a somewhat permanent pool of water depending on the amount of runoff and the time between the storm events. Figure 13-2 shows the required retention volume based on lot size and amount of impervious area for a retention pond that does not have an outlet.

13.4.5.2 Retention with Discharge

The goal of a pond designed with a combination of retention and detention would be to retain the volume of runoff from the site that exceeds the pre-developed volume. The pre-developed volume would then be detained and released at the rates shown in Table 13-1. Figures 13-3 and 13-4 show the required retention and detention volumes based on lot size and amount of impervious area for a retention pond that has an outlet. Figure 13-5 shows the width of the outlet weir depending upon the depth of the detention portion of the pond.

13.5 Open Space Storage

13.5.1 State Regulatory Criteria

Any embankment used for storing water that satisfies the criteria for surface area, volume, or height specified in Colorado Revised Statutes 37-87-105 as amended, shall be designed and constructed in accordance with state criteria and shall require plan approval by the State Engineer’s Office.

13.5.2 Detention Facility Volume

Control storage volumes for detention facilities designed to provide water quality treatment and peak attenuation for runoff control are shown schematically in Figure 13-6. It should be specifically noted that any portion of the storage facility that has been designed for water quality enhancement cannot be included in the storage volume required for flood attenuation. The water quality control volume usually contains stormwater for an extended period of time and it must be assumed that the water quality control portion of the storage facility is full at the beginning of a design storm for flood attenuation.

13.5.3 Grading Requirements

Embankments five feet or less in height shall have a maximum slope of 4 (horizontal) to 1 (vertical), with even flatter slopes preferred. Embankments between five feet and ten feet in height shall have a maximum slope of 3:1. Embankments greater than ten feet in height shall be designed with slopes adequate to maintain structural stability. The minimum bottom slope for all open pond detention facilities shall be 2.0% measured perpendicular to the low flow channel. The minimum longitudinal slope of the low flow channel shall be 1.0%. The maximum side slope for rock-lined embankments shall be 3:1.

13.5.4 Freeboard Requirement

The minimum required freeboard for open space facilities is one foot above the 100-year water surface elevation.

13.5.5 Outlet Configuration

All outlet control structures for detention facilities shall conform to the details in Volumes 2 and 3 of the UDFCD Drainage Criteria Manual. Other configurations that satisfy required release rates must be approved by the City Manager or designee.

13.5.6 Emergency Overflow Structures

Emergency overflow structures to protect the embankment from catastrophic failure due to an extreme storm event that exceeds the design storage capacity or due to obstructions reducing the capacity of the outlet works shall be provided by an emergency overflow spillway.

The emergency overflow spillway shall be designed with a minimum capacity equal to the 100-year developed peak rate of flow into the facility. Structures shall not be permitted in the path downstream of the emergency overflow structure.

13.5.7 Vegetation Requirements

All open space detention facilities shall be vegetated using irrigated sod or natural dry-land grasses in accordance with the criteria adopted by the UDFCD. Additional landscaping that enhances the visual esthetics of the site is encouraged.

13.6 Parking Lot Storage

Detention design for parking lots shall conform to the general hydraulic criteria presented in Chapters 9.0 and 10.0 and to the specific criteria presented in this Section.

13.6.1 Depth Limitation

The maximum allowable ponding depth for the 100-year design storm is 12 inches.

13.6.2 Outlet Configuration

Inlets shall be designed with pipes having a minimum diameter of 18 inches. Weir outlets shall be designed having a minimum width of 3 inches.

13.6.3 Maintenance

The outlet shall be designed to minimize modifications that effect detention functions. The Village shall evaluate resurfacing activities for impact on volumes and release rates.

13.6.4 Flood Hazard Warning

All parking lot detention areas shall be identified by posting a minimum of two signs. The signs shall have a minimum area of 1.5 square feet and contain the following message:

WARNING:
This area is used to detain runoff
and is subject to periodic flooding
to a depth of (design depth).

Sign materials, geometry, and location are subject to approval by the City Manager or designee.

13.7 Underground Storage

Underground storage is considered to be one of the least preferred methods for storage due to the expense of these structures, difficult maintenance, and possible damage to other structures caused by leakage. Permanent structures shall not be placed directly above the underground detention.

13.7.1 Materials

Underground detention storage shall be constructed using corrugated metal aluminum pipe (CMP), reinforced concrete pipe (RCP) or reinforced concrete vaults. The pipe thickness, cover, bedding, and backfill shall be designed for an AAHSTO H-20 loading condition or greater as required by the Village. The use of CMP shall require a soil analysis to ensure that the corrosivity of the soil will not shorten the design life of the culvert.

13.7.2 Pipe Storage Configuration

The minimum pipe diameter shall be 36 inches. Pipe segments shall be sufficient in number, diameter, and length to provide the required design storage volume. Pipe segments shall be placed side by side and connected at both ends by elbow and tee fittings as shown in Figure 13-7. The pipe segments shall be continuously sloped at a minimum of 0.25% to the outlet. Equivalent alternative configurations shall require approval by the City Manager or designee.

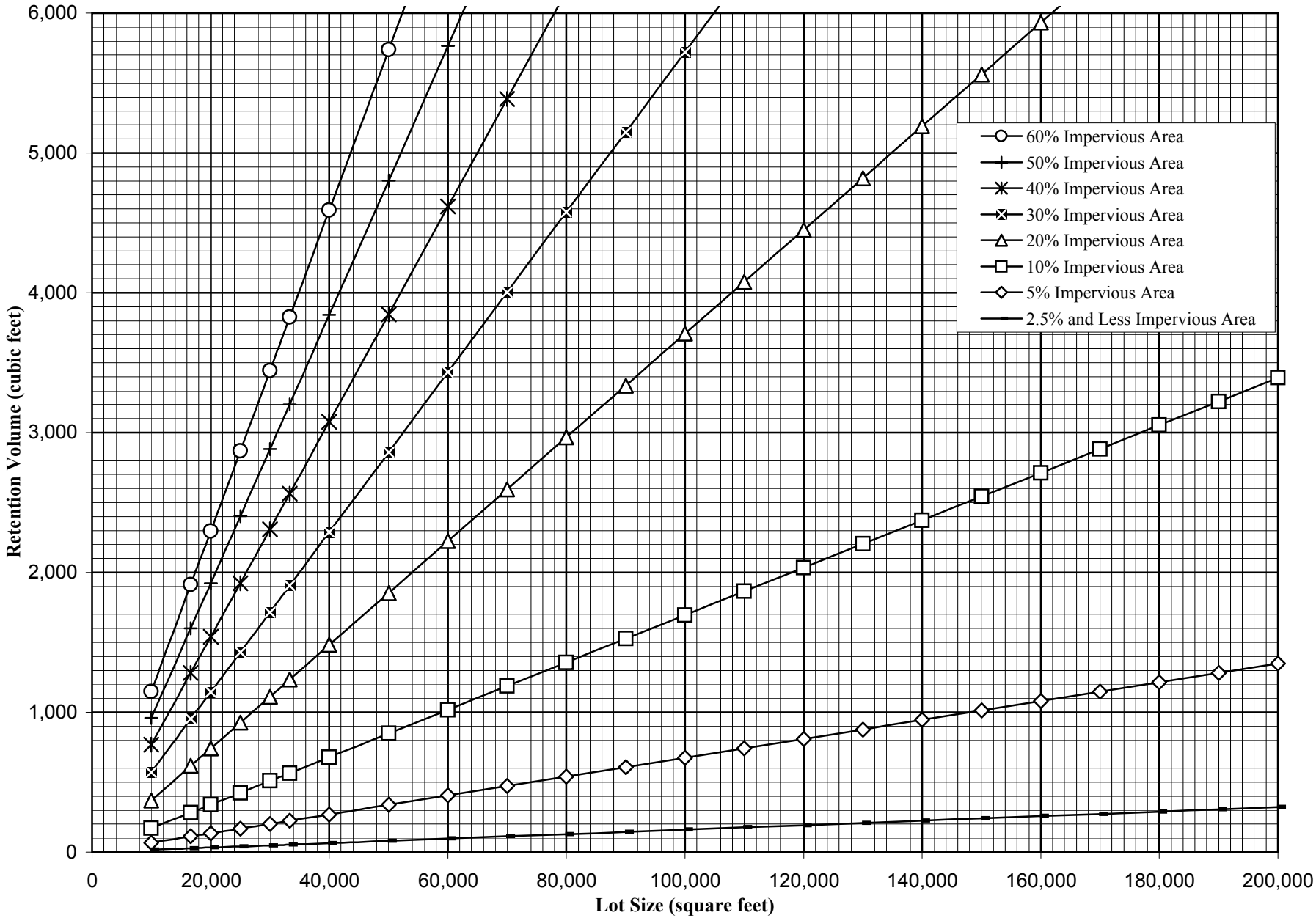
13.7.3 Inlet and Outlet Configuration

The inlets to the detention pipes shall be either surface inlets or subsurface connections within the local storm sewer system. The outlet from the detention pipes shall consist of a pipe with a minimum diameter of 18 inches and a maximum length of 25 feet. A two-pipe outlet may be required to control both the minor and the major design storms. For a two-pipe outlet, the invert of the lowest pipe must be set at the lowest invert of the storage pipes. If an orifice plate is required to control the release rates, the plate shall be hinged to open into the detention pipes to facilitate back flushing of the outlet pipe.

The outlet pipe shall discharge into a manhole or into a drainageway with erosion protection designed in accordance with the criteria presented in Chapter 12.0.

13.7.4 Maintenance Access

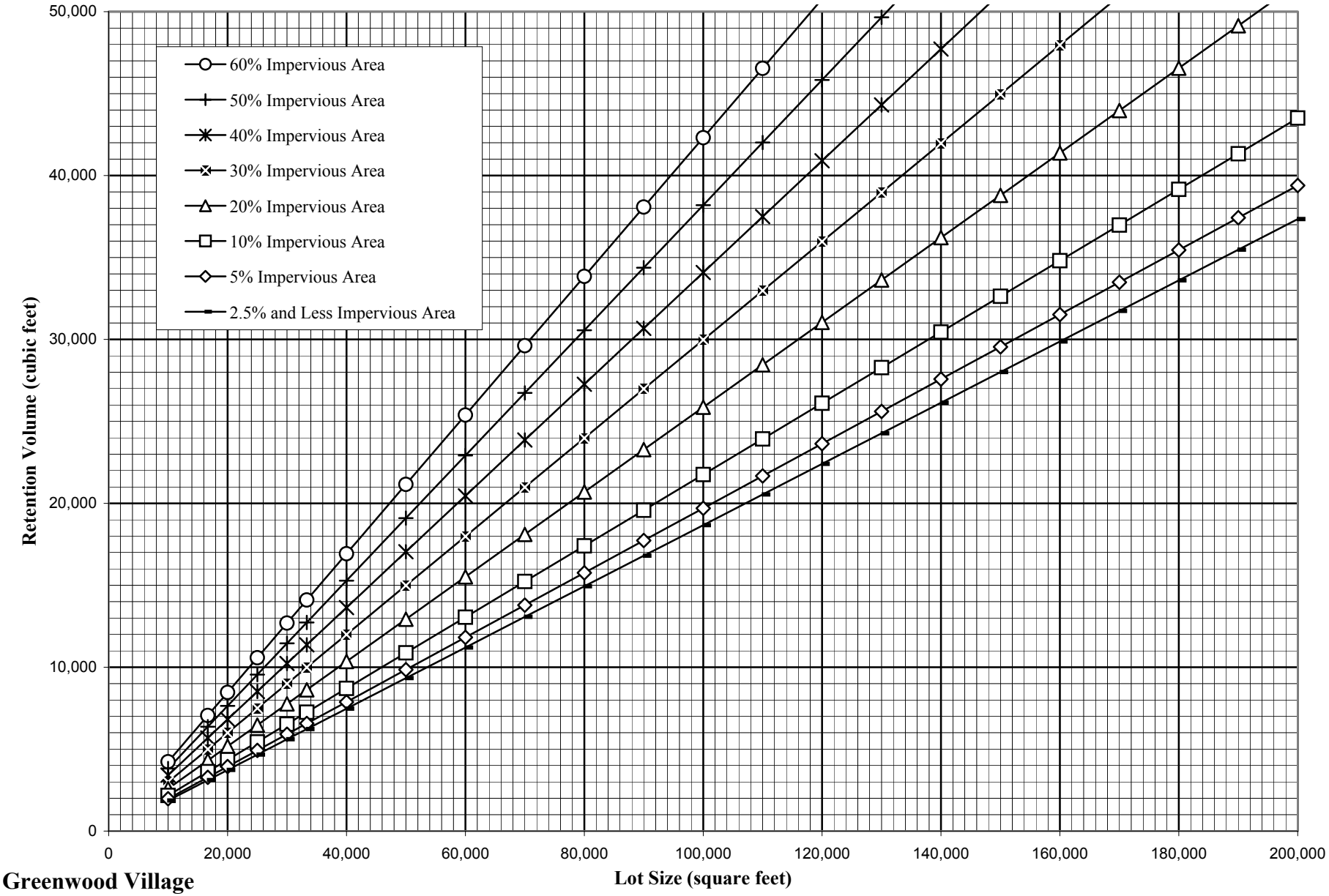
Access manhole locations for the detention facility shall be provided for cleaning the pipe segments and shall be located in accordance with the details shown on Figure 13-7. Maintenance of the pipe segments shall be in accordance with the schedule shown on Figure 13-7.



Greenwood Village
October 2003

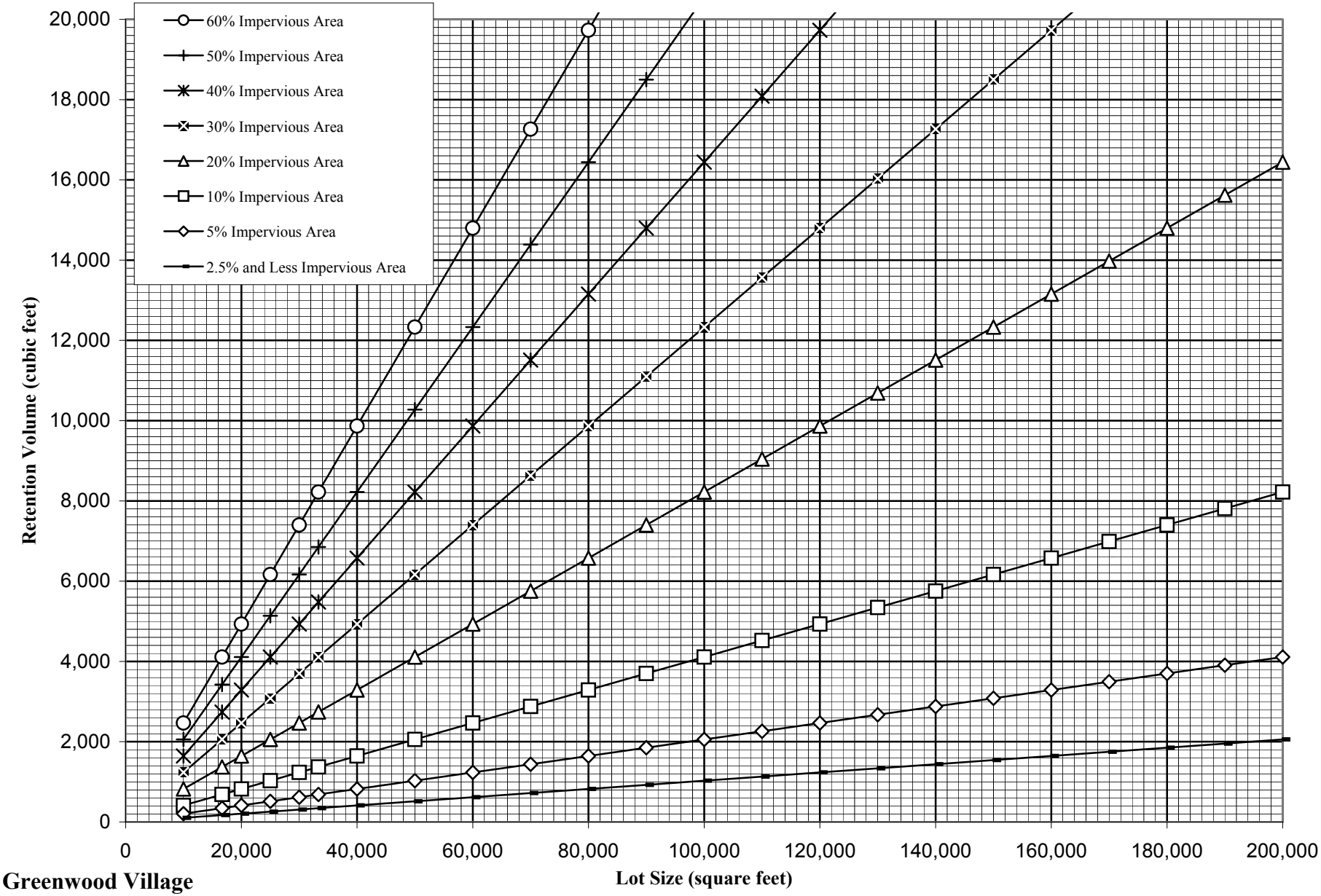
Figure 13-1
Simplified Plan
Retention Requirements

FIG 13-1 -Fig 13-1 Chart



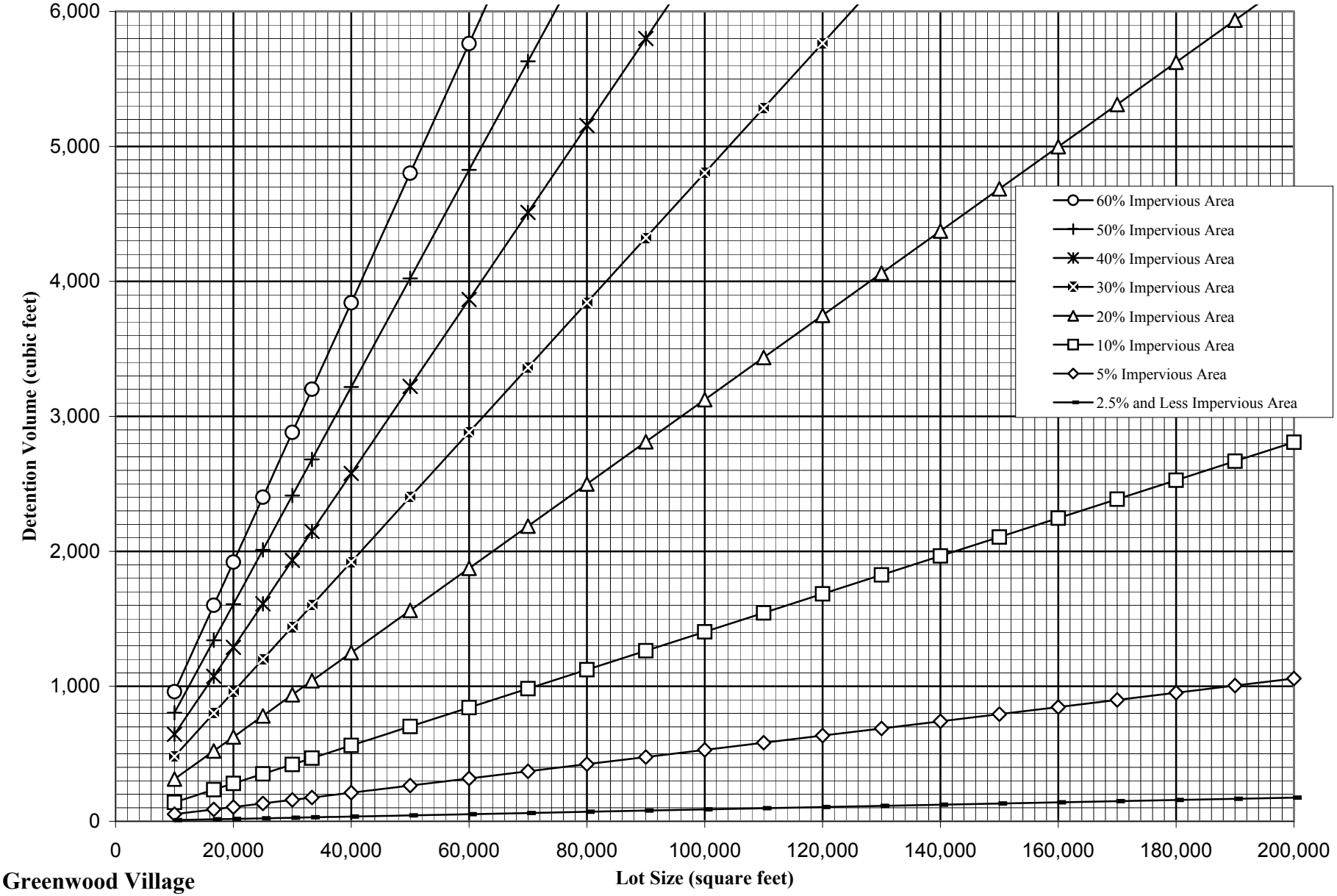
Greenwood Village
October 2003

Figure 13-2
Retention Method - Full Retention with No Discharge



Greenwood Village
October 2003

Figure 13-3
Retention Method - Retention Volume with Discharge



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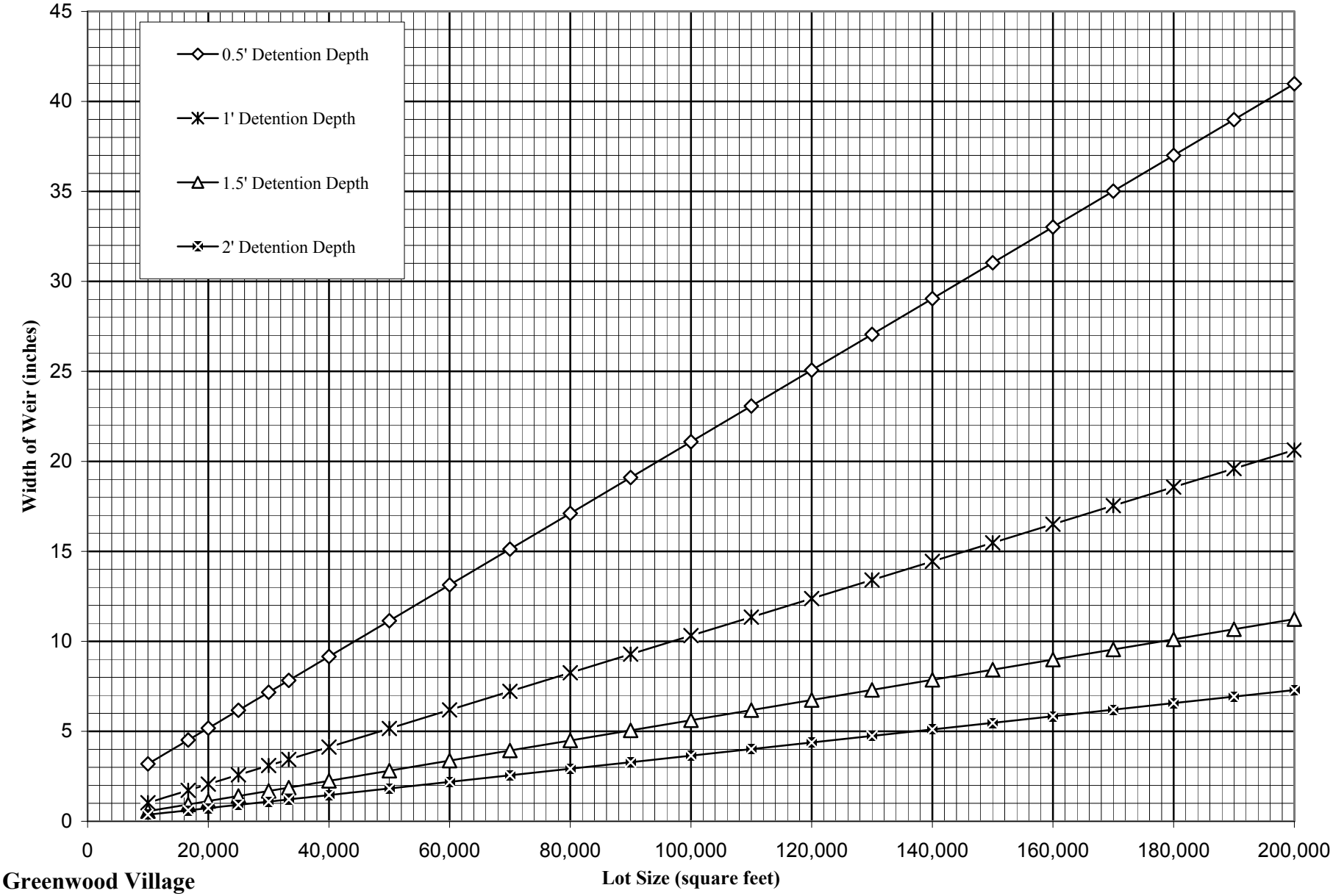
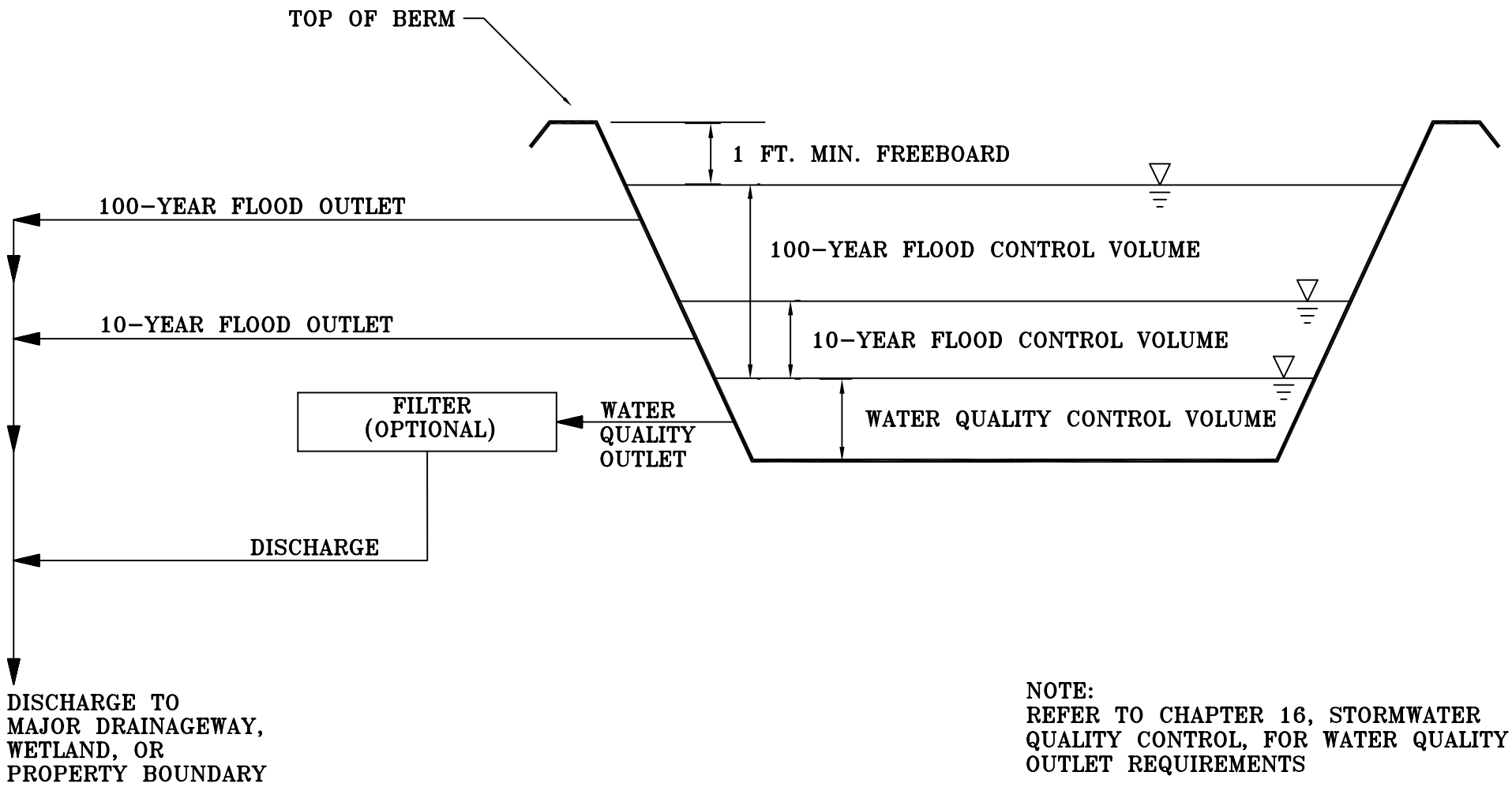
December 2003

Figure 13-4
Retention plus Detention Method - Detention Volume



Greenwood Village
October 2003

Figure 13-5
Retention Method - Detention Weir Sizing



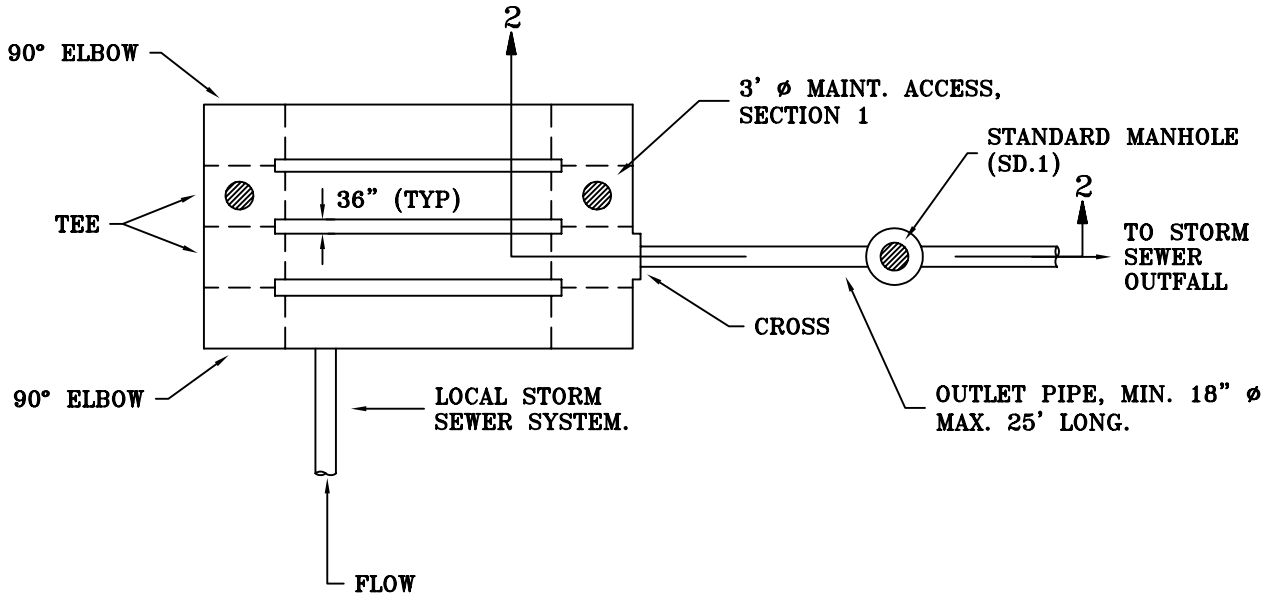
NOTE:
REFER TO CHAPTER 16, STORMWATER QUALITY CONTROL, FOR WATER QUALITY OUTLET REQUIREMENTS

Greenwood Village
Flood Attenuation
October 2003

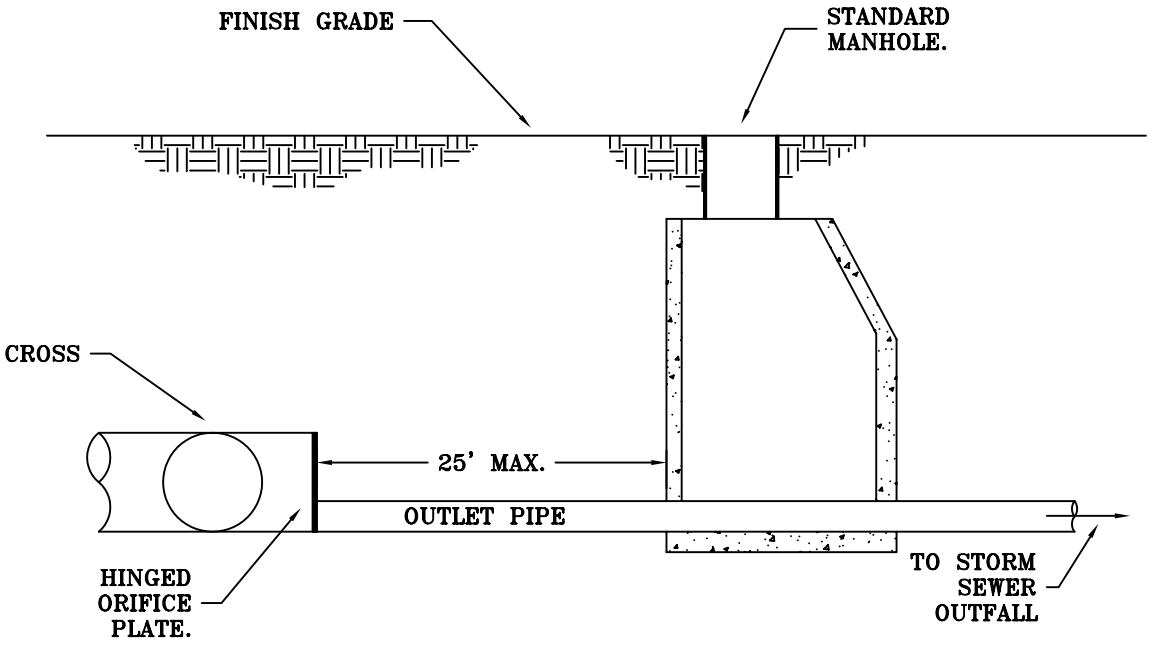
Figure 13-6
Required Distribution of
Detention Facility Volumes

FIG13-6.dwg

GENERAL PLAN
(NTS)



SECTION 2 OUTLET
(NTS)



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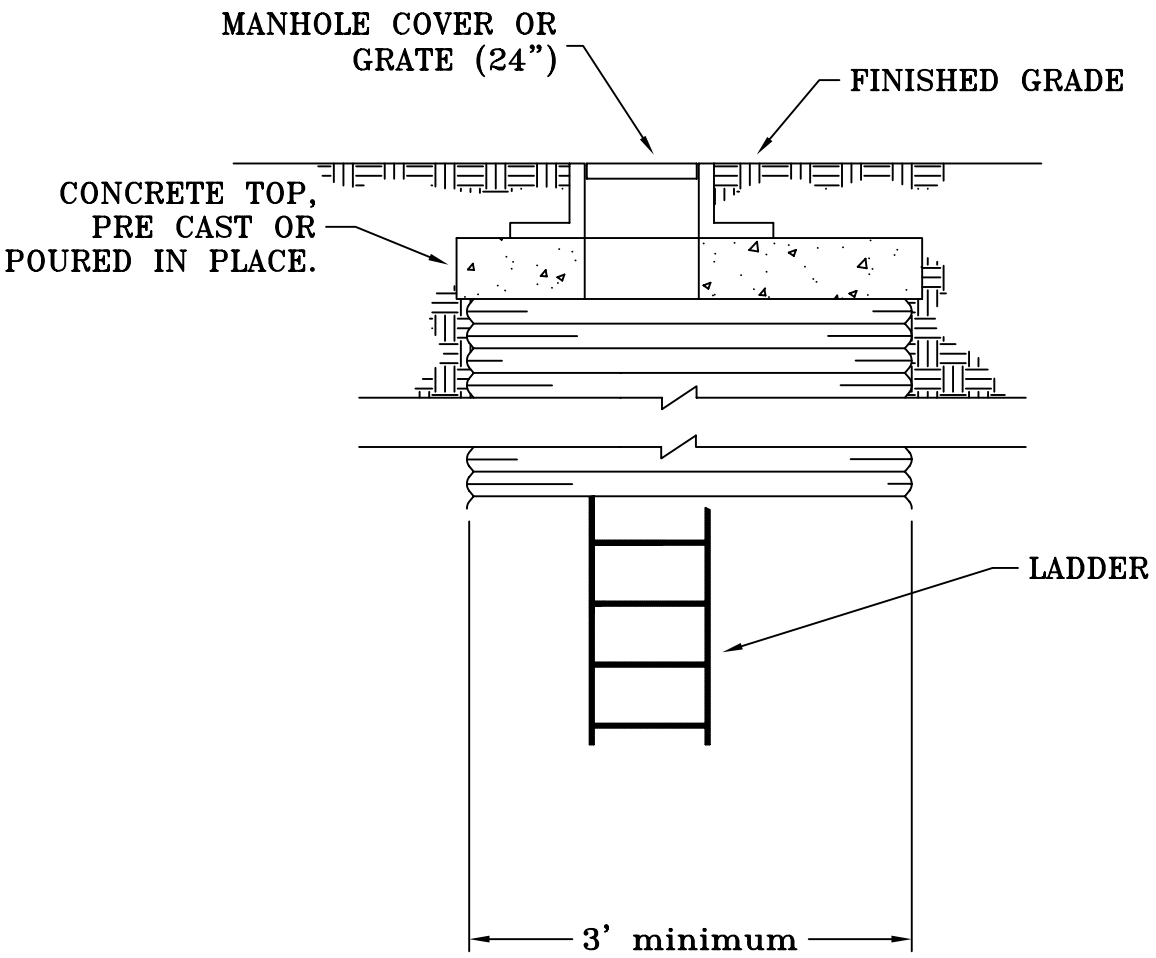
Greenwood Village
Flood Attenuation
October 2003

Figure 13-7
Underground Detention
Sheet 1 of 2

FIG13-7, SHEET 1.dwg



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MAINTENANCE ACCESS REQUIREMENTS

DETENTION PIPE SIZE (INCHES)	MAXIMUM SPACING (FEET)	MINIMUM FREQUENCY
36 to 54	150	Every pipe segment
60 to 66	200	Every other pipe segment
>66	200	One at each of the battery pipes

Greenwood Village
Flood Attenuation
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Figure 13-7
Underground Detention
Sheet 2 of 2

FIG 13-7, SHEET 2.dwg

14.0 Wetlands Criteria

14.1 Introduction

Wetlands provide multiple important functions in a stormwater management system. A wetland can reduce peak flood discharges and improve the water quality of storm runoff. Wetlands also provide wildlife habitat and have become an integral part of the City of Greenwood Village's (Village) park and recreation assets.

The Village will review all drainage studies for potential adverse impacts to a wetland. The Village strongly encourages drainage management proposals that will enhance the wetlands resources within the Village. This includes the construction of new artificial wetlands, which are designed to attenuate flood discharges and provide water quality enhancement.

The Village will not approve a drainage study for a new development or redevelopment, which relies upon existing wetland systems for flood attenuation or water quality enhancement. The Village will approve only those drainage studies which meet the flood attenuation and water quality requirements of this Drainage Criteria Manual prior to the discharge of stormwater into an existing wetland. Furthermore, the Village will not approve any land development project which diminishes the total area or functional values of any existing wetland. These combined requirements are referred to as the “no net loss of wetlands goal.”

14.2 Federal Regulations

The applicant must also demonstrate compliance with federal regulations on wetlands found in 33 CFR Parts 320 through 330 and 40 CFR Part 230. In general, these regulations prohibit the discharge of dredged or fill material into the waters of the United States, which includes wetlands and a permit to discharge dredged or fill material into a wetland can be obtained from the U.S. Army Corps of Engineers (COE). These permits are often referred to as 404 permits.

The COE has limited the scope of the regulatory program somewhat by issuing nationwide permits for some dredge and fill activities. If certain conditions are met, the specific action can take place without the need for an individual or regional permit. The nationwide permit has all the restrictions and conditions set forth, and little or no paperwork is involved. It takes a relatively short time to initiate an individual project. For example, a nationwide permit authorizes discharges into waters that are located above the headwaters. The term “headwaters” is that point on a perennial stream above which the average annual flow is less than 5 cfs. On an intermittent stream the “headwaters” is that point where 5 cfs is equaled or exceeded 50% of the time. Maps of the headwaters have been published and copies may be obtained from the COE. The use of this nationwide permit is limited; however, and is subject to future modification. In many cases,

written coordination with the COE is required. Other nationwide permits address storm drain lines, utility lines, and bank stabilization, and maintenance activities. It is incorrect to assume that a COE permit is not required if the disturbance is small. Prior to any disturbance to a wetland, the COE should be contacted to determine the current permit requirements of the COE.

Regional permits are a type of general permit and can be issued by a division or district engineer. A regional permit may require a case-by-case reporting and acknowledgement system. The regional permit will state what fill actions are allowed, what mitigation is necessary, how to get an individual project authorized, and how long it will take. The time required to initiate an individual project under a regional permit should be less than that for an individual permit. Regional permits may be issued from time to time to the Village, the County, or the UDFCD. Projects that come under a regional permit must have minimal environmental impact.

An individual permit is for one action and the restrictions and conditions are tailored to the individual project. Extensive paperwork is involved and it usually takes a few months to obtain. If there are any environmentally sensitive issues involved, or any objections to the work, it can take several months or even years to obtain an individual 404 permit.

14.3 Wetlands Maintenance

Disturbing or cutting wetland vegetation within designated wetland areas is prohibited except as follows:

1) Hand cutting or removal by hand of noxious weeds,
2) Thinning of wetland vegetation to minimize mosquito habitat, provided that a thinning plan prepared by an environmental specialist has been approved by the City Manager or designee, and
3) Work performed to protect the public health, safety, and welfare.

Designated wetland areas include both naturally occurring wetlands and artificial wetlands constructed for flood attenuation or water quality treatment.

14.4 Wetlands Impact Report

A Wetlands Impact Report (WIR) shall be prepared as an initial step to any land development or redevelopment. The WIR shall be submitted with the drainage study for any proposed land development project. The purpose of the WIR is to identify any impacts or potential impacts to wetlands on-site or down gradient of the project.

The applicant is responsible for demonstrating no impact to on-site and off-site wetlands. The WIR shall contain a wetlands mitigation plan, if the proposed activities will cause any damage, loss, or change in the functional values of a wetland in the Village.

14.3.1 Wetlands Inventory

The Village has prepared a map of existing wetlands along the Major Drainageways. Figure 2.3 is a regional map showing known wetlands areas. This map is not intended to be a final delineation of all wetlands and is provided only as an initial guidance showing probable wetland areas. For information on the types of plant communities within each wetland boundary, refer to Volume I of the Village's Major Drainageway Master Management Plan. The nonexistence of a designated wetland on the Village's wetlands map does not relieve the applicant from inventorying wetlands on-site or hydraulically down-gradient of the project.

A formal site investigation shall be conducted to evaluate vegetation, soils, and hydrology using the most recent guidance from the COE. If wetlands are found to occur within the project boundary or will be impacted by the project, the applicant shall accurately delineate the applicable existing wetland boundaries.

The wetland delineation shall identify wetland plant communities and the dominant plant species for each type of community. Boundaries and acreage of each plant community shall be provided as part of the wetlands map. The wetlands delineation shall also include an assessment of the wildlife habitat and water quality enhancement functions of the wetland.

14.3.2 Evaluation of Grading Plans

To preserve existing wetlands, care should be taken not to encroach on a wetland with either fill or excavation. Overlot grading should minimize the amount of cut and fill in order to preserve original ground contours in the vicinity of wetlands and natural drainage patterns shall not be altered significantly. Culvert configurations and road and overpass embankments shall be designed to minimize impacts to existing wetlands and to provide drainage as nearly "natural" as possible.

14.3.3 Evaluation of Water Sources

Water sources in and around wetlands shall be preserved to the maximum extent possible. Potential changes in water sources shall be identified and considerations shall be made for replacement of surface and subsurface flow locations, both in number and location, as near as practicable to the previous conditions.

Groundwater flow to wetlands shall be evaluated and preserved to the maximum extent practicable by limiting the amount of impervious area, increasing infiltration within the development to pre-development rates, and preserving the original groundwater flow directions. The WIR shall evaluate groundwater flow patterns and identify mitigation measures to minimize the adverse impacts of the proposal.

14.3.4 Evaluation of Utility Line Locations

Utility lines (water, sewer, gas and electricity) may have to cross drainage channels and wetland areas. When excavation is required through or near a wetland area, no excavated material shall be deposited or stockpiled within the delineated wetland boundary. All materials shall be located outside of the normal high water line of the wetlands. Site restoration shall include the replacement at least of the upper one-foot of material excavated from the wetlands with wetland type soils and stabilization of the material to prevent erosion. To the extent possible, no utility lines shall be located in wetlands.

14.3.5 Evaluation of Detention Facilities

No stormwater runoff shall be discharged directly into wetlands without first being detained on-site in accordance with Chapters 13.0 and 16.0.

14.3.6 Evaluation of Recreational Access to Wetlands

A common use of low areas that may contain drainageways or wetlands is to incorporate hiking and biking trails or linear parks along the route. This is a desirable function of the area but the functions and values of the wetland shall not be compromised.

Trails shall be located along the wetlands edge and outside of the delineated wetland boundary. At regular intervals, trails shall depart from the wetlands to leave significant areas of “safe havens” for the wildlife from human and domestic pet intrusion.

14.3.7 Mitigation

Mitigation includes the efforts to avoid and minimize impacts repair, rehabilitate or restore the affected wetlands, reduce or eliminate the impact, or to compensate for impacts by replacing or substituting resources or environment. When mitigating wetland impacts, the impacted wetlands must be replaced with created wetlands that equal the acreage and functional values of the impacted wetlands. In some cases, the replacement acreage may have to be greater than the impacted wetland to achieve the same function and value.

The mitigation plan shall include a preliminary design of proposed mitigation measures and shall be submitted as part of the WIR. Mitigation of the Village’s wetlands shall proceed in the following order with the most desirable condition listed first and the least desirable listed last:

1) Impact Avoidance – The most desirable mitigation technique is to avoid impacts to wetlands.
2) Impact Minimization – Where impact avoidance is not practicable and no alternatives exist for the project; on-site minimization shall be utilized. Minimization involves maintaining the functions and values of the existing wetland.

3) On-site Compensation – Mitigation efforts shall strive for on-site compensation of disrupted wetlands within the limits of the project when minimization of impacts is not sufficient. Compensation shall be used to offset the unavoidable loss of wetlands communities, wetland functions, and wetland values that existed prior to the project. Compensation may include in-kind replacement or enhancement replacement of wetlands within the project boundary.
4) Off-site Compensation – If a project will disturb a larger area of wetlands than can be mitigated on the site (i.e. road fill displacing some wetlands), it may be necessary to mitigate off the project site. This type of mitigation is used when there is insufficient area for on-site compensation or when restoration of the original wetland communities is not desirable (i.e., drainageway development in restricted urban corridors where reestablishment of tree-dominated communities could be detrimental to the success of the project.) Off-site compensation shall occur at a minimum ratio of 2:1 of new to existing wetland area. The off-site compensation shall be located within the Village, preferably within the same major drainage basin.

14.3.8 Wetlands Impact Report Checklist

Table 14-1 is a checklist provided to help the applicant and reviewer make sure that the necessary elements have been included in the WIR. The checklist must be completed and submitted with the WIR.

Table 14-1 Wetlands Impact Report Checklist

Item
1) General Location and Description
a. Location
i. Local streets within and adjacent to the development.
ii. Township, range, section, and ¼ section.
iii. Major Drainageways, drainage facilities, and wetlands near the development.
iv. Names of surrounding developments.
b. Description of Property
i. Area in acres.
ii. Ground cover (type of trees, shrubs, and vegetation).
iii. Major Drainageways and drainage facilities within the development.
iv. General project description.
v. Inventory of wetlands within the development that may be affected by the development.

Item
2) Wetland Mitigation Criteria
a. Regulations
i. Discussion of compliance with or deviation from this Drainage Criteria Manual.
b. Development Criteria Reference and Constraints.
i. Discussion of previous WIR for the property.
ii. Discussion and justification of other criteria or methods used that are not presented in or referenced by this Drainage Criteria Manual.
3) Mitigation Plan
a. General Concept
i. Discussion of impact avoidance and minimization.
ii. Discussion of on-site and off-site compensation.
iii. Discussion of the content of all tables, charts, figures, or drawings.
b. Specific Details
i. Discussion of each measure used to meet the requirements of this Drainage Criteria Manual.
ii. Discussion of mitigation design.
4) Conclusions
a. Compliance with Standards
i. Drainage Criteria Manual.
ii. Compliance with Federal Regulations in 30 CFR Parts 320 through 330 and 40 CFR Part 230, including all consultations with U.S. Army Corps of Engineers.
b. No Net Loss Goal
i. Effectiveness of plan to meet the No Net Loss Goal.
5) References
a. Reference all criteria and technical information used.
6) Appendices
a. Wetlands Inventory
i. Definition of areas.
ii. Vegetation communities.
iii. Function and value of wetland areas.
b. Calculations
c. Assumptions

Item
7) Maps
a. General Location Map
i. A general location map showing the general drainage patterns around the property. The map should be at a scale of 1” = 1000’ or 2000’ and show the path of all drainage to and from any wetlands. The map shall identify any wetlands or facilities (i.e., irrigation ditches, existing drainage facilities, and storm sewers) along the entire path of the off-site and on-site drainage.
b. Wetland Plan
i. Plan of the proposed development shall be provided at a scale of 1” = 10’ to 1” = 200’ on 24” x 36” sheets.
ii. A topographic map shall be provided with two-foot existing and proposed contours tied to the Greenwood Village “Control Diagram” (Figure 2-1). The topographic map shall extend a minimum of 50-feet beyond the property lines.
iii. Property lines, easements, and purposes of easements.
iv. Streets.
v. Existing drainage facilities and structures, irrigation ditches, Major Drainageways, and existing wetlands. All pertinent information such as materials, size, shape, slope and location shall also be included.
vi. Overall drainage area boundary and drainage sub-area boundaries.
vii. Proposed storm sewers and open channels, including inlets, manholes, culverts, and other appurtenances.
viii. Water source for wetlands.
ix. Impacted wetlands.
x. Mitigation details.
xi. Location and elevations of all floodplains affecting the property.

15.0 Stormwater Quality Criteria

15.1 Introduction

The development of open land causes an increase in surface stream flow. The runoff from developed areas also contains a wide range of pollutants including nutrients, oil and grease, metals and complex organic compounds. The concentrations of some of the pollutants are at toxic levels to aquatic life.

If improperly managed, these increased flows can cause streambank erosion, violations of water quality standards and loss of aquatic life. If properly managed, these flows can be used to enhance wetland areas, maintain water quality standards, enhance aquatic life and become an amenity in the City of Greenwood Village's (Village) drainageways and parks and trails systems.

15.2 General Requirements

Six perennial streams pass through the Village:

1) Big Dry Creek
2) Little Dry Creek
3) Greenwood Gulch
4) Prentice Gulch
5) Goldsmith Gulch
6) Cottonwood Creek

Each of these perennial streams support aquatic life and are significant recreational amenities for the Village's parks and trails system. In addition, a portion of the Village drains toward Cherry Creek Reservoir, a major fishery and recreational resource for the region.

The riparian corridors of these streams and their tributaries include significant wetland areas that help support the base flows and maintain the water quality of the streams. Figure 2-2 is a map of the Village showing the locations of perennial streams and Figure 2-3 shows inventoried wetland areas.

Stormwater Quality Management Plans shall be prepared as an integral part of any Drainage Study submitted to the Village. The purpose of the Stormwater Quality Management Plan shall be to demonstrate to the satisfaction of the Village that stormwater discharges will meet the stormwater quality management criteria of this Section. These criteria will apply to any stormwater discharged to a perennial stream, to wetlands or past the property line, whichever is more stringent.

15.2.1 Stream and Reservoir Water Quality Standards

The State of Colorado has established a classification system to protect existing and anticipated beneficial uses of the State's waters. The Colorado Water Quality Control Commission (Commission) has the authority to assign the classifications to all surface waters in the state.

The Commission is required to consider several factors when assigning classifications:

1) Classifications should be directed toward the realization of water quality goals as set forth in the federal and state water quality acts.
2) Compliance with state law and policy to prevent water quality degradation that can interfere with present uses.
3) Upstream classifications cannot jeopardize downstream classifications or actual uses.
4) Classifications must protect all current classifications and actual uses, unless it is determined after a public hearing that downgrading is justifiable.
5) Classifications should be for the highest water quality attainable. Attainability is to be judged by whether or not the use classification can be attained in approximately twenty years using control techniques that are environmentally, economically and socially acceptable as determined by the Commission after public hearings.
6) Relevant physical, chemical, and biological characteristics of water quality.

The classified uses for the streams and reservoirs receiving stormwater discharges from the Village are summarized in Table 15-1.

Table 15-1: Classified Uses of Streams and Reservoirs

Stream	Stream Segment	Classified Uses					
		Aquatic Life Warm 1	Aquatic Life Warm 2	Recreation 1	Recreation 2	Water Supply	Agriculture
Big Dry Creek	Upper South Platte 16		x		x		x
Little Dry Creek	Upper South Platte 17		x		x		x
Greenwood Gulch	Upper South Platte 18		x		x		x
Prentice Gulch	Upper South Platte 19		x		x		x
Goldsmith Gulch	Cherry Creek 3		x		x	x	x
Cottonwood Creek	Cherry Creek Reservoir		x		x	x	x
Cherry Creek Reservoir	Cherry Creek Reservoir	x		x		x	x

The Aquatic Life Warm 1 Classification is the highest quality warm water fishery. It is assigned to those waters that are capable of sustaining a wide variety of warm water biota, including sensitive species with no substantial impairment of the abundance and diversity of the species. Cherry Creek Reservoir is designated as this classification to protect the existing gold medal Walleye fishery and other sport fisheries heavily used by the public.

The Aquatic Life Warm 2 Classification is assigned to those waters not capable of sustaining a wide variety of warm water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.

The Recreation Class 1, the Primary Contact Classification, is assigned to waters that are suitable for recreational activities in or on the water and the ingestion of small quantities of water are likely to occur. It was assigned to the Cherry Creek Reservoir to protect the existing heavy use of the reservoir for swimming and water skiing.

The Recreation Class 2, the Secondary Contact Classification, is assigned to waters that are suitable or are intended to become suitable for recreation users on or about the water but were not included in the Recreation Class 1 category. The anticipated recreation uses include fishing and other streamside or lakeside recreation.

The Water Supply Classification is assigned to waters suitable or intended to be suitable for potable water supplies after receiving standard treatment. It was assigned to the Cherry Creek Reservoir to protect it for potential future development as a municipal water supply. It was also assigned to Goldsmith Gulch because it flows into Cherry Creek at a point upstream of potable water supplies in the Cherry Creek alluvium.

The Agriculture Classification is assigned to waters suitable for irrigation of crops usually grown in Colorado and is not hazardous as drinking water for livestock. It was assigned to the Cherry Creek Reservoir and all other streams to help maintain the existing quality, protect future potential development of this resource, and to protect existing downstream agricultural uses.

The Commission also assigns ambient standards to protect each of the classified uses. These standards include limits on physical, biological, inorganic, metal and macronutrient parameters. These standards apply to all surface waters in the State with the same classified uses.

The Commission has adopted a site-specific chlorophyll a standard for Cherry Creek Reservoir in Regulation 38[1]. The standard requires that the seasonal mean chlorophyll a (Chl a) value measured throughout the water column of the reservoir not exceed 0.018 micrograms per liter

[1] Colorado Water Quality Control Commission January 1, 2010. *Regulation No. 38 Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin.* 5 CCR 1002-38.

(mg/L) for the months of July, August, and September. The Commission also established a Chl a standard assessment period of 5-years, with attainment expected in four out of five years.

Previously in 2000, the Commission had established a chlorophyll a standard of 0.015-mg/L for Cherry Creek Reservoir with an assessment period of 10-years with attainment of nine out of 10-years. In addition, an in-lake phosphorus goal, which was a July through September seasonal average, was set at 40 µg/l based on a 90% confidence level that this goal would result in the attainment of the chlorophyll a standard. Based on the evidence presented in the prehearing filings and at the March 2009 rulemaking hearing, the Commission agreed that a Chl a standard of15 µg/l could not be feasibly attained nine out of ten years and therefore revised the Chl a standard as noted above.

The Commission reached the conclusion about the feasibility of the 2000 standard based on the evidence presented at the March 2009 hearing. The evidence indicated that although the Cherry Creek Basin has experienced unprecedented growth during the past 20 years, the Authority and its partners have succeeded in implementing nutrient controls to help maintain the Reservoir's water quality. The Commission acknowledged that the Authority, its member agencies, and partners have improved wastewater treatment and have installed best available technology, installed nonpoint source controls, and utilized its land use agency responsibilities to control phosphorus in the watershed and inflow to the Reservoir.

The Phase II stormwater discharge permits in the Cherry Creek watershed are mandatory and will be based on the BMPs contained in Volume 3 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. The final development of the TMAL over the next several years may require the placement of more stringent limits on the wastewater discharges and may also require BMPs that are more effective than the designs that are assumed to remove 50% of the total phosphorus load in stormwater.

15.2.2 EPA Stormwater Discharge Permit Requirements

The U.S. Environmental Protection Agency (EPA) has published numerous regulations to control stormwater discharges from industrial and municipal storm sewer systems. It can be anticipated that as the EPA program continues to evolve, there will be additional stormwater management requirements imposed on the Village and property owners within the Village.

EPA's stormwater permitting program is implemented in two parts commonly known as Phase I and Phase II. The stormwater discharges regulated in Phase I typically include those from heavy industry, large and medium-sized municipalities, and large construction sites. The discharges regulated in Phase II include those from light industrial, retail, commercial and institutional facilities, small municipalities, and small construction sites.

The regulated community includes those public and private facilities that discharge stormwater:

1) Via one or more point sources, or
2) Into the waters of the United States, either directly or through a separate municipal storm sewer system.

Facilities are subject to Phase I of the stormwater permitting program if the facility meets the above test and falls within any of the following five categories of stormwater dischargers:

1) Facilities already covered by a (NPDES) permit for stormwater.
2) Facilities that engage in industrial activity.
3) Large, greater than 250,000 population, municipal separate storm sewer systems.
4) Facilities that the EPA administrator, or an NPDES site administrator, determines to have stormwater discharges contributing to a violation of water quality, or that are "significant contributors" of pollutants to the waters to the United States.

Stormwater discharges that meet the test criteria, but do not fall into one of the listed categories, fall under Phase II of the stormwater program. Phase II stormwater discharges generally include:

1) Commercial, retail, light industrial and institutional facilities.
2) Construction activities under five acres.
3) Small, less than 100,000 population, municipal separate storm sewer systems.

EPA's regulatory definition of the term "associated with industrial activity" covers many common industrial operations. For much of the regulated community, the simple fact of conducting such activity will trigger the requirement to obtain an NPDES permit for stormwater discharges. However, the regulations treat "light" industries differently. This is an important distinction, and may determine whether a given facility must obtain an NPDES permit.

The NPDES requirements apply to any discharges of stormwater via a point source either directly or through a separate municipal storm sewer system to the waters of the United States. For all practical purposes, all of the perennial streams in the Village would be considered waters of the United States. Wetlands are also considered to be waters of the United States. For stormwater regulation purposes, the EPA defines wetlands:

> "Wetlands" means those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (40 CFR 122.2)

15.2.3 CDPHE Stormwater Discharge Permit Requirements

EPA has delegated the administration of the NPDES program, including stormwater discharge permits, to the CDPHE. The CDPHE has its own regulations for its stormwater discharge permit system. The Colorado regulations mimic the federal regulations and can be found in Regulation No. 61.

Both the Colorado and the EPA regulations require that all discharge permits ensure compliance with water quality standards. The Colorado Water Quality Control Act specifically states:

> No permit shall be issued which allows a discharge that by itself or in combination with other pollution will result in pollution of the receiving waters in excess of the pollution permitted by an applicable water quality standard unless the permit contains effluent limitations and a schedule of compliance specifying treatment requirements. Effluent limitations designed to meet water quality standards shall be based on application of appropriate physical, chemical, and biological factors reasonably necessary to achieve the levels of protection required by the standards. (CRS 25-8-503(4)).

Colorado's Discharge Permit System Regulations (5 CCR 1002-61) are also clear that discharge permits must ensure compliance with the water quality standards. Rule 61.8(1)(e) restates the relevant portions of Section 25-8-503(4) that no discharge permit may be issued that, in combination with other pollution, will result in the exceedance of a water quality standard unless the permit contains a schedule of compliance. Rule 61.11 provides the Colorado Water Quality Control Division with the procedures to follow "where a permit requires treatment to levels necessary to protect water quality standards and beyond levels required by technology-based limitation requirements."

Rule 61.8(2)(b)(i) of the Discharge Permit System regulations further clarifies that if the effluent limitations otherwise required:

> will not provide sufficient treatment to meet water quality standards . . . the Division will define more stringent effluent limitations based upon water quality standards. . . Effluent limitations designed to meet water quality standards shall be based on application of appropriate physical, chemical and biological factors reasonably necessary to achieve the level of protection required by the standards." This Rule further provides that "such determinations shall be made on a case-by-case basis" and that "limitations <u>must</u> control all pollutants or pollutant parameters which the Division determines are or may be discharged at a level which will cause, have the reasonable potential to cause, or measurable contribute to an excursion above any water quality standard.

The CDPHE issued a Phase II stormwater discharge Permit No. COR-080000 to the Village on March 26, 2003. The permit expires on March 10, 2008 and includes numerous conditions that will be subject to change based on the Village's progress toward meeting the requirements of the permit and the compliance of receiving waters with the water quality standards adopted by the Commission. This is particularly true for stormwater discharges into the Cherry Creek basin because of the current status of the water quality in Cherry Creek Reservoir.

15.3 Stormwater Quality

National and regional studies have been conducted to characterize the types and forms of pollutants found in stormwater runoff. Pollutants have been further characterized based on the type of land use. For regulatory purposes, the results of studies completed for the Denver region shall be used in the Village until more site specific data become available. Two stormwater quality studies have been completed in the Denver region. The first study was funded by the EPA and completed by the U.S. Geological Survey (USGS) in 1979 and 1980. The results are reported in the Denver Regional Council of Governments (DRCOG) report, *Urban Runoff Quality in the Denver Area*. The second study was required as part of the Municipal Stormwater Discharge Permit Applications completed by the City and County of Denver, the City of Aurora, and the City of Lakewood. The field monitoring for the second study was completed in 1992.

Both studies estimated the event mean concentrations (EMC) for various pollutants in stormwater. The EMC is the average concentration of the constituent in stormwater runoff during a storm runoff event. Table 15-3 provides a summary of the EMCs for Industrial, Commercial, Residential, and Undeveloped land uses in the Denver region area. Until more detailed studies are available from specific sites in the Village, it shall be assumed that the EMCs presented in Table 15-3 are characteristic of the uncontrolled stormwater runoff in the Village.

15.4 Stormwater Discharge Water Quality Standards

Substantial data are available on the water quality of Cherry Creek Reservoir and the adverse impacts that stormwater discharges have had on the water quality of the reservoir and compliance with the water quality standards adopted for the reservoir.

Total phosphorus discharges have been identified as the critical parameter for maintaining the water quality standards for Cherry Creek Reservoir. It is also a parameter of critical concern because of ponds located on the main streams of Prentice Gulch and Greenwood Gulch. Table 15-2 provides a detailed comparison of the total phosphorus content in stormwater runoff from undeveloped land with typical stormwater runoff quality from urban land uses. Table 15-3 provides the fraction of total phosphorus runoff in dissolved and particulate forms also are shown for each land use.

Table 15-2: Event Mean Concentration of Phosphorus

Land Use	Total P (mg/L)	Dissolved P (mg/L)	Dissolved P % of Total P	Particulate P (mg/L)	Particulate P % of Total P
Industrial	0.43	0.20	47	0.23	53
Commercial	0.84	0.15	18	0.69	82
Residential	0.87	0.24	28	0.63	72
Undeveloped	0.40	0.10	25	0.30	75

Based on this comparison, the adverse impacts of additional phosphorus discharges can be mitigated by reducing the concentration of the total phosphorus discharges by 60%. This would reduce the total phosphorus concentrations to 0.17, 0.33, and 0.35 mg/L for industrial, commercial, and residential land uses, respectively. These concentrations are below those which occurred prior to development conditions. This reduction in concentration, when combined with the higher water discharge rates resulting from development will likely enhance and help maintain the water quality of Cherry Creek Reservoir and Major Drainageways in the Village.

All Stormwater Quality Management Plans submitted to the Village are required to demonstrate a reduction equal to or greater than a 60 % reduction in the total phosphorus EMC consistent with the requirements of Chapter 16.0. These requirements, for the purposes of consistency, fairness, and ease of regulation, shall be applied uniformly throughout the Village. Data on the effects of other stormwater pollutants on the compliance with water quality standards in the perennial streams in the Village are limited at this time. The uniform application of the control measures described in Chapter 16.0 will provide reasonable reductions of a wide range of pollutants in all of the Villages watersheds and will thus serve to protect the designated uses of these waters adopted by the Commission.

Table 15-3: Summary of Stormwater Quality Characterization

Constituent	Units	Industrial Land Use[1]		Commercial Land Use[1]		Residential Land Use[1]		Undeveloped
		Range	EMC	Range	EMC	Range	EMC	EMC
Total Suspended Solids (TSS)	mg/L	126 - 944	399	41 - 291	165	50 - 458	325	400
Total Dissolved Solids (TDS)	mg/L	30 - 168	58	33 - 296	129	60 - 374	119	678
Biochemical Oxygen Demand, 5 day (BOD)	mg/L	9.0 - 82	29	9.0 - 116	33	8.0 - 54	17	4.0
Chemical Oxygen Demand (COD)	mg/L	36 - 392	232	59 - 457	173	56 - 235	95	72
Total Nitrogen (TN)	mg/L	1.2 - 8.7	2.7	0.80 - 8.4	3.9	1.6 - 9.1	4.7	3.4
Total Kjeldahl Nitrogen (TKN)	mg/L as N	0.90 - 6.8	1.8	0.50 - 5.7	2.5	1.1 - 7.5	3.7	2.9
Nitrate plus Nitrite (NO3+)	mg/L as N	0.30 - 2.1	0.91	0.30 - 5.5	1.35	0.5 - 1.6	0.92	0.50
Phosphorus, total (TP)	mg/L as P	0.14 - 1.3	0.43	0.50 - 1.0	0.84	0.16 - 1.4	0.87	0.40
Phosphorus, dissolved (DP)	mg/L as P	0.10 - 0.85	0.2	0.02 - 0.36	0.15	0.07 - 0.82	0.24	0.10
Cadmium, total recoverable (TCd)	ug/L as Cd	1.0 - 6.0	3.0	nd - 3.0	1.0	nd - 1	0.0	0.0
Copper, total recoverable (TCu)	ug/L as Cu	39 - 130	84	10 - 340	81	10 - 44	31	40
Lead, total recoverable (TPb)	ug/L as Pb	63 - 170	128	16 - 150	59	18 - 95	53	100
Zinc, total recoverable (TZn)	ug/L as Zn	340 - 740	520	80 -730	294	50 - 230	182	100
Oil & Grease	mg/L	3.0 - 11	--	2.0 - 27	--	2.0 - 9.0	--	--
Fecal Coliform	cols/100 ml	320 - 170000	--	13 - 85000	--	40 - 62000	--	--
Fecal Streptococci	cols/100 ml	2000 - 110000	--	310 - 54000	--	1400 - 98000	--	--
pH	s.u.	6.4 - 7.2	--	6.4 - 7.3	--	6.5 - 7.5	--	--
Total Organic Carbon (TOC)	mg/L as C	24 - 94	--	23 - 480	--	18 - 727	--	--
Ammonia (NH3)	mg/L as N	0.35 - 3.0	--	0.35 - 3.6	--	0.41 - 1.7	--	--
Terachloroethylene (a)	mg/L	(b)	--	nd - 3.0	--	(b)	--	--
Toluene (a)	ug/L	nd - 0.8	--	(b)	--	nd - 0.20	--	--
Bis(2-ethelhexyl)phthalate (a)	ug/L	10 - 30	--	nd - 76	--	nd - 64	--	--
Butylbenzyl phthalate (a)	ug/L	nd - 10	--	(b)	--	(b)	--	--
Fluoranthene (a)	ug/L	nd - 21	--	(b)	--	(b)	--	--
Indeno(1,2,3-cd)pyrene (a)	ug/L	nd - 58	--	(b)	--	(b)	--	--
Phenanthrene (a)	ug/L	nd - 17	--	(b)	--	(b)	--	--
Pyranene (a)	ug/L	nd - 13	--	(b)	--	(b)	--	--
Arsenic, total (a)	ug/L as As	nd - 8.0	--	nd - 3.0	--	nd - 3.0	--	--
Nickel, total (a)	ug/L as Ni	7.0 - 21	--	2.0 - 12	--	3.0 - 9.0	--	--
Chromium, total recoverable (TCr) (a)	ug/L as Cr	10 - 27	--	nd - 24	--	3.0 - 12	--	--
Phenols, total (a)	ug/L	4.0 - 18	--	4.0 - 6.0	--	2.0 - 9.0	--	--

[1] EMC values from Metropolitan Wet-Weather Discharge Characterization study. Monitoring completed in 1992
[2] EMC values from DRCOG, *Urban Runoff Quality in the Denver Area*. Monitoring was completed in 1980-1981. Range of data values is not provided in the DRCOG study
nd = not detected
(a) detected in at least 50 percent of samples from a land use
(b) not detected in at least 50 percent of samples from this land use
-- data not reported.

16.0 Water Quality Management Criteria for Developed Land

16.1 Introduction

Stormwater quality control is an integral part of any stormwater management system in the City of Greenwood Village (Village). The Major Drainageways, reservoirs, and wetlands in and near the Village are valuable resources, which must be protected against the adverse water quality effects of stormwater discharges.

The Village has adopted stormwater discharge water quality standards as described in Chapter 15.0. The purpose of this Chapter is to describe the types of facilities and the plans required by the Village.

The design of the facilities shall be in accordance with the criteria presented in the Structural Best Management Practices (BMPs) Chapter, Volume 3 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and are not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

16.2 Stormwater Quality Management Plans

A Stormwater Quality Management Plan shall be prepared as an integral part of all drainage studies, submitted to the Village. The purpose of the Stormwater Quality Management Plan will be to describe, in sufficient detail, the stormwater management improvements necessary to meet the water quality standards of the Village described in Chapter 15.0. The improvements shall include new facilities to be constructed, repairs to existing facilities, and the long-term maintenance activities necessary to keep the facilities fully functional. All water quality management facilities shall be located on the property on which the land development will occur unless approval is received from the City Manager or designee.

16.2.1 Stormwater Quality Management Plan Submission

The Stormwater Quality Management Plan shall be submitted in conjunction with all drainage studies. The Construction Drawings and Record Drawings shall include the improvements identified in the Final Drainage Study. For projects with a disturbed area greater than 1 acre, the

proposed Stormwater Quality Management Plan shall be certified by a professional engineer licensed in the State of Colorado using the following form:

> I hereby certify that this Stormwater Quality Management Plan for (name of site) was prepared by me or under my direct supervision in accordance with the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

The Stormwater Quality Management Plan shall also be certified by Owner of the property using the following form:

> I hereby certify that the stormwater management facilities proposed for (name of site) shall be constructed and maintained in accordance with the design presented in this Stormwater Quality Management Plan. I understand that the City of Greenwood Village does not and will not assume liability for the proposed stormwater management facilities.
>
> _____
> Signature
>
> _____
> Date

Separate certifications are not required if the Stormwater Quality Management Plan is submitted as a part of a drainage study.

16.2.2 Contents of Stormwater Quality Management Plan

The Stormwater Quality Management Plan shall include, as a minimum, the information shown in Table 16-1.

Table 16-1: Stormwater Quality Management Plan Checklist

Item
Engineer's Certificate
Owner's Certificate
1) General Location and Description
a. Location
i. Local streets within and adjacent to the development.
ii. Township, range, section, and ¼ section.
iii. Major Drainageways, drainage facilities, and wetlands near the development.
iv. Names of surrounding developments.
b. Description of Property
i. Area in acres.
ii. Ground cover (type of trees, shrubs, and vegetation).
iii. Major Drainageways, drainage facilities, perennial streams, and wetlands within the development.
iv. General project description and schedule.
v. Groundwater recharge areas and areas of high groundwater.
c. Receiving Waters
i. Existing water quality conditions of Major Drainageways and wetlands that will receive discharges from the property.
ii. Classified uses of Major Drainageways and wetlands that will receive discharges from the property.
iii. Water quality standards of major drainageways and wetlands that will receive discharges from the property.
2) Stormwater Quality Design Criteria
a. Regulations
i. Discussion of compliance with or deviation from this Drainage Criteria Manual.
b. Development Criteria Reference and Constraints.
i. Discussion of previous drainage studies for the property.
ii. Identify facility outlet design method.
iii. Identify hydraulic structure criteria used.
iv. Discussion and justification of other criteria or calculation methods used that are not presented in or referenced by this Drainage Criteria Manual.

Item
3) Stormwater Quality Facility Design
a. General Concept
i. Discussion of existing drainage patterns.
ii. Discussion of proposed drainage patterns.
iii. Discussion of the content of all tables, charts, figures, or drawings.
b. Specific Details
i. Discussion of each water quality treatment measure used to meet the requirements of this Drainage Criteria Manual.
ii. Discussion of facility design.
iii. Discussion of maintenance access to facilities.
4) Maintenance Plan
a. Maintenance Activities
i. Description of routine maintenance activities, including frequency, to maintain the water quality functions of the facilities.
ii. Description of extraordinary maintenance activities following a minor or major storm to maintain the water quality functions of the facilities.
b. Estimated Maintenance Costs
i. Cost estimate for each routine and extraordinary maintenance activity.
ii. Description of the methods by which maintenance costs will be paid, including assurances that sufficient funds will be available at all times.
5) Conclusions
a. Compliance with Standards
i. Drainage Criteria Manual.
ii. UDFCD Drainage Criteria Manual.
b. Stormwater Quality Management Concept
i. Effectiveness of facility design to control pollutants from runoff.
ii. Influence of facility design on the recommendations of other previously approved drainage studies.
6) References
a. Reference all criteria and technical information used.
7) Appendices
a. Pollutant Computations
i. Calculation of average annual pollutant loads without control measures for each land use type and for the entire area proposed for development.
ii. Total phosphorus removal required.

Item
b. Control Measure Computations
i. Net phosphorus into each control measure.
ii. Control measure effectiveness.
iii. Net phosphorus out of each control measure.
iv. Total phosphorus removal at discharge location.
8) Maps
a. General Location Map
i. A general location map showing the general drainage patterns around the property. The map should be at a scale of 1” = 1000’ or 2000’ and show the path of all drainage to and from any off-site basins. The map shall identify any development or facilities (i.e., irrigation ditches, existing flood attenuation facilities, culverts, and storm sewers) along the entire path of the off-site and on-site drainage.
b. Facility Plan
i. Plan of the proposed development shall be provided at a scale of 1” = 20’ to 1” = 200’ on 24” x 36” sheets.
ii. A topographic map shall be provided with two-foot existing and proposed contours tied to the Greenwood Village “Control Diagram” (Figure 2-1). The topographic map shall extend a minimum of 50-feet beyond the property lines.
iii. Property lines, easements, and purposes of easements.
iv. Streets.
v. Existing drainage facilities and structures, irrigation ditches, Major Drainageways, and existing wetlands. All pertinent information such as materials, size, shape, slope and location shall also be included.
vi. Overall drainage area boundary and drainage sub-area boundaries.
vii. Proposed type of street flow, roadside ditches, gutters, and cross pans.
viii. Proposed drainage structures and open channels.
ix. Routing and accumulation of phosphorus at each control measure.
x. Details of control measures.
xi. Location and elevations of all floodplains affecting the property.

When the Stormwater Quality Management Plan is included as part of a drainage study, the additional information that is required above can be incorporated into the appropriate sections of the drainage study.

16.3 Potential Pollutant Loads

The first step in the preparation of a Stormwater Quality Management Plan is to estimate the potential average total annual pollutant load for the proposed land use. Once this load has been estimated, plans can be prepared to remove 60% of the total annual phosphorus load to meet the criteria of this Drainage Criteria Manual.

The average total annual pollutant load shall be estimated using the event mean concentration (EMC) for the pollutant of interest and the annual runoff volume. The EMC for phosphorus and different land uses is shown in Table 15-2. The runoff volume shall be calculated for the various major soil types and proposed impervious area using Figure 16-1. Figure 16-1 was derived by analyzing the distribution of storm events in an average year, estimating the runoff for each event based on Figures 6-2 and 6-3 and summing the runoff from each event for the entire year. The average total annual phosphorus load shall be estimated using Equation 16-1 as follows:

$$\text{Total P} = 0.2266\ (\text{EMC})\ (\text{R})\ (\text{A}) \qquad (16\text{-}1)$$

Where: EMC = EMC for phosphorus from Table 15-2
R = runoff volume in inches from Figure 16-1
A = tributary area in acres

16.4 Effectiveness of Control Measures

A wide range of management options can be selected to meet the stormwater management goals of the Village. The optimum combination of management options can vary substantially from site to site based on local soil conditions and the proposed land use. It is likely that some trial and error will be required in the review of options before a preferred plan can be prepared. The following Sections provide guidance on the effectiveness of removal for water quality facilities.

The options included in the following Sections are not intended to be exclusive. Other options may be available and may receive favorable review from the Village. It is the burden of the applicant to provide credible evidence concerning the effectiveness and reliability of the option.

In order to calculate the effectiveness of a proposed design in terms of the percent removal of the annual total phosphorus load, the removal percentage for each facility must be combined with the percentage that is captured by the facility. This calculation is illustrated by equation 16-2:

$$\text{Annual \% Total P Removed} = (\text{Annual \% Total P Captured})\ (\text{\% Removal Total P}) \qquad (16\text{-}2)$$

Where: Annual % Total P Captured is selected from Figures 6-5, 6-6, or 6-7 based on selected design storm, soil type, and percent impervious of basin discharging into facility.
% Removed Total P is selected from the following Sections for each facility.

For basins with multiple land uses, multiple soil types, and multiple percent impervious areas, area-weighted values can be used in Equation 16-2.

16.4.1 Minimization of Impervious Area

The peak rate and volume of runoff from a site can be significantly reduced by reducing the amount of impervious area. Several options are available for reducing impervious area, including innovative site layouts that minimize paved areas, use of heavily vegetated areas in landscape plans, and inclusion of porous block pavement in parking areas or driving lanes.

The management techniques are intended to reduce the runoff that occurs from a site. For Development projects, the techniques do not contribute directly to a percent reduction for the purpose of literally meeting the Village's water quality goals, but the techniques do improve the economics of the overall management system by reducing the size of the facilities needed to achieve the required percent reductions. For Redevelopment Projects, the techniques do contribute directly to a percent reduction in meeting the Village's water quality goals when the amount of impervious area is reduced as compared to the existing conditions. This can have a significant impact on improving the economics of the overall management system by reducing the size of the additional facilities needed to achieve the required pollutant reductions.

Another technique that relates to management of impervious areas is to reduce the "directly connected" impervious areas. This is a different management technique than reducing the impervious area itself. It includes directing the runoff from impervious areas through buffer strips, into grass swales, or into infiltration basins before it is discharged to other drainage facilities. These techniques are described in more detail in the Structural BMPs Chapter, Volume 3 of the UCFCD Drainage Criteria Manual.

16.4.2 Extended Detention Facilities

Stormwater storage facilities can be designed to achieve the multiple purposes of attenuation of peak flood discharges and water quality management. The capacity of the detention facility can be expanded to provide temporary storage space for the capture of the smaller, non-flood storms that carry the majority of the annual pollution load.

16.4.2.1 Design of Extended Detention Facilities

As discussed in Chapter 13.0, water quality treatment capacity must be provided in addition to the capacity for flood attenuation purposes with no overlap. There is no overlap allowed because the stormwater must be held within the water quality portion of the facility for an extended period of time and that portion of the facility may still be full, or nearly full, at the onset of flood-related runoff event. A reserve capacity equal to 20 percent of the water quality management volume must also be provided for sediment storage. This will provide space for the accumulation of sediment and flexibility for its removal when required.

16.4.2.2 Extended Detention Facility Phosphorus Removal

Extended detention facilities meeting the design criteria in Section 16.4.2.1 will remove 65% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 65% removal rate.. . The. The annual
The water quality capture volume (WQCV) is based on the design storm, not the WQCV from Volume 3 of the UDFCD Drainage Criteria Manual.

16.4.3 Retention Ponds for Water Quality

A retention pond has a permanent pool of water that is mixed with stormwater during storm events. Retention ponds are designed to capture and hold a volume of runoff equal to the design storm selected for water quality control. The drain time for the captured volume is typically 12 hours. After 12 hours, the only volume of water remaining in the facility is the permanent pool.

16.4.3.1 Design of Retention Ponds

Retention ponds are more efficient than extended detention facilities for water quality treatment. Care must be taken, however, in the design of such facilities to be sure that an adequate water supply is available to maintain the permanent pool, which can attract and support aquatic life and waterfowl. The aesthetic considerations of the permanent pool must also be addressed. Landscaping with transitional wetland vegetation and the potential maintenance requirements for removing sediment and excess algae growth from the permanent pool must also be considered.

Retention ponds are typically more effective in removing total phosphorus because during the water quality design storm event, a portion or all of the permanent pool is displaced by the runoff and mixes with the runoff during the storm event. The time interval between storm events can improve the quality of the permanent pool because of biological uptake of soluble phosphorus by plants and algae and the additional detention time for settling of particulate phosphorus. The effectiveness of these processes in removing total phosphorus can be in the range of 10 to 30 percent greater than an extended detention facility with the same water quality capture volume.

16.4.3.2 Retention Pond Phosphorus Removal

Retention ponds meeting the design criteria in Section 16.4.3.1 will remove 75% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 75% removal rate.

The WQCV is based on the design storm, not the WQCV from Volume 3 of the UDFCD Drainage Criteria Manual.

16.4.4 Grass-Lined Swales and Roadside Ditches

Grass-lined swales and roadside ditches can be an effective water quality control design feature in a stormwater management system. Grass-lined roadside ditches can be used as an alternative to curb and gutter. Berms or check dams can be installed in swales and roadside ditches perpendicular to the flow as needed to slow it down and to encourage settling of sediment, filtration by the vegetation, and infiltration. The potential also exists for the development of wetland vegetation in the swales and ditches if there is a reasonably persistent base flow.

A grass-lined swale can also be more aesthetically pleasing and less expensive to construct than a concrete or rock-lined drainage channel. The Village strongly encourages the use of grass-lined swales and roadside ditches because of their aesthetic appearance, their ability to provide some flood attenuation due to slower flow velocities, and their effects on stormwater quality.

16.4.4.1 Design of Grass-Lined Swales and Ditches

There is a wide range of design consideration for an effective grass-lined swale or roadside ditch. It must effectively carry both the flood flow as well as the water quality design storm flow. The most critical parameters in a design flood flow typically include non-erosive velocities and adequate flow capacity. Chapter 7.0 discusses typical design criteria required for open channels. For water quality control, the critical parameters include minimum flow lengths, minimum bottom area for filtration by vegetation, maximum flow velocity, and maximum flow depth.

The channel must be designed to support a hearty turf grass cover or wetland vegetation to be effective in removing pollutants. In some cases, a permanent irrigation system may be required to sustain a hearty turf grass cover.

All grass-lined swales or roadside ditches used for meeting total phosphorus removal goals shall meet the following design criteria for water quality design storm conditions:

1) Maintain irrigated turf grass at 2 to 4 inches tall and non-irrigated native grass at 6 to 8 inches tall,
2) Assume Manning's $n \geq 0.035$ for turf grass or higher as appropriate for wetland vegetation,
3) Maximum velocity for water quality storm is ≤ 1.5 feet per second,
4) Overall swale length ≥ 900 feet or maximum extent practicable,

Refer to Chapter 8.0 for flow velocity limits for design flood conveyance purposes for ditches.

16.4.4.2 Grass-Lined Swales and Ditches Phosphorus Removal

Grass-lined swales and ditches meeting the design criteria summarized in Section 16.4.4.1 will remove 15% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 15% removal rate.

16.4.5 Constructed Wetlands

The Village strongly encourages the inclusion of artificial or constructed wetlands as an integral part of an urban drainage system design.

Constructed wetlands differ from "natural" wetlands because they are constructed for specific purposes such as stormwater quality enhancement. In some cases it may be possible to enlarge a natural wetland to perform this same function. This, however, would likely require both federal and state permits and the applicant is responsible for obtaining the required permits in accordance with Chapter 14.0. The Village also requires the applicant to obtain the necessary federal and state permits for isolated constructed wetlands. The maintenance of the water quality functions of a constructed wetland will likely require occasional dredging and other maintenance activities. These maintenance activities must be specified and allowed by the permit.

16.4.5.1 Constructed Wetland Design

Constructed wetlands can be effectively integrated into extended detention ponds, retention ponds, and open channels. The primary drawback to wetlands is the need for a virtually continuous presence of surface water or groundwater to sustain the wetland vegetation in a healthy state between storm events.

16.4.5.2 Constructed Wetland Phosphorus Removal

Significant research has been completed on the long-term effectiveness of wetland systems for total phosphorus removal. The art and science of effective wetland design is undergoing rapid change. It can be expected that significant advances in this area will be made over then next several years. The Village will consider the merits of these changes and their applicability to a specific proposal by an applicant on a site by site basis. In the interim, the Village will use the following guidelines for the review and approval of wetland designs.

An open channel wetlands will function in a manner similar to grass-lined swales for total phosphorus removal. The same design criteria for the grass-lined swales included in Section 16.4.4.1 will apply to open channel wetland designs. For these design criteria, the total phosphorus removal will be assumed to be 40% for the design storm condition. The annual phosphorus removal can be estimated using Equation 16-2 with a 40% removal rate.

The retention pond wetlands will function in a manner similar to an emergent marsh or a subsurface flow wetland. The key parameters for determining the effectiveness of such a design for the removal of total phosphorus are the annual flow rates and the retention time for the stormwater in the wetland area. In order to provide the maximum effective total phosphorus removal, all ponds with wetlands shall be designed for a 24-hour drain time of the water quality capture volume.

A first-order model has been established for estimating the performance of a retention pond wetland based on water and phosphorus mass balances with some acknowledgement of site-specific factors. The model describes the long-term removal rate which will typically require a few years of adaptation by the plants to local conditions before the long-term steady-state removal rates can be achieved. This model is represented by Equation 16-3:

$$\ln\left(\frac{C_o}{C_i}\right) = -\frac{k}{q} \qquad (16\text{-}3)$$

where: C_i = inflow total phosphorus concentration
C_o = outflow phosphorus concentration
K = 38 ft/year.
q = effective design storm flow rate, feet per year = d_e/t_e
d_e = equivalent depth, feet = V_{ar}/A_w
t_e = equivalent exposure time, 0.10 years
V_{ar} = volume of annual runoff, acre feet
A_w = area of wetland, acres

The equivalent exposure time (t_e) of 0.10 years is based on 35 runoff events per year times the average duration, 24 hours, that each runoff event is exposed to the wetland area.

16.4.6 Infiltration

Infiltration of stormwater into the ground is potentially an effective stormwater quality management tool. Most soils have a high absorption capacity for dissolved phosphorus and excellent physical filtration characteristics for particulate phosphorus. The on-site storage facilities and open grass-lined swales that are used for the attenuation of flood discharges and to provide water quality enhancement through settling and filtration by the vegetation, can provide further water quality enhancement by infiltration of a portion of the stormwater runoff.

16.4.6.1 Infiltration Design

The rate at which stormwater can infiltrate into the ground is limited by the soil infiltration rate (Q_i) or the rate at which it can move laterally through the soil (Q_s) once it has infiltrated into the ground, whichever is less. This is shown schematically in Figure 16-2.

The Q_i is a function of the soil infiltration rate and the surface area available for infiltration. The infiltration rate is dependent upon soil type and the antecedent moisture conditions in the soil at the beginning of the runoff event. The Q_i can be reduced substantially over an extended period of time if the soil becomes plugged by clay and silt sized particles. The Q_s is a function of the saturated hydraulic conductivity of the soil, the slope of the saturated soil water surface and the available cross sectional area through which the water can flow. Both Q_i and Q_s would be the same if the following conditions were true:

1) The soil is homogeneous throughout,
2) a zero head of water is maintained at the soil surface,
3) there is no lateral movement of water,
4) the surface soil does not restrict water movement, and
5) there is atmospheric pressure at all times at the base of the downward advancing water front.

These conditions might occur in sandy soils where the water table or an impermeable layer is very deep. These conditions rarely occur in the Village, thus it is usually necessary to estimate both Q_i and Q_s to determine the limiting rate. In most cases, Q_s will be the limiting rate.

For preliminary planning purposes, assumed values can be used for the hydraulic conductivity (K), groundwater gradient (I), depth to groundwater, and infiltration rates. The following is a summary of these assumptions.

1) For subsurface flow rate calculations, the hydraulic conductivity (K) can be based on the published ranges for hydraulic conductivity for the applicable soil type.
2) Groundwater gradient (I) can be assumed to be equal to the general topographic slope of the area as shown on the Village topographic maps.
3) Depth to groundwater can be assumed to be four feet.
4) The infiltration rate can be assumed to be the same as the hydraulic conductivity rate.

The Village requires field tests to confirm infiltration rates, hydraulic conductivity rates, depth to groundwater, and groundwater slope for any infiltration credits included in a Final Drainage Plan. Methods for field testing infiltration rates and hydraulic conductivity rates are described in the U.S. Department of the Interior Bureau of Reclamation, Drainage Manual. Factors influencing infiltration rates include the structure of the ground surface, the type and condition of vegetation, soil moisture, the type of underlying soil, and the depth to groundwater.

Each of these factors shall be considered when completing infiltration field measurements. Field measurements should be completed in areas were conditions are as similar as possible to the expected future detention facility bottom conditions. Unless there is a good reason to do otherwise, the lowest measured infiltration rates should be used for the basis of design. Factors influencing hydraulic conductivity field tests include soil type, soil density, bore hole wall disturbance, and soil type layering.

Each of these factors shall be considered when completing hydraulic conductivity field measurements. Field measurements should be completed in areas were conditions are as similar as possible to the expected future conditions. Unless there is a good reason to do otherwise, the lowest hydraulic conductivity rate tested should be used for design calculations.

Depth to water can be measured by installing piezometers or observation holes. Installation of piezometers and observation holes is described in the U.S. Department of the Interior Bureau of Reclamation, Drainage Manual. Three or more piezometers or observation holes are required at each detention facility location and piezometers or observation holes must be located at least 100 foot intervals in an open channel to determine groundwater slopes. Field tests must be completed as necessary to determine the depth to the first impermeable layer encountered under the proposed infiltration area.

16.4.6.2 Infiltration Phosphorus Removal

The total phosphorus removal for infiltrated stormwater shall be assumed to be 100% for Type I (clay) and Type II (clay loam) soils and 50% for Type III (sandy) soils. The detention duration for calculating the infiltration volume shall be 40 hours for an extended detention facility, 24 hours for a retention pond, and 1 hour for an open channel. A modification of Equation 16-2 shall be used to estimate the total annual phosphorus removal rate:

$$\text{Annual \% Total P Removed} = (\text{\% of Design Storm Infiltrated})\ (\text{Annual \% Total P Captured})\ (\text{\% Removal Total P}) \qquad (16\text{-}2a)$$

where: % of design storm infiltration is calculated based on the limiting value (Q_i or Q_s) for the required infiltration duration.

The application of equation 16-2a implicitly assumes that the infiltration rate can be sustained indefinitely at the facility. This is unlikely due to plugging of the soil by the clay and silt in the infiltrated water. The Village will not accept this assumption unless the plan includes a reliable maintenance program for maintaining the assumed infiltration rate. The proposed plan must also evaluate potential damage to streets, sidewalks and other structures which may be caused by the infiltrated water.

16.4.7 Filtration

The use of sand and other media filters are gaining acceptance in the field of stormwater quality management. Considerable field testing of filtration devices has occurred over several years and the results have proven that a properly designed filter can provide good performance with reasonable maintenance.

The Village strongly encourages the use of constructed filters as a part of the stormwater management system. The primary concern with filters is the maintenance required to sustain the design filtration rate. Excess sediment accumulation can significantly reduce filtration capacity and the media must be cleaned or replaced. Sand and other open media filters can be used only if they are preceded by an extended detention pond, retention pond, or wetlands to remove at least 50 percent of the total sediment load for the design water quality storm.

16.4.7.1 Filter Design

All filters shall be designed to filter the peak rate of discharge from the upstream extended detention pond, retention pond, or wetlands for the water quality design storm. Provisions shall be included in the design to bypass all flows greater than the design flow rate around the filter.

Other well-designed systems using other media and configurations can be accepted by the Village. The Village strongly encourages filter designs that use landscaped earthen berms to contain the media and landscaping designed to screen the visual impact of a media surface.

16.4.7.2 Filter Phosphorus Removal

The total phosphorus removal for a sand filter system shall be assumed to be 50% of the total phosphorus not removed by the upstream extended detention pond, retention pond, or wetlands. The annual phosphorus removal can be estimated using Equation 16-2 with a 50% removal rate. The removal rates for other media will be determined on a case-by-case basis.

16.4.8 Mechanical Stormwater Treatment Systems

Mechanical systems are also available for treatment of stormwater runoff, including swirl separators and cartridge filters. Systems of this nature usually have higher capital costs and require a higher degree of maintenance than ponds and open channel systems. The applicant, however, may prefer these systems for commercial properties where land may be at a premium.

The Village will consider such systems on a case-by-case basis. The long-term maintenance costs and the proven reliability of these systems will be major factors to be included in the review of these systems by the Village.

16.4.9 Grass Buffers

Grass buffers can be an effective water quality control feature in a stormwater management system and are discussed in detail in Volume 3 of the UDFCD Drainage Criteria Manual.

A grass buffer can also be aesthetically pleasing and incorporated into the landscape design for the site. The Village encourages the use of grass buffers in stormwater management designs because of their aesthetic appearance, their ability to provide some flood attenuation due to slower flow velocities, and the treatment of stormwater runoff.

16.4.9.1 Design of Grass Buffers

There is a wide range of design consideration for an effective grass buffer. The critical parameters include minimum flow lengths and widths, maximum slope, and flow distribution. The grass buffer must be designed to support a hearty turf grass to be effective in removing pollutants. A permanent irrigation system may be required to sustain a hearty turf grass cover.

All grass buffers used as a part of a stormwater management system for meeting total phosphorus removal goals shall maintain irrigated turf grass at 2 to 4 inches tall and non-irrigated native grass at 6 to 8 inches tall.

16.4.9.2 Grass Buffer Phosphorus Removal

Grass buffers meeting the design criteria summarized in Subsection 16.4.9.1 will remove 10% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 10% removal rate.

16.4.10 Porous Landscape Detention

Porous Landscape Detention can be an effective water quality control design feature in a stormwater management system with limited opportunities for larger facilities and are discussed in detail in Volume 3 of the UDFCD Drainage Criteria Manual.

Porous Landscape Detention can also be aesthetically pleasing and incorporated into the landscape design for the site. The Village encourages the use of porous landscape detention in stormwater management designs because of their aesthetic appearance and the treatment of stormwater runoff.

16.4.10.1 Design of Porous Landscape Detention

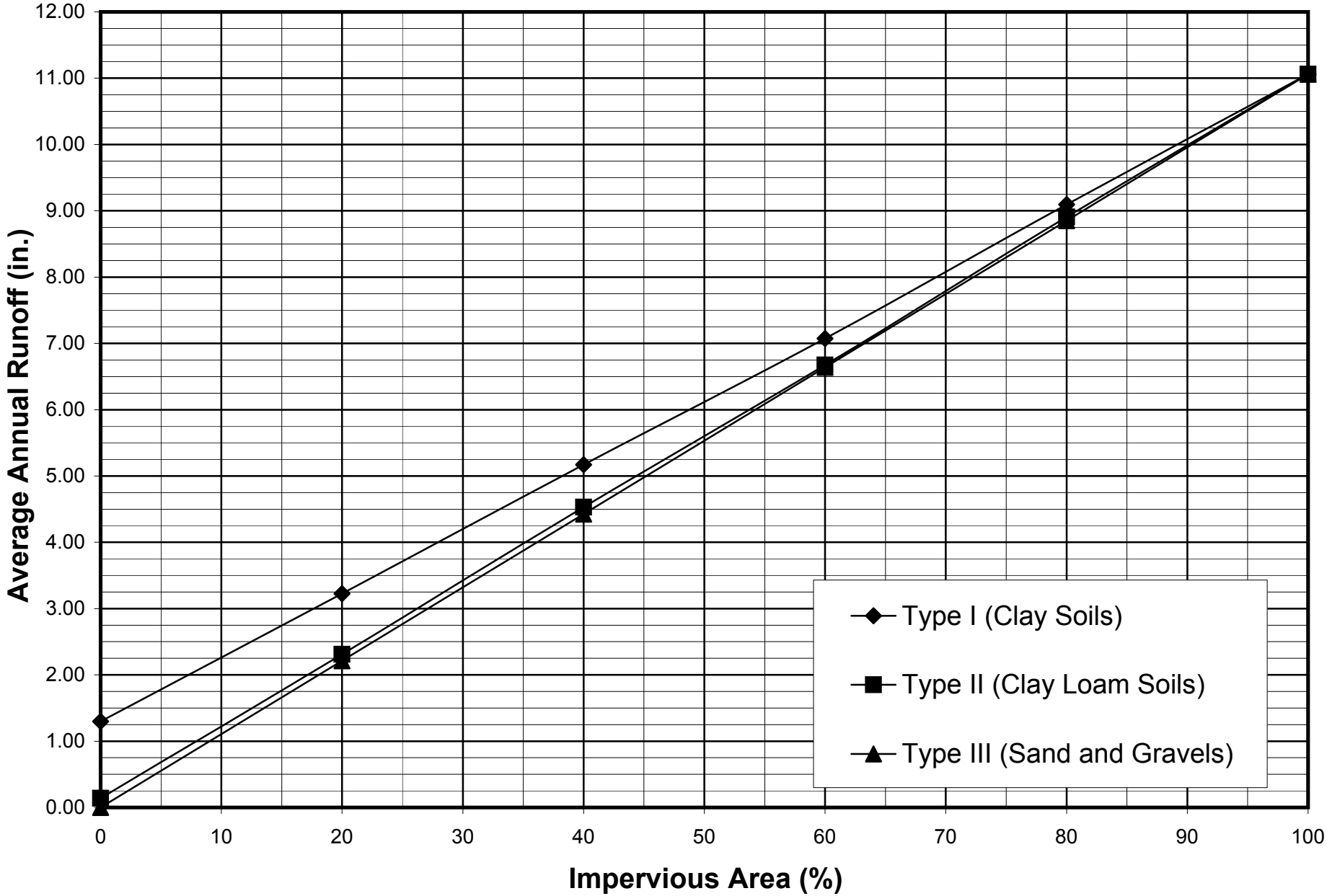
There is a wide range of design consideration for an effective porous landscape detention. One critical parameter is accurately determining the tributary area to ensure that design storm that is selected is appropriate for the size of the facility.

The porous landscape detention must be designed to support a hearty turf grass to be effective in removing pollutants and minimize clogging. In some cases, a permanent irrigation system may be required to sustain a hearty turf grass cover.

Porous Landscape Detention used as a part of a stormwater management system for meeting total phosphorus removal goals shall maintain irrigated turf grass at 2 to 4 inches tall and non-irrigated native grass at 6 to 8 inches tall.

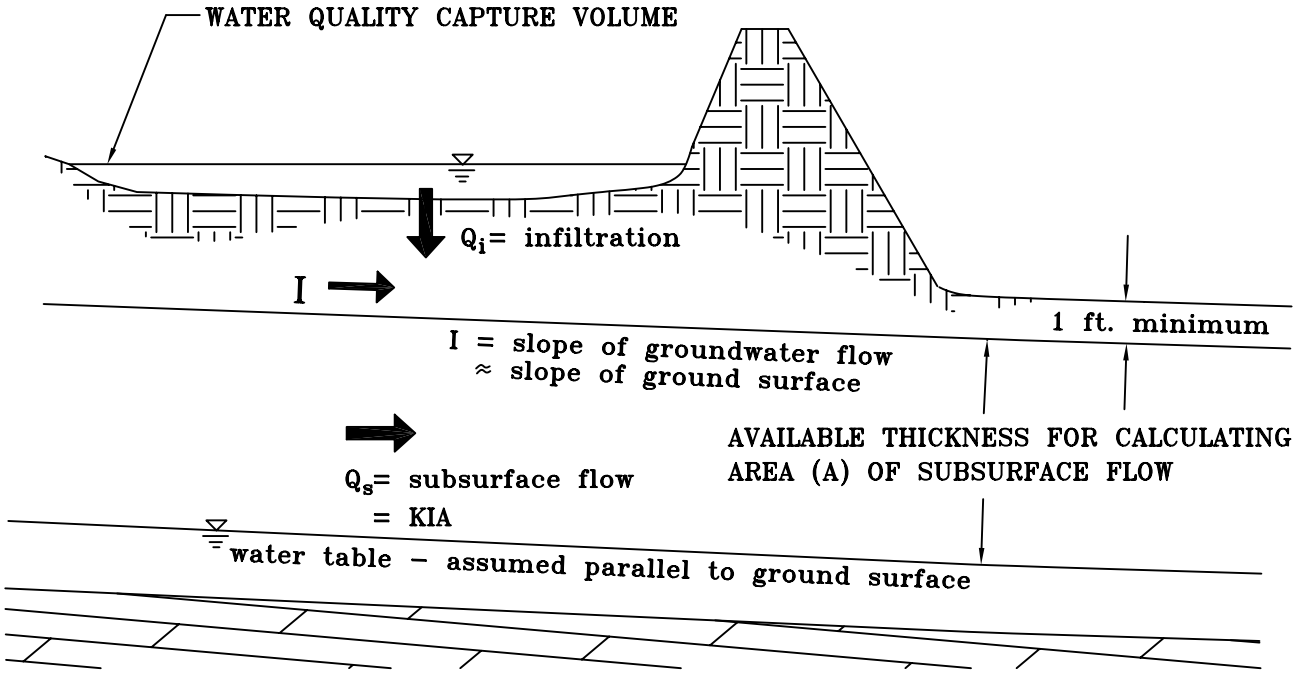
16.4.10.2 Porous Landscape Detention Phosphorus Removal

Porous landscape detention meeting the design criteria summarized in Subsection 16.4.10.1 will remove 60% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 60% removal rate.

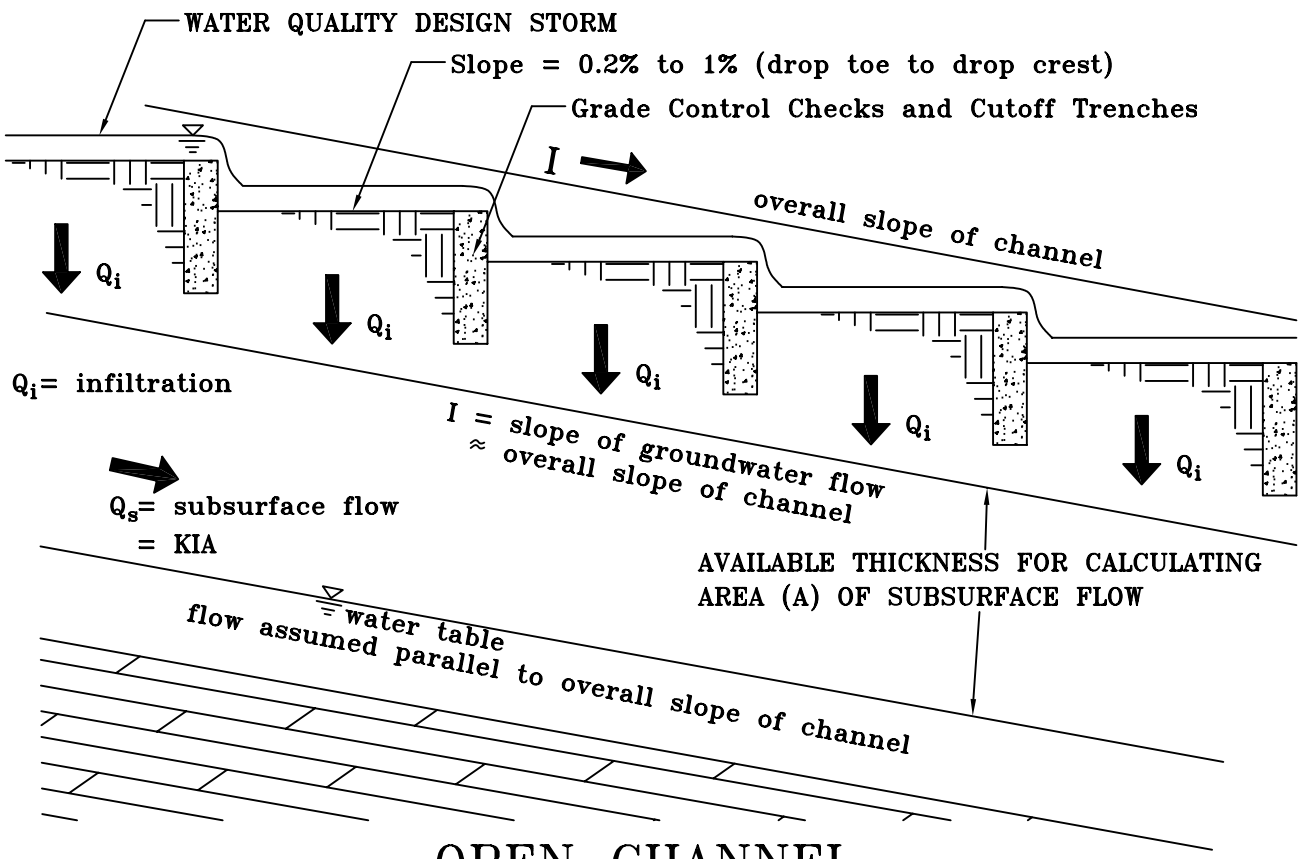


Greenwood Village
October 2003

Figure 16-1
Annual Runoff
for Greenwood Village



STORAGE FACILITY



OPEN CHANNEL

Greenwood Village
Stormwater Quality Control
October 2003

Figure 16–2
Schematic of Infiltration
and Subsurface Flow

FIG16–2.dwg

P:\97003\027 Drainage Code Update 2003\Figures\FIG 16-2.dwg, Layout1, 10/15/2003 11:51:15 AM, 1:0.945309

17.0 Computer Applications

17.1 Introduction

Computer applications can be tools for achieving greater efficiency and increased accuracy of engineering analysis and design. This Chapter presents general guidelines that encourage the use of computerized applications as an extension of, rather than a substitute for, technical analysis. The guidelines presented herein are designed to preserve, rather than obscure, the relationship between engineering theory and computerized computation, and ensure calibration of standardized methodologies against project-specific analysis requirements.

17.2 Submittal Requirements

Documentation of computerized applications shall be provided in hard copy and in electronic format to the City of Greenwood Village (Village). Hard copy of all input and output files shall be included in an appendix of the drainage studies, preferably using computer-generated summaries where available and where appropriate. Relevant intermediate computations should be summarized in the appendix of the drainage studies to assist the Village in review. All software packages shall be clearly identified by name, vendor, version, and date.

17.3 Software Verification

This Section presents guidelines for verifying the accuracy of the computer code with respect to theoretical models, equations, and design procedures adopted in this Drainage Criteria Manual.

17.3.1 Documentation

The Village will not accept the use of any software package that is not commercially available, and not provided with vendor-supplied theoretical documentation and user documentation. Use of proprietary software is subject to approval by the Village. The applicant is responsible for reviewing the theoretical documentation to verify that the fundamental models and equations, as defined and adopted for analysis and design in this Drainage Criteria Manual, have been included in software algorithms with consistency and accuracy. The Village will not accept any software without theoretical documentation. The applicant is also responsible for proper application of the software in accordance with the criteria presented in the user documentation.

17.3.2 Testing

The Village encourages in-house verification of new software applications and revised versions. The Village recognizes that not all software capabilities can be tested but recommends verification of software capabilities specifically required for a proposed project and verification of formally documented revisions to existing software. Minimal recommended testing protocol

should include duplication of design examples provided in the user documentation or duplication of project-specific applications generated by previously verified software.

The Village recommends establishing and maintaining a system of records to document the testing protocol and the project applications for each software package. Software should be consistently referenced by name, vendor, version, and date.

17.4 Software Calibration

This Section presents guidelines for establishing the applicability of the theoretical models and equations to the specific requirements of the project, assuming accurate translation into computer code has been verified in accordance with the criteria presented in the previous Section.

17.4.1 Theoretical Assumptions and Limitations

The applicant shall verify that the simplifying assumptions and limitations used to develop the theoretical models and equations are applicable to the specific project. Source documentation used to establish project applicability shall be the theoretical documentation provided with the software or direct communication with the vendor to resolve technical issues not addressed within the documentation. The Village emphasizes that resolution of ambiguous technical issues requires practical software-generated verification of all verbal communication and written documentation. The following two examples illustrate the type of theoretical calibration required to ensure theoretical correlation between a standardized algorithm and a specific project.

1) Surface Water Hydrology. Rainfall-runoff models typically offer a variety of routing methodologies for use in generating a project-specific model. The applicant shall be familiar with the restrictions governing the application of routing methodologies in modeling and shall select a procedure that is appropriate for the project.
2) Open Channel Hydraulics. Most backwater computations use the standard step method, which is limited to one-dimensional, steady-state, fixed-bed flow conditions and is therefore inappropriate, or requires modification, for use in two-dimensional flow situations, hydrographic analysis of unsteady flow, or in channels with significant sediment transport.

17.4.2 Empirical Calibration

The applicant shall pay close attention to algorithms requiring definition of empirical coefficients, such as loss computations for infiltration, hydraulic friction losses, abutment losses, and culvert entrance losses. Empirical algorithms are restricted in application to the quantitative limits of the source data. When using non-standard configurations, such as culvert entrance designs, computations should be manually verified and it may be necessary to substitute default values for computer-generated values.

17.5 Approved Software

The following engineering software packages have been approved for use:

1) Rainfall-Runoff Models
   a. Colorado Urban Hydrograph Program (CUHP). The CUHP program generates the Colorado Urban Hydrograph in accordance with criteria developed and refined over nearly 30 years for the Denver region. The CUHP software is available through the Urban Drainage and Flood Control District (UDFCD).
   b. Urban Drainage Storm Water Management (UDSWM). UDSWM is the UDFCD modification of the Runoff Block of the Storm Water Management Model (SWMM) sponsored by the U.S. Environmental Protection Agency (EPA). UDFCD modified the SWMM program to accept the Colorado Urban Hydrographs generated by CUHP
   c. HEC-1. HEC-1 is a single-event surface runoff model with numerous simulation options for designing storm events, routing runoff hydrographs through channels and routing runoff hydrographs through storage reservoirs. The model is widely used in planning studies for watersheds which require network modeling to establish design discharges at selected locations. The model includes a kinematic wave routing option that is applicable for watersheds with no significant storm sewer drainage system. HEC-1 is commercially available through third party software vendors.
   d. TR-20 / TR-55. TR-20 is a single-event surface runoff model developed by the Soil Conservation Service (SCS) for use with the 24-hour SCS runoff hydrograph. TR-55 is an abbreviated version of TR-20 appropriate for application to smaller watersheds not requiring modeling options available in TR-20. The simulation options in TR-20 are very similar to those available in HEC-1 with one exception. The use of variable storm locations required for some larger watersheds is more easily implemented in TR-20. TR-20 and TR-55 are commercially available through third party software vendors.
2) Hydraulic Analysis - Open Channels and Bridges.
   a. HEC-2. HEC-2 is a one-dimensional, steady state, fixed bed model of open channel flow that has defaulted into the industry standard for floodplain delineation and open channel hydraulic analysis. HEC-2 is applicable for use in a wide variety of artificial and natural channelized flow situations that do not violate the stated constraints.
   b. HEC-Riverine Analysis System (HEC-RAS). HEC-RAS is a remodeled version of HEC-2 that employs the same or similar theoretical algorithms with sophisticated graphics and interactive file management capabilities. Some of the hydraulic options have been improved or expanded, such as determining friction loss around bridge abutments. HEC-RAS eliminated the cross-sectional sequencing of data associated with subcritical and supercritical flow regimes, greatly improving the ease of modeling hydraulic systems subject to both types of flow.

c. Water Surface Profiles (WSPRO). The WSPRO program is a one-dimensional, steady state, fixed-bed model nearly identical to HEC-2. Historically, before HEC-RAS was introduced, the WSPRO model included more diverse options for bridge abutment friction losses and eliminated the need for sequencing cross-sectional data with respect to subcritical and supercritical flow regime.

3) Hydraulic Analysis - Culverts
   a. Culvert analysis should be performed using software packages derived from the equations and procedures presented in "Hydraulic Design of Highway Culverts".
4) Hydraulic Analysis - Urban Drainage Systems
   a. UDSWM (see above)
   b. AutoCAD Hydraulic Design Modules. Hydraulic design of larger and more complex storm sewer drainage systems can benefit from incorporating the design into the three-dimensional topographical base mapping for the project and using the CAD Hydraulic Design Module for facilities layout, hydrologic modeling and hydraulic routing. This approach can be especially efficient when conveyance properties change as larger storms, which exceed the storm sewer capacity, are routed through the total drainage system.
5) Hydraulic Analysis –Local Detention
   a. UDSWM (see above)